Assessment of vegetation condition - Mulloon Creek Catchment and Mulloon Community Landscape Rehydration Project

2018 Baseline Assessment

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VAST Transformations

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Executive Summary

This report presents the findings of an assessment of vegetation condition conducted within the spatial extents of the Mulloon Community Landscape Rehydration Project (MCLRP) and the broader Mulloon Creek Catchment (MCC). The Mulloon Creek and its adjacent floodplains provides the focus for much of the community action and land manager engagement in the MCLRP. Generally, the MCLRP includes that part of the Catchment which is bounded by Home Farm in the south and the Sandhills watershed in the north west and Palerang in the northeast.

This reach of the Catchment is a mosaic of native and non-native vegetation cover types associated with soil-landscapes which have a long history of management for the production of pastures generally used for sheep and cattle grazing. This baseline assessment is based on selected interviews and field surveys (formal and informal) (Figure 1) and analysis and interpretation of aerial photographs.

The installation of leaky weirs to hydrate and rehydrate soil-landscapes is a land management practice or intervention, the effects of which can be reported and monitored using states (map units) and transitions (causal factors i.e. the drivers of changes between states).

This baseline assessment utilises the Vegetation Assets, States and Transitions (VAST) methodological framework, the method is described elsewhere (Thackway and Lesslie 2006; and 2008, Thackway and Specht 2015; Thackway and Freudenberger 2016; Thackway 2016). This framework is designed to develop two information products about the condition of any managed landscape:

1. maps of extent of classes of native vegetation condition and
2. graphical summaries of the transformation of landscape where change and trend in vegetation condition are assessed at sites

In this assessment of the vegetation condition of the MCC and the MCLRP, the VAST framework is implemented at various spatial and temporal scales. At the site to landscape levels VAST provides an assessment tool to critically appraise the relevance of scientific studies, reports and historical knowledge of on-ground practice to document and account for changes in vegetation structure, composition and function as well as what are the drivers of vegetation condition states and transitions over space and time.

There are extensive patches of native woodland and forest that occur particularly on Landtasia, the Home Farm and on Palerang which are minimally modified (Table 1) from the original vegetation state (pre-European reference state). These patches are associated with soil-landscapes that are found on steeper terrain at higher elevations and where the soil is shallow or skeletal. Based on information compiled and collected much of these woodlands and forests are a combination of regrowth stands i.e. recovering from historic clearing and thinning events and areas which were formerly woodlands which have thickened following the cessation of regular burning to maintain an open grassy understorey. These areas can be classified and mapped as VAST class I (Residual or Unmodified) and class II (Modified) (Table 1).

On the ridges running north south to the west of Hazedell Road and east of the Mulloon Creek area there are discontinuous patches of woodland. It appears that the predominant land management regime across several properties and over an extended period, probably many decades, has been heavy total grazing pressure of the pastures by continuous grazing. Total grazing pressure within the intensive land use zone involves a complex interaction between native and native pastures and several players including; feral grazers and browsers (rabbits, goats, pigs and deer), native animals (grey kangaroos and wallabies) and domestic animals (sheep, cattle and horses). The relative effects of these species of function, structure and composition needs to be determined at the property and paddock and site levels over time.

Opportunistic observations showed that on the whole, regeneration of middle and overstorey trees and shrubs has been inhibited however, there are small patches of dense tree regrowth that occur within these stands of woodland. Many of the woodland trees are mature and senescent. In these native dominated landscapes the ground layer is low and open comprising native grasses, herbs and low shrubs. Bare ground is present in certain areas because of high total grazing pressure. These are areas of highly modified native vegetation and can be mapped as VAST class III i.e. Transformed. This corresponds with the observations recorded in the field.

The VAST framework was used in this project as a tool for consistently and repeatedly assessing and reporting the effects that land management practices have on structure, composition and function of plant communities over time. The states and transitions of the VAST Framework (Table 1) along with the hierarchical indicators and criteria (Table 2) captures the key drivers and stages of the degradation and recovery of ecosystem processes that affect vegetation communities modified by human activity (Thackway and Lesslie 2006 and 2008; Thackway and Freudenberger 2016).

Detailed chronologies of seasonal rainfall (Appendix 1) and production systems compiled for selected properties with the assistance of several land managers (Appendix 2) provide key insights into the modification and transformation of the of the MCC and MCLRP. These chronologies also relate closely to the modification and transformation at the site level. Sites were established, using a plotless sampling unit, i.e. a soil-landscape association, the location and general extent of which remains unchanged over time. The dimensions of the site are georeferenced as a centroid which remains constant back in time, now and into the future.

It should be noted that because of the close association between the attribute frameworks underpinning the Landscape Function Analysis and VAST criteria and indicators, VAST sites are a subset of the LFA sites (Appendix 3). For this reason, the VAST sites were surveyed after the LFA sites were completed. The VAST sites were surveyed for structure and composition (Appendix 4) and the LFA sites provide a complementary set of functional attributes to those of the VAST framework (refer to functional attributes in Table 2).

List of Abbreviations

GPS	Global Positioning System coordinated for latitude and longitude
LFA	Landscape Function Analysis
MCC	Mulloon Creek Sub-Catchment minus the Sandhills watershed
MCLRP	Mulloon Community Landscape Rehydration Project
OEH	Office of Environment and Heritage
TMI	The Mulloon Institute
VAST	Vegetation Assets, States and Transitions

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Introduction

Australia's landscapes have been managed for millennia by indigenous people (Gammage 2011, Pascoe 2014). Aboriginal burning and agriculture, tree clearing by European settlers, and the recent introduction of cropping systems, exotic plants and pasture grasses and domestic and feral animals have variously impacted native vegetation and ecological functions (Saunders et al. 1980). Remnants of natural systems are intimately mixed with these transformed areas, and the boundary between natural and human-created ecosystems is often difficult to determine (Thackway et al. 2006).

For almost 160 years, almost 60% of Australia's landscapes have been managed primarily to produce food and fibre (Thackway and Gardner in press). With Australia's land mass covering almost 7,687,000 km² there is widespread evidence to show the ecological effects that rural production and pest animals and plants associated with agricultural industries have had on the environment (Saunders et al. 1990).

Soil-landscapes that are managed for agricultural production are modified and transformed by land management regimes (Table 1 in Thackway and Lesslie 2006 and 2008; Thackway 2016). Land management regimes transform inherent ecological functions, either deliberately or inadvertently, to enhance the production of various ecosystems goods and services, including agricultural commodities (Thackway et al. 2006; Yapp et al. 2010; Yapp and Thackway 2015). Assessments of indicators of resource condition, function, structure and composition can give insights into vegetation condition (Noss 1990).

The transformation of soil-landscapes in the in the intensive landuse zone by agricultural production systems, including land management practices and regimes, can have a profound effect on ecological functions, compared to the extensive landuse zone. This is because where soil-landscapes have capability for agricultural development and have reliable rainfall patterns, these landscapes have been largely cleared and converted to other managed vegetation and land cover types (Lymburner et al 2010, Thackway and Lesslie 2008). These managed vegetation cover types can be described by the VAST framework (Thackway and Lesslie 2006 and 2008; Table 1 below).

The intensive landuse zone of the MCC is characterised by intensive agriculture and production forestry and are typically areas where a monoculture land-use (e.g. improved pastures and crops) have replaced a more biologically and ecologically diverse landscapes (ABARES 2018). By comparison the extensive landuse zone, 75% of the land mass of Australia comprises the rangelands, are primarily managed by grazing native vegetation for sheep and cattle production. The effects of agricultural production systems, found in both intensive and extensive managed landscapes in the MCC can be assessed using the VAST framework's reporting of states and transitions, as can their impacts on indicators of ecosystem function, structure and composition (Thackway and Freudenberger 2016).

