



ausplots

# AusPlots Rangelands Survey Protocols Manual

Version 1.2.9, 2012

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Published in Adelaide by

The University of Adelaide Press  
Barr Smith Library  
University of Adelaide  
South Australia  
5005  
[press@adelaide.edu.au](mailto:press@adelaide.edu.au)  
[www.adelaide.edu.au/press](http://www.adelaide.edu.au/press)

Electronic Index: this book is available as a down-loadable PDF with fully searchable text. You cannot copy or alter the content but you are welcome to print it.

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For Cataloguing-in-Publication data please contact National Library of Australia:  
[cip@nla.gov.au](mailto:cip@nla.gov.au)

ISBN 978-1-922064-38-7 (electronic)  
ISBN 978-1-922064-39-4 (paperback)

Book Design: Stefan Caddy-Retalic



**Figure 1** The Australian Rangelands cover the majority of Australia, encompassing 52 bioregions, totalling 81% of the continent.

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### Publication details

The TERN AusPlots Rangelands Survey Protocols Manual is produced and published by the University of Adelaide. Please do not republish material from this document or its attachments without written consent. The latest version of this manual may be downloaded as an online resource from [www.tern.org](http://www.tern.org).

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*The Terrestrial Ecosystem Research Network (TERN) is an initiative of the Australian Government conducted as part of the National Collaborative Research Infrastructure Strategy and the Education Investment Fund (EIF) Super Science Initiative.*

# Introduction

## BACKGROUND

The Australian rangelands are a significant area of the continent (81%, Figure 1), represented in 52 bioregions characterised by:

- vast spaces with highly weathered features;
- old and generally infertile soils;
- highly variable and often low rainfall; and
- diverse and variable plant and animal communities.

Climate ranges from monsoonal tropics in the north, arid deserts in the centre, to winter-dominant rainfall in the south. While rainfall can be torrential, providing abundant resources for a diverse and prolific array of plants and animals, these are also adapted to years of low rainfall, as drought can persist for extended periods.

Management of rangelands has a long history. Indigenous inhabitants have used fire for at least 40,000 years to manage the landscape to facilitate hunting and improve access for travel. More recent land uses include: pastoral activities, particularly grazing of natural pastures by domestic livestock; mining of the vast mineral resources; and tourism, with large numbers of domestic and overseas guests visiting icons in the Australian bush such as Uluru.

Environmental monitoring through the rangelands is varied. Most widespread monitoring has been undertaken by state agencies to assess the effects of grazing by domestic herbivores on pasture resources. Some of these activities persist, while others have been abandoned. Other long-term monitoring is generally restricted to defined locations. Undertaken by universities and other research groups, it is designed to research site-specific issues or investigate different aspects of species of interest. Contemporary, broad-scale biodiversity surveys have been conducted in different regions of the rangelands. While they provide valuable biodiversity data in extensive areas, the geographic coverage is far from complete.

AusPlots Rangelands operates at a continental scale across all Australian rangelands jurisdictions. Our objective is to:

*“establish permanent plots throughout the Australian rangeland bioregions where baseline surveys of vegetation and soils will be conducted”.*

Additionally, valuable plant and soil specimens will be collected, curated and analysed. The AusPlots Rangelands team, in collaboration with AusPlots Reference Groups and other experts in their fields, have developed survey methods and sample collection protocols explicitly for the Australian rangelands (Foulkes *et al.* in prep). The survey methods will be applied consistently across the rangelands to collect uniform data, which will be made publically available. AusPlots Rangelands is part of the TERN AusPlots facility based at the University of Adelaide.

AusPlots Rangelands is an important part of the large TERN (Terrestrial Ecosystem Research Network) initiative, a national collaboration of world-class researchers, infrastructure and processes that enables the collection, storage, sharing and use of long-term ecosystem data sets and knowledge. TERN is establishing continental scale data collection processes and mechanisms to facilitate sharing of long-term ecosystem data sets across disciplines. TERN facilities form a network across the country and involve many Australian universities and government agencies. The overall TERN objective is to:

*“provide a national institutional infrastructure network for terrestrial ecosystem research”.*

## AUSPLOTS METHOD

Each of the different survey modules for AusPlots Rangelands, and respective collection protocols (summarised in Figure 2 and Table 2), have been designed so they can be undertaken as individual investigations or, depending on the particular purpose of the survey, in combination with others. For AusPlots Rangelands funded surveys all modules need to be completed at each plot, but for other surveys using the AusPlots methods, not all modules need to be undertaken at all plots. Additional modules are under development to further enhance the consistency of biodiversity survey methods and to add

value to the AusPlots Rangelands plot network. The most up to date modules will be available periodically online at:

[www.tern.org.au/ausplots-pg17871.html](http://www.tern.org.au/ausplots-pg17871.html)

The modularity of the surveys also relates to the hierarchical nature of the different plot levels (Table 1). 'AusPlots' plots involve sampling all the modules in the greatest detail, 'SLATS' plots link with the widely accepted cover method of collecting data to assess land cover change, and 'Rapid' plots consist of a general GPS location, estimates of cover of dominant perennials, and opportunistic collection of voucher specimens. These modules are intended as a minimum data level requirement to consider biodiversity through the provision of consistency in the collection of samples and information on vegetation, land, soil and cover attributes. Location of AusPlots plots should encourage collection and testing of additional data and samples to meet other purposes as required (such as state or national based soil condition monitoring).

The collection of field data has been designed to be undertaken using a purpose-built app on a PDA, smart phone or tablet using an Android operating system in order to streamline data and sample collection and minimise data double-handling. Field samples will be

assigned barcodes which can be scanned by the device and enable easier tracking of specimens. Survey and collection details will be uploaded onto the AusPlots central database with data discoverable through the TERN Eco-informatics ÆKOS system. This will simplify the field collection of data, data storage, tracking of samples through their identification, vouchering and analyses, along with sharing of data with the wider community.

This manual has been prepared to describe the different components of the AusPlots Rangelands surveys and to provide background context. It is anticipated that the methods in this manual will be highly applicable to other Australian environments. In some cases the method used for data collection may need to vary, however in most cases it should be possible to collect data in a compatible way (e.g. wheelpoint data rather than point intercept data – the method is different, but the data are compatible).

Paper copy field data collection forms are included at Appendix 4.

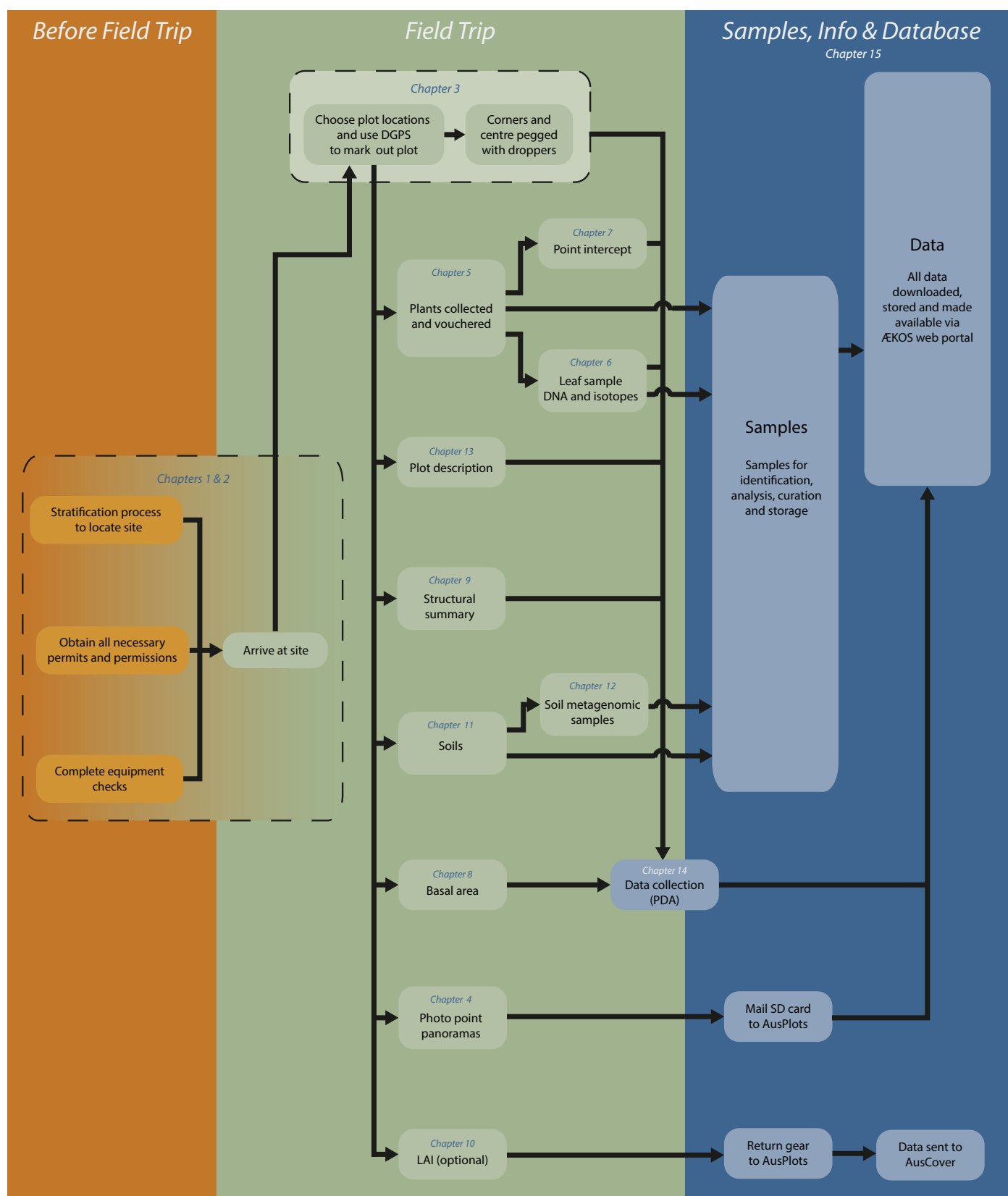
For additional information on AusPlots Rangelands, please contact the authors (address page 2).

**Table 1 AusPlots Rangelands plot hierarchy: survey details and collection requirements and resourcing.**

Plot levels	Plot information				Vegetation							Soils					Funds
	Description	Plot locations & GPS	Photopoints per plot	Vouchers	Point intercept		Genetic profile (leaf samples)		Basal area	Structural summary	LAI	Description	Core to 1m	Samples to 30cm (0–10, 10–20, 20–30)	Bulk density to 30cm (0–10, 10–20, 20–30)	Metagenomics	AusPlots Rangelands
					Perennial	Annual	DNA	Isotope									
AusPlots	Full	DGPS–plot corners & centre	Set of 3	All	Full vegetation – spp., ht.	Collect if defining the system, otherwise record to life form	1 x voucher 4 x replicates of dominant perennials	1 x voucher	Yes	Yes	Yes when available	Full	Yes	9 x 3 depths	1 x 3 depths	9	Yes
SLATS	No	DGPS/GPS–plot centre	Set of 3	No	Functional class	Functional class	No	No	Yes	Yes	Optional	No	No	No	No	No	No – by collection agency
Rapid	No	GPS–general location	None	Opportunistic	Visual estimate of % cover for veg >2% FPC or 5% OPC	Yes if defining the system	No	No	No	No	No	No	No	No	No	No	No – by collection agency



Figure 2. Diagram of the AusPlots Rangelands survey process, referenced to the Survey Protocols Manual chapters





**Table 2. Summary of methods, protocols and estimated timing for an average plot**

Steps	Method	Protocol	Details	Time
1	Plot description	Use Yellow Book for physiography		10 min
2	DGPS - plot layout	Construct a grid and DGPS corners, centre and the start and end of the 10 transects- lay out 10 x 100 m tapes for each plot	Dropper at each corner and centre 20 temporary marker pegs at transect start and end Colour coded to easily identify transects and corners	30 min
3	Photo panoramas	360° panorama from 3 points around the central peg	DGPS location of the 3 photo sites around the central peg	20 min
4	Vascular plant voucher samples	Collect voucher samples for each species	Species list for the plot using field or species name. This is created by collecting a voucher of all species, barcoding the voucher, scanning with app and pressing all specimens	1-2 hrs
5	Genetic and isotope samples	Sub-sample taken from each of the vouchers - replicates for dominant perennial species FPC >2%	Samples placed in tea bags, labelled with a barcode, scanned with app and placed in a plastic box with silica gel	30 min-1hr
6	Point Intercept	Staff with laser pointer and densitometer used to record species cover, growth form and height at 1 m intervals along 5 E/W and 5 N/S transect (1010 points)	Recording stratum, plant cover/ growth form and height in a vertical projection above and below the laser point. Densitometer is used to view the canopy- recording hits or 'in-canopy sky'	3-6 hrs
7	Basal Area	Basal wedge used to determine the basal area of trees and shrubs at 1.3 m (m <sup>2</sup> /ha)	Measures taken at 9 sampling locations throughout the plot. Record the total number of hits per species at each location	20 min
8	Structural summary	For upper, middle and lower strata nominate 3 dominant species in descending order	Complete at end of plot survey as other parameters to inform NVIS level 5 from point intercept	5 min
9	Leaf Area Index (LAI)	Collect at 50 points in quadrat along N/S transect	Only required where canopy height is >2 m	20 min
10	Soils	1. Plot description 2. Soil characterisation to 1 m+ 3. Soil cores at 9 locations 4. Soil bulk density 5. Soil samples	1. Description follows Yellow Book 2. Soil characterisation – at SW corner- record horizon boundaries and depths- Collect 500g sample @ 10 cm increments to 1 m- GPS, barcode and photograph pit/site 3. Soil cores at 0-10, 10-20, 20-30 cm using corer or shovel – photograph pit, GPS, bar code all samples 4. Bulk density samples taken at 0-10, 10-20 and 20-30 cm from pit 5. Soil samples to CSIRO National Soils Archive	2-3 hrs – if basic survey  5-6 hrs – if by soil scientist
11	Soil metagenomics	Surface soil samples taken at 9 locations	200 g sample taken to 3 cm, bar coded bagged with silica gel	30 min

# 1. Plot selection

The plot selection process involves four stages. The first three are desktop exercises based on available datasets and the fourth occurs in the field.

- Stages 1 and 2 – stratification and selection of priority bioregions,
- Stage 3 – plot stratification within each selected bioregion, and then
- Stage 4 – interpretation of selected areas in terms of homogeneity, historical data locations, logistical and access considerations.

The stratification process is undertaken collaboratively with relevant state and federal jurisdictions, researchers and interested conservation groups and individuals. The objectives of each state will be considered in the stratification process, but a continental perspective must be consistently employed in locating plots.

## STAGE 1: BIOREGIONAL STRATIFICATION

Stage one involves a hierarchical cluster analysis of all Australian bioregions (in PATN software v3.0) to produce groups of similar bioregions across Australia. These are then prioritised for potential sampling locations. Spatial data layers used in this clustering include; climate (i.e. Hutchinson agro-climatic classes, Hutchinson *et al.* 2005), landform pattern (Regolith of Australia, National Geoscience Dataset, 2010; the broadest relevant geological classification in Australia, incorporating landscape and regolith class), major vegetation groups (National Vegetation Information System level 3, (ESCAVI 2003)), the rangelands boundary (after Bastin *et al.* 2008) and the IBRA 6.1 bioregion boundaries (DEWHA 2008). The dendrogram produced was interpreted by ecologists at a workshop with state and federal representatives examining the degree of similarity of neighbouring bioregions. Of the 52 rangeland bioregions, 21 groups were produced. Monitoring plots should be located in sufficient bioregions to give adequate geographic and environmental spread to show patterns of vegetation structural and compositional change at relevant jurisdictional/national scales.

## STAGE 2: SELECTING REPRESENTATIVE BIOREGIONS TO SAMPLE

The intention is to sample at least one bioregion in each group derived from the hierarchical cluster analysis. The decision on which bioregions to choose within a cluster will be a collaborative decision between AusPlots and local jurisdictions, based on:

- the need for good spatial coverage;
- state agency priorities;
- data gaps (where little previous information exists);
- areas where co-locating with existing sites will significantly increase the utility of both;
- site access/ownership and security;
- logistical issues;
- the likelihood of longevity of site management for monitoring purposes.

Additional factors will then be used to determine which bioregions are ultimately sampled including:

- extent and currency of previous surveys;
- dominant land uses;
- extent of reservation;
- size and jurisdictional capacity to assist with surveys;
- ease of access; and
- local priorities.

Depending on the amount and scale of relevant available information, much of it will be valuable for the plot selection process at both stages 2 and 3, which can have significant overlap.

The overall decision making framework is hierarchical, based on the different classes of information required for an overall consideration and then more specific detail needed within the larger classes (see Figure 3).

## STAGE 3: STRATIFYING AREAS OF SAMPLING INTEREST WITHIN BIOREGIONS

Within each of the selected bioregions a process will be conducted at a higher resolution to select sample areas based on a hierarchical stratification process. The initial stages will include a GIS desk-top exercise interrogating available layers to identify prospective areas for plot locations based on defined guidelines. Flexibility will be necessary in choosing potential plot locations, with their suitability confirmed ultimately through field visits (Stage 4). Fiscal and logistical constraints mean that a practical design that maximises the likelihood of meeting broad objectives is preferable to a theoretically optimal design. The process will involve collaboration between state jurisdictions and AusPlots to maximise the utility of plots from both a continental and local perspective.

### Level 1: IBRA sub-regions

Most IBRA bioregions are divided into a number of sub-regions defined to encompass the variety of land types within each bioregion. These will be used as the first level in the plot stratification hierarchy.

### Level 2: Land systems

*(Areas with recurring patterns of landform, soils and vegetation that are related geographically and geomorphologically with a similar position in the landscape/catchment)*

Rather than attempting to survey all land types in all bioregions, AusPlots Rangelands will assess and monitor patterns of vegetation and soil change at jurisdictional/national scales in order to identify changes occurring in response to environmental drivers. Plots will be selected in land types that are representative of both extensive ecosystems (often monitored in state pastoral monitoring programs), and more restricted components considered significant for ecosystem function. Restricted ecosystems including riparian zones, rocky

outcrops or sand plains in different regions, are generally under-sampled in inventory and monitoring programs and can be highly significant for biodiversity. It is likely that a few land types in each bioregion may be selected because they are:

- characteristic of the bioregion;
- restricted to that bioregion;
- under greatest pressures; or
- where greatest change in vegetation structure and composition is considered likely.

In many bioregions higher resolution data than land systems will be available for use in the stratification i.e. finer scaled and more homogeneous land units or vegetation mapping. Where available, these datasets will be used in preference to land systems, however land systems data has a much wider coverage and so will be available in most bioregions. Plot geomorphology needs to be considered and an assessment of the position of plots from a landscape and catchment perspective will be included.

### Level 3: BOO (Best On Offer) or disturbance regime

To enable comparisons based on disturbance regimes (e.g. land management/anthropogenic activities such as livestock grazing or controlled burning, feral animals or stochastic factors such as uncontrolled wildfires) monitoring will occur at areas that represent BOO plots (Landsberg and Crowley 2004), and disturbed plots. Measurements at disturbed plots will provide comparative data to help quantify the effects of the disturbance factors and can also be used to relate AusPlots data to historical data sets across most of the rangelands jurisdictions. Disturbed plots will be in intermediate condition and constitute a maximum of 20% of the total number of plots.

Figure 3. Plot location decision-making framework

## Pragmatic decision-making based on:

### Scientific and Environmental Information

- Climate
- IBRA bioregions and subregions
- Land systems and units
- Vegetation community
- Regional Ecosystems (QLD)
- Landforms
- Availability of spatial and textural data for region
- Location of other TERN activities
- Location of similar research sites
- Land use and management regime
- Distance from water

### Historic Information

- Existing monitoring sites
- Location of site
  - Ability to accurately relocate
  - Location of biological survey sites
  - Land use and management history
  - Types of data collected
  - Compatibility of previous data
  - Quality of previous data

### Logistic Considerations

- Ease of access to bioregion
- Ease of access to suitable sites
  - Vehicle access
  - Traversability
- Financial limitations

### Political Considerations

- State priorities
- NRM body priorities
- Site ownership and tenure
- Location within NRS Covenants
- Potential future policy drivers
  - Carbon storage
  - Listed ecosystems, communities & species
  - Regions at high risk of climate impact
  - Landscape primary productivity
  - Biodiversity corridors
  - Biodiversity refugia

## Level 4: History of the Plot or of Monitoring

The history of a potential monitoring plot, both the previous land management and/or any preceding monitoring, will help determine its suitability. If a potential area satisfies the stratification guidelines, has been monitored previously and has relevant, freely available data, then co-locating an AusPlots Rangelands plot would value-add to both past monitoring and the AusPlots Rangelands survey efforts. Any collaboration could incorporate:

- more targeted species-specific monitoring undertaken by other agencies or researchers;
- plots from the extensive range of pastoral monitoring activities of other jurisdictions; or
- long-term monitoring plots investigated by universities.

If a potential plot has an unusual climatic or poorly documented management history, thereby presenting difficulties in locating suitable replicate plots, these may prove of little value in describing the regional conditions in an Australian context.

Where plots may be located on pastoral properties, Indigenous land or other private enterprises, landholders/managers must be contacted prior to a trip to discuss the project and obtain approval for their property to be included in the surveys. This could require significant lead-in time, but their involvement in the decision making process is critical in ensuring the likely longevity of the plots with minimal disturbance. Access to plot locations should be assured for current and future field trips.

Information important in deciding whether or not any previous monitoring is relevant and compatible will include

- the location of the area monitored;
- the ability to accurately relocate the site;
- the actual monitoring data collected;
- the monitoring methods used and its compatibility with the AusPlots data;
- consistency of data;

- the period over which monitoring was undertaken;
- the frequency of monitoring;
- the dates monitoring occurred (especially relative to seasons and rainfall);
- data robustness and reliability;
- data availability, format and accessibility; and
- the availability of other incidental data (e.g. local rainfall, land management records).

Important plot history information includes details of:

- previous use and management;
- fires (both wildfire and managed);
- seasonal conditions (both long and short-term); and
- the presence and impact of other pressures such as feral animals or weeds.

## STAGE 4: CHOOSING PLOT LOCATIONS IN THE FIELD BASED ON AREAS OF INTEREST

It is unlikely that a precise plot location will be determined by stages 1 to 3 of the stratification, but rather, will highlight priority areas within which a site can be located. Decisions on plot locations at the local level will be made in the field, based on locations with large homogeneous areas with a consistent and constant mix of vegetation, slope, relief and soil. All plots should be 1 hectare in area in all circumstances. Plots should be orientated N/S, E/W in line with the map grid. On occasions where this is not possible, orientation may need to be altered, and in rare instances the quadrat shape may need to be altered (e.g. 200 x 50 m orientated at 330 degrees to capture a dune crest in the Simpson Desert).

The data collection app works on a standard 100 m x 100 m plot. Where site factors make these dimensions unachievable it is recommended that data sheets be used for the point intercept method. Notes on this final site selection taken in situ will form part of the dataset collected at each of these sites.

## 2. Trip planning

### Guidelines

These trip planning guidelines should not replace local guidelines and operating procedures, but rather ensure that field teams have considered all requirements for conducting AusPlots surveys. Where these guidelines conflict with local guidelines it is recommended that local guidelines are used, except sections relating to specific methods and equipment. Any queries can be addressed to the AusPlots Rangelands Team:

[tern.adelaide@adelaide.edu.au](mailto:tern.adelaide@adelaide.edu.au)

### Funding

Initial funding to develop the method and conduct the first round of surveys has been provided through TERN from the Australian Government.

