

Discussion Paper

AusPlots-Rangelands monitoring site stratification and survey methods within TERN (Terrestrial Ecosystem Research Network)

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Executive summary

The Australian rangelands cover 81% of the continent (Bastin *et al.* 2008, Figure 1) and include some of the most poorly understood of Australia's ecosystems. AusPlots-Rangelands will provide the research infrastructure and baseline measurements across the Australian rangelands from which change can be determined. This will be achieved through establishing a network of up to 1000 permanent biodiversity monitoring plots throughout the rangelands and developing a sampling methodology to provide a consistent, systematic, repeatable and widely accepted monitoring method at each of the plots. The initial field survey will involve monitoring of vegetation species, structure and cover, and collection of voucher specimens (Table 3) of plants and soils across many rangeland bioregions. Where possible the AusPlots-Rangelands network will integrate with compatible historic and current survey and monitoring plots to value-add to both. They will be characteristic of significant areas across both widely distributed and restricted ecosystems and will include areas both 'best on offer' (for biodiversity benchmarks) and a spectrum of degradation states (for current baseline ecosystem assessment). They will be established and assessed in collaboration with state and federal agencies, private conservation organisations, companies and individuals across the region, and Bush Blitz, the national biodiversity discovery project.

The plot network established through AusPlots will further the understanding of rangeland ecosystems and progress analytical and predictive modelling. Through plot-based methods, AusPlots-Rangelands will provide the ecological infrastructure that will enable subsequent studies to:

- quantify the diversity and abundance of vegetation;
- assess the state and structural complexity of vegetation, including life-stage;
- identify which vegetation components are subject to change and the environmental drivers responsible for that change;
- record vegetation and soil parameters that assist with the validation of remotely sensed ecological products;
- analyse vegetation structure and change based on a series of photo reference images;
- better estimate soil carbon and nutrient stocks;
- enable researchers to assess current land 'condition' for a variety of purposes depending on how the data is used;
- identify the climate zones, bioregions, land types and ecosystems where changes are occurring and the management regimes and/or pressures contributing to these changes;
- conduct taxonomic validation studies based on collected plant voucher specimens;
- conduct DNA barcoding and population genetic profiling based on collected tissue samples.

The purpose of this document is to outline the objectives, the intended stratification process and the survey methods that will be conducted at each of the plots within the AusPlots-Rangelands network.

The overall TERN objective is to provide a national institutional infrastructure network for terrestrial ecosystem research and management.

In the context of TERN, the plots, data and specimens are infrastructure

AusPlots-Rangelands

The objective of AusPlots-Rangelands is to:

Establish permanent plots throughout the Australian rangeland bioregions where baseline surveys of vegetation and soils will be conducted.

To achieve this we will:

Develop and implement a stratification process to decide the locations of plots, which is applicable at a continental scale

and

Develop standardised plot assessment methods to be used for measuring and sampling vegetation and soils.

In achieving this objective AusPlots-Rangelands will also collect specimens and provide information and data to be managed and made available by the TERN Eco-informatics facility for use by the broader ecological and management community to:

- *increase the understanding of the dynamics of plant species and soils;*
- *substantially increase the knowledge of the carbon and other important nutrient budgets of the rangelands through the analysis of soils and vegetation;*
- *input into DNA barcoding of Australian vegetation;*
- *determine the genetic diversity, evolution, distribution, abundance and threatening processes impacting Australian rangeland ecosystems;*
- *assist in the field validation of remotely sensed ecological products;*
- *assist state and federal agencies to meet their monitoring and reporting obligations;*
- *create a photographic reference of Australia's rangeland bioregions to enhance existing state photo reference libraries.*

Thus making it easier to answer important questions on:

- *Ecosystem process, structure and function;*
- *The magnitude and responses to disturbance and longer term environmental changes;*
- *Sustainable management practice.*

Timeline :

- *NCRIS funding for the infrastructure component finishes at the end of 2012, requiring that all the sites are located and initially surveyed by that time.*

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Background – The Rangelands

The rangelands cover 81% of the Australian continent (Figure 1), encompassing a wide range of ecosystems including: tropical woodlands and savannas (far north), grassy plains (mid-north Downs country), deserts, hummock grasslands, shrublands, mulga and other Acacia woodlands (mid-latitudes) and saltbush and bluebush shrublands (fringing agricultural zones and in the Great Australian Bight) (Bastin *et al.* 2008). Regular cropping is not practised and the predominant agricultural use is grazing native vegetation by sheep and cattle.

A general rainfall gradient exists from summer dominant in the north (monsoonal) to winter dominant in the south. Rainfall variability is one of the major drivers of spatial patterns and of change in rangelands (Stafford Smith and Morton 1990), temporal and spatial variability being particularly evident in arid areas. Significant variation also occurs in temperature, seasonality and evapotranspiration. Understanding and managing short-term variability in the context of longer term climate change is a major challenge for sustained primary production for pastoralism as well as biodiversity conservation throughout these areas. Additionally, Australia has a high proportion of nutrient poor soils (Oriens and Milewski 2007, Morton *et al.* (2011) and comparisons are lacking with other soils across the continent and globally.