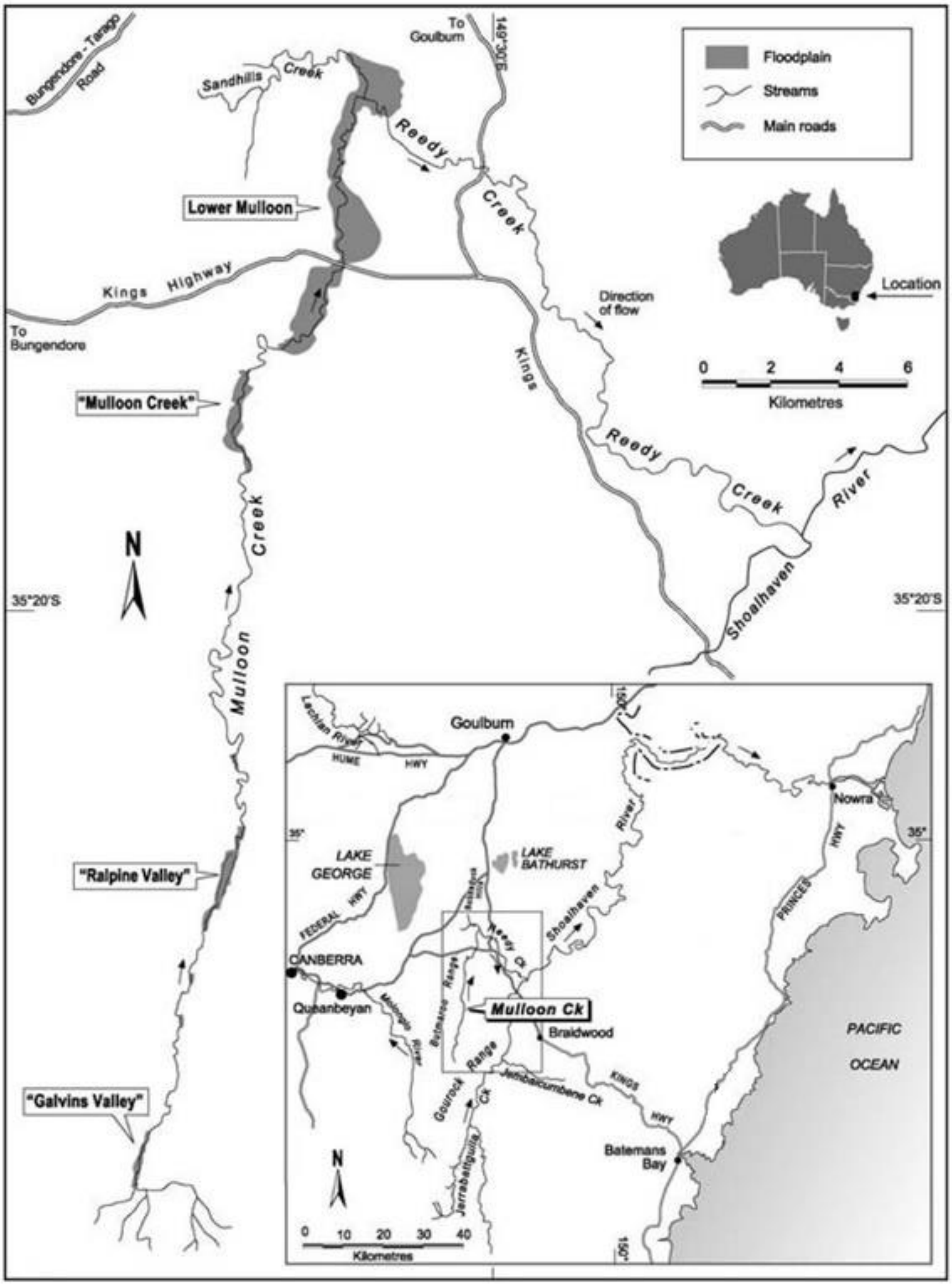
The establishment of physical and biological structures to hydrate or rehydrate landscapes, be it on mid and upper slopes, or lower slopes and on riparian flats; installation of these structures and systems is a land management practice or intervention. Reasons for controlling and managing surface water in the landscapes are various. These include the restoration of ecological function that have been historically lost or degraded through inappropriate land management regimes or natural events such as severe climate events such as floods that scour-out previously stable wetland ecosystems or a combination. Other reasons for hydrating a soil-landscape can be to enhance the production of food and fibre.

The Mulloon Creek Sub-Catchment (MCC) provides a representative example, in the intensive landuse zone, of the impacts that an intensively managed sub-catchment can have on soil and vegetation condition and water quality. Mulloon Creek drains an area of around 400 km2 in a north-south aligned sub-catchment of the Upper Shoalhaven River in the Southern Highlands of New South Wales (Johnston and Brierley 2006).

Since the arrival of Europeans in the Catchment in 1820s, by the late 1890s much of the original native vegetation particularly in the mid and lower reaches of the Creek (i.e. intensive land use zone), were cleared and converted into agricultural vegetation for grazing and agriculture (Thackway and Lessie 2008). Adjacent to the Creek, two of the four main floodplains “Lower Mulloon” and “Mulloon Creek” (Figure 1), have a relatively long history of agricultural development including intensive grazing because of the relatively extensive area of high-water table and productive soils. Today these soil-landscapes continue to be managed as improved pasture (exotic species) for animal production (mainly cattle). In some small areas of the floodplain associated with the MCLRP, it is expected that intensive agriculture including: tillage and cropping which denudes the soil surface carbon and soil biology and modifies soil hydrology; the use of herbicides, pesticides and chemical fertilisers, has modified and transformed soil condition. Patches of willows were planted on stream banks adjacent to incised streams to control bank erosion in the 1970s and 80s. Incision of the Mulloon Creek channel is expected to be closely associated with the land management regimes of the MCC.

Development of these grassy open woodlands on the mid and lower slopes in the mid and lower reaches of the Creek, from the mid-1800s to early 1900s, left largely cleared landscapes that were converted to non-native pastures with isolated trees.

Today there are isolated patches of open to low open woodlands (Jenkins, 1996). Since the 1950s some regrowth stands (mainly eucalypts and Teatree) have replaced the previously cleared woodland, particularly in less productive areas.



Source: Modified from Johnston and Brierley (2006).

Figure 1. Mulloon Creek Catchment (MCC) showing the location and extent of four main floodplains.

In higher rainfall open forests on the elevated ranges to the south and southwest in the Catchment, the native hardwood forests were harvested in the early to mid-1900s. Today most of these open forests are managed as part of Tallaganda National Park.

Between the 1850s and the mid-1970s large areas of native vegetation in the mid and lower MCC, were cleared and developed for agricultural production. This process transformed many of the soil-landscapes. Total grazing pressure, combined with variable seasonal rainfall patterns (Appendix 1), exposed bare ground caused by over grazing, led to the loss of top soil, the development of erosion gullies and the consequential incision of creeks on the floodplain. Despite interventions to stabilise the incised Mulloon Creek over the 1960s and 1970s, these efforts proved to be of little value in restoring and/or repairing the ecological function of the landscape in the MCC (Tony Coote pers comm).

Through the relatively recent establishment of The Mulloon Institute's (TMI), Mulloon Community Landscape Rehydration Project (MCLRP), an opportunity now exists for land managers along the MCC (Figure 2), to develop a baseline assessment of vegetation condition on different land types. One of the aims of the MCLRP is to restore and/or repair the ecological function of the landscape in the MCC (Luke Peel pers comm). While some instream interventions were installed in the Mulloon Creek, i.e. leaky weirs, before this report was commissioned, most of the substantive instream interventions commenced after 2016.

This report presents a baseline assessment of the condition of the vegetation in the MCC and MCLRP, using the VAST framework. Condition is assessed at three scales; landscape, farm and site-based scales. These three scales are presented separately. Each assessment is consistent with the VAST framework's focus on assessing condition using: 1) criteria and indicators of ecological function, vegetation structure and species composition; 2) reference states; a fully natural reference state is used at the landscape and site scale, while at the farm scale, a contemporary reference state provided by the land manager; 3) the degree of vegetation transformation (spatial and temporal) caused by anthropogenic drivers (i.e. management regimes) and interactions with climate over time, to assess and classify status, change and trend; and 4) systematically documenting the anthropogenic drivers i.e. land management practices and regimes that have been used over time in different land types to modify the key criteria and indictors of condition.

Method

Study area

Located to the east of Bungendore, NSW, the study area has a temperate, sub humid to humid climate with a mean annual rainfall of 600−800 mm, reaching 1000 mm in the ranges to the south (Jenkins, 1996). Average maximum monthly temperatures range from 7−25°C in January to 0−11°C in July.

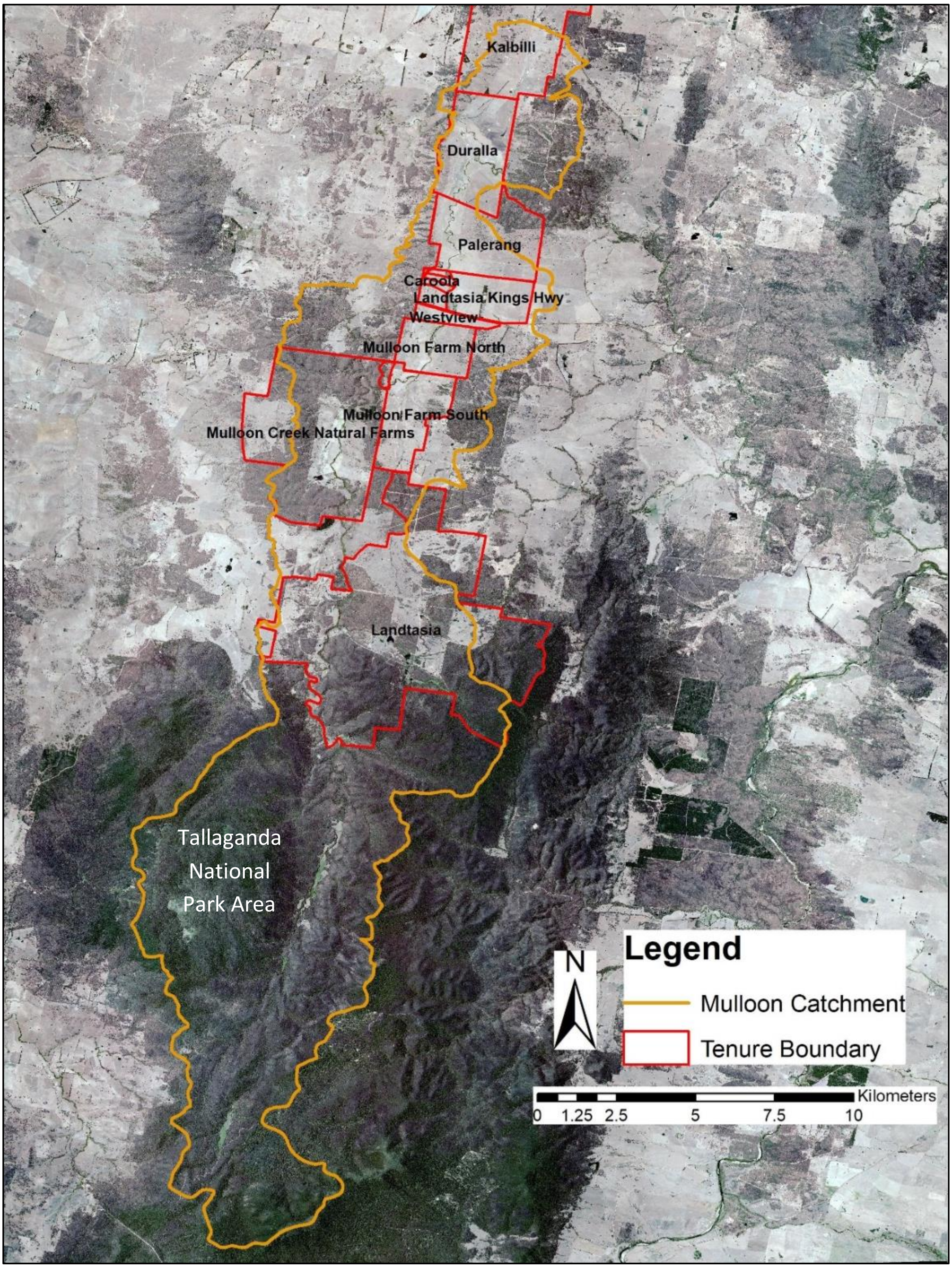


Figure 2. Land tenure of the Mulloon Creek Catchment (MCC), minus Sandhills watershed.