Given the utility of this data for state and territory monitoring there may be significant in-kind contributions from jurisdictional agencies.

Compatibility with the DAFF-funded ground cover monitoring project (coordinated by ABARES through ACLUMP) and possibility of co-funding of plots may assist with the cost of data collection.

### Permits and Quarantine

Each jurisdiction will have a requirement to complete a field trip approval/advice form prior to conducting field surveys, with associated standard operating procedures or local guidelines for communication, vehicle equipment etc. These requirements must be fulfilled.

Conducting AusPlots surveys may require several permits to be obtained from local institutions such as:

- » Permit to collect
- » Permit to interfere with wildlife
- » Permit to conduct scientific research
- » Permits to access Aboriginal Lands
- » Aboriginal Areas Protection Authority approval
- » Import and export permits – Quarantine
- » Defence permits

- » Parks permits
- » Quarantine areas: weeds, pathogens etc.

### Consultation/Access permissions

- » Contacting landholders
- » Indigenous lands

### Field Equipment, Vehicles and Checklists

Equipment lists and checklists are provided for each section in this manual to serve as both an indicative minimum requirement and also as a basis from which to develop individual requirements (See Appendix 2). Back-up contingencies should also be developed to minimise the likelihood of trips being abandoned or disrupted due to equipment malfunction. Data collection on the PDA or tablet has been designed so that collected data is robustly stored. Data back up to another device or laptop is possible, however if data is stored on a memory card on your device this should not be necessary. Hardcopy data sheets are provided in the appendices, but their use is discouraged due the difficulty in getting that data into the database.

As well as generic field equipment sheets, additional checklists and inventory sheets should be developed by individual operators to ensure a complete field equipment complement is carried on each trip.

Field operation will usually need a 4WD vehicle that is equipped appropriately for the environment where the work is to be undertaken. All vehicles should have suitably stocked first aid kits. In some instances, i.e. trips of long duration, a trailer may be needed for transportation of samples collected over the trip. Ensure organisational procedures and guidelines developed for 4WD use and remote area work are followed. This manual makes the assumption that local guidelines will be followed.

Please follow the OHSW procedures that are detailed for your organisation.



## Scientific Equipment

Equipment lists and checklists are detailed in each section and summarised in Appendix 2. Provision of equipment is to be negotiated with each jurisdiction and field team. Core scientific field equipment specific to the AusPlots surveys e.g. the differential GPS, LAI meter, basal wedges, PDA will be provided for the field work and will be returned to AusPlots at the end of the project.

Other field equipment such as vehicles and fit out will be the responsibility of the survey organisation.

## Vouchers

Adhesive barcode labels with voucher labels will be assigned and provided to each jurisdiction. Code conventions for each label follow strict protocols based on state, IBRA bioregion and plot type (see Appendix 1). Vouchering protocols are discussed in detail in Chapter 5.

## Survey participants

Surveys should have a minimum of two participants, one survey participant with vegetation survey expertise and one with experience in soils surveys and descriptions. Where volunteers are included, the necessary arrangements need to be completed prior to the trip with the necessary forms, approvals and notifications finalised. These will differ from jurisdiction to jurisdiction. Most surveys will likely have a requirement for camping for extended periods of time. It is therefore essential to understand remote environments and the risks involved in undertaking surveys in these environments.

Field teams should include participants with current Senior First Aid Certificate and experience and/or qualifications for operating a 4WD in off-road situations.

## Pre-survey meeting

Conduct at least one pre-survey meeting to ensure all participants are in agreement regarding the aims and objectives of the trip, equipment provided, likely timelines, trip duration and flexibility on return times etc. This is also necessary for planning logistics for the trip and for assigning responsibilities between trip participants. This will become routine after completion of the first couple of trips.

At this meeting an inventory should be compiled of relevant data available for the areas being surveyed e.g. plant lists for the area obtained from the local herbarium, details of past biological surveys etc. and copies made to take into the field.

## Scheduled call-ins

Scheduled call-ins are essential to satisfy occupational health and safety requirements, though in most cases there will be local requirements for this in remote areas. If there are no local requirements, or you are working independently of state or territory jurisdictions, please call AusPlots to arrange for a schedule call-in protocol.

## Data collection/return

Data processing requirements on return from the field should be minimal with the field data collection app and PDA. Specific details will be provided within each section of the manual. All vouchers need to be prepared i.e. changing paper or silica granules or drying soils and putting them into approved containers, and then submitted to relevant institutions.

## Time requirements

Given the large potential variability between plots, three survey participants (one vegetation expert, one soils expert and one generalist) should be able to complete up to three plots every two days (see Table 2). This assumes easy access to the plots and minor travel between plots, with travel to the plots being an additional time commitment. On return there is also a time requirement for preparation and dispatch of samples as well as updating data bases when results are returned (see Chapter 15).



### 3. Plot layout and positioning

General plot location is largely determined before going into the field. Initial stages in the process involve a desktop exercise using multiple GIS layers to identify suitable areas based on the process outlined in Chapter 1: Stratification stage 3. Decisions on broad areas of interest are based on the best available biological and geographical information and historical, political and logistical considerations.

While a general location can be decided through a desk-top exercise, the decision on a precise location requires visiting potential locations determined remotely and selecting the most suitable. The decision in the field is the culmination of an extensive process designed to maximise the utility of the plot and the value of the data and specimens collected at the plot and the summary of information derived from the plot data. The field decision is best achieved by an operator with extensive field experience.



The differential GPS (DGPS) unit should be turned on (see Start up below) on arrival at a plot as it can take 5-10 mins to acquire best position accuracy.

## PLOT LAYOUT & POSITIONING

### Guidelines:

Appropriate plot layout and positioning are critical to the success of the survey and utility of the data. Poor layout and positioning may create difficulties for both the current survey as well as any possible future visits. This section deals with both the final plot selection (following from pre-trip location selection) and the method by which the quadrat is laid out using differential GPS.

### Final plot location selection

Plot selection and orientation should also try to avoid major anthropogenic influences (roads, cattle yards, fences, bores, etc).

The location should be as representative of the chosen vegetation type and as homogeneous as possible.

### Plot orientation

The plot grid must align in a north-south direction wherever possible.

Careful consideration should be given to this when assessing homogeneity of any potential plot.

Note: A compass can sometimes be a more helpful tool in visualising the plot than the GPS.

## Plot marking

All plot locations are to be determined using DGPS collected at the four corners and the centre.

The four corners and centre of each plot should be permanently marked using star droppers (pickets). In cases where this is not possible (some Indigenous lands, private or leasehold lands, rocky outcrops etc.) the southwest corner must be marked as a minimum.

Plots may be marked with an aluminium tag at the southwest corner of each plot. Tags will identify the plot as a TERN plot as well as including the plot code.

## Plot naming convention

The plot name follows the alpha-numeric coding convention of:

State (2 letters) and Plot type (single letter) Bioregion code (3 letters) Plot number (4 numbers), e.g.:

SAA STP 0001

This translates to: SA (South Australia) A (AusPlots) STP (Stony Plains) 0001 (Plot 1).

For the code conventions for states, plot types and IBRA codes, see Appendix 1.

## Identification numbering convention

Two dimensional barcodes (code 128 type) will be provided as printed adhesive labels. Separate barcodes will be used to identify:

- each plant voucher collected;
- each genetic sample collected;
- each soil sample collected; and
- each soil metagenomic sample collected.

Barcodes will be scanned with the PDA to initially link the barcoded item to its location and then to the database.

## PLOT POSITIONING USING THE DGPS (PROVIDED FOR USE WITH AUSPLOTS PLOTS)

### Batteries

- The batteries (2x) for both the hand unit (Zeno) in the red case and the receiver (1x9AH battery) in the backpack should be charged nightly when in the field
- The charger can be left plugged in to the 9AH battery in the backpack, but when charging the battery, remove the charger from the bag to prevent it from overheating
- The backpack charger needs to remain within the backpack after use.

Note: If batteries fail to hold charge from the mains power, try charging with the car charger. If this is still unsuccessful contact AusPlots and the distributors:

**C.R. Kennedy Survey Solutions**

**Adelaide**


**08 8410 1366.**



The differential GPS (DGPS) unit used in the AusPlots Rangelands survey protocols

## Procedure

### Start up

1. Turn on the receiver unit in the back pack (on/off button at the top left corner of the unit).
2. Screw the DGPS antenna onto the pole and attach the cable. Extend the antenna by gently twisting the top part of the pole anti-clockwise and extending the pole. Do not extend the pole beyond the 'Stop max' line and do not pull the antenna out of the back pack. Turn the top part of the pole clockwise to tighten.
3. Pull the loose end of the grey data cable from the backpack and connect it to the corresponding jack on the bottom of the Zeno hand unit. Zip up the backpack ensuring the battery pack and receiver unit are secure within.
4. Turn on the Zeno hand unit by pressing the grey button with the red  symbol. Start up may take around 20 seconds.



*Ensure that both the Zeno hand unit and the receiver antenna have an un-obstructed view of the sky. The GPS antenna for the Zeno hand unit is located in the GPS cap at the opposite end to where the cable enters. Avoid covering the top of the unit with hands as the Zeno GPS cap is the GPS location point.*

### Operation

1. Fit backpack onto your back. Ensure the DGPS antenna is positioned above your head.
2. Having followed the guidelines for plot homogeneity/selection (see start of Chapter 3) start at the southwest corner of the plot.
3. Leica Viva Lt should open up automatically on start up (wizard). The program can also be opened by tapping the brown Viva LT icon on the screen twice with the stylus. The stylus is clipped to the back of the hand unit.

**Note:** Once the program is running, the Zeno hand unit may flash and say "RTK Data link down". This generally means that the antenna has a poor signal. Try moving it so that the view of the sky by the antenna is not obscured by your body or by trees.

If error persists, the almanac (stored memory of the satellites position) may need to be updated. This will occur if the DGPS has not been used for some time or has been moved a significant distance from where it was last used. To correct this, place both the antenna and the Zeno hand unit in the open with a clear view of the sky and allow approximately 20 minutes for the almanac to update.

4. The program will begin by asking 'Which Job do you want to use?' Select 'New job' and click 'Next'.

5. Under the 'General' tab in the New Job screen:

Name the site following the plot naming conventions (see Plot Naming Convention above: State - Plot type – Bioregion code-4 digit number e.g. SAA-STP-0001) and press the red **OK** button.

Enter your name or initials in the 'Creator' field.

Ensure for **Device**: 'Internal memory' is displayed.

6. Click on the 'Codelist' tab ensure 'None' is selected.

7. Click on the 'Coord system' tab and select the correct coordinate system for the area where you are working. As an example below, the correct system for Adelaide is MGA 54. Click **OK**. This coordinate system will reappear for subsequent plots so does not have to be changed provided you remain in the same UTM zone. The other categories on this screen should not need changing (i.e. Residuals: No distribution, Transformation: <None>, Ellipsoid: WGS 84, Projection: UTM 54 (to match the MGA zone), Geoid model: <None>, CSCS model: <None>.)

8. Click on the **Averaging** tab and ensure that 'Off' is selected, then select 'Store'.

9. Ensure that **UNIGRID** is selected as the Control Job by selecting 'Jobs & Data', then on the next screen select 'Choose control job', then selecting 'UNIGRID' on the next screen and 'OK'.

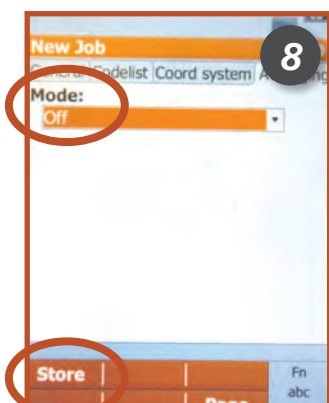
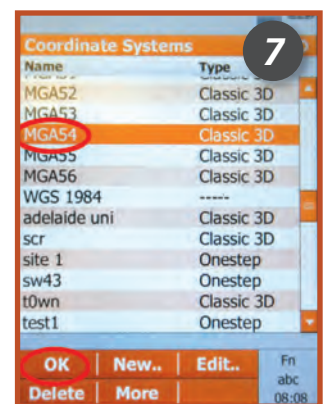
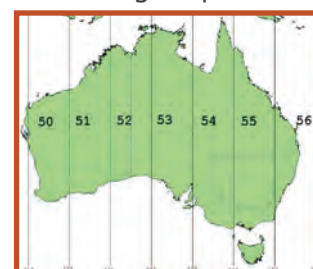
*If you want to check any of these settings you have just entered, go to the 'Jobs & Data' icon in the start screen by pressing the ↶ key at the top right side of the screen a number of times.*

10. Select 'Go to Work!'.

11. Select 'Survey +' then 'Quick Grid', then 'OK'.

12. For 'Method' select 'Single point' from the drop down menu and then 'OK'.

13. On the next screen, ensure that for the **Local point**: 'From control job' is selected from the drop down menu. For **Point ID**, ensure '100SW' is selected, if it does not automatically appear, click the drop down icon at the right side of the box and either chose **100SW** from the **Points** tab or from the **Map** tab on the next screen. 100SW represents the southwest corner of the plot and is the starting point for marking the plot.





All points below 100SW (101, 102, 103 etc) should follow in sequence when the plot is being marked out. These points represent the transect ends, corners and centre of the plot. (Note: on some devices point 101W1 is incorrectly marked as 101WS)

Ensure the boxes next to 'Ignore local height & use WGS84 height' and 'Use geoid' are not selected and then select 'OK'.

14. Select 'Meas' (measure). The 2D accuracy of the site location is most important and accuracy below 2 m is to be aimed for. Leave the device running at the plot for up to 5 minutes to obtain the desired accuracy. (If accuracy does not reach these levels after 5 minutes, accept a compromise. This is more likely at plots with dense canopy cover.)

Select 'Stop' when accuracy is reached.

**Antenna height** (Zeno hand unit) should be set at 1.2 m.

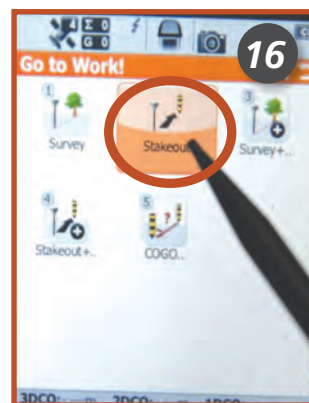
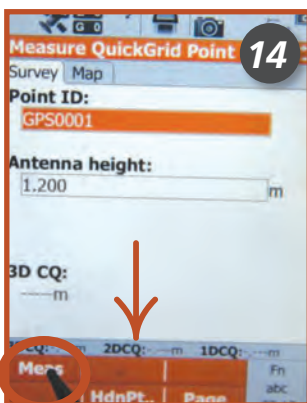
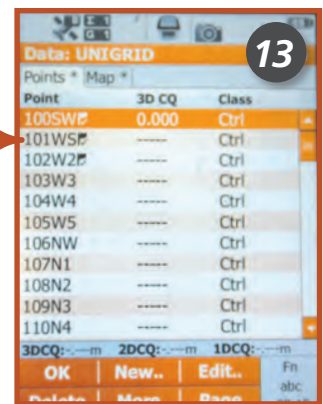
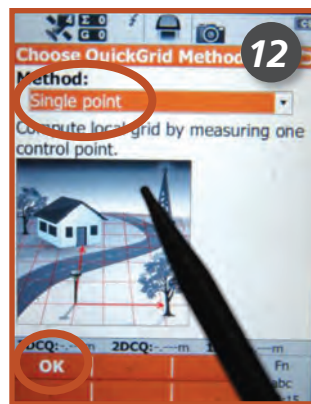
15. Hit the 'Store' tab to save the coordinate system using the plot name.
16. Return to the Start screen by pressing the ↶ key a number of times, select 'Go to Work!' and then 'Stakeout'.

17. Set **Control job** to **UNIGRID** and select 'OK'.

18. Using the **Point ID** drop down menu and following the path on the diagram below, mark and record the 28 reference points within the plot. Mark the SW corner (100SW using 'Measure' and 'Stop/Store') then in sequence: the transect ends W1 through to W5 (102 to 106); the NW corner (107); then transect ends N1 to N5 (108 to 112); the NE corner (113); transect ends E5 through to E1 (114 to 118); the SE corner (119); returning via transect ends S5 to S1 (120 to 124) to the SW corner (already marked as 100SW, but can be re-marked as 125SW); finishing with the centre (126) and the three photo panorama points around the centre.

It can sometimes be easier to select points using the map tab on the DGPS.

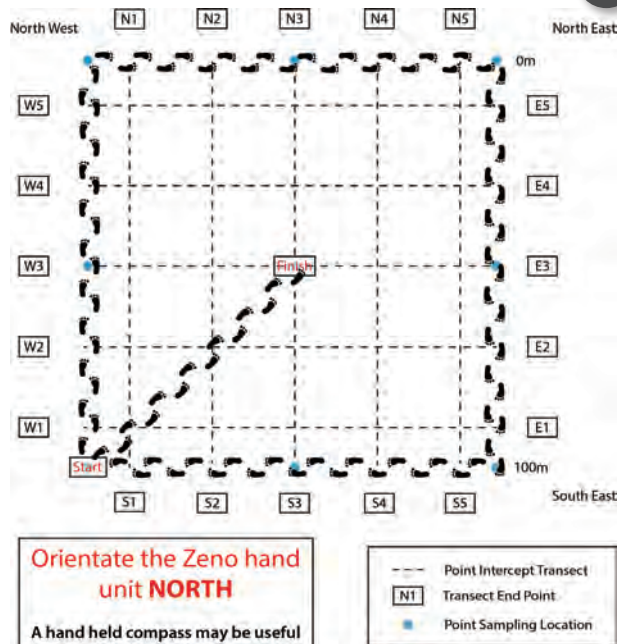
19. An arrow appears on the screen indicating the direction to the next point. This assumes the Zeno hand unit is orientated north. A circle will appear on the screen when you are close to the point. When the accuracy is below 1 m, hit the **Measure** button. The hand unit will announce when it has stored the point and the drop down menu will automatically move to the next point (if this takes longer than



1 minute hit the **Stop** and then **Store** buttons). Ensure that the unit has gone to the next point in the sequence (it doesn't always!). If it hasn't, use the drop down menu or the map to choose the next point.

20. At the completion of the process the following points should have been marked:
- the four corners of the plot (using star pickets),
  - the centre (using a star picket). This may also be used as the reference peg in the three photo points and therefore the dropper height needs to be 1.3 m above ground level and marked at 25 cm below the top of the dropper (see Chapter 4),
  - the start and finish of the 10 transects (20 points using pegs. The pegs will be removed at the completion of sampling as their locations will be stored in the DGPS), and
  - the three photo points.

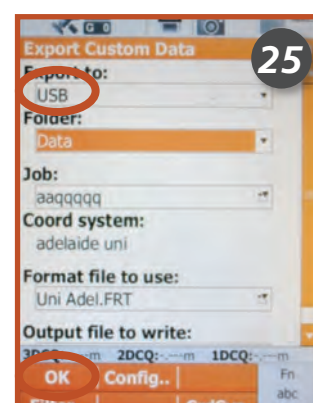
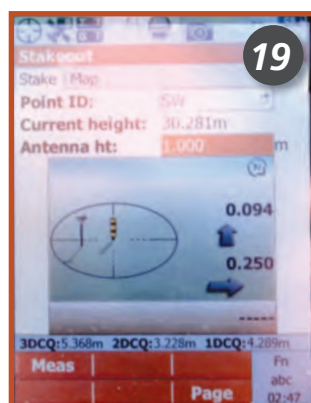
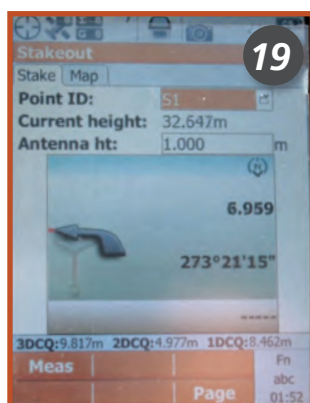
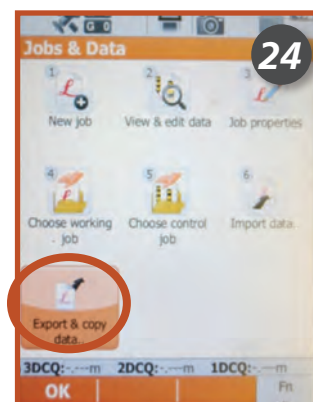
18



21. Ensure that both the Zeno hand unit and the back pack unit are turned off completely (no lights illuminated on the console of the Zeno unit). Disconnect the cable from the Zeno hand unit from the cable and return this to the back pack. Carefully unscrew the antenna cable and the antenna (gently twist the white section). Place this in the back pack to prevent it being damaged while in transport.

### Downloading the data (back in the office)

22. If the unit has been switched off, follow the start up process for the hand unit (point 4 above).
23. To export the data, insert a USB drive into the hand unit and go to the 'Jobs & Data' menu in the start screen.
24. Click on the 'Export & copy data' icon
25. Click on the 'Export custom data' tab and then export to the USB as shown. This will export the data as a text file.



## ALTERNATIVE SHOULD DGPS MALFUNCTION

The plot can still be laid out should the DGPS not work. The reduced accuracy means that this should only be used as a last resort.

If possible, return to the plot once the DGPS is functioning again to more accurately mark the points.

### Procedure

Alternative plot locations can be undertaken with a standard Garmin® or other similar GPS unit.

1. Stand at what will become the southwest corner of the plot and hit the 'Mark' button on the GPS. Record this figure on a piece of paper/notepad.

Sample: SW corner  
362038  
6196647

2. Adding 100 m (ignore decimal places) to the above coordinates in both a northerly and easterly direction will create the grid. (Changes in coordinates indicated by large orange figures)

NW Corner	NE Corner	SE Corner
6196647	6196 <b>6</b> 47	6196 <b>6</b> 47
362 <b>1</b> 38	362 <b>1</b> 38	362038

Location of the centre is obtained by adding 50 m to both values for the SW corner

Centre  
3620**8**8  
61966**9**7

3. Re-enter these coordinates into the GPS.
4. Once the four corners have been marked on the ground (using star droppers), a 100 m survey tape is used to measure and mark the intervals between transects. The first north-south transect should commence 10 m east of the southwest corner and should head in a northerly direction, with further north-south transects spaced 20 m apart from the first transect. The first east-west transects starts 10 m north of the southwest corner and heads in an easterly direction, with further east-west transects spaced 20 m apart from the first transect.

## Equipment

The HPRC Red case contains the following:

- Zeno – hand-held DGPS Unit
- 240V charger (to plug directly into Zeno)
- Battery charger cradle + 240V charger + 12V cigarette lighter cable (to charge batteries in cradle)
- 2 lithium-ion batteries
- USB download data cable
- Touch screen pen & lanyard
- Manuals

The back pack contains the following:

- DGPS antenna and mounting pole
- 9AH battery pack
- 2AH battery charger (check this has been placed back into backpack)
- DGPS Receiver unit
- Data cable for connection to hand unit.