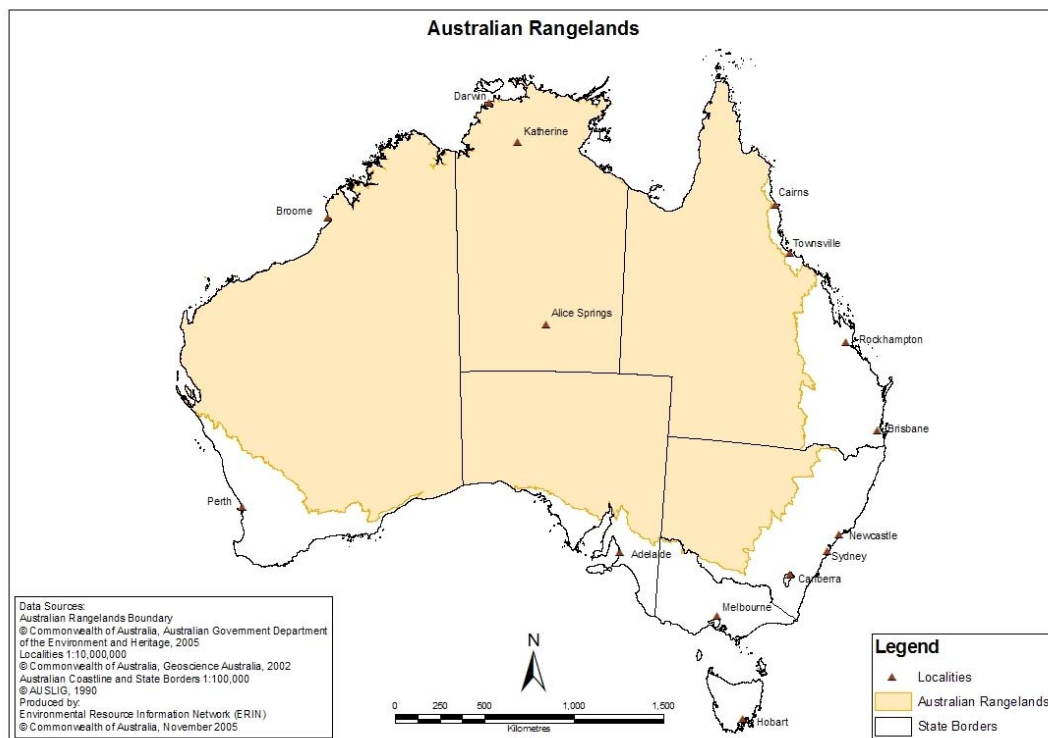


Figure 1. Extent of rangelands in Australia (after Bastin *et al.* 2008).

Australian rangeland ecosystems are some of the most poorly understood and reporting on biodiversity change is difficult because of inadequate data (Bastin *et al.* 2008). Methods used to survey and monitor these areas must be readily repeatable, and the data collected must be sensitive to changes in the structure, groundcover and landscape function of these ecosystems. To determine the current state of ecosystems, data will be obtained through standardised field surveillance surveys of plants and soils and from subsequent analyses of collected samples (Table 3). AusPlots-Rangelands will provide data and samples to further inform a number of questions raised by Morton *et al.* (in press) which relate to soil fertility, plant life histories and production in order to clarify linkages and processes in Australian rangelands. Likewise data and samples from this study will assist in addressing some of the

knowledge gaps in quantifying and understanding environmental change that currently inhibit environmental management as identified by Morton *et al.* (2009).

Much of our current understanding of vegetation/ecosystem dynamics, and condition trends in rangelands, reported in the 2008 ACRIS Report (NLWRA 2001, Bastin *et al.* 2008), is derived from pastoral monitoring programs. However, different jurisdictions have used inconsistent methods resulting in data that is not always comparable for activities such as determining national benchmarks. One of the major problems acknowledged with existing monitoring programs is the lack of benchmark plots (Watson *et al.* 2007) against which change is assessed. The Queensland BioCondition assessment framework (Eyre *et al.* 2008) uses plot-based attributes that are compared against values measured at benchmark plots (Eyre *et al.* 2006). AusPlots-Rangelands will incorporate current and historic monitoring plots where appropriate (e.g. compatible data sets accessible to a wide audience, significant data collection timeframes, interesting changes recorded), and will complement the current pastoral monitoring schemes present in each rangelands jurisdiction.

The AusPlots Network

The AusPlots-Rangelands network will represent rangelands bioregions that characterise the diverse vegetation and landscapes. The majority of plots will be positioned in areas considered as 'best on offer' (BOO) and the remainder will include areas subjected to different disturbance regimes. The plot network will integrate with current and historic survey and monitoring activities (state, federal and others) where suitable, and will allow the co-analysis of a range of historical plot-based data. In some instances it may be possible to incorporate a temporal aspect of monitoring into the spatial coverage of the AusPlots-Rangelands network by inclusion of Long Term Ecological Research (LTER) plots, and other long term monitoring plots. All activities will be executed in collaboration with state, territory and national jurisdictions as well as conservation groups, companies and individuals to further the understanding of rangeland ecosystems and progress analytical and predictive modelling.

Plot measurements will be restricted to vegetation and soils, with samples being collected for further analysis. Benchmarks will examine the distribution of vegetation species in relation to their environment in BOO plots and the effects of the disturbance regimes. Differences between the BOO and disturbed plots will indicate a change in biodiversity.

The use of plot measurements to validate remotely sensed data will provide the potential for assessment of additional attributes and the extension of land cover assessment, both by upscaling from the plot scale to landscape scales, and temporally with analysis of historic images. Variations observed through retrospective extrapolation of the remote sensing data could indicate trends in the vegetation and soil indicators in a spatially continuous manner throughout all of the rangelands rather than at individual points. These analyses would be in collaboration with the TERN AusCover facility.

Through the field surveys a variety of collections will be made - plant specimens for herbarium vouchering verify field determinations and to track taxonomic change, leaf samples for DNA barcoding and soil samples for chemical analysis. The data obtained from these samples will provide quantitative background information on the ecological dynamics of the rangelands. The information gathered will also provide insights into the relationships between plant species, plant assemblages, management actions and environmental variables. AusPlots-Rangelands will significantly advance a new range of monitoring and assessment methods, including photographic based assessment of ecosystem change, integration and calibration of remote sensing methods, and new DNA-based assessment of phylogenetic diversity, biogeographic structuring, connectivity and demographics. This will progress the capacity to predict the response of plant species and ecosystems to environmental stressors by:

- Providing the first major estimate of soil nutrient stocks for the region (through analyses of collected soil samples);
- Highlighting which vegetation components are most subject to change and which have highest landcover persistence (from comparisons of historic site datasets and complementary BOO plot data, through comparing differences between the BOO plots and the disturbed sites investigated;
- Identifying the disturbance regimes and/or pressures likely to contribute to the observed changes including fire, drought, total grazing pressure, management and climate change (evident from differences between the BOO plots and the corresponding disturbed plots);
- Determining the climate zones, bioregions, land types and ecosystems where changes are occurring (from comparison of historic site datasets and from complementary BOO plots data); and
- Establishing the environmental drivers of change/abundance (from comparison of historic site datasets where environmental factors have been recorded and data from complementary BOO plots, and through future changes determined from ongoing monitoring).