Based on the author's knowledge of the transformation of soil-landscapes in the MCC an intensive land use zone was defined including parts of Landtasia and north of Landtasia to Kalbilli. Similarly, an extensive land use zone was defined including parts of Landtasia and south of Landtasia to the headwaters of the Mulloon Creek, located in the

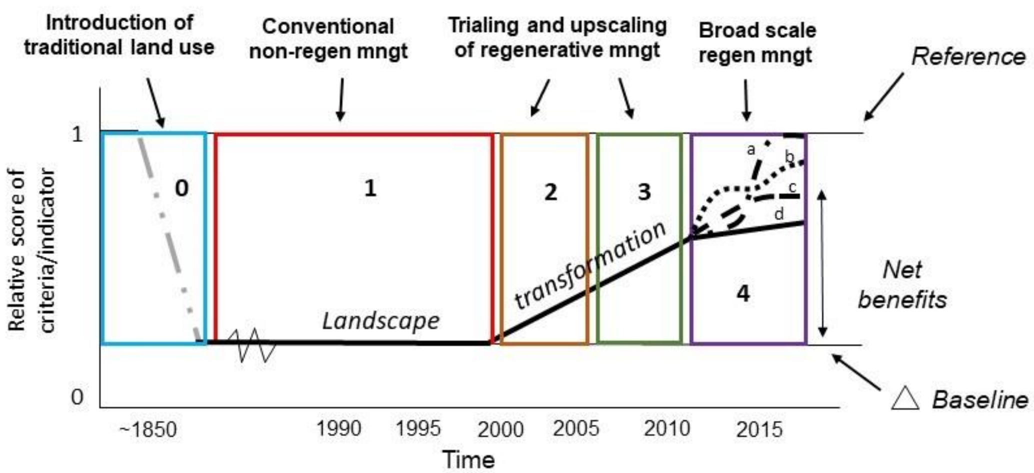
The VAST framework was used to assess condition of the vegetation in the MCC generally, and the MCLRP specifically to provide:

1. a landscape scale map of classes of native vegetation condition across the catchment, and
2. a graphical summary of the transformation of vegetation condition at selected sites

A framework for assessing vegetation condition

The VAST framework provides an effective means of assessing and classifying the degree of vegetation transformation (spatial and temporal) caused by anthropogenic drivers (i.e. management regimes) and interactions with climate over time. Table 1 presents the framework as a series of standardized classes bounded by diagnostic attributes of ecological function, vegetation structure and species composition (Thackway and Lesslie 2008). These vegetation condition classes (Table 1) can be used to map classes at preferred scales depending on the requirements of the decision maker (Thackway and Lesslie 2008).

The VAST framework links spatial and temporal changes in land management practices and regimes and consequential changes in vegetation condition i.e. responses of ecological function, vegetation structure and species composition. This framework defines the condition of native plant community types relative to a reference state or a baseline (Figure 3).



Modified from Thackway and Gardner (in press).

Figure 3. Conceptual model illustrating four potential landscape transformation trajectories in response to landscape management regimes.

Table 1. VAST classes used for classifying and mapping states of vegetation condition.

Increasing vegetation modification from left to right

			Native vegetation extent Dominant structuring plant species indigenous to the locality and spontaneous in occurrence – i.e. a vegetation community described using definitive vegetation types relative to estimated pre1750 states			**Non-native vegetation extent** Dominant structuring plant species indigenous to the locality but cultivated; alien to the locality and cultivated; or alien to the locality and spontaneous		
Vegetation condition state (mapping criteria)		State 0: NATURALLY BARE areas where native vegetation does not naturally persist and recently naturally disturbed areas where native vegetation has been entirely removed. (i.e. open to primary succession)	State I: RESIDUAL native vegetation community structure, composition, and regenerative capacity intact – no significant perturbation from land use/land management practice	State II: MODIFIED native vegetation community structure, composition and regenerative capacity intact - perturbed by land use/land management practice	State III: TRANSFORMED native vegetation community structure, composition and regenerative capacity significantly altered by land use/land management practice	State IV: REPLACED - *ADVENTIVE* native vegetation replacement – species alien to the locality and spontaneous in occurrence	State V: REPLACED - *MANAGED* native vegetation replacement with cultivated vegetation	State VI: REMOVED vegetation removed - alienation to non-vegetated land cover
Diagnostic criteria	Current regenerative	Complete removal of in-situ regeneration capacity except for ephemerals and lower plants	Natural regenerative capacity unmodified	Natural regeneration capacity persists under past and /or current land management practices	Natural regenerative capacity limited / at risk under past and /or current land use or land management practices. Rehabilitation and restoration possible through modified land management practice	Regeneration potential of native vegetation community has been suppressed and in-situ resilience at least significantly depleted. May still be considerable potential for restoration using assisted natural regeneration approaches	Regeneration potential of native vegetation community likely to be highly depleted by intensive land management. Very limited potential for restoration using assisted natural regeneration approaches	Nil or minimal regeneration potential. Restoration potential dependent on reconstruction approaches
	Vegetation	Nil or minimal	Structural integrity of native vegetation community is very high	Structure is predominantly altered but intact e.g. a layer / strata and/or growth forms and/or age classes removed	Dominant structuring species of native vegetation community significantly altered e.g. a layer / strata frequently and repeatedly removed	Dominant structuring species of native vegetation community removed or predominantly cleared or extremely degraded	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
	Veget	Nil or minimal	Compositional integrity of native vegetation community is very high	Composition of native vegetation community is altered but intact	Dominant structuring species present - species dominance significantly altered	Dominant structuring species of native vegetation community removed	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
Examples		Bare mud; rock; river and beach sand, salt freshwater lakes, rock slides and lava flows	Old growth forests; Native grasslands that have not been grazed; Wildfire in native forests and woodlands of a natural frequency and/or intensity;	Native vegetation types managed using sustainable grazing systems; Selective timber harvesting practices; Severely burnt (wildfire) native forests and woodlands not of a natural frequency and/or intensity	Intensive native forestry practices; Heavily grazed native grasslands and grassy woodlands; Obvious thinning of trees for pasture production; Weedy native remnant patches; Degraded roadside reserves; Degraded coastal dune systems; Heavily grazed riparian vegetation	Severe invasions of introduced weeds; Invasive native woody species found outside their normal range; Isolated native trees/shrubs/grass species in the above examples	Forest plantations; Horticulture; Tree cropping; Orchards; Reclaimed mine sites; Environmental and amenity plantings; Improved pastures. (includes heavy thinning of trees for pasture); Cropping; Isolated native trees/ shrubs/ grass species in the above examples	Water impoundments; Urban and industrial landscapes; quarries and mines; Transport infrastructure; salt scalded areas

Modified from Thackway and Lesslie 2008.

In Figure 3, the choice of either selecting a fully natural reference state (phase 1) or a contemporary baseline (phase 2) to assess vegetation status, change and trend depends on the requirements of a decision maker. Both types of condition assessment involve a relative assessment of status, change and trend. In both cases, key diagnostic indicators/attributes of ecological function, vegetation structure and species composition are needed. The purpose for this definition is to enable decision makers to track the condition of plant community types over time due to spatial and temporal changes in land management practices, and to monitor and report on the effects that these regimes and practices have on response indicators/attributes of ecological function, vegetation structure and species composition.

For example, areas managed primarily for conservation; rehabilitation, restoration and regeneration of natural ecosystems, a decision maker is likely to require a fully natural reference state (phase 1). Alternatively, in areas that a managed primarily for production, a decision maker is likely to require an assessment of condition relative to a contemporary baseline (phase 2).

The VAST framework also provides a comprehensive set of criteria and indicators for assessing status, trend and change in condition of a site in any landscape. Changes in the status, change and trends in vegetation condition found on different land types can be assessed using 10 criteria and 22 indicators. The interactions of seasonal rainfall (Appendix 1) with ecosystem types and management regimes are key drivers of the responses of these 22 indicators (Thackway and Freudenberger 2016). A site/s is considered representative of the broader land type.

In the VAST framework a distinction is made between reference state and a contemporary baseline. Most environmental monitoring and tracking the responses of plant communities seek to measure and observe change relative to a current baseline. The VAST framework readily compiles and synthesises data and information that are measured relative to a contemporary baseline, where the attribute data being measured can be directly related to the fully natural reference state for the criteria and indicators listed in Table 2.