Also required:

- 5 x 1.8 m galvanised star droppers/pickets
- 23 x steel pegs (tent pegs or equivalent)
- Flagging tape (for marker pegs and droppers)
- Dropper rammer or sledge hammer
- Compass
- A good quality inverter unit or generator to charge equipment during extended field work

## Time requirements

Setup: 10 mins

Plot layout: 30 mins

## Data Use / Reason for Collection

The AusPlots Rangelands program is resourced to undertake initial plot surveys to collect baseline biological, physical and chemical data. The program has been designed with the intention that plots will be re-sampled at regular intervals to provide quantitative measures to define change. Hence, spatial accuracy to define plot locations is of vital importance.

Conventional GPS units do not provide this required level of spatial accuracy, but can be used as back-up.



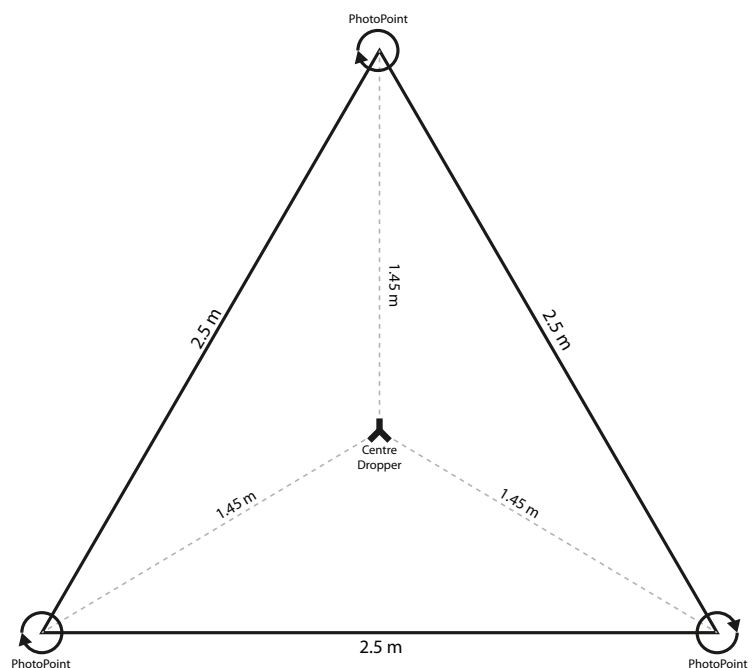
# 4. Photo-panoramas

## Guidelines

- 3 photopoints are to be established at each plot configured in an equilateral triangle (with sides 2.5 m in length) around the plot centre, marked with a star dropper and location recorded with the DGPS.
- Use a digital SLR camera with minimum 15 megapixel resolution, the ability to export raw images and a 35 mm fixed focal length lens.
- At each photopoint take photographic sequences in a 360° panorama, with up to 40 photographs per panorama (ensure minimum 30% overlap between consecutive photographs).
- All photographic sequences are to be preceded by an identifier photograph that includes the plot identity code e.g. SAA STP 0001, date and photopoint number (1-3).
- Photographic sequences are to commence with an image of the central dropper, height 1.3 m with a line marked 25 cm from the top of the dropper.
- Photographic sequence to end at the central dropper, ensuring the complete 360° panorama is included.
- The camera is to be mounted on a suitable tripod with the height of the centre of the lens at 1.3 m.
- The photographic sequences should be taken between 10 a.m. and 4 p.m. (where possible) to minimise sun and shadow effects on the photographs.
- In some communities where the vegetation is very dense (e.g. Acacia and Melaleuca shrublands), it may not be possible to photograph the vegetation using photo-panoramas. Where no useful information will be provided (e.g. dense vegetation which will give no depth to the photograph), take several representative photographs of the community as a reference for the plot.

## Procedure

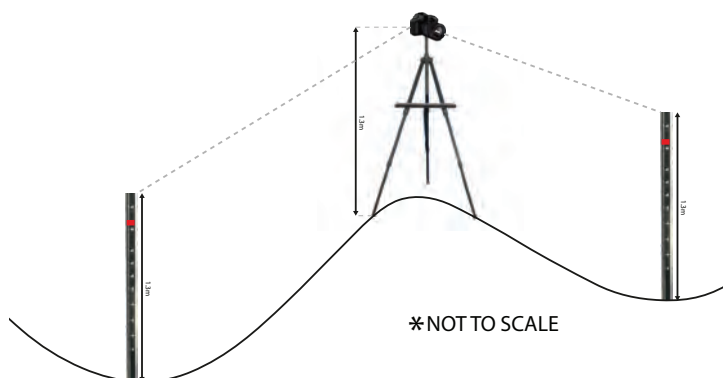
1. Determine the best position for the plot photographs. This will usually be around the central dropper. Where the central dropper is not suitable (e.g. it is next to a large tree which will obscure large sections of the panorama), place a dropper to use as the centre of the photograph and record its location and the photo points with the DGPS. The top of the dropper should be 1.3 m above the ground and there should be a line marked at 25 cm from the top of the dropper.



2. Place 3 ropes (2.5 m length) on the ground to form an equilateral triangle with the corners of the triangle at approximately equal distances from the central dropper (see diagram above). Photograph locations (i.e. the corners of the triangle) may need minor relocation if trees hinder the positioning of the photographs or unnecessarily obscure the potential images. This is the preferred method. However, if using star droppers with three ribs to mark the plot centre, an alternative method to the 2.5 m ropes is to extend a line out from each rib of the central dropper to a distance of 1.45 m, and mark the three end points as photo-location points (see diagram above).
3. Mount the camera on a tripod. Adjust the tripod so the height of the middle of the camera lens is 1.3 m above ground level.

4. Position the camera at one of the corners of the triangle. Adjust the tripod so the camera sits horizontally on it and the 360° photographic sweep will be in a consistent horizontal plane. This assumes the plot area captured within the photograph will have a horizontal land surface (below).

In circumstances where this is not the case (e.g. the crest of a sand dune or the side of a hill, the plane of the photograph should follow the land surface (see below)).





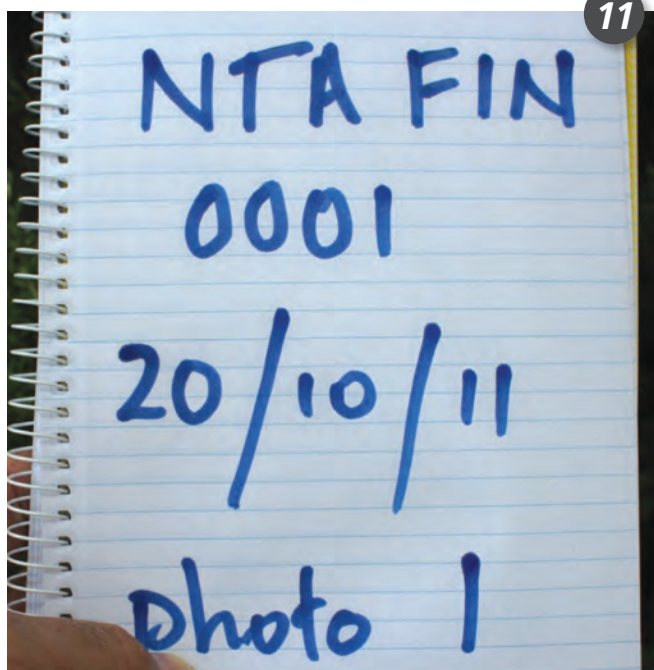
5. Take the GPS location using datum WGS84 (i.e. in eastings and northings).
6. Set the camera to take RAW format (or RAW+JPEG) images (the default will be only JPEG).
7. Set the focal length to 35 mm.
8. Set the aperture to F11.
9. Set the camera ISO to 100
10. To determine the appropriate shutter speed, set the camera to **aperture priority mode**. Point the camera in the four major compass directions while half depressing the shot button to obtain a shutter speed value in each direction. Take the slowest of these, set the camera on **manual** and adjust the shutter speed to this value.  
Set the focus to **automatic**, take a test photo and view it on the screen to ensure it is exposed properly. If still too dark, slow the shutter speed further until the exposure is suitable. Delete the test photo.

*Low shutter speeds will mean that the camera must be kept very stable when taking photographs to avoid blurring.*

**Note: Settings vary for different cameras. It is therefore recommended that until familiar with the camera, the operator refer to the manual for that camera to ensure that the desired settings**

**(fully automatic, manual, RAW format photos, etc) have been successfully achieved.**

11. Keep the focus on **automatic** and take a photo of a sheet of paper with the plot identifiers (Plot – ID, date and photograph number 1, 2 or 3) clearly recorded.
12. Point the camera so that the marker tape 25 cm from the top of the dropper is clearly visible in the frame, slightly above the lower edge of the frame (as shown below). While still on **automatic** focus, half depress the shot button. The camera will focus at a suitable distance. Retain this focus and continue to the next step. Note the location of the horizon in relation to the proportion of sky to ground.
13. Set the focus to **manual** (maintaining the same focus as for the last step) and commence the photographic sequence commencing on the central pole. Ensure the same proportion of sky to ground is maintained as in the previous photographs.
14. Take a sequence of photographs to cover the 360° panorama, rotating the camera in a clockwise direction. Ensure a minimum 30% overlap between successive pictures (i.e. around 40 photographs per panorama). If in doubt, take more photographs rather than less.



15. Move the camera and tripod in a counter clockwise direction to the next corner of the triangle and repeat steps 10 to 14. When re-focussing at this corner, either focus on the same object as previously, or ensure that the line of the horizon has a similar proportion of sky to ground as in the previous photograph.
16. Move the camera and tripod in a counter clockwise direction to the final corner of the triangle and repeat steps 10 to 14. Again, when re-focussing at this corner, either focus on the same object as previously, or ensure that the line of the horizon has a similar proportion of sky to ground as in the previous photographs.
17. Remove the ropes.
18. Photographs can be downloaded onto a field laptop if considered necessary.
19. When the SD card is approaching capacity (i.e. at the completion of a site or a number of sites and ensuring no single site photographs run over more than one card), remove it from the camera, label with site identifiers and forward to:

AusPlots Rangelands  
Terrestrial Ecosystem Research Network (TERN)  
Level 12 Schulz Building  
University of Adelaide  
North Terrace Campus  
Adelaide SA 5051

## Equipment

- SLR digital camera with 15 megapixel memory and able to shoot in RAW format with a 35 mm lens
- Operational manual for the camera
- Spare batteries for camera, or ability to recharge batteries (if rechargeable battery supplied)
- SD cards – 8GB or larger, high speed SD cards, class 6 or ideally class 10, (enables the photographs to be taken faster)
- Tripod at least 1.3 m in height (with an advantage being the ability to be levelled)
- Star dropper (1.8 m in length) marked with tape at 25 cm from the top

- Tape measure (5 m)
- 3 steel tent pegs
- Rope(s) tied to form an equilateral triangle with sides of 2.5 m
- Note book and thick pen
- DGPS

## Resourcing and time requirements

- 1 person
- 20 minutes

## Data Use/ Reason for Collection

The photos taken as part of the photo-panorama method will be uploaded to a server for storage. They will be processed to produce publicly available panoramas for each survey plot. With the use of suitable algorithms, images can also be processed to provide 3D reconstructions of each plot which can be used to monitor change over time to track plot condition as well as providing a unique, fast measurement of basal area and biomass.

## Settings at a glance

- 35 mm focal length
- F11 aperture
- ISO 100
- RAW (or RAW+JPEG) format
- 1.3m height (from centre of lens)
- 1.3m height of dropper, marked 25cm from top
- GPS using WGS84 datum

# 5. Vegetation vouchering – vascular plants

## Guidelines

Recording, collection and identification of vascular flora is a major component of the AusPlots survey methods. The presence of all perennial and annual plant species and cover of individual perennial species and annual species grouped into life form (e.g. annual grasses, forbs, etc) is fundamental information to be recorded at each plot. Plant classification is constantly changing and shifts in species alignments and groupings are made as new evidence comes to light. Identifications are subject to change and voucher specimens help cross-reference these changes to previous research. They also ensure the currency and longevity of the data collected at sites compared to data collected on vegetation at sites in the absence of vouchering. Additionally, it is likely that a number of regions sampled will have been poorly sampled in the past and voucher collections will contribute to both distributional data for a range of species but also assist in refining taxonomy.

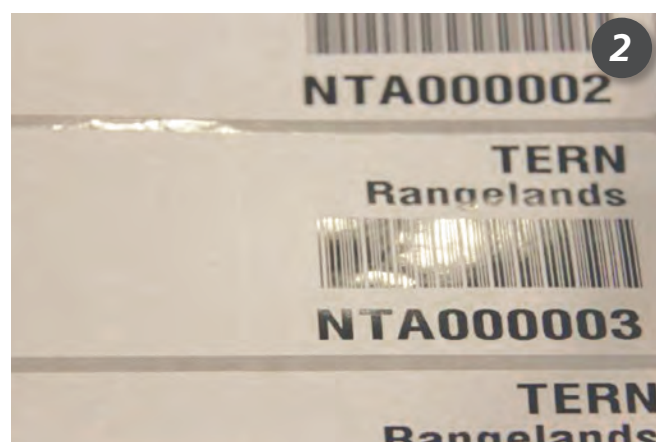
The data and sample collection will be undertaken in collaboration with Australian rangelands jurisdictions. It is intended that plant specimens will be identified by herbarium botanists and a subset of specimens will be included in the respective local herbaria, subject to the standards prescribed by each institution.

## Procedure (see Figure 4)

1. Collect specimens of each different plant species with enough material to fill an A3 size herbarium sheet. Each sample should ideally contain flowers or buds, leaves, fruit, bark (for trees) and should be represented by as few separate pieces as possible. Where possible, ensure young, actively growing material is collected for genetic sub-sampling. During some surveys only sterile or vegetative material will be available - such material is still to be collected. The quantity of leaf material collected needs to be sufficient to enable removal of samples for genetic profiling (see Chapter 6).



2. At the time of collection, tag each specimen securely with a unique voucher label provided by AusPlots. Place the label on stems, away from any plant parts that are needed for examination during the identification process. Use paper envelopes for small specimens, with a voucher label attached to the envelope. Smaller specimens should be represented by a whole plant, including basal material and roots, particularly for Gramineae (Poaceae), Cyperaceae and Juncaceae. For smaller annuals and ephemerals, collect a number of individuals.





3. Scan voucher labels with the field data collection PDA as part of the data collection process. This links the sample to the field name and the field trip (plot details, collection date, collector, etc) and will enable subsequent tracking by the relevant jurisdiction's herbarium or AusPlots on the AusPlots database.
4. The collector will assign a field name to each sample. Where the collector is confident of the identification the assigned name should be a definitive species name. If the plant is unknown to the collector it should be ascribed a descriptive name e.g. "yellow daisy flower". This will also be the field name for the point intercept data collection. Use consistent taxonomy across the rangelands jurisdictions following published names used in APNI (Australian Plant Names Index at <http://www.cpbr.gov.au/databases/apni-about/index.html>.)
5. After labelling and scanning, place larger specimens directly into a plastic bag pending transfer to a plant press. Use paper bags to store individual specimens in the plastic bag to keep specimens separate and avoid contamination/mixing of specimens. To assist in the drying process, especially with wet plants, wrap each specimen with newspaper. Smaller plants

can be kept in a small snap-lock bag with a little paper if the plant is wet until ready to put them in the press.

6. Place each voucher specimen in a plant press in the field, preferably before leaving the plot. At the time of pressing, remove a sub-sample of leaves for genetic analysis (point 9 below), taking care to minimise handling. Specimens must be pressed by the end of each day's field work. Use one folded full tabloid sized newspaper sheet for each specimen and separate with corrugated cardboard dividers frequently, particularly between bulky specimens. Pressing plants in the field ensures that none are lost and improves identification, as diagnostic characters will be better preserved.
7. Change newspaper in the press regularly to prevent specimens becoming mouldy, particularly if the plants were damp when collected or were succulent species. Keep succulent plants in a separate press to facilitate easier changing of paper and reduce the risk of damaging other specimens.
8. Upon return from each trip, deliver voucher specimens to the local herbarium for identification and possible inclusion in herbarium collections. The procedures for lodging specimens for identification vary with each herbarium and are detailed in separate agreements with the herbaria and the Council of the Heads of Australasian Herbaria. Details of agreements that relate to the delivery of samples can be released to collection agencies where this is appropriate.



9. For genetic profiling to enable DNA and isotope analyses, remove adequate leaf material (approximately 10 cm<sup>2</sup>) from each voucher specimen. This process is covered in detail in Chapter 6.

## Equipment

- Secateurs
- Hand trowel
- Paper bags (small) for temporary storage of plant specimens at the plots
- Envelopes for storage of seeds and other small plant material
- Plastic bags (large) for storage and transport of plant specimens at the plots
- Plant presses & straps
- Newspaper (tabloid size) & cardboard (100 x 40 mm)
- Adhesive voucher labels with barcodes
- Plant references for the region
- Field data collection PDA/tablet with data collection app and barcode scanning software

## Time requirements

1 hour, but could be more with high species richness at a plot

## Data Use / Reason for Collection

Systematic collection and identification of voucher specimens across the rangelands will add substantially



to knowledge about the distribution of Australian plant species and groups. This is especially valuable when linked with the vegetation genetic profiles from the leaves collected from each species.

### Barcodes on voucher labels

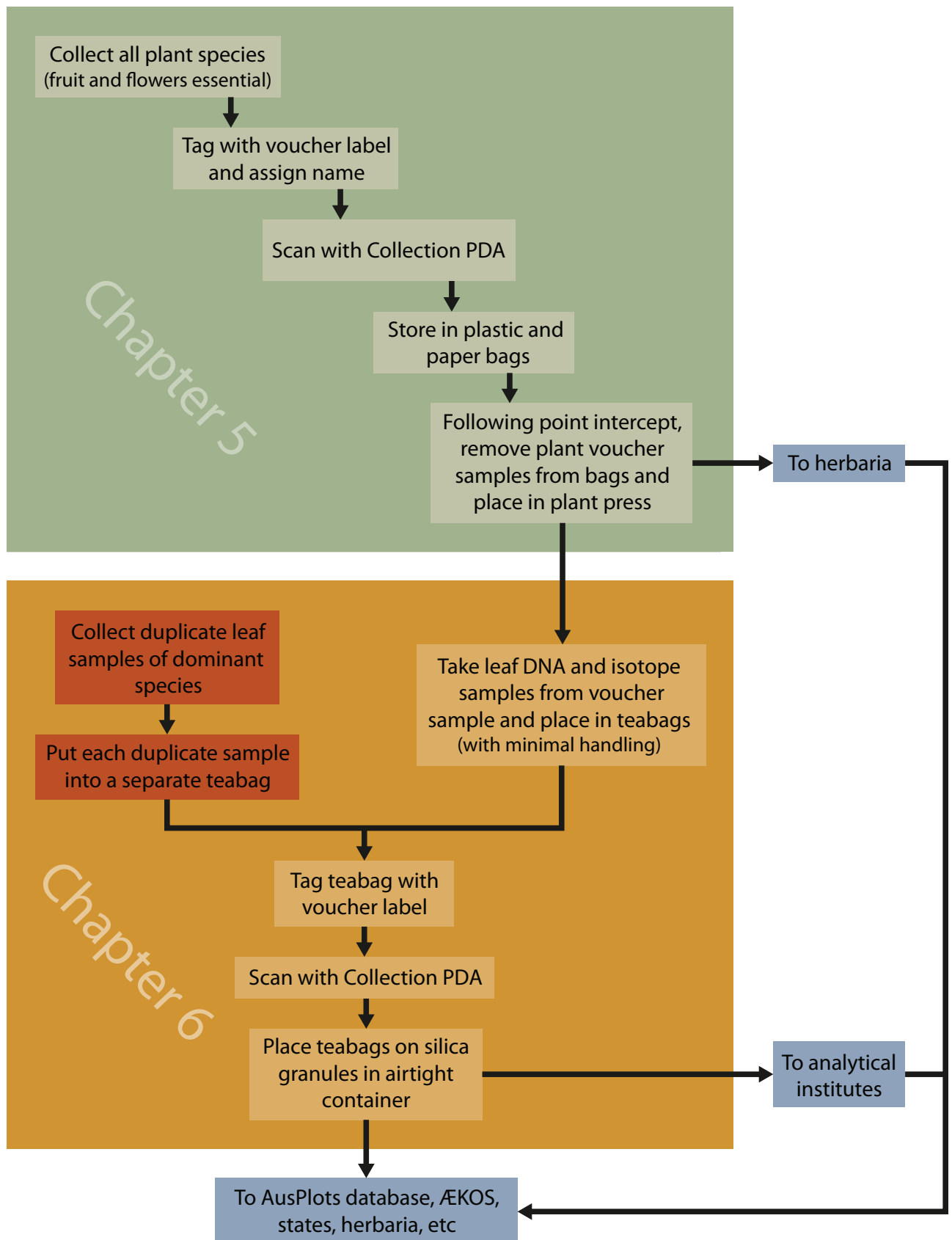
The use of voucher labels with barcodes in the field is an important part of the method that enables samples to be linked and tracked through all stages of collection, processing and storage. The ability to scan the barcodes using the field data collection PDA device and the ability to link these to the data through the app and the database are imperative for the efficient operation of the method. Barcodes will be used to identify:

- each plant voucher specimen,
- the leaf samples collected for genetic profiling (collected as a single sample in the field and subsequently divided into two samples, one for DNA and the other for isotope analyses. At the time of division an additional barcode is assigned to the isotope sample),
- replicate leaf samples from dominant perennial species,
- each soil sample,
- each soil metagenomic sample.

At a plot with 70 plant species, it is possible that almost 300 barcodes could be used for that plot.



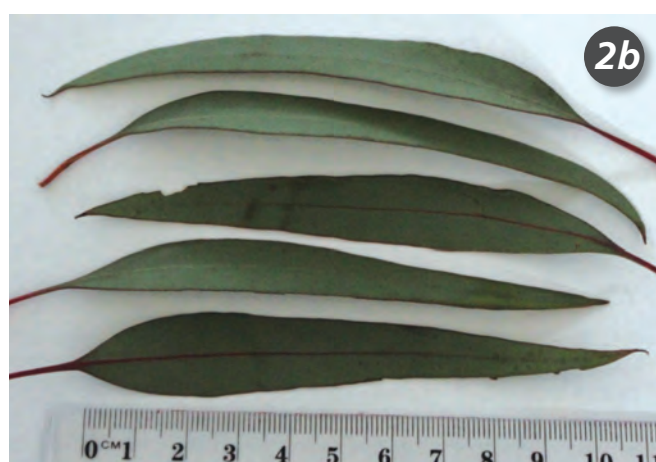
Figure 4. Plant voucher, and genetic and isotope process



# 6. Genetic and isotope sample vouchering

## Guidelines

As part of the AusPlots sampling procedures, leaf samples will be collected from each plant species at each plot and dried to enable subsequent genetic analyses (Figure 4). By collecting these samples in synthetic tea bags and gathering a sufficiently large volume of material, one field sample can be sub-sampled to enable both genetic and isotope analyses to be undertaken. Smaller amounts of replicate leaf samples will also be taken from dominant perennial species present at each site to be used for genetic profiling only (not isotope).



## Procedure

1. Collect voucher specimens as a representative sample of each species occurring at each plot, for identification and lodging in state herbaria (as per the vouchering protocol, Chapter 5).
2. From each voucher specimen, take a small sub-sample (equivalent to around 10 cm<sup>2</sup> or five eucalypt leaves) of green leaves. The collected material should be young and free from disease, insect or fungal contamination wherever possible.

Handle the sample to minimise skin contact and hence contact with other sources of organic carbon (important for the isotope analysis). For broad-leaf plants, hold the leaves by the petiole (leaf stem) or by the base of the leaves for grasses where possible. This sample should then be carefully placed into a synthetic teabag and sealed.