The baselines determined through the initial AusPlots-Rangelands survey will provide the foundations from which future monitoring can determine the direction and degree of change in biodiversity, ecological function and environmental carbon budgets. The infrastructure developed will offer multiple use (non-destructive) opportunities and additional benefits including:

- The framework on which to base other research and monitoring components (e.g. fauna monitoring, Bush Blitz surveys of plants and animals undertaken at selected properties in Australia's National Reserve System);
- Biological baselines to direct restoration outcomes for large-scale development projects and environmental offset schemes;
- Integration of the extensive plot-based survey and monitoring undertaken by state and territory efforts in the rangelands and the opportunity for the jurisdictions to develop benchmarks/controls which have previously been beyond the logistical and financial resources of that jurisdiction; and
- Sites for joint projects within TERN, such as co-locating Ozflux towers at Super sites and AusCover sites with an AusPlots-Rangelands data collection plot.

BOO (best on offer) sites

The concept of BOO and the acquisition of BOO data is critical to the interpretation of biological data. There are numerous definitions of BOO sites, and while most come from the aquatic sciences (e.g. Johnson 2000) they are entirely applicable to the terrestrial environment (see Landsberg and Crowley 2004). Ideally, BOO sites represent those systems with the most intact, naturally functioning biological conditions found across the landscape, typically encountered in systems undisturbed by anthropogenic stressors. Recognising that these "pristine" habitats are rare or non-existent, resource managers must decide on an acceptable level of disturbance to represent an attainable or existing BOO state. In all situations, BOO data represent areas within an ecosystem that are least disturbed.

BOO plots (controls/benchmarks) that can be used to compare extant monitoring plots are typically limited in number or non-existent. Some authors equate exclosures that exclude herbivores and other ecosystem "engineers" with BOO areas (e.g. Watson *et al.* 2007), however the use of exclosures adds a further level of complexity in understanding change and vegetation dynamics. Some jurisdictions have substantial biodiversity inventory programs with useful baseline data on plant and vertebrate distributions collected in many rangeland bioregions (e.g. South Australia; Owens 2000). These will be incorporated where

appropriate and compatible. However, there are no current coordinated broad-scale and comprehensive biodiversity monitoring programs (Whitehead *et al.* 2001, Day 2007) and AusPlots-Rangelands will provide the infrastructure and develop the methods to address this need for flora and soils with the possibility to collaborate with other projects (e.g. ACRIS, Bush Blitz) to include fauna monitoring or to obtain future funding to expand the project to include fauna monitoring as well.

Disturbed Sites

Monitoring plots within the current pastoral monitoring programs have biased distributions. Typically, a greater number of plots are located in the more extensive land types of higher productivity within a certain distance from waterpoints (generally <3 km). Rarely sampled areas include restricted landscapes such as riparian zones and rocky outcrops (see Pringle *et al.* 2006) due to their size and shape presenting sampling challenges, and some extensive lower productivity landscapes such as deserts. To monitor disturbance regimes, existing pastoral monitoring plots will be used where they satisfy the disturbance parameters and have compatible data. The site history and current management will also need to be obtained, where available, in order to gain an appreciation of the level of disturbance.

Fire is the other major disturbance regime evident in the rangelands, with significant spatial and temporal variability. Fire monitoring plots will also be incorporated that satisfy the AusPlots-Rangelands stratification requirements and site history will be included.

The Site Selection Process

The site selection process involves several stages; stratification and selecting priority bioregions, plot stratification within each bioregion, and then interpretation of selected areas in terms of homogeneity, historical data locations along with logistical and access considerations.

The stratification process will be undertaken collaboratively with relevant state and federal jurisdictions and interested conservation groups and individuals. The objectives of each state will be considered in the stratification process, but a continental perspective must be employed in deciding plot locations.

Stage 1: Bioregional Stratification

To expedite site selection, a bioregional stratification process was developed and applied to all Australian bioregions, including the 52 present in the Australian rangelands (Figure 2). Each jurisdiction has between 9 and 25 rangeland bioregions, with the extent of some limited in some jurisdictions (Bastin *et al.* 2008). Monitoring plots will be located in sufficient bioregions to give adequate geographic and environmental spread to show patterns of vegetation structural and compositional change at jurisdictional/national scales.

To decide the bioregions to be monitored a number of spatial data layers were used in a series of hierarchical cluster analyses (in PATN) to produce dendrograms grouping similar bioregions. A number of variables were investigated. Some were poorly defined, or poorly synthesised across Australia and were subsequently rejected as they confounded the analyses. Variables retained were climate i.e. Hutchinson Agro-climatic classes (Hutchinson *et al.* 2005), regolith (Regolith of Australia (National Geoscience Dataset) the broadest relevant geological classification in Australia, incorporating landscape and regolith class), major vegetation groups (NVIS level 3, ESCAVI 2003), the rangelands boundary and the IBRA 6.1 sub-region boundaries. Areas (km²) of each polygon were calculated and the data summarised by a combination of bioregion and its occurrence in the rangelands. After the final analysis the results were interpreted and X groups of bioregions were determined, with Y of these occurring within the rangelands.

Table 1 Proposed factors to be considered in different stages of the bioregional stratification.

Factor to consider	How Used	Assumptions	Stratification Stage	How utilised
Financial Limitation	Objectively	Limited funding requires many pragmatic decisions on many of the above points	All	Office
Climate	Objectively	Climate effects the distribution/ types of ecosystems	Stage 1	PATN analysis
Landscape pattern	Objectively	Landscape patterns affect the distribution of ecosystems	Stage 1	PATN analysis
Major Vegetation groups	Objectively	Landscape patterns affect the distribution of ecosystems	Stage 1	PATN analysis
Bioregions	Objectively	These are well defined and well explain/ describe broad environmental differences.	Stage 1	PATN analysis
Ease of access of to bioregions	Heuristically	Unsustainable to pick all bioregions that are difficult to access although it's acknowledged that some difficult ones will need to be sampled	Stage 2	Workshop
State priority areas	Heuristically	Need to align our work to state priorities where possible, although sampling within each bioregion group as determined in Level 1 is of primary importance	Stage 2	Workshop
Good national spatial coverage	Heuristically	Need to sample across the spatial range of environments	Stage 2	Workshop
Previous monitoring	Heuristically/ objectively	The historical data and our new method will be compatible - Need to use some previous monitoring sites to add value to both data sets and to be able to link AusPlots to historical analysis	Stage 2	Workshop
Data Deficient Bioregions	Heuristically/ objectively	There is a need to fill data gaps and increase knowledge on poorly known bioregions	Stage 2	Workshop
Site Ownership	Heuristically/ objectively	Ownership will affect access as well as management and hence the likelihood a site can be used long-term. Establishing NRS sites increases the likelihood they will be useful long term and should also minimise TGP	Stage 2 / Stage 3	Workshop