The VAST system can also present a simple graphical report card showing the drivers of change and trend relative to a reference state (i.e. natural benchmark) (Thackway and Specht 2015). Existing reference states can be obtained from published sources or were elicited from skilled local ecologists and botanists. The graph represents a transformation trajectory for a plant community where the condition (i.e. vegetation status) is scored out of a potential 100% (i.e. an unmodified reference state). The total score is comprised of three weighted components: function (regenerative capacity; 55% weighting); vegetation structure (27% weighting); and species composition 18%. This weighting was applied in the same manner across all case studies. The total vegetation status score was calibrated to the six VAST classes enabling the broad description of types changes in condition over time. The degree of divergence between the reference state and the vegetation scores over time for each case study, represent the degree of modification. Scores are grouped according to the following intervals:

80-100% of the reference state corresponds to a Residual /Unmodified state;

60-80% corresponds to a Modified state;

40-60% corresponds to a Transformed state;

20-40% corresponds to VAST class IV– Replaced and adventive; as well as

0-20% corresponds to VAST class V– Replaced and managed; and VAST class VI – Replaced

These five intervals provide a meaningful basis for describing and summarising status and change. Access to continuous measures for key indicators will enable actual scores out of 100% to monitored and reported rather than aggregating scores into classes.

Condition components Level 3	**Key functional, structural and composition criteria Level 2**	**Indicators Level 1**
Functional	Soil hydrology	Rainfall infiltration and soil water holding capacity
		Surface and subsurface flows
	Soil physical status	Effective rooting depth of the soil profile
		Bulk density of the soil through changes to soil structure or soil removal
	Soil nutrient status	Nutrient stress – rundown (deficiency) relative to reference soil fertility
		Nutrient stress – excess (toxicity) relative to reference soil fertility
	Soil biological status	Organisms responsible for maintaining soil porosity and nutrient recycling
		Surface organic matter, soil crusts
	Severe climate events	Area /size of disturbance events - foot prints (e.g. major storm cells, floods, wildfire, cyclones, droughts, ice)
		Interval between disturbance events
	Reproductive potential	Reproductive potential of overstorey structuring species
		Reproductive potential of understorey structuring species
Structural	Overstorey structure	Overstorey top height (mean) of the plant community
		Overstorey foliage projective cover (mean) of the plant community
		Overstorey structural diversity (i.e. a diversity of age classes) of the stand
	Understorey structure	Understorey top height (mean) of the plant community
		Understorey ground cover (mean) of the plant community
		Understorey structural diversity (i.e. a diversity of age classes) of the plant
Compositional	Overstorey composition	Densities of overstorey species functional groups
		Richness – the number of indigenous overstorey species relative to the number of exotic species
	Understorey composition	Densities of understorey species functional groups
		Richness – the number of indigenous understorey species relative to the number of exotic species

Modified from Thackway and Freudenberger 2016

Table 2. Indicators, criteria and components of condition used to assess status, change and trend at sites.

This study

Two approaches were used in the assessment of vegetation condition in the MCC and MCLRP:

1. A spatial assessment of native vegetation condition for the catchment and for farms within the catchment; and
2. A temporal assessment of vegetation condition within selected farms at two scales:
    a. Whole farm level, and
    b. Soil-landscape level

It is envisaged that these assessments of baseline vegetation condition could be repeated as part of monitoring and reporting the MCLRP in the immediate, short, medium and longer-term.

Assessing the distribution and extent of mapped native vegetation condition classes

Maps of condition that use the VAST attribute framework reflect the effects that land management regimes, practices and interventions have had on modifying and transforming the function, structure and composition of plant communities (Thackway and Lesslie 2008). Class 1 (unmodified) represents a fully natural reference state, against which other classes are benchmarked.

A spatial assessment of mapped native vegetation condition for the Catchment, and for farms within the catchment, was addressed using a state-wide regional scale map of the VAST classes of vegetation condition. This dataset was developed for State of the Catchment reporting by the Office of Environment and Heritage (OEH) (Dillon et al. 2009). The six VAST classes of vegetation condition (Table 1) were generated by OEH using an expert model of the relative impacts that land use and management regimes have on indicators of function, structure and composition. Access to this GIS dataset was obtained from the authors and this GIS dataset was used to generate a report of the condition classes mapped in on each property and across the sub-Catchment.

Assessing temporal status and change at sites

A geospatial and temporal assessment of vegetation condition was done on farms at two scales:

a. Land types at the whole of farm level, and
b. Soil-landscape level within farms

Site-based graphical summaries of status and trend of vegetation condition can be generated for specific geospatial map units, the dimensions of which remain constant through time e.g. a farm, a soil-landscape unit. It is assumed that, over time such geographically-defined map units maintain a fixed geographic position and outer bounding polygon. A site is characterised by three core pieces of information: 1) a description of its fully natural or unmodified ecosystem i.e. pre-European ecosystem 2) a chronology of production systems e.g. land management regimes, practices and interventions that have been used to manage the ecological function, structure and composition of the site; and 3) an assessment of the differential effects that these management regimes, practices and interventions have had on the 10 criteria relative to a baseline sate when the land manager commenced managing their property. A graphical summary is produced for a site.

Land types at the whole of farm level

Selecting farms

A group of key land holders and properties within the MCLRP were identified and selected by the TMI (Peter Hazell and Luke Peel). These land holders and properties provide representative samples along the north-south axis of the MCC. Apart from providing an understanding of what and how the production systems have affected the ecosystem function, structure and composition of each property over time, this chronology also provided a baseline of the social and cultural history of the MCLRP.

The land managers were interviewed to establish a chronology of production systems for each land type level within farm-level over time.

It is envisaged that these interviews and the chronologies that were generated could be repeated as part of monitoring and reporting the MCLRP in the immediate, short, medium and longer-term.

Assessing ecological responses of 10 key indicators over time

The response of the soil-landscape for one property in terms of structure, composition and function was completed for one of the five properties. The consequential status and trend in vegetation condition was done using the following 10 ecological response criteria:

A. Resilience of ecosystems to the effects of extreme climatic events (e.g. drought, fire, flood);
B. Status of soil nutrients including soil carbon, major and minor elements;
C. Status of soil hydrology including infiltration, percolation and water availability to plants;
D. Status of soil biology including bioturbators i.e. nutrient recyclers, fungi and bacteria ratios and soil organic matter;
E. Status of soil physical properties including bulk density and soil as a medium for plant development and growth;
F. Status of the reproductive potential of the plant species and plant community;
G. Status of tree and shrub structure;
H. Status of ground layer/ground cover/grass and herb structure;
I. Status of tree and shrub species richness and functional traits; and
J. Status of the ground layer/grass and herb species richness and functional traits

This property provides a representative example of the value of understanding and documenting the land manager's knowledge of the ecological responses of their soil-landscape to their land management regimes and practices. Other properties in the MCC could have been assessed using this approach. This required land management practices (or actions/interventions) supplied by the land manager (Appendix 2) to be aggregated into management regimes as discussed by Thackway and Freudenberger (2016 Table 2). The responses of a plant community to these regimes were classified based on how the practices of each regime individually and collectively transform indicators of vegetation structure, composition and function over time. Collectively, the outcomes of these regimes are variously the maintenance, enhancement, restoration, degradation, and or removal and replacement of a plant community found soil-landscapes over time.

Where quantitative data had been collected over time by the land manager, these were used to "bookend" the respective responses of each criteria. However, because of a paucity of quantitative data, expert elicitation was used to assess the ecological effects of implementing production systems on ecological criteria associated with ecosystem function, structure and composition over time.

Expert elicitation involved asking the land manager to self-assess how their management ideals affected their landscape management regimes (i.e. production systems) and subsequently, what ecological responses they observed. Change was assessed graphically relative to the baseline which was when the land manager started managing their property.

This assessment method acknowledges the land manager's reliance on working with climate variability, as it plays a major role in influencing the land manager's decision-making process and their capacity to implement farm plans. In turn, the effects of climate variability have major impacts on ecological, economic and social wellbeing. Like most agricultural land managers, time since last rainfall and available soil moisture are used as a gauge of climate variability. A summary of the seasonal rainfall from 1900 to 2017 for the mid to lower reaches of the MCC[1] showing variants around the mean is presented in Appendix 1.

Soil-landscape units within farms

Selecting land units and sites

For each site, 10 criteria and 22 indicators (Table 1) was used as a checklist to search for and compile relevant spatio-temporal sources of data and information over time to generate a systemic and comprehensive site history. Sources of information included: published and unpublished accounts, scientific surveys, long term ecological monitoring sites, land manager interviews, remote sensing and public-private data archives. A literature review included what is known about the *Unmodified* or reference state plant community type for each site, which is described by the same 10 criteria and 22 indicators. Indicators from the reference state were used in a relative sense to assess the transformation of each site over time.

The 10 criteria and 22 indicators were used to assess the response of each plant community to the effects of the management practices. This process involved integrating and evaluating the site-based environmental histories and the response of the plant community over space and time. The integration of the relative difference between the transformation of a site and its reference state determined the relative effects that land management practices have had on vegetation condition and resilience over time. An aggregate index for each year in the chronology of a site is scored across four levels in a hierarchy (Table 2).

Because of the similarity and complementarity between the ecological functional attributes in the VAST and Landscape Function Analysis (LFA) frameworks, an array of 25 sites that were previously permanently marked and surveyed using the LFA field survey methodology were also considered suitable for an assessment using the VAST framework.