3. Label the teabag with an adhesive voucher label.
4. Scan with the PDA. The app will automatically link it to the plot and provide instructions to link it to the voucher specimen. (This sample will later be sub-sampled by AusPlots staff at the University of Adelaide and part will be used for DNA analysis and part for isotope analysis).
5. Place the teabag in a sealable lunch box with 1 cm of silica granules (10% self indicating mixed with 90% standard non-indicating granules) and seal. If



possible a single lunchbox, clearly labelled with the plot identifier should be used for each plot.

6. Store the container in a cool location out of direct light.
7. Over the duration of a trip replace the silica granules when necessary. When the self-indicating granules change colour from blue to pink their moisture absorbing capacity has been reached and the granule mix should be replaced with fresh silica mix. Do not discard the used silica, as it can be oven dried and re-used.
8. For each dominant perennial species in the plot i.e. FPC >2% or opaque canopy cover >5% ( see Chapter 18: Definitions) collect further leaf material (approximately 5 cm<sup>2</sup>) from an additional four individuals plants of the same species distributed across the plot i.e. a total of four replicates per species.

NOTE: Some plants can appear very variable e.g. mulga (*Acacia aneura* ssp.) and *Senna* spp., and may be difficult to confidently identify. In this instance take replicate samples from what appear to be morphologically different species. It is better to take more samples rather than less as it is preferable to be able to lump many specimens together in the lab (from DNA) rather than trying to separate them based on inadequate specimen numbers.

9. Place the leaf material from each replicate into a new teabag labelled with a new voucher label.
10. Scan the barcode with the data collection PDA to link it to the voucher specimen and plot. Scan replicate 1, followed by the voucher, then replicate 2 followed by the voucher, then replicate 3 and the voucher then replicate 4 and the voucher.
11. Store the teabags in an airtight container on silica granules (as for Step 5).





12. On return from the field, forward the samples to AusPlots at the University of Adelaide. If this is not immediately possible and the collected samples are stored for an extended period before being sent to AusPlots (i.e. weeks), samples should be stored in a freezer at -20°C until forwarding.
13. At the University of Adelaide, the leaf samples taken from the voucher specimens will be divided for both DNA and isotope analyses. All teabag samples will then be forwarded to approved analytical institutions using standard exchange or export/import protocols.

## Equipment

- Tea bags, synthetic or nylon (not paper, cotton) – supplied by AusPlots
- Sealable airtight lunchboxes (e.g. 'Sistema' brand)
- Silica granules: self indicating (10%) and standard (90%) mixed to a combined depth of 1 cm in the box
- Field data collection PDA/tablet with data collection app and barcode scanning software
- Adhesive voucher labels with barcodes

## Time requirements

30 minutes in addition to standard vouchers

## Data Use / Reason for Collection

DNA barcoding is a system designed to provide rapid, accurate, and automatable species identifications by

using short, standardised gene regions as internal species identifiers. As a consequence, it will make the Linnaean taxonomic system more accessible, with benefits to ecologists and conservationists. By collecting multiple samples of dominant species within a plot and from different plots across regions and IBRA bioregions, variability in plant DNA can be determined. AusPlots represents the first attempt to undertake continental scale sampling to provide valuable genetic information on species and population connectivity and diversity both at fine and broad scales. This information is important for modelling communities.

Isotope analysis is conducted to find accurate information of carbon and nitrogen content of the leaves of the specimens. Collections at the plot scale and across regions and IBRA bioregions provide the opportunity for scale-based comparisons. Carbon isotopes vary depending on stress levels of a plant in a given locality. Relative to other localities and other species, isotopes will provide an indication of where a plant is best adapted, where it is struggling and how this adaptation varies between and within species.

Isotope measures can also be combined with other data from the plant, such as physical signs of stress, morphological and genetic variations. These data can inform models of how each species will be affected by climate change. For a given area, it may be possible to predict which species are more likely to become extinct locally (i.e. those that are already struggling), and which are more likely to persevere.



# 7. Point intercept

## Guidelines

The point intercept method is a rapid, repeatable and accurate method for quantifying cover of individual plant species and total vegetation cover as well as substrate types (e.g. bare soil, litter, rocks or biological soil crusts) and height of lower, mid and upper level vegetation strata. With this method, cover is measured along linear transects and is based on the number of “hits” for each plant species or substrate type from the total number of points measured along all transects.

The point intercept method is used when precise, repeatable measurements of vegetation and substrate are required. References relevant to the rangelands indicate that a minimum of 1,000 points are required for robust measurements to characterise species within a plot and enable determination of species change (e.g. Lodge and Gleeson 1979; Friedel and Shaw 1987a and b; Watson and Novelty 2004; Vittoz and Guisan 2007; Stehman *et al.* 2009).



## Procedure

The plot arrangement is described in Chapter 3 Plot layout/positioning. The data collection app assumes a standard 100 m x 100 m plot is used. Where site factors make this unachievable, it is recommended that data sheets be used for the point intercept method.

1. For each transect lay out a 100 m tape or graduated cord between the start and end points/pegs. Ensure the tape is:
  - orientated to align with the grid,
  - straight, and
  - on the ground (where possible) and not draped over shrubs.
2. Using a staff with laser pointer mounted on the pole at a height of 1.5 m and densitometer at the top of the pole (for plots with upper storey), start at the 0 m mark of the first transect. Place the bottom of the staff at the 0 m mark, ensure the staff is vertical and the laser pointer is pointing downwards and the track of the laser pointer is parallel with the direction of the transect.





3. Press the button on the laser pointer to determine the substrate at the point of contact of the laser beam and the vegetation the laser beam intersects with (below 1.5 m).
4. If the beam intersects with vegetation or litter whilst recording substrate, move the vegetation aside to determine what the beam contacts at the ground surface/substrate level. Record the substrate using the mobile PDA. Substrate categories listed on the app are:
  - bare (bare soil);
  - outcrop/bedrock
  - rock (particles < 20 cm) ;
  - gravel (particles 2 mm to 2 cm);
  - Crypto – cryptogam (any lichen, moss, algae etc.) present on the soil surface with a different colour to the base soil);
  - litter: dead vegetation not attached and not identifiable; if litter is attached and identifiable as a species, it should be recorded as this species but flagged as being dead);
  - CWD – coarse woody debris (detached wood with > 10 cm diameter at the intercept point); and
  - unknown.
5. Where the laser beam intersects with a plant, its uppermost height at the point of intersection is recorded (estimated to the nearest cm from the graduations marked on the staff) along with species name and growth form. If the species has not been collected during the vouchering process (see Chapter 5) or the identification is uncertain, record a field name and collect a voucher specimen. Species names are listed on the app to facilitate data collection. Continue recording all plant species (and height) that intersect with the beam to 1.5 m.
6. Record all plants (species and uppermost height) that the staff touches between the laser pointer (1.5 m) and the densitometer (eye level).
7. The densitometer is used to view canopy intercepts (i.e. intercepts taller than the densitometer). Look through the densitometer to determine whether any portion of a tree or shrub crown intersects the vertical line of sight through the densitometer. The vertical line of sight is obtained by levelling both of the densitometer bubble-levels and then sighting through the instrument so that the sighting marks are aligned (cross-hairs/circle in the far lens is at the centre of the circle in the near lens).



If foliage or branches are sighted in the cross hairs, record each species name and provide an estimate of the height of that species at the uppermost intercept. If no part of the foliage or branches are sighted in the cross hairs but the vertical line is still within the canopy boundary, record as “**in-canopy sky**” (see Figure 5). When the tree is dead, in-canopy sky is not recorded. Where the vertical line projects on to bare sky that is not within a canopy then nothing is recorded for the upper stratum.

Bright sunlight may make viewing difficult through the lenses. A coloured cellophane sheet placed over the top of the densitometer with a rubber band can help alleviate this.

8. Continue recording the same information (as per points 3 to 7) at each 1 m interval along each of the 10 transects, laying out the tape for each transect. This will give a total of 1010 points for each plot (i.e. 10 transects x 101 points per transect).
9. At the completion of point intercept data collection, save the data by selecting ‘**Save all transects to SD card**’ (either JSON or CSV).
10. Data can be stored on the microSD card or uploaded to the AusPlots database when in 3G coverage.



On the main screen, select ‘**manage plot**’;  
on the plot screen select ‘**upload and close off plot**’. An activity symbol is displayed. If 3G coverage is not available, the data will be saved to the microSD card.

## Equipment

- 100 m tape/s or non-stretch cord marked with 1 m graduations
- Graduated staff (extendable pole that can be adjusted to eye height for different operators)
- Densitometer with ability to be mounted on top of staff (required for use on plots with over-storey tree canopy cover)
- Laser pointer (taped to staff at approx 1.5 m and pointing downwards)
- Field data collection PDA/tablet with AusPlots data collection app and camera to scan barcodes
- Star droppers to mark plot corners (should have already been completed as detailed in Chapter 3)
- Pegs to mark ends of transects
- Flagging tape (brightly coloured to make sighting transect ends easier)





## Time requirements

3-6 hours depending on richness and complexity of vegetation.

## Data Use / Reason for Collection

The point intercept method is a straightforward method that is readily repeatable and requires little instruction to produce reliable plot information. It provides accurate benchmark data at each plot including substrate type and cover; as well as species structural information such as growth form, height, cover, abundance and population vertical structure.

The demographic information produced at each plot can be compared spatially to indicate plot differences, and temporally to indicate change over time. Additionally, the cover data collected at each plot can be used to validate cover data extrapolated through remote sensing techniques.

Due to the diversity in vegetation expected across the rangelands, 1000 intercept points are considered the minimum count per plot needed to reliably characterise vegetation (Lodge and Gleeson 1979; Friedel and Shaw 1987a and b; Watson and Novelty 2004; Vittoz and Guisan 2007; Stehman *et al.* 2009).

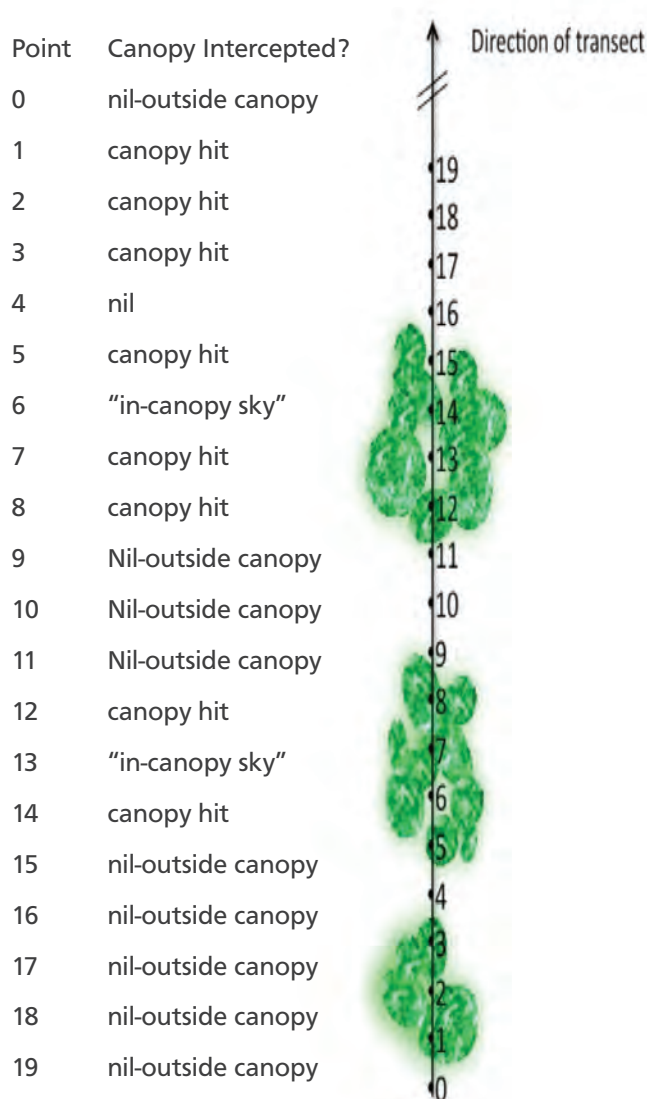
## In-canopy sky

The canopy perimeter, from an aerial or vertical perspective, is typically described by the extent of the outer layer of leaves of an individual tree or shrub. Within the canopy, openness or density of foliage varies considerably depending on species and leaf shape. For Australian vegetation, canopy density is typically between 40 and 70%. Figure 5 describes when to apply "in-canopy sky".

When under a canopy use the densitometer to view the canopy at each metre along the transect (e.g. Figure 5):

- if foliage or branches are not intercepted (points 6, 13) it is recorded as "in-canopy sky"
- If foliage or branches are intercepted (points 1, 2, 3, 5, 7, 8, 12, 14) the species is recorded as a canopy hit and an estimate of the height is recorded.

Figure 5. When to apply "in-canopy" sky



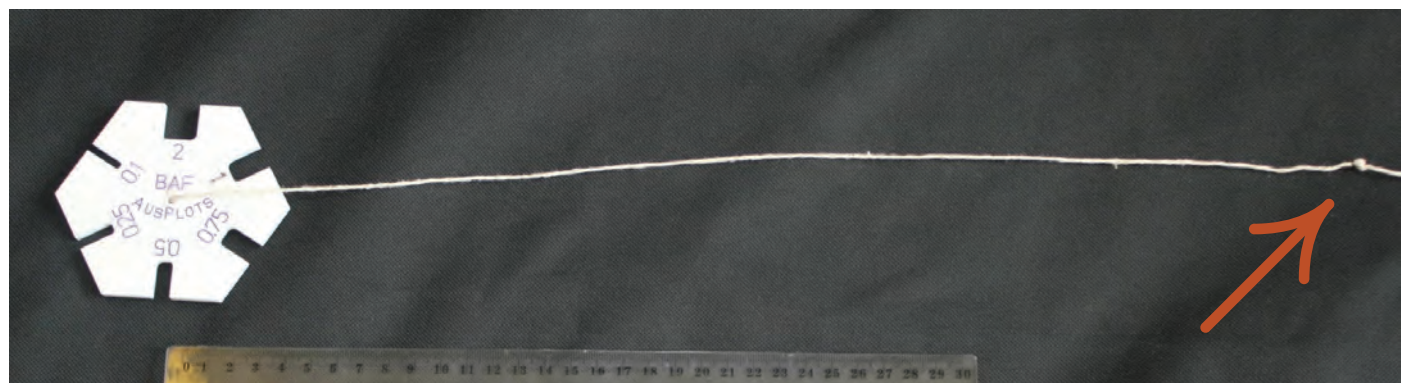
## 8. Basal area

### Guidelines

Use of a basal wedge is a rapid and simple method to determine basal area of trees and shrubs. Basal area is the cross-sectional area of all the trees and shrubs at breast height (1.3 m, or nearest point above if there is a deformity at 1.3 m) per hectare ( $\text{m}^2/\text{ha}$ ). Using a basal wedge extends the area sampled beyond the actual 1 ha plot to provide a good approximation of basal area for each species and total basal area in the vegetation type surrounding the plot. Plants outside the plot are included to better represent the broader vegetation community where tree species are homogeneous at scales  $> 1$  ha. Basal area can also be used to calculate biomass based on allometric equations.



*A basal wedge used to determine basal area*



*A basal wedge, with string attached. The string is knotted at 50cm for use in the AusPlots Rangeland survey protocols*

### *Should we use the basal wedge at this plot?*

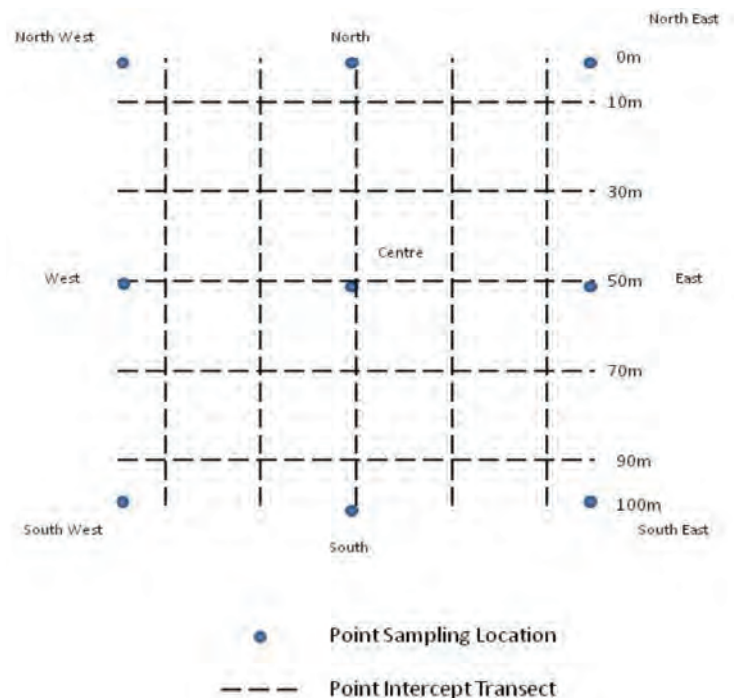
- Is there a dominant growth form of tree, shrub or mallee?

No – Do not use the basal wedge

Yes – Do any of the species record at least seven hits (see point 5 below) for any of the basal wedge apertures at any of the point sampling locations?

Yes – Use the basal wedge at the plot

No – Do not use the basal wedge at the plot



## Procedure:

Basal wedge measures are taken at each of the 9 sampling locations throughout the quadrat, i.e. the NW, N, NE, W, E, SW, S, and SE points around the perimeter of the plot and the centre of the plot (see Point Sampling Locations in the plot layout diagram above).

1. Determine if use of the basal wedge is warranted at the plot i.e. are there sufficient stems of trees or tall shrubs that are large enough to produce greater than 7 "hits" for any species (see point 5).
2. Stand at one of the 9 point sampling locations (see plot layout above).
3. Hold the end knot of the 50 cm length of string attached to the wedge on your cheek below one eye. Close the other eye.
4. Hold the wedge so that the string is taut.
5. Establish which of the six wedge apertures (0.1, 0.25, 0.5, 0.75, 1 and 2) to use for each individual species. This is determined by undertaking a brief sweep across the site to determine the largest of the apertures that will achieve greater than 7 "hits" for a species. A hit is achieved when a stem or trunk, at breast height (1.3 m, or nearest point above if there is a deformity at 1.3 m), is wider than the chosen aperture. A minimum of 7 hits is needed for the results to be meaningful. Selecting the largest suitable aperture increases efficiency as it reduces the number of hits likely to be recorded.



6. Once you have chosen the appropriate wedge aperture for a species, at a sampling point rotate through a complete 360° sweep and, looking through the eye above the string, count the number of stems or trunks of that species, at breast height, that are wider than the chosen aperture as a hit.

Using the same wedge aperture, where the stem or trunk is exactly the same width as the aperture, count this as half a hit.



+ 1



+1/2



0

*These photographs show stem widths in relation to basal wedge apertures*



Using the same wedge aperture, where the trunk is narrower than the aperture, this is not counted as a hit.

**Note:** the three photographs on the previous page illustrate stem widths relative to wedge apertures – to be included in a 360° sweep the aperture used to score a species would need to be consistent. Record the number of “hits” per species and the wedge factor (aperture size) at each point sampling location.

7. It is more more efficient if the same wedge factor is used for a species at all sampling locations (and for all species), however this is not always practicable.

## Equipment:

- Basal Wedge with attached string knotted at 50 cm from the wedge (for AusPlots wedge)
- Pen and notebook for recording basal wedge details
- Field data collection PDA/tablet with data collection app and barcode scanning software

## Time requirements:

Up to 20 minutes per plot

## Data Use / Reason for Collection:

Basal area provides information useful for calculating biomass and carbon levels and for structural studies.

The wedge aperture, the length of string – 50 cm (and hence the distance from the eye and subsequent angle from the eye to the edges of the wedge aperture) and species count are all important in calculations.

Algorithms developed for use with the basal wedge include the above data to calculate plant basal area on a per hectare basis even though species are counted outside the one hectare plot area. The method is plot-less but used because it is based on the concept of circles (trunks/basal area) within circles (circular plots) – the area of one varies proportionally to the change in the area of the other.

Use of the basal wedge may be superceded by further improvement of the 3D photopoint method and development of algorithms to provide information on vegetation community structure. Please check the latest updates from AusPlots Rangelands at University of Adelaide:

[www.tern.org.au/AusPlots-Rangelands-pg17871.html](http://www.tern.org.au/AusPlots-Rangelands-pg17871.html)

# 9. Structural summary and homogeneity

## Guidelines

Whilst the point intercept measures across the plot are informative on structure, most common methods to quantify structure measure dominant species per stratum. Defining strata is an intuitive assessment by a skilled ecologist and it is difficult to create this structural summary from the point intercept data. Ecosystem structure is usually defined in terms of vegetation structural attributes and structural complexity.

It is recommended that a structural summary be completed once the other vegetation work at the plot has been completed. This is because the other information recorded at the plot will inform the structural summary and significantly speed up the process of providing the structural summary.

## Procedure

For each of the three vegetation strata (Table 3; upper, middle and lower) nominate in descending order the

three most dominant species in each strata. All the additional parameters to inform NVIS level 5 can be obtained from the other information recorded at the plot.

## Equipment

Field data collection PDA/tablet with data collection app and barcode scanning software

## Time requirements

Five minutes at completion of the other site data collection.

## Data Use / Reason for Collection

To provide NVIS level 5 (association level) vegetation structural description.

Table 3. Stratum types and growth forms allowed within each stratum type

Stratum type	Growth forms	Not allowed
upper	trees, tree mallee	grasses, shrubs, low mallee, shrubs
middle	shrubs, low trees, mallee shrubs, tall grasses, grass trees	mid and low grasses, sedges, rushes
ground	grasses, forbs, rushes, sedges, lichens, low shrubs, ferns, grass trees	trees, tree mallees

## Plot homogeneity

A “homogeneity measure” is recorded for each site. The homogeneity measure is defined as “a record of the visual estimate (in metres) of the shortest distance from the plot centre to a vegetation community different to the one that you are sampling in”. Where there is uncertainty, it is recommended that this measure be an under-estimate, so be conservative in estimating the distance. Where it is not possible to directly observe the distance to a different community, then estimate the furthest distance that you are sure is the same community as the one you are sampling within.

# 10. Leaf Area Index (LAI)

## Guidelines

The LAI-2200 is an instrument that calculates Leaf Area Index (LAI) at a plot by using a fish eye lens and calculating canopy light interception at 5 zenith angles (Licor manual). It does this by comparing the amount of light intercepted with an above canopy reference.

The LAI meter should be used for an AusPlots plot in areas with canopy cover. Its use is optional for SLATS plots. As there are only a limited number of instruments, determine the availability of an LAI-2200 well before any particular trip.

### *Should we use the LAI at this plot?*

- Is there a dominant growth form of all classes of trees, shrubs or mallee greater than 2 m tall?