Ease of access to suitable sites	Heuristically/objectively	Need access to most sites fairly easily - Large equipment needs.	Stage 3	GIS
Location of other TERN sites	Objectively	Co-locating with these sites value adds across the TERN network.	Stage 3	GIS
IBRA Sub-Regions	Objectively	That sub-regions have been accurately delineated to account for large differences within each bioregion - Will stratify by including sites within a wide variety of sub-regions	Stage 3	GIS
Distance from water	Objectively	That cattle have little influence on species diversity of ground cover beyond 10 or 12 km from water, sheep have little effect beyond 6 km.	Stage 3	GIS
Land systems	Objectively	Land systems well describe a complex environmental unit in terms of re-occurring patterns of soil, vegetation and landform - At a scale below that of the bioregion	Stage 3	GIS
Vegetation mapping	Objectively	Accurately divides the landscape into consistent vegetation communities which inform and influence biodiversity	Stage 3	GIS
Regional ecosystems	Objectively	Usefully subdivides the land based on landscape and vegetation and geology, Widely accepted and each RE has a conservation significance allowing the ability to specifically target or avoid rare and/ or protected ecosystems.	Stage 3	GIS
Road and track layers	Objectively	Need ready access to sites but also need to ensure that sites are not unduly influenced by their proximity to roads	Stage 3	GIS
Location of previous monitoring sites.	Objectively (location), Heuristically (quality of data)	Assumes old data can be made compatible with AusPlots method - this needs to be included when considering sites	Stage 3	GIS
Location of good quality biodiversity survey sites	Objectively (location), Heuristically (quality of data)	Assumes old data can be made compatible with AusPlots method - this needs to be included when considering sites	Stage 3	GIS
Location within the NRS	Objectively	Assumes that sites located in the NRS are better protected	Stage 3	GIS

Land Units	Objectively	Supersedes land systems when Land units are available - at a finer scale and aim to map homogeneous units	Stage 3	GIS
Dominant land use	Objectively/ heuristically	Land use influences management, and as a result what pressures will be applied to a site.	Stage 3	GIS
Site homogeneity	Heuristically	That a skilled experienced field ecologist is able to accurately identify 1 ha sites in the field that are as homogeneous as possible. - Consistent and constantly mixed in terms of soil, slope, relief, vegetation etc	Stage 4	Field
Site Orientation	Heuristically	Sites to be oriented N/S, E/W unless essential for orientation to meet the homogeneity criteria above - Assume a skilled field ecologist able to make this call accurately	Stage 4	Field

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Stage 2: Selecting representative bioregions to sample.

At least one bioregion in each group from the hierarchical cluster analysis will be sampled. The bioregion decisions will be based on logistical issues, 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, the likelihood of longevity of site management for monitoring purposes and ease of access.

Factors including previous surveys, dominant land uses, extent of reservation, size and jurisdictional capacity to assist with surveys, ease of access and local priorities will then be used to determine which bioregions are ultimately sampled. This will ensure that bioregions representing the variety of climates, geology and vegetation types are sampled.

Stage 3: Stratifying areas of sampling interest within bioregions.

Within each selected bioregion a stratification process will be conducted to select sample areas based on a hierarchical stratification process (Figure 3).

The initial stages of the process will include a GIS desk-top exercise interrogating available layers to identify prospective areas for plots. Guidelines will be employed in the stratification process, but flexibility will be necessary in choosing plot locations and potential locations will often need to be visited to determine their suitability.

Important considerations in the stratification of monitoring plots have been discussed previously (e.g. Smyth *et al.* 2003, Smyth & James 2004, Fisher *et al.* 2007, Kuttet *et al.* 2009) and have been considered in the proposed stratification. In addition, fiscal and logistical constraints mean that a practical design that maximises the likelihood of meeting broad objectives is preferable to a theoretically optimal design.

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 geomorphically with a similar position in the landscape/catchment)

AusPlots-Rangelands will not attempt to sample all land types in all bioregions, but rather assess and monitor patterns of vegetation change at jurisdictional/national scales and changes in responses to environmental drivers. Plots will be selected both in land types that are most representative of extensive ecosystems (cf. pastoral monitoring programs), as well as more restricted components considered significant for ecosystem function. These are generally under-sampled in inventory and monitoring programs but are highly significant for biodiversity. Such “restricted” ecosystems may include riparian zones, rocky outcrops or sand plains in different regions. 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; those under greatest pressures; or where greatest change in vegetation structure and composition is considered likely. Kutt *et al.* (2009) suggested two land types be selected a “sensitive” (slow recovery response following release of “pressure”) and a “resilient” (quick recovery response following release of “pressure”). The geomorphological implications of the plot locations need to be considered and an assessment of the position of the plots from a landscape and catchment perspective will be included to ensure comparable BOO and disturbed comparison plots are surveyed.

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.