Several criteria were used to select the subset of the LFA sites:

1. Fewer VAST sites were needed because the VAST attribute framework has a complementary set of functional criteria to those found in the LFA framework.
2. Fewer VAST sites were needed because TMI was aware that the VAST attribute framework surveys ecological function, structure and composition whereas LFA framework focuses on functional attributes, which are generally faster to assess and record.
3. VAST attribute framework required a field botanist to generate a full list of plant species found at the site. A full species plant survey at a site requires relatively more time per site than an LFA survey.

[1] Source: Bureau of Meteorology modelled 5-kilometre resolution rainfall data. Seasons are defined as the standard 3 monthly intervals e.g. summer comprising December, January and February

Assessing baseline ground cover and composition

Two survey methods were used at the subset of LFA sites:

1. Assessment of ground cover
2. Floristic survey

Assessment of ground cover

On sites dominated by native understorey and overstorey (where present) ground cover types were surveyed using a point intercept method along a 50 m tape. Each 0.5m was recorded as a survey point. Types of ground cover types included; native graminoid (grasses, sedges and Lomandras), exotic herb, native herb, organic (cryptogram, dung, wood and litter) and inorganic (bare ground and rock). Ground cover was defined as less than 2m in height.

Overstorey was recorded to the species level where a native tree was present. No differentiation was made when recording the presence of the overstorey between the following: leaf (living/dead), and branch (living/dead).

On sites dominated by a non-native understorey, ground cover was not surveyed and recorded because the pasture type generally had high percent cover including photosynthetic /green vegetation and non-photosynthetic /brown vegetation and litter and with minimal bare ground.

Floristic survey

A full list of plant species observed using a random walk within a 50 radius of each permanently marked Landscape Function Analysis sites was recorded.

Understorey species were defined as less than 2m in height and included native and exotic, annual and perennial as well as pasture species. Unidentified species were recorded as number 1, number 2 and so on.

Overstorey species were defined as greater than 2m in height and included native and exotic trees and shrubs.

Results

Catchment and farm vegetation condition

Depending on the farm, various production systems have historically been used to convert and /or simplify the pre-European ecologically complex landscape into a mosaic of intensively and extensively managed soil-landscapes:

1. Native plant communities that are typically found on upper slopes and ridges on the larger farms where the soils are generally shallower and are skeletal. Generally extensive use or minimal use production systems are used to manage these areas, including:
    a. Rough-grazing of native pastures that are infrequently grazed or are continuously grazed with low stock numbers.
    b. Pastures that are fenced-out and protected from livestock grazing.
2. Non-native pastures are typically found on soil-landscapes in the valley floors and lower slopes where the soils are deeper and more productive. These soil-landscapes are generally more intensively managed using a combination of:
    a. grazing improved pastures, and
    b. seasonal cropping/grazing.

Figure 4 shows the extent of VAST condition classes and the 13 properties in the MCC. Table 3 shows the relative areas of the 13 properties and the vegetation classes found in each property.

Landtasia, the Home Farm and Palerang are the largest properties in the Catchment; 3333.4 ha, 1577.1 ha and 616.7 ha, respectively. These three properties also have extensive contiguous areas of native woodland and forest which are relatively intact i.e. modified; Landtasia 2405.7 ha, The Home Farm 988.6 ha and Palerang 121 ha, respectively. Some of the relatively intact areas are fenced from domestic grazing, although total grazing pressure in these fenced off areas from kangaroos, wallabies and wombats and deer are limiting the landscape's ability to naturally regenerate.

There are four properties that have large areas of class III/V Transformed/ Replaced managed, >450 ha, including Kalbilli 626.9 ha, Landtasia 586.5 ha, Mulloon Creek Natural Farm – Duralla 514.2 ha and Palerang 467.9 ha. As a general rule, all farms have extensive areas >75% of each property managed as mixed native grasses and non-native /improved pasture species which are variously used for intensive grazing, mainly with cattle. These areas correspond to class III/V Transformed/ Replaced managed in Figure 4 and Table 3. The exceptions to this, area two large properties, Landtasia and Mulloon Creek Natural Farm - The Home Farm, with <30% of the property mapped with class III/V Transformed/ Replaced managed (Table 3). with 17.6% (586.5 ha) and 28.2% (444.4 ha) respectively (Table 3). This shows that compared to other properties in the catchment, the managers of Landtasia and Mulloon Creek Natural Farm, have kept and maintained relatively small areas of class III/V Transformed/ Replaced managed pastures. It is worth noting that, according to this OEH dataset (Dillon et al. 2009), these two properties have maintained relatively large areas of native pasture and woodland/forest in class II Modified. This would suggest that that Landtasia and Mulloon Creek Natural Farm - The Home Farm have at the whole farm level established an appropriate balance between the extents of native and non-native vegetation cover types and between agricultural productivity and biodiversity conservation.

The more intensively managed soil-landscapes occur in the mid and lower reaches of the Catchment (class V e.g. improved pastures and cropping areas) (Figure 4). Generally, these areas support pastures that are dominated more so by exotic species than native species. The less intensively managed pastures on the mid and upper slopes have pastures that are dominated more so by native species than exotic species.

Pastures on the low slopes and valley floors are managed with smaller paddocks with more access to watering points including the Mulloon Creek. These higher productivity grasses and seasonal crops carry a higher biomass of grasses but with fewer species in the pasture mix.

Total grazing pressure on continuously grazed native pastures on the mid and upper slopes has generated low biomass pastures that are dominated by a few native and/or exotic species. The composition and structure of these species are known for their grazing tolerance.

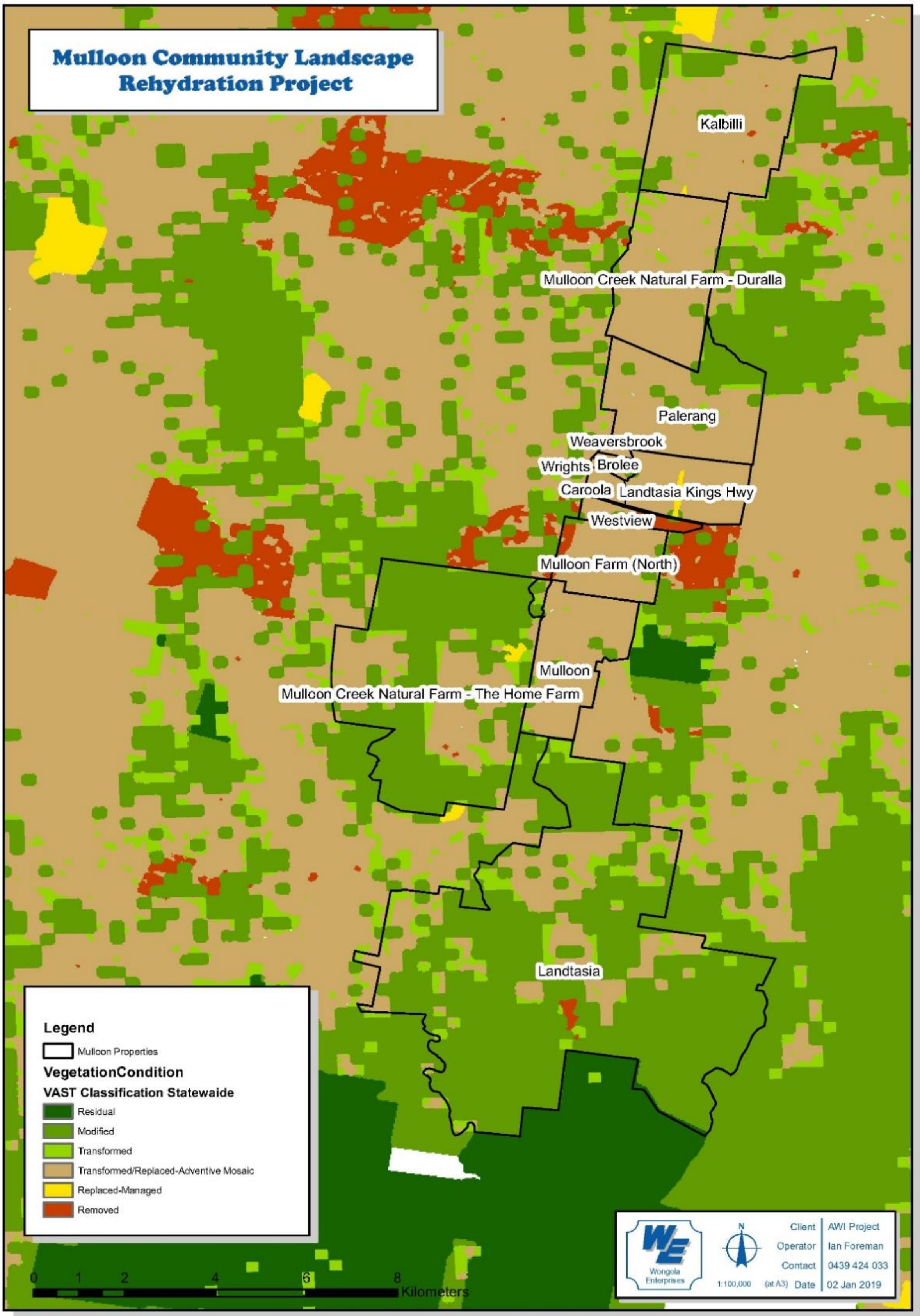


Figure 4. Condition classes and properties in the Mulloon Creek Catchment.