Yes – Use LAI meter and collect 50 points;

No – Use of the LAI meter is inappropriate – do not use

### *What are the right light conditions for use?*

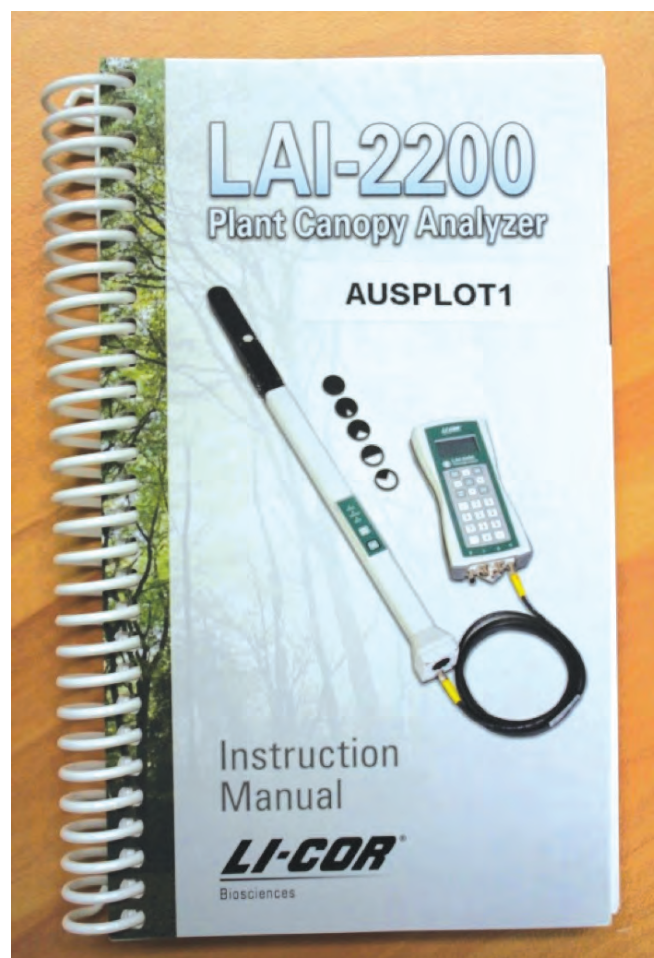
The LAI-2200 is best used when the sun is obscured. It is important to avoid taking measurements in direct sunlight, so the best times are at sunrise, sunset or under homogeneous cloud cover that provides diffuse light. It is possible to take measurements under different light conditions, but it is far more complex. If it is not possible to take measurements in diffuse light it is suggested that pages 4-11 to 4-14 of the LAI instruction manual be referred to (provided with the instrument in the storage case).



*The LAI-2200 used in the AusPlots Rangelands Survey Protocols*

## Procedure

Prior to the survey, the batteries in the LAI meter will be replaced and it will be confirmed that the device is correctly storing the date and time. This will be done by Adelaide AusPlots staff if the device is to be delivered from Adelaide. Otherwise the local team will replace batteries and ensure the meter is working correctly. (If an LAI is to be sourced from elsewhere the owner of that particular device needs to confirm the compatibility of the device settings for recording AusPlots data). With this done, it should then only be necessary to use the wand as specified.

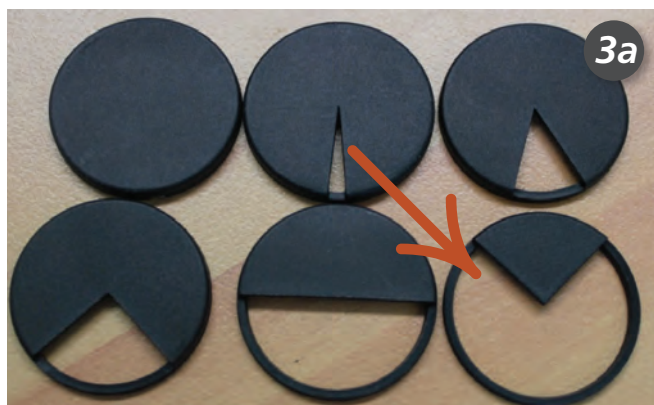
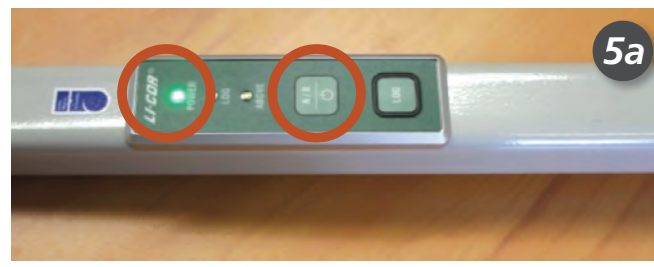


*Instruction manual for the LAI-2200*

1. Remove the LAI-2200 wand from the storage case.
2. Carefully remove the full lens cap, ensuring not to touch the lens.
3. In the small black spares box stored in the case, choose the lens cover with only 25% blocked out. Place this on the lens with the blocked out area closest to the operator i.e. in line with the handle of the meter. This lens obscures the operator when taking measurements thereby ensuring their image is not included in the LAI calculation.

**It is important that this cover is in place for both the 'above' or 'A' canopy references and the 'below' or 'B' canopy samples.**

4. Find a reference area where the sky is not obscured, remembering that the device has a wide field of view (as a rule of thumb ensure that the distance to the closest vegetation is three times the height of that vegetation).
5. Turn the wand on by pressing the A/B (on/off) button until the power (green) light comes on.
6. Ensure the 'above' light on the device is on i.e. the blue colour is illuminated. This is achieved by pressing the A/B (on/off) button to toggle between 'above - A' (blue colour) or 'below - B' (no colour).
7. In the area clear of canopy i.e. the sky is not obscured (remembering the LAI meter has a wide field of view), bend the head of the wand so that





it is pointing upwards. Ensure the device is level by checking the bubble gauge, raise the wand above your head and press the log button once. The orange 'log' light will illuminate briefly and the device will beep twice, once at the start and once at the end of the sample. Each sample will only take a second or so.

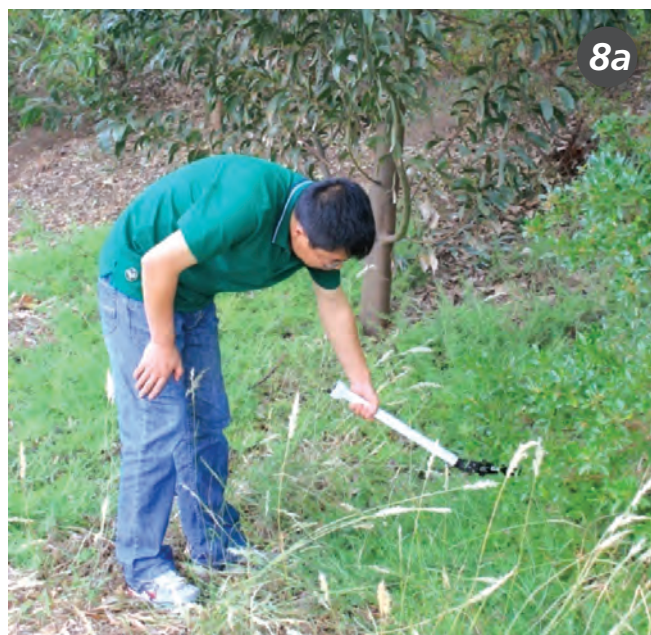
**Orientation of the wand needs to be consistent when taking all measurements including in the canopy.**

8. Now return to the plot and start sampling. To take samples bend the head of the wand in the other direction. Place the head of the wand slightly above ground level and ensure the device is level i.e. the bubble is within the circle on the gauge. To take the first sample ensure the blue above light is no longer illuminated (may require pressing of the A/B (on/off) button) and then for each sample simply press the log button once. Repeat this process across the plot until the samples are completed, ensuring all canopy cover levels are included in the samples.

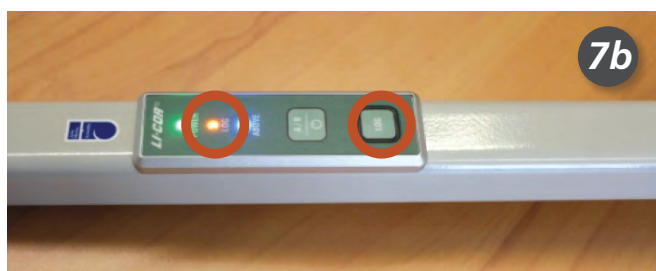
For 50 points sample along the north/south transects and take 10 measures along each transect i.e. take measures at 10 m intervals along each transect.



7a



8a



7b



8b

9. Once the plot is finished, return to the cleared area and once again log a further above point. Press the A/B (on/off) button until the blue light is illuminated, place the wand overhead and press the log button.
10. Turn the wand off by holding down the A/B (on/off) button.
11. Take the 25% lens cap off and replace it with the full cover. Return the 25% lens cap to the box and replace in the storage case.
12. Replace the wand in the storage case.
13. Record the date and time range for the sampling. This can be done by pressing the LAI button on the app if not already collected by the app.
14. After the trip return the LAI to AusPlots (University of Adelaide) along with the date, time, plot name and location information so the collected data can be linked back to the plot.
15. On return of the LAI meter to AusPlots (University of Adelaide) the collected data will be downloaded.

## Equipment

- LAI-2200 storage case containing all the required equipment
- Pen, paper or notebook as backup to record date, time and plot details
- Field data collection PDA/tablet with data collection app and barcode scanning software

## Time requirements

2.5 m canopy – 10 to 20 minutes.

## Data Use / Reason for Collection

LAI is an internationally used measure of the ratio of leaf area to ground area at a given location. As it is a ratio it has no units, however it provides information on productivity. Commonly, remote sensing products calculate LAI, but these measures need equivalent field measures for calibration and validation and to determine their accuracy. The LAI measures obtained through AusPlots will provide a range of such field measures. Additionally, the field LAI measures will assist in calibrating between LAI and foliage projected cover (FPC) remote sensing products and understanding the field relationship between LAI and FPC (as gathered by the point intercept method) in different community types.

# 11. Soils and Landscapes

## Guidelines

Large swathes of the Australian rangelands have limited or no soils information. The AusPlots Rangelands survey results and collected samples will be a valuable resource to help resolve this. When the recommendation is to sample to 30 cm or to 1 m, every effort should be made to satisfy these requirements, however, after three failed attempts, (curtailed due to rock, hardpan, water etc.) then the attempt should be abandoned and the reason documented. (If subsequent analyses of limited samples collected from a plot indicate the plot(s) to be of particular interest, then future surveys can target these areas and additional equipment included to facilitate soil characterisation).

The soil samples will be stored in collaboration with the CSIRO National Soil Archive in Canberra. The samples represent a considerable and important addition to the national collection. A number of the collected samples will have preliminary chemical and/or mid infrared spectroscopy analyses and all samples will be available for future description and analyses as per National Soil Archive guidelines.

The recommended soil surveys and samples collected are based on a spatial hierarchy across each 1 ha plot. A 25 x 25 m focus area will be located in the southwest corner of the AusPlots plot, and is consistent with SCaRP (Soil Carbon Research Program), National Soil Condition Monitoring protocols and developing national ASRIS (Australian Soil Resource Information System), TERN Soils Facility and international soil data products (e.g. Global Soil Map). Additional sampling will be spread across the remainder of the plot to extend the coverage to enable a better representation of plot variability in the rangelands.

Transport of soil and plant samples across state borders must satisfy relevant quarantine requirements.

The five separate activities that occur within the soils survey and sampling processes:

- a) Plot description
- b) Soil characterisation to 1m+- pit/core/samples

- c) Soils observations across the plot – 9 cores to 30 cm
- d) Soil bulk densities are covered in different sections within this chapter

as well as the processes dealing with:

- e) Soil samples

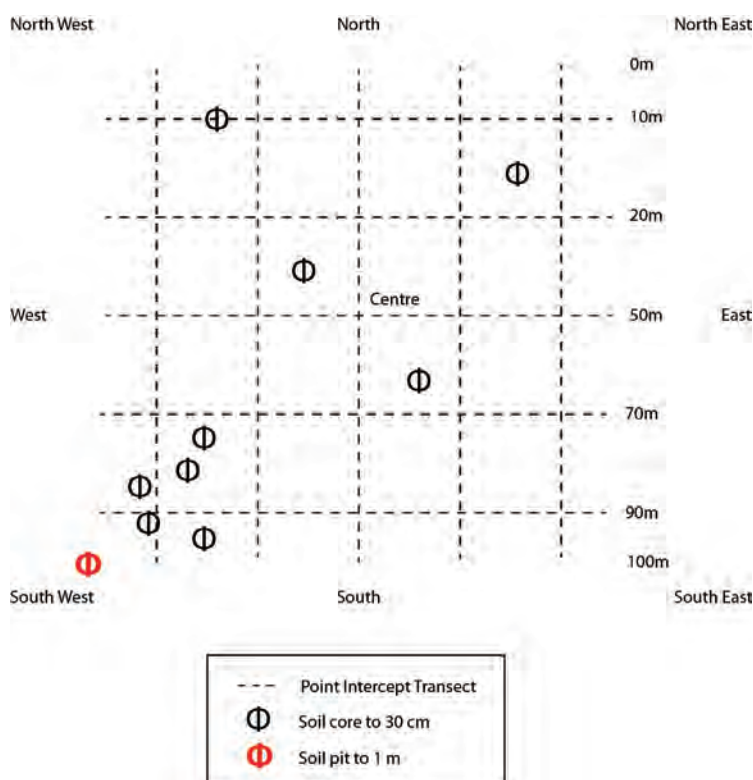
***The activities undertaken for all these (but especially 11b) will depend on the level of knowledge and experience of the field operator. People with experience in collecting or describing soils (pedologists), are able to undertake more detailed descriptions in the field, this being the preferred approach. A less experienced operator can collect samples for more detailed descriptions back in the lab, but some site-based descriptions e.g. profile characteristics, are not possible. This chapter details the essential soil survey methods, while Appendix 3 details the procedures and descriptions possible when a pedologist undertakes the surveys.***

The soils survey process and soils description are based on the third edition (2009) of the “Australian Soil and Land Survey Field Handbook”, referred to as the “Yellow Book”. Relevant pages are listed in brackets (YB) on the field data collection sheets and in the data collection app for reference when describing different aspects of the soils.

## Background Information

On the field data app, some background information will be collected automatically, but on the data sheets the following information must be recorded:

- State
- Agency
- Project (AusPlots Rangelands)
- Date
- Described by (name of person/s collecting the information)
- Location description – a general description to assist with plot re-location e.g. 3.2 km southwest of “Deadcat bore” 100 m to the north of the track



**Figure 6. An AusPlots Rangelands survey plot, with the preferred orientation, layout of the 10 point intercept transects and indicative locations of the soil pit and 9 soil cores to 30 cm across the plot. (Refer to the text for guidelines on the location of these 9 cores).**

## A) PLOT DESCRIPTION

The plot description covers important aspects of the plot (generally of the land surface) not recorded in the preliminary description. Some overlap in collected information does occur due to the modular nature of the survey processes. The description provides significant background information to gain an appreciation of the plot history, topography, position in the landscape and for understanding the likely relationship between the soils, vegetation and fauna.

Parts of the process are essential and must be undertaken in the field, whereas other parts can be completed at a later stage from samples collected (see Appendix 3(a)).

### Plot Name

Described in Plot Naming Convention (Chapter 3 and Appendix 1)

### Plot location

Plot location at SW corner:

The PDA will automatically record GPS coordinates.

If using data sheets, record the easting, northing, zone and datum from the DGPS.

Also record the method used to record the location i.e. standard GPS or DGPS (differential GPS) by circling the appropriate method.

### Erosion

Erosion (YB p133-139) refers to accelerated/induced erosion rather than natural erosion.

If present, use the codes below to describe the

- type of erosion
  - » wind-W
  - » scald-C
  - » mass movement-M
  - » water
    - › sheet-S
    - › rill-R
    - › gully-G
    - › tunnel-T
    - › stream bank-B
    - › wave erosion-V
- state of erosion:
  - » active-A
  - » stabilised-S
  - » partly stabilised-P
- extent of erosion:
  - » not apparent-X
  - » none-0
  - » minor/present-1
  - » moderate-2
  - » severe-3
  - » very severe-4



## Microrelief

Microrelief (YB p129-133) refers to relief up to a few metres above the plane of the land surface.

Type should be indicated:

- Gilgai (YB p129)
  - » crabhole gilgai-C
  - » normal gilgai-N
  - » linear gilgai-L
  - » lattice gilgai-A
  - » melonhole gilgai-M
  - » contour gilgai-G
- Hummocky relief (YB p130)
  - » debil-debil-D
  - » swamp hummock-W
- Biotic relief (YB p131)
  - » ant mound-J
  - » termite mound-X
  - » rabbit warrens-Y
  - » pig disturbance-B
  - » vegetation-V
- Other (YB p132)
  - » mound/depression-U
  - » karst microrelief-K
  - » sinkhole-I
  - » mass movement microrelief-S
  - » terracettes-R
  - » contour trench-T
  - » spring mound-P
  - » spring hollow-H
  - » other-O
- No microrelief-Z (YB p129)

Proportion of gilgai components (p130)

- » mound=depression, no shelf-A
- » mound>depression, no shelf-B
- » mound<depression, no shelf-C
- » mound, shelf and depression, shelf a prominent part of gilgai-D

Component of microrelief sampled (YB p133)

- » mound-M

- » elongate mound-E
- » depression-D
- » elongate depression-L
- » shelf-S
- » flat-F
- » hummock-K

## Drainage

(YB p202-204) Provide a statement about soils and plot drainage likely to occur in most years

- very poorly drained-1
- poorly drained-2
- imperfectly drained-3
- moderately well drained-4
- well drained-5
- rapidly drained-6

## Disturbance of plot

(YB p128)

- 0-no effective disturbance, natural
- 1-no effective disturbance except grazed by hoofed animals
  - » 1L-light grazing
  - » 1M-medium grazing
  - » 1H-heavy grazing
- 2-limited clearing (e.g. selective logging)
- 3-extensive clearing
- 4-complete clearing, pasture improved but not cultivated
- 5-complete clearing, pasture improved and cultivated at some stage
- 6-cultivation, rain-fed
- 7-cultivation, irrigated past or present
- 8-highly disturbed (e.g. quarry, mining, landfill, road works)

## Soil surface condition *when dry*

(YB p189-191)

Many surface soils have a characteristic appearance when dry and this should be recorded.

- Cracking-G
- Self-mulching-M

- Loose-L
- Soft-S
- Firm-F
- Hard setting-H
- Surface crust-C
- Surface flake-X
- Cryptogam-Y
- Trampled-T
- Poached-P
- Recently cultivated-R
- Saline-Z
- Sandy veneer-V
- other-O

## Procedure

Each of these characteristics is to be described for the plot. This can be done once the plot boundaries have been decided and marked out. The sequence for descriptions will be based on the data collection app, with fields to be filled out. The plot characteristics (see quoted YB page numbers) are based on the description contained in the third edition (2009) of the “Australian Soil and Land Survey Field Handbook” commonly

referred to as the “Yellow Book” (see Appendix 3 for collection of additional non-essential soil description elements).

## B) SOIL CHARACTERISATION TO 1 M+

As close as possible to the southwest corner of the AusPlots plot (i.e. outside and immediately adjacent to the plot), characterise the soils by exposing the profile to a depth of 1 m+ by:

1. digging a pit, or
2. using a core tube or hand auger to collect soils and laying out the profile, or
3. collecting a 500 g sample from 10 cm increments down the profile to 1 m+ (by hand auger or pit).

The minimum requirement for AusPlots Rangelands sampling is to collect a sample of at least 500 g of soil from 10 cm incremental layers down the soil profile, taking care not to sample across horizon boundaries. Record horizon boundaries and their depths, as well as sampling depths. Samples to be placed in zip lock bags avoiding (as much as possible) disruption to any peds or aggregates. If the soils contain coarse fragments they should also be included as part of the sample and the



*Mallee soil from Calperum supersite*



*Floodplain soil from Calperum supersite*

size of the overall sample increased to ensure that there is at least 500 g of soil.

At some later date the extracted soil samples could be laid out in sequence to produce a profile which can then be described in terms of morphology and chemical properties in accordance with “the Yellow Book” 3rd edition, 2009.

The preferred approach is to engage a pedologist to undertake the sampling. The exposed soil profile can be characterised in situ (methods 1 and 2) to derive an understanding of the physical properties of the soil along the profile (e.g. arrangement of layers, root penetration, water penetration and storage, profile drainage and aeration) which are of prime importance in understanding ecological responsiveness. Samples (500 g) should be collected within each horizon. Where depth of a horizon exceeds 30 cm, collect samples from within each 30 cm and label appropriately.

An expensive option to characterise the plot is to transport an intact soil core (obtained using a soil corer and transported carefully) to a pedologist. It is not the intention of AusPlots surveys to attempt to collect or transport intact profiles.

## Procedure

The minimum requirement is to collect 500 g samples in 10 cm increments down the soil profile to a depth of 1 m+ where possible.

For the soil characterisation at the SW corner of each plot the type of observation needs to be recorded, and if it was stopped, what caused the stoppage, the depth characterised and details of any obvious soil profiles.

If a pit is to be dug and photographed ensure the pit is aligned to maximise illumination of the pit face to be photographed at the time of photographing.

### Type of soil observation

Choose from the following categories

- soil pit – P
- auger boring – A
- existing vertical exposure – E (not always reliable)
- relatively undisturbed soil core – C
- 10 cm samples – S (need to record how the samples were extracted i.e. P, A, E, C)

### Stopped by

- rock-R
- gravel-G
- too hard-D
- hard pan-H
- too wet-W
- too loose-L



*Identifying soil horizons*



*Collecting samples along the soil profile*



*Digging a pit to expose the soil profile*



At the different depths descriptions should include:

#### Depth

Indicate the upper and lower depth of each specimen, measured from the soil surface e.g. 0-10 cm, 20-30 cm

#### Horizon (YB p148-158)

A soil horizon is a layer of soil approximately parallel to the land surface with morphological properties different from layers below and/or above it. Horizons can be described in the field by a pedologist from a pit, core or exposure. If 500 g soil samples are collected for analysis and description back at the lab, care should be taken to not collect samples across horizons (where possible) and bags should be labelled accordingly.

(See Appendix 3 for collection of additional non-essential soil characterisation elements.)

## C) SOIL OBSERVATIONS

Locate nine 30 cm deep soil cores or small pits across the plot, five within a 25 m x 25 m zone in the south west corner of the plot and the remaining four cores spread across the plot. Location of the five cores within the 25 m x 25 m zone should cover the entire range of vegetation types, cover classes and litter classes e.g. from bare ground to dense litter, through sparse cover of ephemerals or grasses or forbs, to dense cover of forbs, grasses, trees etc. If the core is positioned relative to a tree the distance from the tree stem/s should be recorded in the comments. Likewise the remaining 4 cores across the rest of the plot should also attempt to cover diversity present in vegetation and cover.



## Procedure

All nine soil cores should be to a depth of 30 cm unless stopped by rock, calcrete pans etc, in which case the reason for not attaining the 30 cm depth should be recorded on the app or data sheet.

1. Collect a 500 g soil sample at each depth increment of 0-10 cm; 10-20 cm; and 20-30 cm.
2. Bag each sample in a large plastic bag labelled with the unique sample barcode and record a plot general description (e.g. bare soil, % cryptogam cover, adjacent perennial grass, under shrub, under tree etc.) and record GPS location on the field data collection app (or sheet).
3. Photograph the bags with the three soil samples and the 30 cm pit or the area around the auger hole to indicate the type of cover and vegetation sampled at that observation.
4. On return to the lab, dry all samples, either air-dried or oven-dried at 40°C until dry.
5. Place samples in an approved standardised airtight storage container (Cospak A572 1 L) clearly labelled with the AusPlots barcode and place an identical barcode inside the container (adhesive surface folded onto itself and placed in a small zip lock bag).
6. Collate samples and forwarded in batches to the CSIRO National Soil Archive. Inform the Archive before delivery with number of samples, dates etc. (see Chapter 11e).