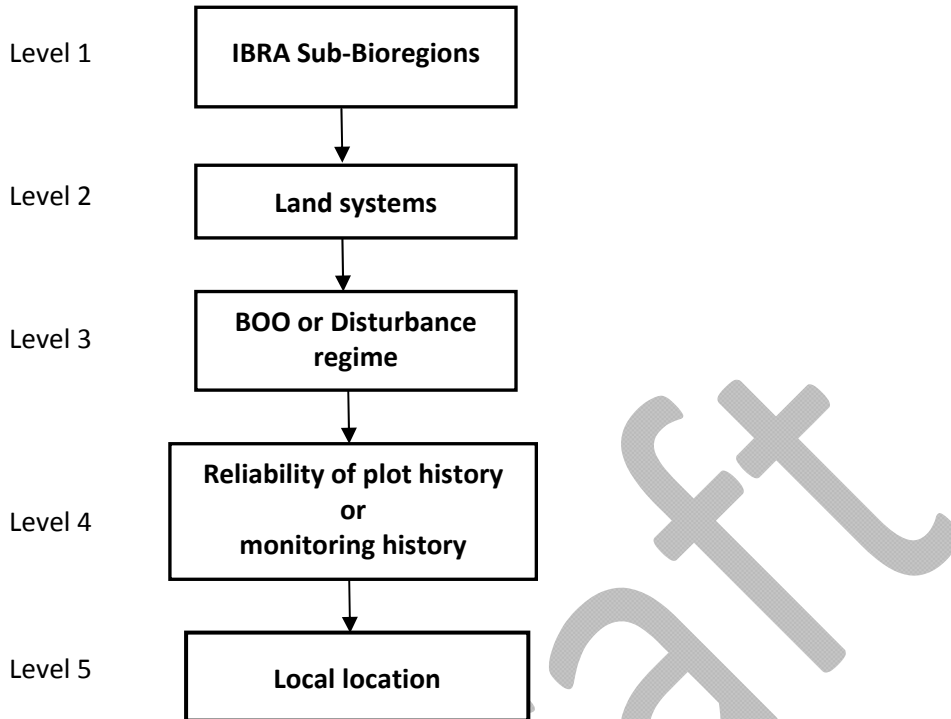


Figure 3. Indicative plot stratification levels within each rangeland bioregion. (modified from Kutt *et al.* (2009)).

Level 3: BOO or Disturbance regime

Monitoring plots will include areas that represent BOO sites (Landsberg and Crowley 2004), and disturbed plots.

BOO plots will be located where the dominant threatening process/es are minimised, often within the National Reserve System (Figure 2) which includes jurisdictionally managed parks and reserves, Indigenous Protected Areas and private reserves owned and managed by organisations such as Bush Heritage Australia, or Australian Wildlife Conservancy. History of the reserves, especially total grazing pressure (livestock, feral and native animals) and fire will need to be considered to determine the current disturbance level of any plot. It is likely that the BOO plots for any particular stratification combination will be along a continuum of states.

To differentiate between drivers of change which are natural e.g. seasonal conditions, and those that can be managed e.g. anthropogenic factors such as land use, the range of anthropogenic disturbance factors will be identified. Where knowledge of the changes resulting from the disturbance will be informative, e.g. in collaboration with current grazing plots, comparison disturbed plots will be included within the survey process. Characteristics of the BOO plots and corresponding disturbed plots will need to be closely matched. Inclusion of these plots will allow some quantification of the historic, current and future disturbance.

In rangelands, the threatening processes or disturbance regimes are generally restricted to land use such as pastoral, conservation, mining, tourism, Indigenous use etc., fire, TGP, feral animals or weeds. BOO plots are ideally located beyond the effect of maximum grazing degradation around stock watering points i.e. piospheres (Lange 1968), generally >6 km from water, (Brook *et al.* 2004; Fensham and Fairfax 2008), or other areas with historically low grazing pressure due to lack of suitability for grazing (poor pastures, low water quality or availability). These situations are depicted in Figure 4, an example of a pastoral property demonstrating both “unwatered” low stocking rate areas and highly grazed zones or piospheres surrounding watering points. BOO plots will be preferentially located in the unwatered (unhatched areas) which theoretically represent the most intact and functional parts of ecosystems. Realistically however, especially with the more productive or more localised land types e.g. riparian or floodout areas, BOO plots will need to be located in areas of intermediate landcover, broadly representative of that land type/land use combination. On pastoral lands these would typically be 3-4 km from water. (It is acknowledged that watering point location, as displayed, can sometimes only be a crude indicator of likely disturbance level and may prove of limited value. The stratification process will be applied to guide site selection in all instances, but reconnaissance visits of potential plots are essential to confirm plot locations, as detailed in Stage 4 of this stratification.)

Level 4: History: Plot or Monitoring

The history of a potential monitoring plot, both the previous land management and/or any preceding monitoring, will help decide the suitability of the area. If a potential plot has an unusual climatic or management history, thereby presenting difficulties in locating suitable replicate plots, these may prove of little value in describing the regional conditions. However, if the area has been monitored previously and good quality, relevant data collected that can be made widely available, then co-locating an AusPlots-Rangelands plot would value-add to both past monitoring and the AusPlots-Rangelands survey efforts. This collaboration can incorporate more targeted species-specific monitoring undertaken by other agencies or researchers, and will include plots from the extensive range of pastoral monitoring activities of other jurisdictions, or long-term monitoring plots investigated by universities.

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

- the location of the area monitored and the ability to accurately relocate the site;
- the actual monitoring data collected;
- the monitoring methods used and the compatibility of the data;
- who undertook the monitoring and the consistency of data collector;
- the period over which monitoring was undertaken and the number of times monitoring occurred;
- the dates monitoring occurred (especially relative to seasons and rainfall);
- data robustness and reliability;
- data availability, format and accessibility;

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; presence and effect of other pressures such as feral animals or weeds.