Property		VAST Classes						Total Area (ha)	% Area
		Residual Class I	Modified Class II	Transformed Class III	Transformed/ Replaced Class III/V	Replaced managed Class V	Removed Class VI		
Brolee	(ha)	0	2.3	0.9	12.9	0	0	16.1	0.2
	%	0.0%	14.3%	5.6%	80.1%	0.0%	0.0%		
Caroola	(ha)	0	0	0	41.3	0	0	41.3	0.5
	%	0.0%	0.0%	0.0%	100.0%	0.0%	0.0%		
Kalbilli	(ha)	0	112.6	58.4	626.9	2.4	5	805.1	9.9
	%	0.0%	14.0%	7.3%	77.9%	0.3%	0.6%		
Landtasia	(ha)	19.3	2405.7	301.7	586.5	0.2	20	3333.4	41.1
	%	0.6%	72.2%	9.1%	17.6%	0.0%	0.6%		
Landtasia Kings Hwy	(ha)	0	7.3	1.3	262.7	10.7	1.6	283.6	3.5
	%	0.0%	2.6%	0.5%	92.6%	3.8%	0.6%		
Mulloon	(ha)	0	26.9	11.3	388.7	0	6.1	432.9	5.3
	%	0.0%	6.2%	2.6%	89.8%	0.0%	1.4%		
Mulloon Creek Natural Farm – Duralla	(ha)	0	26	40.4	514.2	0.2	10.9	591.6	7.3
	%	0.0%	4.4%	6.8%	86.9%	0.0%	1.8%		
Mulloon Creek Natural Farm - The Home Farm	(ha)	0	988.6	125.6	444.4	11.2	7.4	1577.1	19.5
	%	0.0%	62.7%	8.0%	28.2%	0.7%	0.5%		
Mulloon Farm(North)	(ha)	0	23.1	7.9	250.9	21.5	0	303.4	3.7
	%	0.0%	7.6%	2.6%	82.7%	7.1%	0.0%		
Palerang	(ha)	0	121.1	22.2	467.9	0	5.5	616.7	7.6
	%	0.0%	19.6%	3.6%	75.9%	0.0%	0.9%		
Weaversbrook	(ha)	0	0	0.6	9.3	0	0.5	10.4	0.1
	%	0.0%	19.6%	3.6%	75.9%	0.0%	0.9%		
Westview	(ha)	0	9.6	0.9	32.6	1.1	33	77.2	1
	%	0.0%	12.4%	1.2%	42.2%	1.4%	42.7%		
Wrights	(ha)	0	3	0.1	13.7	0	0.2	17	0.2
	%	0.0%	17.6%	0.6%	80.6%	0.0%	1.2%		
Total area (ha)		19.3	3726.1	571.2	3652.1	27.2	110	8105.9	100
% area (ha)		0.2	46	7	45.1	0.3	1.4	100	

Table 3. List properties in the MCC and the area (ha) and per cent of each VAST condition classes recorded on each property.

Five land holders/managers were interviewed, all of which are variously involved in the MCLRP (Table 4). Those interviewed included: former property land holders e.g. Dimity Davy; current and former land managers e.g. Jim Guilfoyle and Martin Teece; current and former land holders e.g. Tony Coote, Richard Graham, Sue and Ulli Tuisk and Ruth Cooper; long term resident in the district e.g. Forbes Gordon. A detailed description of the production systems documented in the interviews is presented Appendix 2.

Name of land manager	Name of property (Figure 4)	Date of interview
Marlene Cantwell (nee Cooper) and Ruth Cooper	Mulloon Farm	19 August 2015
Forbes Gordon	Manar Creek	1 December 2015
Tony Coote	Mulloon Creek Home Farm	9 April 2016
Dimity Davy	Landtasia	11 March 2016
Jim Guilfoyle	Mulloon Creek Home Farm	11 March 2017
Richard Graham and Martin Teece	Landtasia	5 December 2018
Sue and Ulli Tuisk	Palerang	5 December 2018

Table 4. List of land managers/land owners

Land manager self-assessment vegetation condition

Land manager self-assessment of their condition of their vegetation on their property over time provides useful insights for decision makers involved in the MCRLP. An example of this self-assessment for 10 ecological criteria, for Palerang, is shown in the Figures 5-14. Given more resources the author would document the land manager's reasons for assigning scores over time for each criterion. An example of this more detailed linking of production systems and response criteria is presented in the Soils for Life Case study "The Jillamatong Story" http://www.soilsforlife.org.au/assets/doc/Jillamatong_round_2/Jillamatong_full_report_round_2.pdf

These ten criteria correspond to the 10 criteria presented in Table 2 (Level 2). The Tuisk's commenced running Palerang in 1989. Palerang has two land types; river flats and low rolling hills. Each of the figures show a positive increase in scores for the 10 criteria since 1998 for the river flats. In contrast, the low rolling hills, show a more subdued response over time in response the production systems, or a slight increase in condition.

The key drivers for the response graphs are the droughts (millennium and the past 2 years) and filling of the leaky weirs after 2008-09.

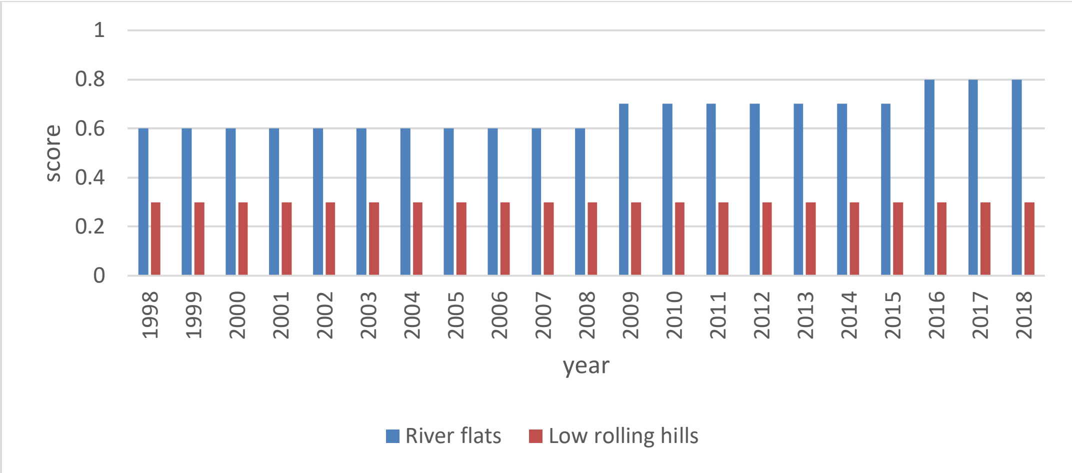


Figure 5. Resilience of Palerang to severe climate events.

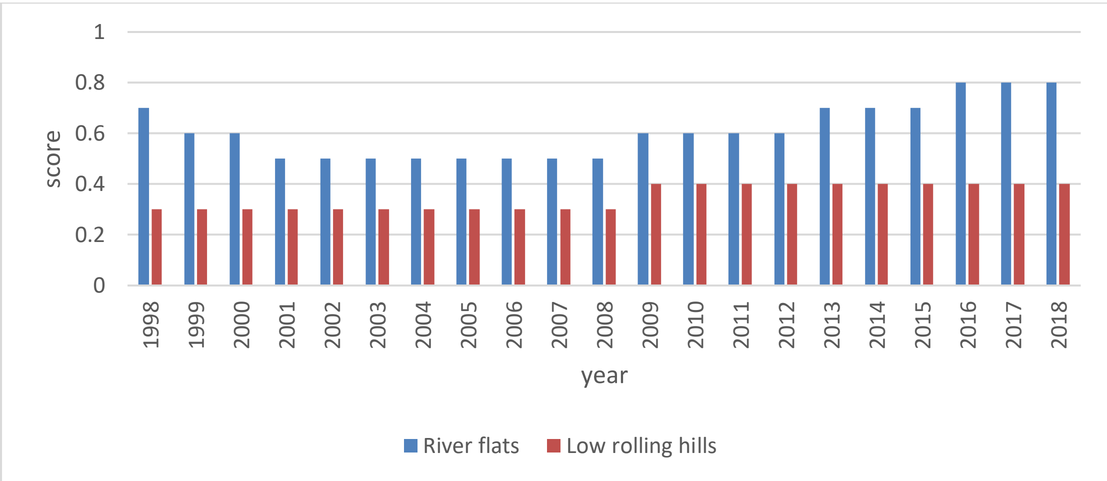


Figure 6. Status of soil nutrients.

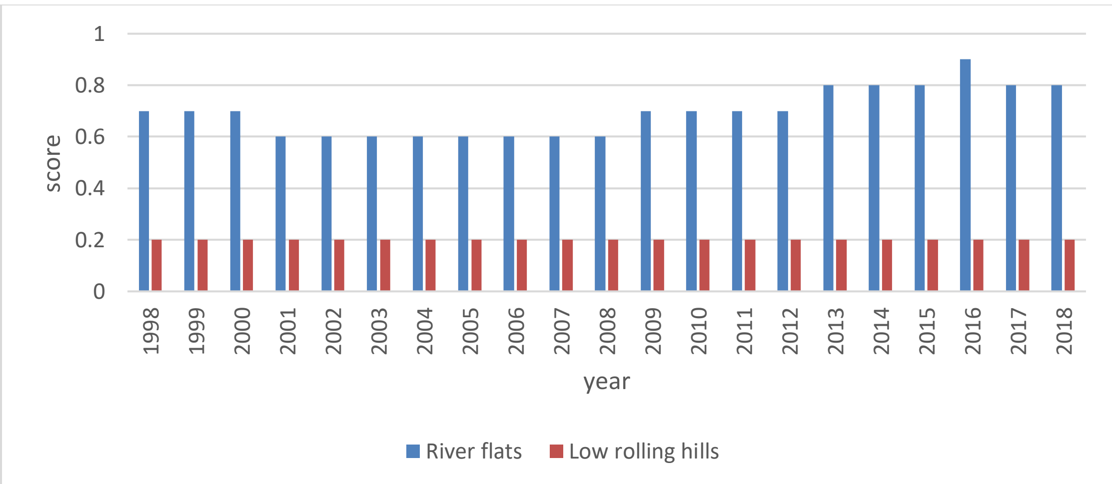


Figure 7. Status of soil hydrology.