## D) SOIL BULK DENSITY

An indicative measure of the bulk density of the soil is necessary to quantify important soil parameters, particularly carbon content. Soil bulk density values are needed to calculate soil properties per unit area e.g. tonnes of carbon per hectare. From a preliminary investigation, it is acknowledged that to ensure the measure is reliable, multiple samples will need to be taken across each plot in different surface substrate classes and at different distances from trees or shrubs. To achieve this is beyond the scope of the initial survey process, so the intention is to obtain an indicative value only for each plot.

$$\text{Soil bulk density (g/cm}^3\text{)} = \frac{\text{mass of oven dried soil (g)}}{\text{total volume of core (cm}^3\text{)}}$$

The core method is recommended for taking bulk density measures. This involves inserting a metal cylinder (bulk density ring) of known volume into the soil at three depth increments: 0-10 cm; 10-20 cm; and 20-30 cm and removing a soil core from each. These samples are sealed and then taken back to the lab where they are oven dried and weighed.

The accuracy of this method depends on the precise collection of undisturbed soil in the bulk density ring, ensuring the soil occupies the total volume of the ring

without overflow, hollows or voids. Care is also needed to ensure all soil is included when weighing the sample.

Accuracy is also influenced by the proportion of coarse fragments in the soil and where significant compaction occurs as a result of inserting the corer. Coarse fragments (soil particles greater than 2 mm diameter) need to be considered in determining soil bulk density (see point 12).

### Procedure

For a soil sample at a depth of 0-10 cm:

1. Clear litter and vegetation from a 30 cm x 30 cm area of the soil surface without disturbing the soil to any degree.
2. Remove the plastic caps from a bulk density ring and put the ring, bevelled edge down, into the soil corer frame.
3. Place the frame over the cleared area. Using the mallet gently tap the frame into the soil until the top edge of the ring is a few millimetres below the soil surface. Depending on the presence and size of any soil coarse fragments the ring may need to be inserted further. If the soil surface is uneven, an





- estimate of the mid-point should be used. In order to avoid chipping or bending the cylinder on rocks or other unseen hard material (and thereby changing the volume of the ring) do not use excessive force when tapping the frame into the soil.
4. Using a trowel or spatula, dig out the soil adjacent to one half of the ring.
  5. Depending on the cohesion of the soil, either,
    - (a) using a spatula or knife carefully trim the soil until it is level with the top rim of the ring, cap the top of the cylinder in situ, insert a trowel a few centimetres under the cylinder and with your other hand on the top cap, remove the ring and excess soil ensuring the soil in the cylinder is not disturbed.
    - or
    - (b) insert the trowel a few centimetres under the cylinder and with your hand on the top of the ring for stability, remove the ring and excess soil ensuring the soil in the ring is not disturbed.
  6. Using a spatula or knife, carefully trim the soil at the exposed end of the ring until it is level with the rim. Ensure there are no hollows i.e. the soil level does not go below the rim of the ring, or that the soil does not protrude beyond the rim of the ring.

Slight wetting of clay soils using a spray bottle and deionised/distilled water may assist in the trimming process to get the soil flush with the ring ends. Care should be taken to not over-wet the soils as this may affect the volume through filling voids or expanding shrink/swell clays.





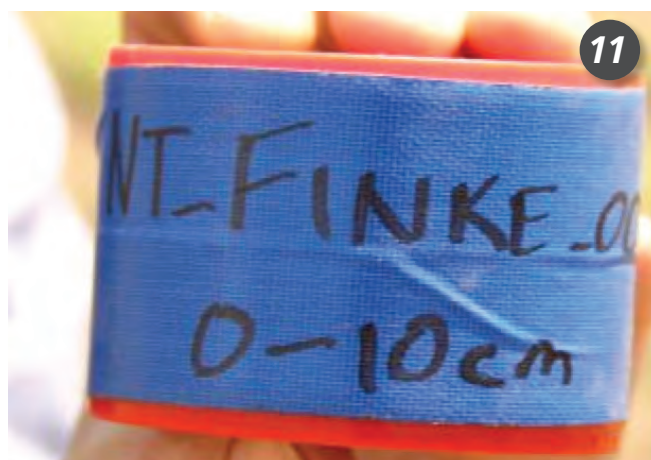
7. Without disturbing the soil, cap that end of the ring.
8. If the soil sample is not level with the end of the ring due to the presence of rocks, gravel or air spaces (meaning the volume of the soil is not identical to the volume of the ring), reject the sample and repeat the process until a suitable sample is obtained.

If an accurate volume cannot be obtained after three attempts in an area, then abandon this area and try elsewhere within the plot.
9. Carefully trim the soil at the other end of the ring ensuring it is level with the rim of the ring (as above).
10. Cap that end of the ring or tip the entire volume of soil into a sealable (i.e. zip lock) plastic bag for storage. (Soil remains in this vessel for transport to the drying oven, so if the soil has high moisture content or is reactive and is likely to interact with the ring, then a plastic bag should be used).
11. Ensure that whatever vessel is used, it is suitably labelled with the appropriate voucher number, sample number, depth, date, plot ID, GPS coordinates and collector.
12. If coarse fragments contained within any sample are estimated to constitute greater than 30% of the volume of that sample, then accuracy levels are compromised and the sample should be discarded. Try again in an adjacent area but if, after three attempts, coarse fragment levels are still >30% of the volume of the sample, then try somewhere else within the plot.

If the whole site is gravelly and coarse fragment levels consistently exceed 30%, then take double samples from each depth i.e. use two rings at each depth. These can then be combined during the drying process providing acceptable accuracy levels.

13. Pack rings or plastic bags into a suitable container to protect them during transport back to the lab.
14. At the local lab where suitable facilities are available, samples will be processed to determine soil bulk density. Where facilities are not available, samples can be re-packed and forwarded to AusPlots in Alice Springs for drying and processing (see Chapter 11e for Alice Springs address).
15. Fill in the hole when all samples from all depths have been collected.
16. Laboratory analysis involves drying the soil samples in an industrial/scientific oven (i.e. non-domestic) at 105°C for 48 hours and then weighing the samples. Samples should be weighed on scientific scales in grams accurate to three decimal places.

If the soils are very dry or have limited clay content the process may be enhanced by slight wetting of the soils and leaving them for a while to increase the adhesion of the sample to ensure it remains in the ring. However, over-wetting can alter soil properties (see point 6), so should only be used as a last resort. If the soil is very adhesive and cannot be easily removed from the ring into a plastic bag for storage and transport, then moisten the inside of the cylinder with distilled water from a spray bottle or with vegetable oil.



For sub-surface soil samples (depths of 10-20 cm or 20-30 cm), dig a pit to the required depth (10 cm or 20 cm) of sufficient size to accommodate the soil core frame, and sample as for steps 2 to 13. Ensure that no soil falls into the pit from the upper layer/s. When removing the ring (step 5 above) ensure that no soil material from upper layer/s falls into the ring.

Where suitable local facilities are available (or the TERN Alice Springs lab), soil samples are oven dried (105°C for 48 hours) to a constant weight and then weighed. If the procedure is followed rigorously, the volume of all the samples will be identical (as the volume of all rings is identical), so sample volume will only need to be determined for an initial sample. However, where coarse fragments are present in the soil these need to be given due consideration in calculating soil bulk density. Two main methods exist, either leaving the coarse fragments in the samples that are dried and weighed, or sieving the sample to remove the coarse fraction (particles >2 mm), and using only the mass and volume of the fine earth fraction. The appropriateness of the method will be dependent on the use of the soil bulk density measures. It is recommended that coarse fragments be removed by sieving, but their mass and volume be determined and made available for any future calculations. (For greater detail see Chapter 11e, Soil samples.) All sieved coarse material should be retained and sent to the National Soil Archive in a separate plastic bag within the container.



*Collecting Soil Bulk Density samples using the AusPlots Rangelands Survey Protocol*

## Equipment

### a. Plot description

- GPS or DGPS
- Field data collection PDA/tablet with data collection app and camera for scanning barcodes
- Back-up data collection sheets, pens and pencils

### b. Soil characterisation to 1 m+

- Long-handled shovel
- Spade
- Trowel
- Crowbar
- Mattock
- Axe
- Geo pick
- Lump hammer
- Secateurs
- Soil auger (Jarrett hand auger 75 mm) with 10 cm depths marked on the handle
- Paint brush
- Wire scrubbing brush
- Ground sheet
- Towel
- Pit tape
- GPS
- Adhesive voucher labels (with barcodes)
- Zip-lock plastic bags (27 x 33cm)
- Sample bags
- Field data collection PDA/tablet with data collection app and barcode scanning software
- Back-up data collection sheets, pens and pencils
- Australian Soil Classification Handbook
- Yellow book
- Munsell colour chart\*
- EC meter/pH meter\*
- pH/EC sample bottles\*
- deionised water\*
- Water drums\*
- 2 mm sieves\*

\*(non-essential equipment)



### c. Soil observations

- Long-handled shovel
- Spade
- Trowel
- Crowbar
- Mattock
- Zip-lock plastic bags (27 x 33cm)
- GPS
- Adhesive voucher labels (with barcodes)
- Camera/ tripod/ SD card
- Zip-lock plastic bags (27 x 33cm)

### d. Soil Bulk density

- Tanner sampling kit for bulk density kit including frame, stainless steel rings, plastic end caps, rubber mallet, gaffer tape
- Nail clippers
- Small spray bottle
- Spatula or knife
- Trowel
- Bolster and hammer
- Wire scrubbing brush
- Stanley knife

### e. Soil samples

- Adhesive voucher labels (with barcodes)
- Standardised 1 L airtight storage container – Cospak A572
- Packaging materials for forwarding containers to CSIRO National Soil Archive

## Time requirements

Depends on the soil type and method used. Can take from 1 hour (where shallow hard pans stop the soil characterisation and soil observations) to 6 hours where a pit is dug and analyses undertaken in the field.

## Data Use / Reason for Collection

Soils descriptions i.e. information recorded, number of recordings and coverage of locations, are generally poor across the rangelands region of Australia. Details of location and data available from current descriptions

should be obtained prior to the surveys to direct the choice of survey location. The plot descriptions and soil characterisations collected will substantially alleviate this paucity of information.

The data collected can also be used to increase the reliability of the rangelands component of the Soil and Landscape Grid of Australia, produced by the TERN facility consistent with the Global Soil Map specifications. Analyses of the collected samples will greatly enhance the level of knowledge (e.g. nutrient and carbon levels) and hence understanding of rangelands soils and how they will respond to climate change and management options. The nine soil observations can be analysed by a number of different methods e.g. wet chemistry, MIR or NIR (mid infrared spectrometry or near infrared spectroscopy) either individually to provide a measure of variation of the parameter being measured across a plot or bulked together and a sub-sample extracted and analysed to provide a mean value for that parameter across a plot. For AusPlots, keep the samples separate.

Knowledge of bulk density values of rangelands soils and likely variability across the plot is largely unknown. This needs to be considered in deciding number and location of samples across the plots.



*Soil samples down the profile*

## E) SOIL SAMPLES

Two different soil sample types will be collected:

- a) standard 500 g samples from both the soil characterisation cores (to 1 m+) and those from the nine soil observations (to 30 cm) across the plot, and
- b) soil bulk density samples collected in the metal rings.

The two different sample types require different processing after collection.

### Standard 500 g samples

All of these samples are to be submitted to the CSIRO National Soil Archive for inclusion in the national collection. All samples need to conform to the submission criteria to facilitate inclusion and minimise double handling. This includes:

- the provision of background observational data on each sample, contained within the AusPlots barcode and available from the AusPlots database. Data needs to include: location (coordinates of the site location where the specimens were obtained, the datum of the coordinates, the method used to acquire the coordinates – recorded as either map reference, GPS or Survey); type of soil observation (soil pit, existing vertical exposure, relatively undisturbed soil core or auger boring); depth interval (upper and lower depth (m) of the soil specimens); collector (name and contact details of the person who collected the specimens); date collected. Additional data such as bulk density measures will also be provided.
- as the National Soil Archive uses their own barcode system to reference the soil samples and have their

own established database (NatSoil), it is imperative that the data can be readily shared between the two different databases. In addition, analyses such as MIR or chemical tests will be conducted in conjunction with the National Soil Archive and outcomes will be downloaded onto ÆKOS.

- the National Soil Archive needs to be contacted and advised the data is available to them before, or at the same time, the samples are sent.
- soil samples to be non-toxic.
- preparation of soils to meet submission standards. Soil samples should weigh approximately 500 g and need to be either air-dried or oven-dried at 40°C.
- submission of each sample in an approved standardised airtight storage container (Cospak A572 1 L). Containers need to be clearly labelled with the AusPlots barcode with an identical barcode (adhesive surface folded onto itself) placed in a small snap-lock bag inside the container.
- AusPlots will provide the soil containers as per National Soil Archive specifications.

When a suitable batch size has been collected, this should then be dispatched to the National Soil Archive.

**CSIRO National Soil Archive**  
**Attention: Linda Karssies/David Jacquier**  
**CSIRO Land and Water**  
**Clunies Ross Street**  
**Black Mountain, ACT 2601**

Contact details for the Archiver to be advised of the pending shipment, are

**(02) 6246 5824 or (02) 6246 5916.**

## Bulk density soil samples

Samples collected for bulk density determination will either be stored in the metal rings in which they were collected or in plastic zip lock bags. Both storage vessels will be labelled with a barcode which will have been scanned in the field using the field PDA and details recorded on the AusPlots database.

The procedure for determining soil bulk density is simple. Put the soils in an oven-proof container e.g. an aluminium take-away tray, making sure that all of the soil from each sample is included. If the soil is still in the metal rings, this can be put into the oven inside a paper bag (once the plastic end caps are removed) and then put on an aluminium tray. If the soil is in a plastic zip-lock bag, remove all the soil from the bag and place it all in a paper bag which is then placed on an aluminium tray. The aluminium tray/s is then put in an oven for 48 hours at 105°C to remove all moisture from the soil matrix. Soils are then removed from the oven and the weight of each soil sample determined (to an accuracy of 0.01 g) and recorded. Either weigh each sample still in the container and subtract the weight of the container, or remove the entire sample from the container and weigh the sample.

Coarse fragments need to be considered. After drying, remove the coarse fragment component from each sample by sieving it through a 2 mm sieve. Weigh the coarse fragments and record the weight and then determine the volume of the coarse fragments by the displacement of water in a measuring ring. These measurements, plus the known volume of the metal collection cylinders, can then be combined to provide bulk density values of the entire soil sample, or of the fine earth component, particles < 2 mm i.e. the total soil component minus the coarse fragments.

If the collecting agency does not have access to required laboratory facilities, the bulk density samples collected as part of the survey process need to be suitably packaged and then forwarded to the AusPlots Rangelands Alice Springs office.

**AusPlots Rangelands**  
**c/- Department of Resources**  
**Arid Zone Research Institute**  
**South Stuart Hwy**  
**Alice Springs, NT 0800**

# 12. Soil metagenomics

## Guidelines

Soil samples to be taken at the 9 soil observation locations across each plot as described in Chapter 11(c), “Soil observation”, generally immediately before the soil observation samples are taken. The soil samples are located to cover the variety of micro-habitats within the plot, this method of sample location being ideal for both soil observations and soil metagenomic samples.

## Procedure

1. Scrape any loose and obvious plant material and animal scats from the soil surface.
2. Use a trowel or small shovel (ensuring that it is not contaminated with soil from another location) to remove approximately 200 g of the soil surface layer (max 3 cm depth).
3. Place this sample in a calico bag and label it with a barcode that details the plots and location.



4. Scan the barcode with the field data collection PDA.
5. Place this calico bag in a larger snap lock bag with half a cup of mixed silica granules (self indicating 10% mixed with standard non-indicating granules 90%) as used for the leaf DNA samples. More silica mix may be required if the sample is damp. Label this bag with site details and date. Silica will need to be checked regularly and changed until the self indicating granules retain their original colour. A change in colour from blue to pink of the self-indicating granules reveals its moisture absorbing capacity has been reached and it needs to be replaced with fresh silica. Do not discard the used silica as it can be oven dried and re-used.
6. Place all nine samples in a large calico bag and label this clearly with the plot name details.
7. Location details of all the soil samples collected are recorded through the field data collection app by scanning the barcodes of the different samples with the PDA.
8. On return from the field please forward the samples to AusPlots at the University of Adelaide. If this is not immediately possible and the collected samples are stored for an extended period (i.e. weeks) before being sent to AusPlots, samples should be stored in a freezer at -20°C until forwarding.





## Equipment

- Trowel or small shovel
- 9 small calico bags per plot
- 9 medium sized snap lock bags per plot
- Silica granules: self indicating (10%) and standard (90%) mixed , ½ cup of mix per bag
- 1 large calico bag for the plot
- Field data collection PDA/tablet with data collection app and barcode scanning software
- Adhesive voucher labels (with barcodes)

## Time requirements

The time for this task is included in the soil sampling task – they are collected at the same time.

## Data Use / Reason for Collection

As part of TERN AusPlots there is a commitment to collect soil samples for metagenomic analysis. Metagenomics is the study of genetic material recovered directly from environmental samples. Soil metagenomics provides the opportunity to understand what organisms are present at survey plots and provides an indication on their abundance. The collection techniques result in a bias towards higher order organisms.

# 13. Plot and Physical Descriptions

## Guidelines

The plot description and physical description can both be completed at the beginning or end of the plot visit. The information recorded in both is important as baseline descriptions and for comparison between plots. Some of the data is repeated on the soils and landscapes field data sheets as the modular nature of the data collection means duplication can occur.

## Equipment

- The Yellow Book
- Site description Sheets (Appendix 4)

## Time requirements

10 minutes

## Procedure

Complete the data categories as instructed on the attached data sheets (Appendix 4), with reference to the “Yellow Book” where needed. Include a diagram of the plot with photo points and directions marked. A ‘mud map’ is very informative with indications of distance and direction from roads/tracks, gates or significant landmarks, enabling easier relocation of plots. Include comments on aspects of the plot which can help describe the differences or similarities with other plots, or unique aspects of this plot.

# 14. Field data collection app

The AusPlots Rangelands field data collection app provides:

- a structured and sequential process to direct the data collection process;
- the ability to record data electronically in the field and download it onto a database, thereby removing the need for double-handling through transcribing data; as well as
- the ability to label samples with barcodes and scan them into the database in the field, thereby referencing them to sites, dates etc, to track them through identification processes and subsequent entry onto databases.

An effective field data collection app complements the need for the instructional aspect of this manual, which still has value for the background context it provides.

**THIS MANUAL WILL BE PROGRESSIVELY  
UPDATED WITH ONGOING APP DEVELOPMENT -  
Current Version Alpha 1.003**

The latest version of the manual will be posted on the TERN website and updated versions of the app will be identified. Please ensure the versions you are using are the latest.

[www.tern.org.au/ausplots-pg17871.html](http://www.tern.org.au/ausplots-pg17871.html)

**BEFORE DATA COLLECTION ENSURE THE TABLET HAS  
BOTH A MICRO SIM AND SD CARD**

## Guidelines

The app consists of 7 sections on data collection:

### 1. Vegetation vouchering – vascular plant specimens (see Chapter 5)

Plant vouchering includes assigning a field name (either from the species list or a descriptive name) and scanning a unique barcode for each specimen collected at each plot. This provides a reference list of species collected at each plot and must be undertaken before other sections can be executed. Scanning the barcode is most effective when it is on a flat surface before it is attached to the specimen. Ensure the barcode scans correctly. At the completion of vouchering, the list of vouchered specimens is not fixed and can be added to while undertaking the point intercept.

The vouchering screen provides a direct link to the genetic vouchering screen. It is recommended that, at the time of plant vouchering, the genetic/isotope samples be taken from the voucher specimen, assigned a barcode and placed in a tea bag in a container with silica. While taking more time up front, this reduces subsequent processing time and double handling.



## 2. Genetic vouchersing (see Chapter 6)

On the genetic vouchersing screen, select the species from the vouchered list present, scan a unique barcode, place the leaf sample in the tea bag and attach the adhesive barcode to the tea bag. Scanning the barcode is more effective while the barcode is flat before it is attached to the tea bag. Store in an airtight container with silica granules. It is highly recommended that this be undertaken simultaneously with the plant vouchersing process.

## 3. Point intercept (see Chapter 7)

Data will be collected at 1010 points at each plot consisting of ten transects, with points from 0 to 100 at each. Substrate must be recorded from the categories on the point intercept screen, and then species (from the reference list present on the screen), height at intercept (or in-canopy-sky) and if dead. Annual forb and annual grass are acceptable categories for use in the point intercept as the cover of perennial species is the major focus.

## 4. Basal wedge (see Chapter 8)

Basal area is collected using a basal wedge at 9 assigned points across the plot. Wedge apertures used can vary between species or for a species across the plot.

## 5. LAI (see Chapter 10)

Save location if LAI is recorded at the plot. Collection of LAI data is optional.

## 6. Photo panorama (see Chapter 4)

Save location if a photo panorama is taken at the plot.

## 7. Structural summary (see Chapter 9)

Record up to three dominant species for the upper, middle and lower strata.

Save the collected data to the SD card, or if able, download to the TREV database.

## Equipment

- Field data collection PDA/tablet with data collection app and barcode scanning software
- Sample barcodes

## Data Use / Reason for Collection

Reduces total data collection/recording time while delivering data with a consistent format.



# 15. Post field trip procedures

## Samples

All samples need to be maintained on return from the field until the time of dispatch.

### *Vegetation*

For vascular plant voucher samples, the paper and cardboard need to be changed until samples are dry, before delivery to herbaria for identification. All samples should have a barcode label attached. A proportion of samples will be accessioned into the herbarium collection after identification, otherwise they will be stored at the herbarium or at AusPlots at the University of Adelaide until genetic analyses are completed and additional samples identified for accession.

For DNA and isotope leaf samples, the silica gel needs to be changed until the blue colour is maintained, meaning all the moisture has been removed. Samples should be kept in the teabags in which they were collected, labelled with an adhesive barcode and stored in sealed lunchboxes. Samples should be stockpiled for bulk dispatch to AusPlots at the University of Adelaide (forwarding address page 2). When samples are to be stored for an extended period before being dispatched, they should be stored in a freezer at -20°C until sent to AusPlots at the University of Adelaide.

### *Soils*

Soil samples being dispatched to the CSIRO National Soil Archive (forwarding address Chapter 11e) need to be thoroughly dried and contained within an approved archive container (Chapter 11e). Barcode labels should be displayed on the exterior of each container and a duplicate placed inside the container in a small zip lock plastic bag. Stockpile samples until a suitable amount is collected for dispatch.

Bulk density samples collected in the field must be dried and weighed. The process is detailed in Chapter 11d and 11e. The soil bulk density values must be provided to both AusPlots at the University of Adelaide (forwarding address page 2) and the CSIRO National Soils Archive

(forwarding address Chapter 11e).

For soil metagenomic samples, the silica gel needs to be changed until the blue colour is maintained, meaning all the moisture has been removed. Stockpile samples until a suitable amount is collected for dispatch to AusPlots at the University of Adelaide (forwarding address page 2). As for vegetation samples, when soil samples are to be stored for an extended period before being dispatched, they should be stored in a freezer at -20°C until sent to AusPlots at the University of Adelaide.