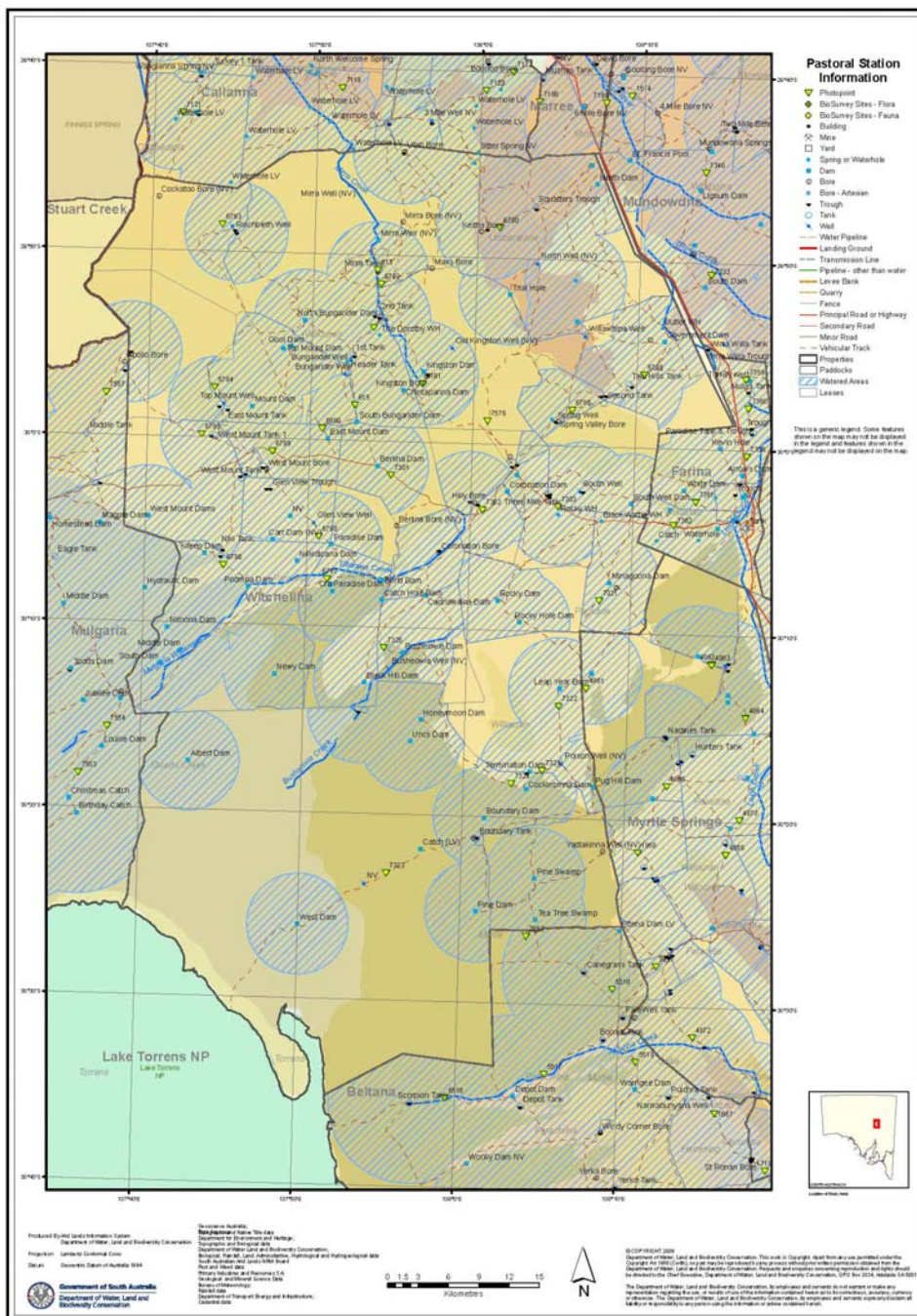


Figure 4: Map of pastoral property showing piospheres (hatched areas) overlaying IBRA subregional boundaries (shaded areas). Monitoring plots would be located in non-hatched, shaded areas.

Stage 4: Choosing plot location in the field based on areas of interest.

It is unlikely that a precise plot location will be determined by the stratification, but rather a priority area within which to locate a site. At the local level it is important to locate the site in a large area that is as homogeneous as possible. The plot location should be, where possible, orientated in a N/S, E/W orientation 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). One hectare should be aimed for in all circumstances. It is important to locate these plots in as large and relatively homogeneous areas as possible and avoid any

ecotonal effects within the quadrat. Notes on this final site selection taken in situ should form part of the dataset collected at each of these sites.

Additional considerations: Statistical framework

With the environmental variation at different spatial scales a characteristic of rangelands and the relatively low number of sites proposed for the project, a Bayesian framework is proposed as an alternative to traditional frequentist statistics (McCarthy 2007). A Bayesian framework can give greater flexibility in the analysis and evaluation of monitoring data and can be used to inform decisions for better use of resources (Newman and Evans 2002).

The Bayesian approach requires the specification of prior knowledge, or the “prior” which can be defined from a combination of expert knowledge and quantitative data and can be revised to obtain results or “posterior” knowledge. The Bayesian approach has been increasingly recommended for use in monitoring programs as well as in biogeography and community ecology (Martin *et al.* 2005; Kéry and Royle 2008, Kutt *et al.* 2009).

Frequentist statistics require the setting of adequate sample sizes and replicates to obtain an appropriate level of statistical power. There is increasing discussion that statistical significance may not relate to ecological significance (Quinn and Keogh 2002).

Plot Assessment Methods

The plots chosen in conjunction with the state and territory agencies will be permanently marked to facilitate relocation and future monitoring. The methods used will be repeatable, quantifiable and suitable for all the vegetation classifications being studied (Hnatiuk *et al.* 2009). However, some flexibility will be included to encompass the variability of land types to be monitored (e.g. in plot layout for riparian areas), and the stochastic nature of arid zone ecosystems (e.g. recording total vegetation cover but separating it into annuals and perennials).

AusPlots-Rangelands will only include an initial survey. To determine reliable biodiversity trends at least two future assessments should be undertaken within a biologically meaningful timeframe i.e. from annual to 5 to 10 years depending on location and seasons. This however is reliant on future funding outside the current TERN timeframe.

An adaptive process has been developed through the AusPlots-Rangelands Protocols and Standards Reference Group which includes state and Territory representatives, and includes many well respected rangeland ecologists. The monitoring outcomes will be reviewed by this group to guide future monitoring processes. The survey parameters, method to be used and their application and are summarised below (Table 2).

Table 2. Survey parameters, methods, indicators and applications for AusPlots-Rangelands surveys.