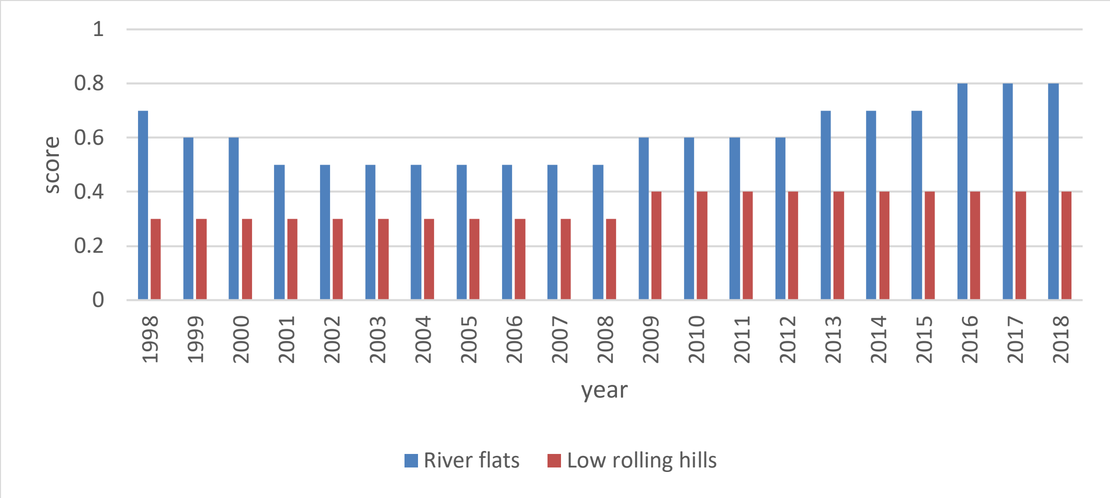


Figure 8. Status of soil biology.

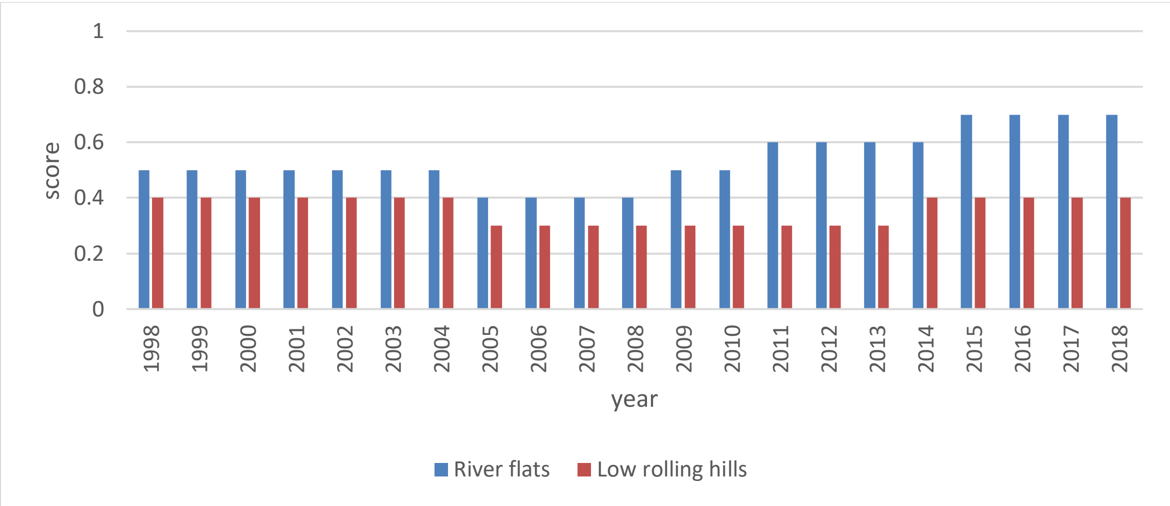


Figure 9. Status of soil physical properties.