## Data

Most site and sample data will be collected via the app and PDA and downloaded to the AusPlots database. From here data will be made available via the ÆKOS web portal.

At the time of delivery of the samples, relevant information needs to be made available to the identifying herbarium in a spreadsheet so that plant identifications can be confirmed or amended. Likewise for dispatch of soils to the Archive, relevant information needs to be made available to the Archive in a spreadsheet to enable details to be recorded in their database.

## Tracking

All samples have adhesive barcodes to enable tracking and updating of details. The status of samples will be identified and updated in the database so they can be tracked during the collection through identification to analyses and storage process.

## Reporting

Contracts with collaborative bodies include reporting requirements. These are generally quarterly and detail progress made in the number of sites sampled, the number of samples collected, stored and identified to what taxonomic level. Analyses undertaken will also be reported and updated in the database.



# 16. Checklists

## AUSPLOTS:

The full suite of data is collected:

1. Full site description;
2. DGPS Plot location recorded at corners and centre;
3. Photo panoramas – set of three;
4. Complete vegetation voucher specimens;
5. Genetic profile – Leaf samples for DNA and isotope analyses and four replicates of dominant perennials for DNA;
6. Point intercept – full perennial vegetation collected if defining the system, otherwise record to life form;
7. Basal area;
8. Structural summary;
9. LAI (when LAI meter is available);
10. Soils: Full Plot description  
Soil characterisation to 1+ m (minimum requirement is samples collected at 10 cm increments)  
Soil observations (9 x three depths per plot)  
Soil bulk density (1 x three depths SW corner)
11. Soil metagenomics – 9 samples at the edges and centre of the plot

## SLATS PLOTS:

(coloured text indicates difference from AusPlots)

The data collected is:

1. No site description;
2. GPS plot location recorded at centre;
3. Photo panoramas – set of three;
4. No vegetation voucher specimens;

5. Genetic profile – none;
6. Point intercept – perennial vegetation to functional class annual vegetation – Yes;
7. Basal area;
8. Structural summary;
9. LAI (optional);
10. Soils: No plot description  
No soil characterisation to 1+ m  
No soil observations  
No soil bulk density
11. No soil metagenomics

## RAPID PLOTS:

(coloured text indicates difference from AusPlots)

1. No site description;
2. GPS – general plot location recorded;
3. Photo panoramas – none;
4. No vegetation voucher specimens;
5. Genetic profile – none;
6. Point intercept – perennial vegetation visual estimate of cover (%) dominant veg annual vegetation – NO;
7. No basal area;
8. No structural summary;
9. No LAI;
10. Soils: No plot description  
No soil characterisation to 1+ m  
No soil observations  
No soil bulk density
11. No soil metagenomics

# 17. Future Additional Components

- Fauna Survey Module
- Mammal and Reptile DNA module
- Avian DNA module
- Invertebrate Survey Module
- Invertebrate DNA module

# 18. Definitions

**ABARES:** Australian Bureau of Agricultural and Resource Economics and Sciences

**ACLUMP:** Australian Collaborative Land Use and Management Program

**AEKOS:** Australian Ecological Knowledge and Observation System – the data management system devised by the Eco-informatics facility of TERN

**app:** Data collection application downloaded on the PDA/tablet for data entry in the field

**ASRIS:** Australian Soil Resource Information System

**DAFF:** Australian Government Department of Agriculture Fisheries and Forestry

**DGPS:** Differential global positioning system

**Dominant Species:** Those species occurring in the plot with Foliage Projective Cover (FPC) > 2% or Opaque Canopy Cover > 5%

**EC:** Electrical conductivity

**FPC:** Foliage projective cover – the percentage cover (%) of the vertical projection of foliage

**GPS:** Global positioning system

**IBRA:** Interim Biogeographic Regionalisation for Australia

**LAI:** Leaf Area Index-a ratio of the area of leaf area compared to ground area at a location

**MIR:** Mid-infrared spectrometry

**NIR:** Near-infrared spectroscopy

**NRS:** National Reserve System

**OPC:** Opaque canopy cover - The vegetation cover of plant canopy, expressed as a percentage (%), given the assumption that the canopy is opaque

**PDA:** Personal digital assistant or personal data assistant – a mobile device such as a mobile phone that can be used for data management and collection. The app has been developed to operate on an Android operating system (not Mac or Windows operating systems). The PDA will also have barcode scanning software to record barcodes in the field.

**SCaRP:** Soil Carbon Research Program

**SLATS:** Statewide Land and Tree System

**TERN:** Terrestrial Ecosystem Research Network, [www.tern.org.au](http://www.tern.org.au)

**UoA:** University of Adelaide

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# APPENDIX 1: CODE CONVENTIONS FOR SITE DESCRIPTION PROTOCOLS

## States/Territory – rangelands

Northern Territory	NT
South Australia	SA
New South Wales	NS
Queensland	QD
Western Australia	WA

## States/Territory – non rangelands

Australian Capital Territory	CT
Tasmania	TC
Victoria	VC

## IBRA bioregions – rangelands

Arnhem Coast	ARC
Arnhem Plateau	ARP
Broken Hill Complex	BHC
Burt Plain	BRT
Central Arnhem	CA
Carnarvon	CAR
Channel Country	CHC
Central Kimberley	CK
Coolgardie	COO
Cobar Penepplain	CP
Central Ranges	CR
Cape York Peninsula	CYP
Daly Basin	DAB
Darwin Coastal	DAC
Desert Uplands	DEU
Dampierland	DL
Davenport Murchison Ranges	DMR
Darling River Plains	DRP
Einsaleigh Uplands	EIU
Finke	FIN
Flinders Lofty Block	FLB
Gascoyne	GAS
Gawler	GAW
Gibson Desert	GD
Gulf Fall and Uplands	GFU
Great Sandy Desert	GSD

Gulf Coastal	GUC
Gulf Plains	GUP
Great Victoria Desert	GVD
Hampton	HAM
Little Sandy Desert	LSD
MacDonnell Ranges	MAC
Murray Darling Depression	MDD
Mitchell Grass Downs	MGD
Mount Isa Inlier	MII
Mulga Lands	ML
Murchison	MUR
Northern Kimberley	NK
Nullarbor	NLL
Ord Victoria Plain	OVP
Pine Creek	PCK
Pilbara	PIL
Riverina	RIV
Simpson Strzelecki Dunefields	SSD
Stony Plains	STP
Sturt Plateau	STU
Tanami	TAN
Tiwi Coburg	TIW
Victoria Bonaparte	VB
Yalgoo	YAL

## TERN plot types

AusPlots Rangelands	A
Transects	T
LTERN	L
AusPlots Forests	F
General Use	G
Super Sites	S
Training	TRA

## IBRA bioregions – non rangelands

Australian Alps	AA
Avon Wheatbelt	AW
Brigalow Belt North	BBN
Brigalow Belt South	BBS
Ben Lomond	BEL
Central Mackay Coast	CMC
Esperance Plains	ESP
Eyre Yorke Block	EYB
Flinders	FLI
Geraldton Sandplains	GS

Jarrah Forest	JF
Kanmantoo	KAN
King	KIN
Mallee	MAL
Nandewar	NAN
Naracoorte Coastal Plains	NCP
New England Tablelands	NET
NSW North Coast	NNC
NSW South Western Slopes	NSS
Sydney Basin	SB
South East Coastal Plain	SCP
South East Corner	SEC
South Eastern Highlands	SEH
South Eastern Queensland	SEQ
Swan Coastal Plain	SWA
Tasmanian Central Highlands	TCH
Tasmanian Northern Midlands	TNM
Tasmanian Northern Slopes	TNS
Tasmanian South East	TSE
Tasmanian Southern Ranges	TSR
Tasmanian West	TWE
Victorian Midlands	VM
Victorian Volcanic Plain	VVP
Warren	WAR
Wet Tropics	WT

## APPENDIX 2: EQUIPMENT LIST AND CHECK SHEETS

### Chapter 1: Plot selection

### Chapter 2: Trip planning

### Chapter 3: Plot layout/positioning

*The pelican case contains the following:*

- Zeno – hand-held DGPS Unit
- 240V charger (to plug directly into Zeno)
- Battery charger cradle + 240V charger + 12V cigarette lighter cable (to charge batteries in cradle)
- 2 lithium-ion batteries
- USB download data cable
- Touch screen pen & lanyard
- Manuals

*The back pack contains the following:*

- DGPS antenna and mounting pole
- 9AH battery pack
- 2AH battery charger (check this has been placed back into backpack)
- DGPS Receiver unit
- Data cable for connection to hand unit

*Also required:*

- 5 x 1.8 m galvanised star droppers/pickets
- 23 x steel pegs (tent pegs or equivalent)
- Flagging tape (for marker pegs and droppers)
- Dropper rammer or sledge hammer
- Compass
- A good quality inverter unit or generator to charge equipment during extended field work

### Chapter 4: Photo-panoramas

- SLR digital camera with 15 megapixel memory able to shoot in RAW format with a 35 mm lens
- Camera manual
- Spare batteries for camera, or ability to recharge batteries (if rechargeable battery supplied)
- SD cards - 8GB or larger, high speed SD cards enables the photographs to be taken faster

- Tripod at least 1.3 m height
- Star dropper (1.8 m in length) marked with tape at 25 cm from the top
- 3 steel tent pegs
- Tape measure (5 m)
- Rope(s) tied to form an equilateral triangle with sides of 2.5 m
- Note book and thick pen
- DGPS

### Chapter 5: Vegetation Vouchering - Vascular plants

- Secateurs
- Hand trowel
- Paper bags (small) for temporary storage of plant specimens at the plots
- Envelopes for storage of seeds and other small plant material
- Plastic bags (large) for storage and transport of plant specimens at the plots
- Plant presses & straps
- Newspaper (tabloid size) & cardboard (100 x 40 mm)
- Adhesive voucher labels
- Plant references for the region
- Field data collection PDA/tablet with data collection app and barcode scanning software

### Chapter 6: Genetic & Isotope sample vouchering

- Tea bags - synthetic or nylon (not paper, cotton)
- Sealable airtight lunch boxes (e.g. 'Sistema' brand)
- Silica granules: self indicating (10%) and standard (90%) mixed together
- Adhesive voucher labels (with barcodes)
- Field data collection PDA/tablet with data collection app and barcode scanning software

## Chapter 7: Point intercept

- 100 m tape/s or non-stretch cord marked with 1 m graduations
- Graduated staff (extendable pole that can be adjusted to eye height for different operators)
- Densitometer with ability to be mounted on top of staff (required for use on plots with tree canopy cover)
- Laser pointer (taped to staff at approx 1.2 m and pointing downwards)
- Field data collection PDA/tablet with data collection app and barcode scanning software
- Star droppers to mark plot corners (should have already been completed see Section 2)
- Pegs to mark ends of quadrats
- Flagging tape (brightly coloured to make sighting transect ends easier)

## Chapter 8: Basal area

- Basal wedge with attached string knotted at 50 cm from the wedge
- Pen, paper or notebook for recording basal wedge details
- Field data collection PDA/tablet with data collection app and barcode scanning software

## Chapter 9: Structural summary

- Field data collection PDA/tablet with data collection app and barcode scanning software

## Chapter 10: Leaf area index

- The LAI-2200 storage case containing all the required equipment
- Pen, paper or notebook as backup to record date, time and plot details
- PDA with AusPlots app

## Chapter 11 Soils

### *a. Plot description*

- GPS or DGPS
- Field data collection PDA/tablet with data collection

app and barcode scanning software

- Back-up data collection sheets, pens and pencils

### *b. Soil characterisation to 1 m+*

- Long-handled shovel
- Spade
- Trowel
- Crowbar
- Mattock
- Axe
- Geo pick
- Lump hammer
- Secateurs
- Soil auger (Jarrett hand auger 75 mm)
- Paint brush
- Wire scrubbing brush
- Ground sheet
- Towel
- Pit tape
- GPS
- Adhesive voucher labels (with barcodes)
- Zip-lock plastic bags (27 x 33cm)
- Sample bags
- Field data collection PDA/tablet with data collection app and barcode scanning software
- Back-up data collection sheets, pens and pencils
- Australian Soil Classification Handbook
- Yellow book
- Munsell colour chart
- EC meter/pH meter
- pH/EC sample bottles
- Deionised water
- Water drums
- 2 mm sieves
- *\*(non-essential equipment)*

### *c. Soil observations*

- Long-handled shovel
- Spade
- Trowel
- Crowbar



- Mattock
- Zip-lock plastic bags (27 x 33cm)
- GPS
- Adhesive voucher labels (with barcodes)
- Camera/ tripod/ SD card
- Zip-lock plastic bags (27 x 33cm)

#### d. Soil Bulk density

- Tanner sampling kit for bulk density kit including frame, stainless steel rings, plastic end caps, rubber mallet gaffer tape
- Nail clippers
- Small spray bottle
- Spatula or knife
- Trowel
- Bolster and hammer
- Wire scrubbing brush
- Stanley knife

#### e. Soil samples

- Adhesive voucher labels (with barcodes)
- Standardised 1 L airtight storage container – Cospak A572
- Packaging materials for forwarding containers to CSIRO National Soils Archive

## Chapter 12: Soil metagenomics

- Trowel or small shovel
- 9 small calico bags per plot
- 9 medium sized snap lock bags per plot
- Silica granules: self indicating (10%) and standard (90%) mixed , ½ cup of mix per bag
- 1 large calico bag for the plot
- Adhesive voucher labels (with barcodes)
- Field data collection PDA/tablet with data collection app and barcode scanning software

## Chapter 13: Plot and Physical Description

- Yellow Book
- Site Field Sheets (Appendix 4)



*Assessing soil texture grade*

## APPENDIX 3: SOILS BACKGROUND INFORMATION

### Chapter 11a. Plot description

*Non-Essential Elements (coloured text)*

- **Surface Coarse Fragments** (YB p139-143) Particles coarser than 2 mm including unattached rock, shells, charcoal but not segregations of pedogenic origin.
- **Abundance** (YB p139-141) - use YB Figure 11, p141 as a guide
  - » 0-no coarse fragments
  - » 1-very slight or few <2%
  - » 2-slight or few 2-10%
  - » 3-common e.g. medium gravel, stony, common medium pebbles 10-20%
  - » 4-moderate or many 20-50%
  - » 5-very or abundant 50-90%
  - » 6-extremely or very abundant >90%
- **Size** (YB p140)
  - » 1-fine gravelly or small pebbles 2-6 mm
  - » 2-medium gravelly or medium pebbles 6-20 mm
  - » 3-coarse gravelly or coarse pebbles 20-60 mm
  - » 4-cobbly or cobbles 60-200 mm
  - » 5-stony or stones 200-600 mm
  - » 6-bouldery or boulders 600-2000 mm
  - » 7-large boulders >2000 mm
- **Shape /type** (YB p142, 143)
  - » Angular-A
  - » Sub angular-S
  - » Sub rounded-U
  - » Rounded-R
  - » Angular tabular-AT
  - » Sub angular tabular-ST
  - » Sub rounded tabular-UT
  - » Rounded tabular-RT
  - » Angular platy-AP
  - » Sub angular platy-SP
  - » Sub rounded platy-UP
  - » Rounded platy-RP
- **Lithology** (YB p142, p 214)

For categories, see Coarse Fragment section for Soil Characterisation

ASC (Australian Soils Classification: Isbell 1996)

To accurately categorise soils within the ASC requires the specialised skills of a pedologist and should not be attempted by inexperienced observers. It will only be possible following all the non-essential descriptions under the soil characterisation.

An ASC categorisation describes:

Soil Order  
Sub group  
Great group  
Subgroup  
Family

**Uncertainty codes:** 1 – uncertain, 4 –least certain

**Codes to use where match cannot be determined:**

yy – may match but unsure

ZZ – there is no correct match which fits

### Chapter 11b. Soil characterisation to 1 m+

*NON-Essential Elements (coloured highlight)*

**Texture** (YB p161-166)

Field texture classes are based on field determination of texture and are based on the size distribution of mineral particles finer than 2 mm.

Field texture grade - characterised by the behaviour of the moist bolus



Assessing soil colour

- S - sand: nil to slight coherence; cannot be moulded; medium sized sand grains; single sand grains adhere to finger; <5% clay content
- LS - loamy sand: slight coherence; medium sized sand grains; can be sheared between thumb and forefinger to give minimum ribbon of 5-15 mm; about 5% clay content
- CS - clayey sand: slight coherence; medium sized sand grains; sticky when wet; many sand grains will stick to fingers; will form minimum ribbon of 5-15 mm; discolours fingers with clay stain; 5-10% clay content
- SL - sandy loam: bolus coherent but sandy to touch; will form minimum ribbon of 15-25 mm; dominant sand grains are medium sized and readily visible; 10-20% clay content
- L - loam: bolus coherent and rather spongy; smooth feel when manipulated with no obvious sandiness or silkiness; may be greasy to the touch if much organic matter is present; will form ribbon of about 25 mm; clay content about 25%
- ZL - silty loam: coherent bolus; very smooth to often silky when manipulated; will form ribbon of about 25 mm; clay content about 25% or >25% with silt
- SCL - sandy clay loam: strongly coherent bolus, sandy to touch; medium sized sand grains visible in finer matrix; will form ribbon of 25-40 mm; clay content of 20-30%
- CL - clay loam: coherent plastic bolus, smooth to manipulate; will form ribbon of 0-50 mm; clay content 30-35%
- CLS - clay loam sandy: coherent plastic bolus; medium sized sand grains visible in finer matrix; will form ribbon of 40-50 mm; clay content 30-35%
- ZCL - silty clay loam: coherent smooth bolus, plastic and often silky to the touch; will form ribbon of 40-50 mm; clay content 30-35%, with silt 25% or more
- LC - light clay; plastic bolus; smooth to touch; slight resistance to shearing between thumb and forefinger; will form ribbon of 50-75 mm; clay content 35-40%
- LMC - light medium clay: plastic bolus; smooth to touch; slight to moderate resistance to ribboning shear; will form ribbon of 75 mm; clay content 40-45%
- MC - medium clay: smooth plastic bolus; handles like plasticine and can be moulded into rods without fracture; moderate resistance to ribboning shear; will form ribbon of 75 mm or more; clay content 45-55%
- MHC - medium heavy clay: smooth plastic bolus; handles like plasticine; can be moulded into rods without fracture; moderate to firm resistance to ribboning shear; will form ribbon of 75 mm or more; clay content <50%
- HC - heavy clay: smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to ribboning shear; will form ribbon of 75 mm or more; clay content <50%
- Field texture qualification (recorded after the field texture) - the non-clay field texture grades (clay loams and coarser) may be qualified according to whether they are at or near the light (lower clay content) or heavy (higher clay content) end of the range for that field texture grade
  - - light
  - + heavy

If the soils are appreciably organic they are qualified

- A - Sapric: organic and non-fibrous; dark organic stain discolours fingers; greasy feel in clayey textures and coherence in sandy textures; fibres (excluding living roots) or plant tissue remains are not visible to the naked eye and little or none visible with x10 hand lens
- I - Fibric: organic and fibrous; dark organic stain discolours fingers; greasy feel in clayey textures and coherence in sandy textures; fibres (excluding living roots) or plant tissue remains are visible to the naked eye or easily visible with x10 hand lens

Field texture modifiers - the above sands are defined as having medium-sized grains. Coarse or fine sands can be identified using K or F as below. Each of the clay field texture grades may also be modified according to the sand or silt fraction as below

- K - coarse sandy
- S - medium sandy
- F - fine sandy
- Z - silty

### Colour (YB p159, 161)

Should be described in terms of Munsell or Revised Standard Soil colours for both moist and dry soils, with the following abbreviations used

- R - red
- O - orange
- B - brown
- Y - yellow
- G - grey
- D - dark: values 3 or less and chromas 2 or less for all hues
- L - gley: gley charts only
- P - pale: values 7 or more and chromas 2 or less for all hues

### Mottles (YB p 159-161)

Mottles are spots, blotches or streaks of subdominant colours different from the matrix colour and different from the colour of the ped surface. Segregations of pedogenic origin are not considered to be mottles (see below)

*Colour* - see colour categories above

*Abundance* (use Figure 11, p141 as a guide)

- 0 - no mottles or other colour patterns
- 1 - very few (<2%)
- 2 - few (2-10%)
- 3 - common (10-20%)
- 4 - many (20-50%)

*Size* - measure size along the greatest dimension except for streaks or linear forms, in which case measure width

- 1 - fine (<5 mm)
- 2 - medium (5-15 mm)
- 3 - coarse (15-30 mm)
- 4 - very coarse (>30 mm)

### Coarse fragments (YB p139-143, 170, 214)

See surface coarse fragment section - abundance, size and shape categories used are the same.

### Lithology (YB p214 table)

Describe coarse fragment lithology when the same as substrate (M), rock outcrop (R) or if different:

- AC - alcrete (bauxite)
- AP - aplite
- BA - basalt
- KC - calcrete
- KM - calcareous mudstone
- CC - charcoal
- CH - chert
- CG - conglomerate
- CU - consolidated rock (unidentified)
- SD - detrital sedimentary rock (unidentified)
- DR - dolerite
- DM - dolomite
- FC - ferricrete
- GA - gabbro
- GS - gneiss
- GN - granite
- GV - gravel
- GW - graywacke
- GY - gypsum
- HO - hornfels
- IG - igneous rock (unidentified)
- IS - ironstone
- JA - jasper
- LI - limestone
- ME - metamorphic rock (unidentified)
- MU - mudstone
- OW - opalised wood
- OT - other
- PH - phyllite
- PU - pumice
- QZ - quartz
- QU - quartzite
- QS - quartz sandstone
- M - same as substrate material-M
- RB - red-brown hardpan



- R - same as rock outcrop
- SA - sandstone
- ST - schist
- SH - shale
- SS - shells
- LC - silcrete
- ZS - siltstone
- SL - slate
- TU - tuff

### Segregations (YB p196)

*Abundance* (use Figure 11, p141 as a guide)

- 0 - no segregation
- 1 - very few (<2%)
- 2 - few (2-10%)
- 3 - common (10-20%)
- 4 - many (20-50%)
- 5 - very many (>50%)

*Size*

- 1 - fine (<2 mm)
- 2 - medium (2-6 mm)
- 3 - coarse (6-20 mm)
- 4 - very coarse (20-60 mm)
- 5 - extremely coarse (>60 mm)

*Nature*

1. U - unidentified
2. K - calcareous (carbonate)
3. Y - gypseous (gypsum)
4. M - manganiferous (manganese)
5. N - ferromanganiferous (iron manganese)
6. F - ferruginous (iron)
7. A - aluminous (aluminium)
8. S - sulfurous (sulfur)
9. Z - saline (visible salt)
10. H - organic (humified, well-decomposed organic material)
11. G - ferruginous-organic (iron-organic matter)
12. L - argillaceous (clayey)
13. E - earthy (dominantly non-clayey)
14. O - other

*Form*

- C - concretions: spheroidal mineral aggregates; crudely concentric internal fabric visible with the naked eye
- N - nodules: irregular, rounded mineral aggregates; no concentric internal fabric
- F - fragments: broken pieces of segregations
- X - crystals: single or complex clusters of crystals visible with the naked eye or x10 hand lens
- S - soft segregations: finely divided soft segregations; contrasting with surrounding soil in colour and composition but not easily separated as discrete. Boundaries may be clear or diffuse.
- V - veins: fine (<2 mm wide) linear segregations
- R - root linings: linings of former or current root channels
- T - tubules: medium or coarser (>2 mm wide) tube-like segregations which may be hollow
- L - laminae: planar; plate-like or sheet like segregations

### Structure (YB p171-182)

Refers to the peds (individual natural soil aggregates), their size, shape and distinctness.