Survey parameter	Parameter element	Measurement method	Indicator	Application
Vegetation: - perennial - annual - ephemeral	- trees - shrubs - forbs - grasses - vegetation cover - substrate cover	identification to species level	- species distribution - species abundance - species/community persistence - site condition - site variability	- population structure - demographic profile - condition assessment - species distribution and dynamics modelling (e.g. bioclimatic envelope predictions)
		point intercept at species level	- site diversity measures - cover of individual species - total cover (with annuals) - species abundance - population vertical structure - species/community persistence.	- population structure - demographic profile - condition assessment - remote sensing validation - geographic extrapolation of interpretations - temporal extrapolation of interpretations - retrospective : refine / enhance / accuracy assessment for AusCover products
		LAI meter	Leaf Area Index (LAI)	- remote sensing validation - retrospective: refine / enhance / accuracy assessment for AusCover products
		1 x voucher specimen collected for each species within a 50 km area	- taxonomic identification and tracking taxonomic change through the data. - DNA barcoding - vegetation carbon content	- biodiversity discovery - genetic assessment of broad scale population connectivity and diversity - carbon budget changes
		Photopoint (new method being developed with ACVT)	- life form - site patchiness - population height/vertical structure - plot basal area	- population structure/ structural complexity - population dynamics - demographic processes - condition assessment (contributing information)
Vegetation: - perennial only	- trees - shrubs - forbs - grasses	5x leaf specimens collected for each species per plot	- DNA barcoding	- genetic assessment of fine scale population connectivity and diversity
Soils	soil samples	MIR and wet-chemistry per plot : 8 x soil cores to 30 cm, 1 x soil core to 1 m+	- soil nutrition (N, P, K etc) - soil carbon - bulk density	- enhanced knowledge of rangelands soils - carbon and other nutrients budgets
	soil crusts	soil metagenomics (genetic material from environmental samples)	- taxonomic identification - DNA barcoding for population genetics	- microbial diversity - genetic assessment of population connectivity and diversity
		cryptogam identification 1 x surface sample per plot	- taxonomic identification - DNA barcoding for population genetics	- biodiversity discovery - genetic assessment of population connectivity and diversity

Guisan, 2007) which enables the calculation of vegetative cover of each species. For the overstorey a class of "in Canopy - Sky" will be collected, i.e. the point being sampled is within an overstorey canopy, but is actually "bare" sky. This is different to no overstorey (outside Canopy - Sky) and will enable the use of either opaque canopy cover or Foliage Projective Cover as a cover measurement.

Plant specimens and soil samples will be collected as per the following sections. To provide a complete vegetation suite and minimise field identification issues, data collection will include annual, ephemeral and perennial species. The presence or absence of perennials is influenced less by seasonal conditions immediately preceding a survey, while the influence of stochastic rainfall events is indicated by the measure of annual/ephemeral cover. The identification of annual or perennial species is best resolved once definitive identifications are returned from the herbaria.

Software is being developed to allow field data collection directly onto a computer or PDA. This will automatically collect location information at each point allowing spatial heterogeneity (and hence information on landscape function) to be derived from the data (Figure 5). Vegetation species that are observed within the plot but not recorded during the point intercept collection, will be collected and recorded, thus allowing the data to be used for species richness and other presence/absence analyses. Additionally species located outside the plot may be collected, with their record being clearly identified as being outside the plot. This allows the data to be used as an opportune record to inform distributional studies, whilst having no impact on the "within-quadrat" data.

Plot configuration can be modified where the area of a significant land type is not adequate, ensuring 1 ha is assessed and plot dimensions i.e. corners, are recorded. These plots will not be used for remote sensing validation. Homogeneity is a criteria that must be met to enable the data to influence macroecological studies at the continental scale.

Table 3 The information recorded and location within the plot.

	Information collected/ recorded	Locations
Point samples	Marked Picket	SW
	Photo points	All 9 (NW,N,NE,W,C,E,SW,S,SE)
	Basal Wedge Sweep	All 9
	LAI Meter Readings	30 within a plot
	Bulk Density Sample - 0-10, 10-20, 20-30	SW
	Standard Soil Sample - 0-10,10-20,20-30	All 9
	Soil Core to > 1 m	SW
	Full soil profile description	SW
	Soil Meta-genomics Sample	tbd
	Plant Vouchers	As required
	Plant Genetic samples	As required
Transect measures	Species	At point taken every 1 m of transect
	Cover	
	growth form	
	Senescence	

The data will be collected to enable subsequent determination of total cover, areal cover and spatial heterogeneity, as well as the separation of perennial species cover from annual/ephemeral cover and basic phenological detail (see Griffin 1989). The height of a certain layer is measured from the ground to the top of the vegetation being measured.

Additionally the three most dominant species per strata (ground, mid and upper) will be recorded, along with an estimate of cover for that strata, a dominant growth form per species, and an average height class for each strata. This informs studies that look at vegetation structure and aids in an accurate NVIS level 5 description of each site.

Basal Wedge Measures:

In some instances (areas of particularly sparse overstorey) 1 ha may be inadequate to accurately quantify the overstorey. The AusPlots method will include 9 basal wedge sweeps per plot, at the point sampling locations (Figure 5). The Basal Area Factor (BAF) and the number of "hits" per species will be recorded at each of these locations. Given the sparseness of rangeland vegetation, wedges will be made with the smallest BAF of 0.1. This information will allow calculations of basal area per species, and biomass calculated if additional information is known on the species of interest. Additionally these AusPlots measures will enable the relationship between FPC and basal area to be calculated for common overstorey species frequently encountered at sites. This technique will only be used at sites where it is as sensible to do so (i.e. not in grasslands).

LAI (Leaf Area Index) Measures:

LAI measurements will be recorded using a LAI2200 meter at 30 points within the plot. This technique is simple and quick (five minutes per plot) and enables the relationship between Foliage Projective Cover and LAI to be developed. When done at a large variety of vegetation communities through the rangelands it will assist with validation of remote sensing products developed by the AusCover TERN Facility. AusCover Facility will better understand the relationships between their products and field conditions which will in turn lead to more accurate and higher quality imagery products to be produced for use by the entire ecological research community.

2) Photopoints/Photoplots

Photopoints will be established at multiple locations within plots. Photopoint protocols are being developed in collaboration with ACVT (Australian Center for Visual Technologies) at the University of Adelaide, taking into consideration the significant recent research conducted by this group on extracting biologically meaningful parameters from image data. Whilst this research is ongoing, it is anticipated that a series of digital images will be collected and archived for each plot for future use to extract both qualitative and quantitative information to enable assessment of structure, age profile and recruitment of vegetation within the plots. It is anticipated that significant height and structural information will be available from the photopoint photo series. To facilitate relocation and repeat photographs, camera details and settings, location and direction of photopoints will be standardised and recorded with detailed divergences noted.

3) Soils

Soil collections and hence detailed knowledge can be very sparse across the rangelands and the samples collected as part of AusPlots-Rangelands will provide valuable background information. Samples will be collected at 9 locations across each plot with the collection protocol and subsequent analyses developed in collaboration with the TERN Soils Facility.