- Grade (degree of development and distinctness (YB p171, 172)

*Apedal soils*

- » G - single grain
- » V - massive

*Pedal soils*

- » W - weak
- » M - moderate
- » S - strong

*Size (YB p172,173)*

1. <2 mm
2. 2-5 mm
3. 5-10 mm
4. 10-20 mm
5. 20-50 mm
6. 50-100 mm
7. 100-200 mm
8. 200-500 mm
9. >500 mm

#### Type (YB p173-180)

- PL - platy
- PR - prismatic
- C - columnar
- AB - angular blocky
- SB - sub angular blocky
- PO - polyhedral
- LC - lenticular
- GR - granular
- CA - cast

#### Fabric (YB p181-182)

The appearance of the soil (under a x10 hand lens). Australian soil fabric definitions are incomplete.

- E - earthy
- G - sandy (prominent grains)
- R - rough-ped
- S - smooth-ped

#### pH (YB p198)

Soil pH is determined in the field using a field pH kit, or a portable pH meter. As pH can vary with depth, it is also necessary to record sample depth. Follow instructions and record the method used.

#### Electrical Conductivity (EC)

Electrical conductivity can be determined in the field using a portable EC meter. Follow instructions for the particular meter being used.

#### Effervescence of carbonate in fine earth (YB p198)

This measure is only of value in soils with a carbonate component. Effervescence is determined by dropping two to three drops of 1 molar Hydrochloric Acid onto an exposed area of soil.

- N - non-calcareous: no audible or visible effervescence
- S - slightly calcareous: slightly audible but no visible effervescence
- M - moderately calcareous: audible and slightly visible effervescence
- H - highly calcareous: moderate visible effervescence
- V - very highly calcareous: strong visible effervescence

## APPENDIX 4: FIELD SHEETS

This appendix includes the following AusPlots Rangelands field data sheets:

- Appendix 4A: Plot description and physical description
- Appendix 4B: Point intercept data sheet
- Appendix 4C: Soil and landscape full site and yellow book cheat sheet
- Appendix 4D: Soil and landscape reduced site and yellow book cheat sheet

**AusPlots Rangelands****PLOT DESCRIPTION**

ausplots

Observer(s)

Plot ID

Date:

Bioregion Name

Property

(Paddock)

MGA Zone

Easting

Northing

(SW corner)

Method

1 = GPS

2 = differential GPS

Datum

1 = WGS84

2 = AGD84

3 = AGD66

4 = GDA94

PDOP

Is plot permanently marked?

☐

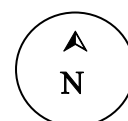
Y/N

Is plot aligned to grid?

☐

Y/N

Please mark location of photopoint



Location Comments:

## PHYSICAL DESCRIPTION

## Landform Pattern

\_\_\_\_\_

**Common subset** (refer to Yellow Book p55 – 72 for full list)

**ALF**=alluvial fan, **ALP**=alluvial plain, **SAN**=sandplain, **FLO**=floodplain, **PLA**=plain, **ANA**=anastomotic plain, **DUN**=dunefield, **PED**=pediment, **RIS**=rises, **PLT**=plateau, **LOW**=low hills, **HIL**=hills, **ESC**=escarpment, **MOU**=mountains.

## Landform Element

--	--

**Common subset** (refer to Yellow Book p31 – 44 for full list)

**PLA**=plain, **PLY**=playa/pan, **LUN**=lunette, **BRK**=breakaway, **DDE**=drainage depression, **DUN**=dune, **DUC**=dune crest, **DUS**=dune slope, **SWL**=swale, **HCR**=hill crest, **HSL**=hill slope, **GUL**=gully, **CLI**=cliff, **SCA**=scarp, **STC**=stream channel, **FLD**=floodout, **FAN**=fan-alluvial, **LAK**=lake, **SWP**=swamp,

## Site Slope

11

degrees from horizontal

## Site Aspect

\_\_\_\_\_

(degrees from North)  
N=360, no slope=0

**Outcrop Lithology**  
(if known)

11

**Common subset** (refer to Yellow Book p214 for full list)

**KC**=calcrete/limestone, **SA**=sandstone, **ZS**= siltstone, **SH**=shale, **AR**=arkose, **QV**=quartzite, **GS**=gneiss, **ST**=schist, **QZ**=quartz, **GN**=granite, **GV**=gravel

**Other:**

(or subdominant)

--

## Surface Strew Size

11

**9** = none apparent,    **1** = pebble (5 - 50mm),    **2** = cobble (51 - 250mm),  
**3** = boulder (250mm)

**Surface Strew Lithology**  
(if known)

11

**Common subset** (refer to Yellow Book p214 for full list)

**KC**=calcrete/limestone, **SA**=sandstone, **ZS**=siltstone, **SH**=shale, **AR**=arkose, **QV**=quartzite, **GS**=gneiss, **ST**=schist, **QZ**=quartz, **GN**=granite, **GV**=gravel

<b>Plot 100m x 100m</b>	<b>Y/N</b>
-------------------------	------------

--	--

**Y/N**

## Plot Dimensions

5

**m**

**X**

11

m

(if plot not 100m x 100m)

## Climatic Conditions

11/11/2019

## Vegetation Condition

\_\_\_\_\_

**Wet**=recent rain, **Dry**=no evidence of recent rain

**BurntN**=no regeneration, **BurntR**=regenerating,

**Active vegetative growth,    Flowering/fruiting,    Dry**

## Comments

[illegible]



# AusPlots Rangelands-Point Intercept Data Sheet



ausplots

Plot ID:

Date:

Transect Start:

Transect End:

Observers:

Dist	Subst.	Species 1	H1	Species 2	H2	Species 3	H3
0							
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
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36							
37							
38							
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40							
41							
42							
43							
44							
45							
46							
47							
48							
49							
50							

# AusPlots Rangelands-Point Intercept Data Sheet



ausplots

Plot ID:

Date:

Transect Start:   Transect End:   Observers:

Dist	Subst.	Species 1	H1	Species 2	H2	Species 3	H3
51							
52							
53							
54							
55							
56							
57							
58							
59							
60							
61							
62							
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64							
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92							
93							
94							
95							
96							
97							
98							
99							
100							
101							

AusPlots Rangelands Plot Sheet - Soils and Landscape (full site)



Project: AusPlots-Rangelands

Date:

Described by:

State:

Agency:

Plot description

Plot-ID

SW corner

Easting

Northing

Zone

Datum

Method: GPS

DGP

Erosion p133-9 Microrelief p129-33 Drainage p202-4 Disturbance p128 Soil surface condition p189-91

type-state-extent type-comp-prop sampled

Surface coarse frags abundance

size type lithology

p139-43

Version: September 2012

Soil characterisation

Type of observation: PIT CORE AUGER 10cm SAMPLES EXPOSURE

Stopped by:

ASC

Layer	Depth (m)		Horizon	Texture p161-70			Colour p159		Mottles p159-61			Coarse Fragments p139-43				Segregations p196			Structure p171-172				Fabric p181-182	pH p198	EC 1:5 (dS/m)	Effervescence p198			
	barcode: _____	upper		lower	grade	qualifier	modifier	moist	dry	colour	abundance	size	abundance	size	shape	lithology p214	abundance	size (mm)	nature	form	grade	Size (mm)					Type (p173)		
																						smallest					next size	smallest	next size
1																													
2																													
3																													
4																													
5																													
6																													
7																													
8																													
9																													
10																													

Soil observations (type and location)

Coordinates		Sample barcode:		Comments		Metagenomics barcode:	Photo No.
Site-ID	Ob_id	Purpose	Eastings	Northings	Volume (500g)		
SubSite_ID	1	Soil Characterisation 1m+			0-0.1m 0.1-0.2m 0.2-0.3		
SubSite_ID	1	Sample to 30cm					
SubSite_ID	2	Sample to 30cm					
SubSite_ID	3	Sample to 30cm					
SubSite_ID	4	Sample to 30cm					
SubSite_ID	5	Sample to 30cm					
Site-ID	6	Sample to 30cm					
Site-ID	7	Sample to 30cm					
Site-ID	8	Sample to 30cm					
Site-ID	9	Sample to 30cm					

Site notes:

# Yellow Book Cheat Sheet

## EROSION

Type		Water		p135-137
W	Wind	S	Sheet	
C	Scald	R	Rill	
M	Mass movement	G	Gully	
E	Other	T	Tunnel	
		B	Stream bank	
		V	Wave	

State				p134
A	Active	S	Stabilised	
P	Partially stabilised			

Extent				p134
X	Not apparent	2	Moderate	
0	No erosion	3	Severe	
1	Minor or present	4	Very severe	

## MICRORELIEF

Type of microrelief				p129-133
A	Lattice gilgai	N	Normal gilgai	
B	Pig rooting	O	Other	
C	Crabhole Gilgai	P	Spring mound	
D	Debil-debil	Q	Holes	
F	Wallows	R	Terracettes	
G	Contour Gilgai	T	Contour trench	
H	Spring hollow	U	Mound/depression microrelief	
I	Sinkholes	W	Swamp hummock	
J	Ant mounds	X	Termitaria	
K	Karst microrelief	Y	Rabbit warrens	
L	Linear gilgai	Z	Zero or no microrelief	
M	Melonhole gilgai			

Component of microrelief sampled				p133
M	Mound	E	Elongate mound	
D	Depression	L	Elongate depression	
S	Shelf	K	Hummock	
F	Flat			

Proportions of gilgai components				p130
A	Mound = depression, no shelf			
B	Mound > depression, no shelf			
C	Mound < depression, no shelf			
D	Mound, shelf and depression			

## SOIL WATER REGIME

Run off				p144-145
0	No runoff	3	Moderately rapid	
1	Very slow	4	Rapid	
2	Slow	5	Very rapid	

Permeability				p201-202
1	Very slow	3	Moderate	
2	Slow	4	High	

Drainage				p202-204
1	Very poor	4	Moderately well	
2	Poor	5	Well	
3	Imperfect	6	Rapid	

## DISTURBANCE OF SITE

				p128
0	No effective disturbance			
1	No effective disturbance except grazing by hoofed animals			
1L	Light grazing			
1M	Medium grazing			
1H	Heavy grazing			
2	Limited clearing			
3	Extensive clearing			
4	Complete clearing, pasture, but never cultivated			
5	Complete clearing, pasture, cultivated at some stage			
6	Cultivation, rain fed			
7	Cultivation, irrigated, past or present			
8	Highly disturbed, e. g. mining, urban			

## CONDITION OF SURFACE SOIL WHEN

DRY				p189-191
C	Surface crust	R	Recently cultivated	
F	Firm	S	Soft	
G	Cracking	T	Trampled	
H	Hard setting	V	Sandy veneer	
L	Loose	X	Surface flake	
M	Self-mulching	Y	Cryptogam surface	
O	Other	Z	Saline	
P	Poached			

## SOIL PROFILE

Type of soil observation				p147
P	Soil pit	E	Existing vertical exposure	
A	Auger boring	C	Relatively undisturbed soil core	

## SOIL EXPOSURE

Stopped by				N/A
R	Rock	G	Gravel	
H	Hard Pan	W	Too wet	
L	Too loose	D	Too hard	

## FIELD TEXTURE

Texture Grade				p161-166
S	Sand	LS	Loamy sand	
CS	Clayey sand	SL	Sandy loam	
L	Loam	ZL	Silty loam	
SCL	Sandy clay loam	CL	Clay loam	
CLS	Clay loam, sandy	ZCL	Silty clay loam	
LC	Light clay	LMC	Light medium clay	
MC	Medium clay	MHC	Medium heavy clay	
HC	Heavy clay			

Field texture qualification				p167
L	Light	H	Heavy	
A	Sapric	I	Fibric	

Texture modifiers				p166
K	Coarse sandy	S	Medium sandy	
F	Fine sandy	Z	Silty	

## MOTTLES AND OTHER COLOUR

PATTERNS				p159-161
Type				
M	Mottles	X	Biological mixing	
Y	Mechanical	Z	Substrate influence	
R	Root stains			

Contrast				p160
F	Faint	D	Distinct	
P	Prominent			

Colour				p161
R	Red	O	Orange	
B	Brown	Y	Yellow	
G	Grey	D	Dark	
L	Gley	P	Pale	

## COARSE FRAGMENTS

Shape				p139-143
A	Angular	RT	Rounded tabular	
S	Subangular	UT	Subrounded tabula	
U	Subrounded	AP	Angular platy	
R	Rounded	SP	Subangular platy	
AT	Angular tabular	RP	Rounded platy	
ST	Subangular tabular	UP	Subrounded platy	

Lithology				p214
AC	Alcrete (bauxite)	IS	Ironstone	
AP	Aplite	JA	Jasper	
BA	Basalt	LI	Limestone	
KM	Calcareous mudstone	ME	Metamorphic rock (unidentified)	
KC	Calcrete	MU	Mudstone	
CC	Charcoal	OT	Other	
CH	Chert	PH	Phyllite	
CG	Conglomerate	QZ	Quartz	
CU	Consolidated rock (unidentified)	QU	Quartzite	
SDD	Detrital sedimentary rock (unidentified)	QS	Quartz sandstone	
DR	Dolerite	RB	Red-brown hardpan	
DM	Dolomite	M	Same as substrate material	
FC	Ferricrete	R	Same as rock outcrop	
GA	Gabbro	SA	Sandstone	
GS	Gneiss	ST	Schist	
GN	Granite	SH	Shale	
GV	Gravel	SS	Shells	
GW	Graywacke	LC	Silcrete	
GY	Gypsum	ZS	Siltstone	
HO	Hornfels	SL	Slate	
IG	Igneous rock (unidentified)	TU	Tuff	

## SEGREGATIONS OF PEDOGENIC ORIGIN

Nature				p196
U	Unidentified	M	Manganiferous	
N	Ferromanganiferous	F	Ferruginous	
A	Aluminous	S	Sulphurous	
Z	Saline (visible salt)	H	Organic (humified)	
G	Ferruginous-organic	L	Argillaceous	
E	Earthy	Y	Gypseous	
K	Calcareous	O	Other	

Form				p196
C	Concretions	N	Nodules	
X	Crystals	S	Soft segregations	
V	Veins	T	Tubules	
L	Laminae	F	Fragments	
R	Root linings			

## STRUCTURE

Grade of pedality				p171-172
G	Single grain	M	Moderate	
V	Massive	S	Strong	
W	Weak			

Type of pedality				p173
PL	Platy	PO	Polyhedral	
PR	Prismatic	LE	Lenticular	
CO	Columnar	GR	Granular	
AB	Angular blocky	CA	Cast	
SB	Subangular blocky			

## FABRIC

				p181-182
E	Earthy	R	Rough-ped	
G	Sandy	S	Smooth-ped	

## EFFERVESCENCE OF CARBONATE

IN FINE EARTH				p198
N	Non-calcareous	S	Slightly calcareous	
M	Moderately calcareous	H	Highly calcareous	
V	Very highly calcareous			



ausplots



AusPlots Rangelands Plot Sheet - Soils and Landscape (reduced site)



Version: September 2012

State:	Agency:
--------	---------

Project: AusPlots-Rangelands		Date:		Described by:		Location description:											
<u>Plot description</u>		SW		Easting		Northing		Zone		Datum		Method:		GPS		DGP	
		corner															

Erosion	p133-9	Microrelief	p129-33	Drainage	p202-4	Disturbance	p128	Soil surface condition	p189-91				
type-state-extent		type-comp-prop sampled											

Soil characterisation

Type of observation:	PIT	CORE	AUGER	10cm SAMPLES	EXPOSURE
----------------------	-----	------	-------	--------------	----------

Stopped by:
-------------

Layer	Depth (m)	
	upper	lower
1		sample barcode
2		
3		
4		
5		
6		
7		
8		
9		
10		

Site notes:
-------------

Soil observations (type and location)

Soil observations (type and location)			Coordinates		sample barcode: (500g samples)				Comments	Metagenomics barcode:	Photo No.
			Eastings	Northings	0-0.1m	0.1-0.2m	0.2-0.3m				
Site-ID	Ob_id	Purpose	Soil Characterisation 1m+								
SubSite_ID	1	Sample to 30cm									
SubSite_ID	2	Sample to 30cm									
SubSite_ID	3	Sample to 30cm									
SubSite_ID	4	Sample to 30cm									
SubSite_ID	5	Sample to 30cm									
Site-ID	6	Sample to 30cm									
Site-ID	7	Sample to 30cm									
Site-ID	8	Sample to 30cm									
Site-ID	9	Sample to 30cm									

# Yellow Book Cheat Sheet

## EROSION

Type		Water		p135-137
W	Wind	S	Sheet	
C	Scald	R	Rill	
M	Mass movement	G	Gully	
E	Other	T	Tunnel	
		B	Stream bank	
		V	Wave	

State				p134
A	Active	S	Stabilised	
P	Partially stabilised			

Extent				p134
X	Not apparent	2	Moderate	
0	No erosion	3	Severe	
1	Minor or present	4	Very severe	

## MICRORELIEF

Type of microrelief				p129-133
A	Lattice gilgai	N	Normal gilgai	
B	Pig rooting	O	Other	
C	Crabhole Gilgai	P	Spring mound	
D	Debil-debil	Q	Holes	
F	Wallows	R	Terracettes	
G	Contour Gilgai	T	Contour trench	
H	Spring hollow	U	Mound/depression microrelief	
I	Sinkholes	W	Swamp hummock	
J	Ant mounds	X	Termitaria	
K	Karst microrelief	Y	Rabbit warrens	
L	Linear gilgai	Z	Zero or no microrelief	
M	Melonhole gilgai			

Component of microrelief sampled				p133
M	Mound	E	Elongate mound	
D	Depression	L	Elongate depression	
S	Shelf	K	Hummock	
F	Flat			

Proportions of gilgai components				p130
A	Mound = depression, no shelf			
B	Mound > depression, no shelf			
C	Mound < depression, no shelf			
D	Mound, shelf and depression			

## SOIL WATER REGIME

Run off				p144-145
0	No runoff	3	Moderately rapid	
1	Very slow	4	Rapid	
2	Slow	5	Very rapid	

Permeability				p201-202
1	Very slow	3	Moderate	
2	Slow	4	High	

Drainage				p202-204
1	Very poor	4	Moderately well	
2	Poor	5	Well	
3	Imperfect	6	Rapid	

## DISTURBANCE OF SITE

				p128
0	No effective disturbance			
1	No effective disturbance except grazing by hoofed animals			
1L	Light grazing			
1M	Medium grazing			
1H	Heavy grazing			
2	Limited clearing			
3	Extensive clearing			
4	Complete clearing, pasture, but never cultivated			
5	Complete clearing, pasture, cultivated at some stage			
6	Cultivation, rain fed			
7	Cultivation, irrigated, past or present			
8	Highly disturbed, e. g. mining, urban			

## CONDITION OF SURFACE SOIL WHEN

DRY				p189-191
C	Surface crust	R	Recently cultivated	
F	Firm	S	Soft	
G	Cracking	T	Trampled	
H	Hard setting	V	Sandy veneer	
L	Loose	X	Surface flake	
M	Self-mulching	Y	Cryptogam surface	
O	Other	Z	Saline	
P	Poached			

## SOIL PROFILE

Type of soil observation				p147
P	Soil pit	E	Existing vertical exposure	
A	Auger boring	C	Relatively undisturbed soil core	

## SOIL EXPOSURE

Stopped by				N/A
R	Rock	G	Gravel	
H	Hard Pan	W	Too wet	
L	Too loose	D	Too hard	

## FIELD TEXTURE

Texture Grade				p161-166
S	Sand	LS	Loamy sand	
CS	Clayey sand	SL	Sandy loam	
L	Loam	ZL	Silty loam	
SCL	Sandy clay loam	CL	Clay loam	
CLS	Clay loam, sandy	ZCL	Silty clay loam	
LC	Light clay	LMC	Light medium clay	
MC	Medium clay	MHC	Medium heavy clay	
HC	Heavy clay			

Field texture qualification				p167
L	Light	H	Heavy	
A	Sapric	I	Fibric	

Texture modifiers				p166
K	Coarse sandy	S	Medium sandy	
F	Fine sandy	Z	Silty	

## MOTTLES AND OTHER COLOUR

PATTERNS				p159-161
Type				
M	Mottles	X	Biological mixing	
Y	Mechanical	Z	Substrate influence	
R	Root stains			

Contrast				p160
F	Faint	D	Distinct	
P	Prominent			

Colour				p161
R	Red	O	Orange	
B	Brown	Y	Yellow	
G	Grey	D	Dark	
L	Gley	P	Pale	

## COARSE FRAGMENTS

Shape				p139-143
A	Angular	RT	Rounded tabular	
S	Subangular	UT	Subrounded tabula	
U	Subrounded	AP	Angular platy	
R	Rounded	SP	Subangular platy	
AT	Angular tabular	RP	Rounded platy	
ST	Subangular tabular	UP	Subrounded platy	

Lithology				p214
AC	Alcrete (bauxite)	IS	Ironstone	
AP	Aplite	JA	Jasper	
BA	Basalt	LI	Limestone	
KM	Calcareous mudstone	ME	Metamorphic rock (unidentified)	
KC	Calcrete	MU	Mudstone	
CC	Charcoal	OT	Other	
CH	Chert	PH	Phyllite	
CG	Conglomerate	QZ	Quartz	
CU	Consolidated rock (unidentified)	QU	Quartzite	
SDD	Detrital sedimentary rock (unidentified)	QS	Quartz sandstone	
DR	Dolerite	RB	Red-brown hardpan	
DM	Dolomite	M	Same as substrate material	
FC	Ferricrete	R	Same as rock outcrop	
GA	Gabbro	SA	Sandstone	
GS	Gneiss	ST	Schist	
GN	Granite	SH	Shale	
GV	Gravel	SS	Shells	
GW	Graywacke	LC	Silcrete	
GY	Gypsum	ZS	Siltstone	
HO	Hornfels	SL	Slate	
IG	Igneous rock (unidentified)	TU	Tuff	

## SEGREGATIONS OF PEDOGENIC ORIGIN

Nature				p196
U	Unidentified	M	Manganiferous	
N	Ferromanganiferous	F	Ferruginous	
A	Aluminous	S	Sulphurous	
Z	Saline (visible salt)	H	Organic (humified)	
G	Ferruginous-organic	L	Argillaceous	
E	Earthy	Y	Gypseous	
K	Calcareous	O	Other	

Form				p196
C	Concretions	N	Nodules	
X	Crystals	S	Soft segregations	
V	Veins	T	Tubules	
L	Laminae	F	Fragments	
R	Root linings			

## STRUCTURE

Grade of pedality				p171-172
G	Single grain	M	Moderate	
V	Massive	S	Strong	
W	Weak			

Type of pedality				p173
PL	Platy	PO	Polyhedral	
PR	Prismatic	LE	Lenticular	
CO	Columnar	GR	Granular	
AB	Angular blocky	CA	Cast	
SB	Subangular blocky			

## FABRIC

				p181-182
E	Earthy	R	Rough-ped	
G	Sandy	S	Smooth-ped	

## EFFERVESCENCE OF CARBONATE

IN FINE EARTH				p198
N	Non-calcareous	S	Slightly calcareous	
M	Moderately calcareous	H	Highly calcareous	
V	Very highly calcareous			



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*TERN is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy and Super Science Initiative.*