Soil Core/ Soil description:

At one of the nine locations (usually the south west corner) a soil core will be taken to a depth greater than 1 m. This core will have a soil description including bulk density samples taken at the depths of 0-10, 10-20 and 20-30 cm and will be stored in the national soil archive, CSIRO Canberra. Samples will also be taken at the 8 other locations within the plot (Table 3), to a depth of 30 cm (0-10 cm, 10-20 cm and 20-30 cm) using a push tube and the samples bagged and submitted to the CSIRO National Soils Archive and the TERN Soils

facility. Samples from the 1000 sites will significantly increase the soils knowledge (samples number and distribution) in the rangelands.

Soil Chemical and Physical properties:

Due to the significant costs, a sub set of soil samples will be submitted for comprehensive chemical and physical analyses. These samples will also have MIR (mid infrared) and NIR (near infrared) spectrometry analyses to increase the accuracy of calibration equations between soil parameters and MIR. This data will contribute to filling data gaps through the rangelands and increase the accuracy of MIR analyses.

The MIR technique reflects light energy in the mid infrared range (4000 to 500 cm^{-1}) from the surface of a soil sample to produce a number of characteristic spectral peaks. The use of MIR (see Janik *et al.* 1995, 1998, 2007) offers an acceptable compromise between accuracy of soil attribute predictions (Table 4) and costs and effort in collecting an adequate number of samples. MIR predicts (not directly measures) a wide range of chemical and physical soil properties that are closely related to the bulk properties of soil. Given that the MIR technique predicts many soil properties and does not measure them directly, correlation coefficients indicate a high level of precision (e.g. total organic carbon $r^2=0.93$, total N. $r^2=0.89$, cation exchange capacity $r^2=0.93$). This technique has been used successfully to estimate a range of physical and chemical soil properties e.g. clay, organic matter, moisture content, organic carbon (OC), total nitrogen (N), cation exchange capacity (CEC), exchangeable cations (Ca; Mg, K; Na), quartz, kaolinite and smectites (<http://www.clw.csiro.au/services/mir/routine.html> for more detail).

Soil carbon is the largest terrestrial carbon pool and the largest biospheric carbon pool subject to anthropogenic influences. Better knowledge of the size of the soil carbon pool and its dynamics is therefore essential for conducting carbon dioxide flux inventory and for modelling the global carbon cycle. Site history, i.e. details of preceding fires and rainfall, will be necessary to understand these dynamics. Soil carbon also affects many other soil variables; e.g. water holding capacity, cation exchange capacity and erodability. It is anticipated that the data gathered in this study will significantly improve our understanding of soil carbon, its role and fluxes in the rangeland regions of Australia.

Table 4 Typical soil properties predicted by MIR

Chemical Properties	Physical Properties
carbon pool; total organic, charcoal, particulate organic, inorganic C, tot N	bulk density
exchangeable cations; Ca, Mg, K, Na, CEC	particle size; clay, silt, sand
phosphorus buffering index	volumetric water contents: (0,1,3,5,10,50,500,1500kPa)
pH; water, CaCl	quantitative XRD: quartz, kaolinite, smectite
electrical conductivity	quantitative XRF: Si, Al, Fe, Ca, Mg
exchangeable sodium percentage	

(taken from CSIRO Land and Water website 2010)

4) Plant specimens and DNA Barcoding Samples

The identification, investigation and description of species can inform our understanding of their roles in ecosystem function. The identification of species-rich areas can be helpful to determine priority areas for conservation, particularly those areas acting as refugia in arid zone ecosystems. The decline in species richness in a plot or across similar plots is an indicator of pressures on the environment and can help to define conservation measures or understand ecosystem processes. See Dugan *et al.* (2007) for a detailed method for surveying and collecting plant vouchers for morphological and DNA analysis for a large sampling area.

Vouchering Protocols

1. Existing herbarium records and their currency will be examined prior to each survey to determine collection requirements or the need for duplicates
2. First occurrence of all vegetation species to be sampled as a voucher within the sample cluster of 50 km radius (approx) and a unique barcode assigned to each sample.
3. Five samples of leaf tissue of each perennial species to be collected across the plot and dried in silica gel for future DNA analysis (population genetics and community phylogeny/phylogeography analyses)
4. Taxa with uncertain identity or those of conservation value to be collected.
5. Additional samples will be collected from subsequent plots if they provide better material
6. Replicates of taxa from different bioregions and land types to be collected (irrespective of 50 km radius)
7. Samples to be housed with collaborating state and territory agencies

Herbarium vouchers of each species from each population will be collected where material is for genetic analysis. This is particularly relevant for plant groups with taxonomic uncertainty. Samples are to be housed with collaborating state and territory agencies.

Data Collection

To streamline data collection and handling, field data will be collected directly as digital data onto GPS enabled PDAs and downloaded automatically onto field based computers. The appropriate software and applications are being developed in collaboration with ALA (Atlas of Living Australia). To enable people/juristictions to use their current devices the application will be developed and programmed to be available for use on a wide variety of devices and operating systems. The field data collection application will be developed as a heirarchical model with a number of separate forms (e.g. site details, point intercept data, voucher/sample details) and fields to ensure that all data collected is compatible and collected to the required standards. Protocols for data backup and storage and update to AusPlots/Eco-informatics will also be developed. Vouchering methods and field barcode use are also being developed to be compatible with digital data collection, management and updating, as part of the end2end protocol being investigated by ALA.

Accuracy assessment

It is important for the future utility of the data that data errors, data accuracy and repeatability of collection methods are well understood and documented. This is essential to avoid the data being used for purposes beyond its accuracy levels. The accuracy of the AusPlots-Rangelands methods will be investigated with a number of collectors to guide its future use. Godínez-Alvarez *et al.* (2009) in a comparison of vegetation monitoring methods in a range of plant communities concluded that foliar cover estimates were most precise in the least time with the line-point intercept method and species richness measures were maximised through ocular estimates, both methods are used here.

Data Curation

The data collected as part of the AusPlots-Rangelands project will be stored and managed by the TERN Eco-informatics Facility who will also be responsible for data management and delivery. It is also acknowledged that not only the raw plot data but the method standards and the stratification process and outputs all constitute valuable information that need to be collected and stored as part of the project to provide valuable context for the data collected. The required process is under development.

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