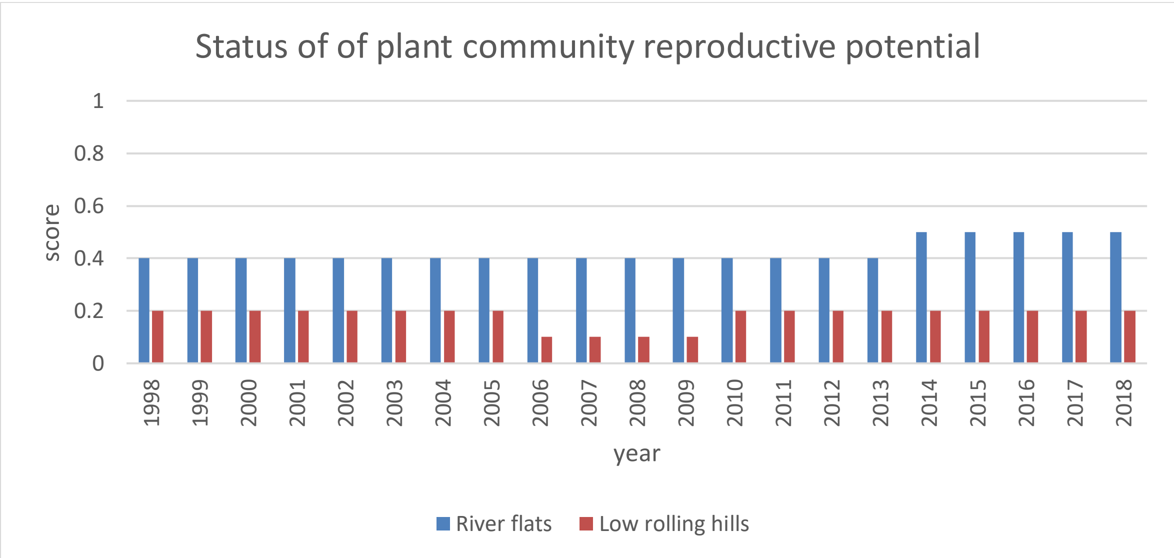


Figure 10. Status of plant community reproductive potential

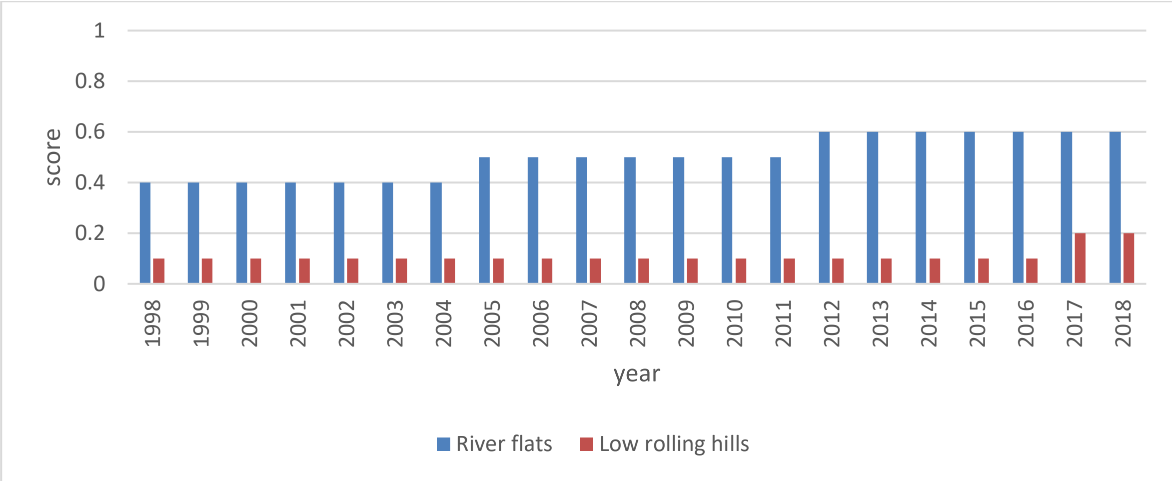


Figure 11. Status of tree and shrub layer structural attributes

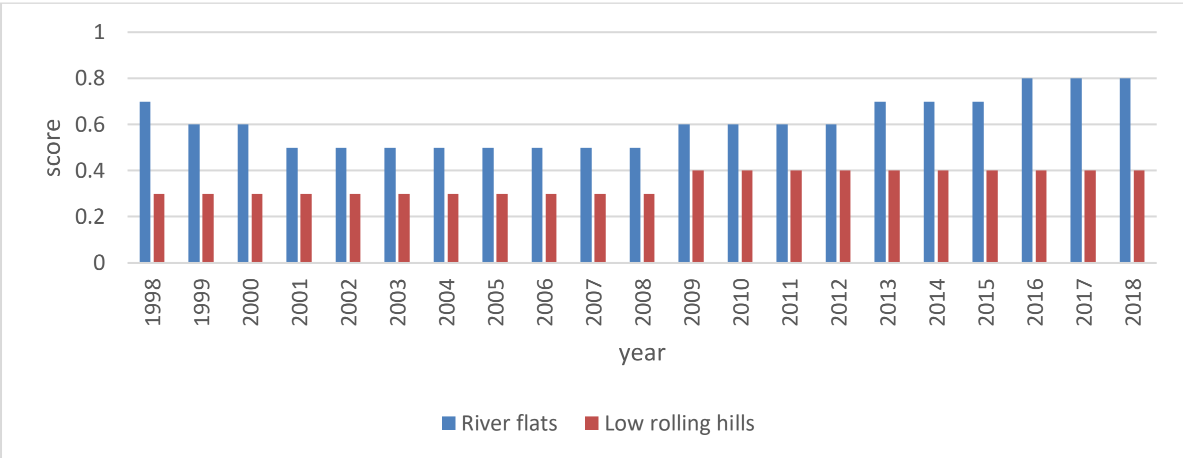


Figure 12. Status of grass and herb layer structure

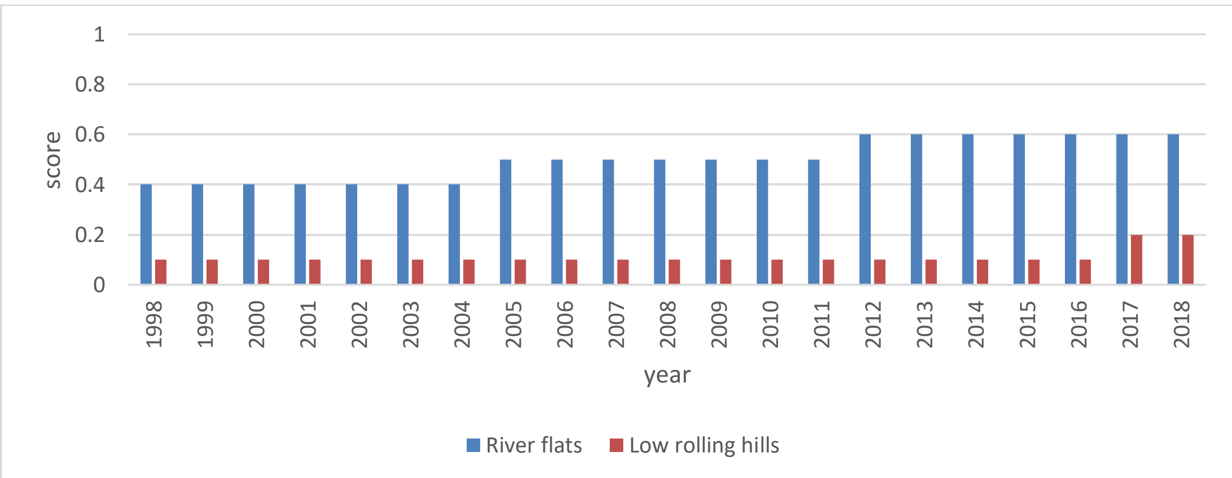


Figure 13. Status of tree and shrub layer composition

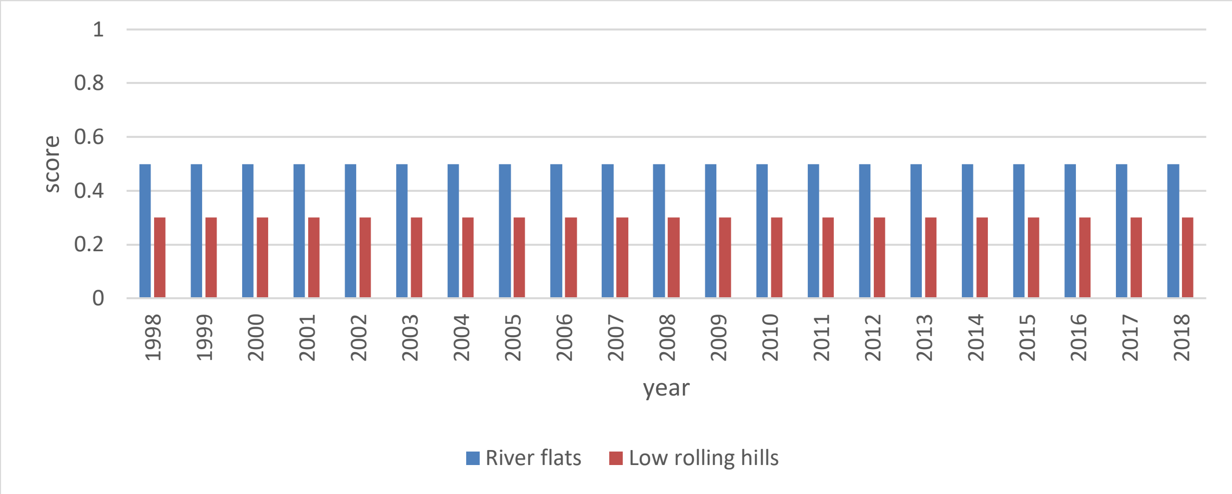


Figure 14. Status of ground layer composition

Site-based assessment of vegetation condition

Eight LFA sites were selected from the available 25 LFA sites (Table 5 and Figure 15). A full list of LFA sites is presented in Appendix 3 including GPS coordinates.

VAST site	TMI Site #	Property name
1	PLG2	Palerang
2	DLA1	Duralla
3	DLA3	Duralla
4	MFN2	Mulloon Farm North
5	MFS3	Mulloon Farm South
6	MFS4	Mulloon Farm South
7	MCNF7	MCNF
8	MCNF6	MCNF

Table 5. List of eight VAST sites and corresponding TMI site number and name of property participating the MCLRP.

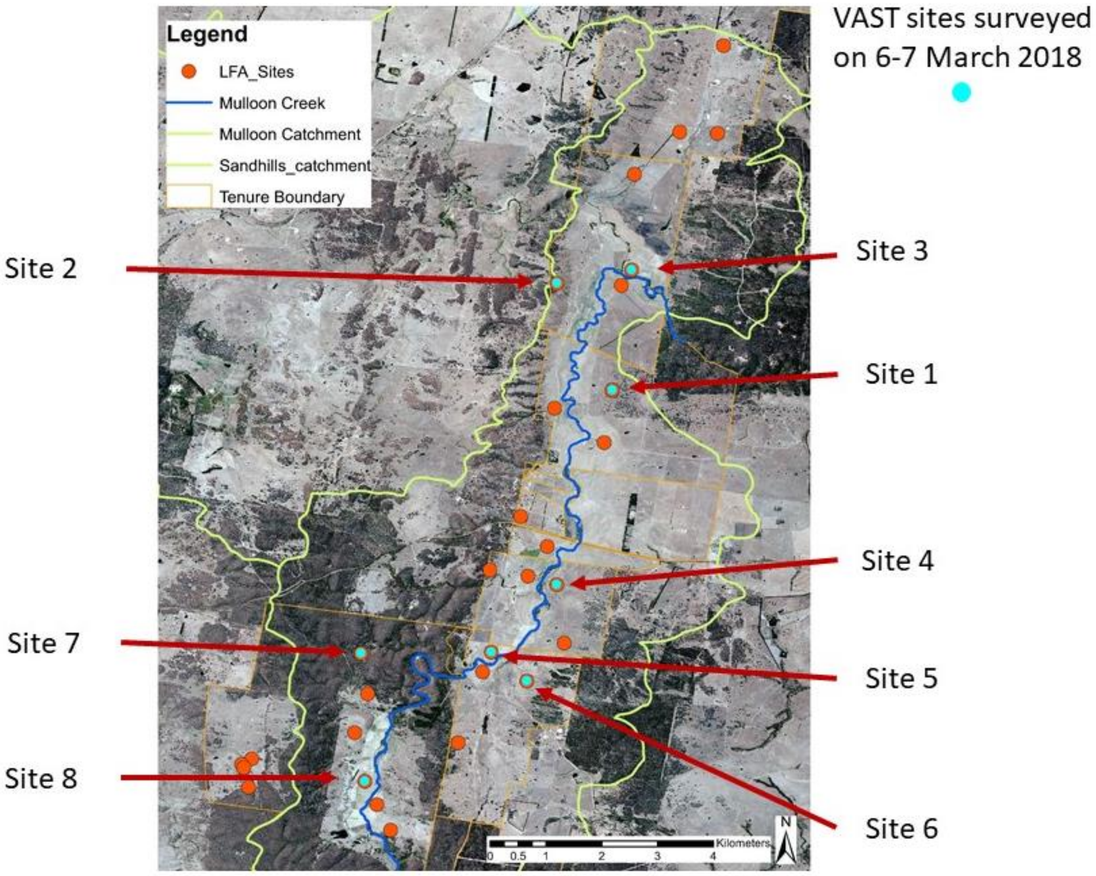


Figure 15. Location of sites surveyed in the field using the LFA and VAST methodologies. Blue circles show sites surveyed using VAST as well as LFA. Orange circles show sites surveyed using LFA.

These eight sites have been classified into VAST classes (Table 6) using data collected in the field and boundary information presented in Table 1. A description of the sites is also presented in Table 6.

Five of the sites consisted of non-native vegetation (sites 3, 4, 5, 6 and 8) and three sites of native vegetation (sites 1, 2 and 7). All non-native sites are found in the lower slopes and floodplain, while the native sites are found on the mid and upper slopes (Table 6).

This on-ground assessment of vegetation condition at sites shows that site 7 has the highest score (VAST class I) for vegetation condition relative to a fully natural reference state. While sites 1 and 2 scored VAST class III. Thackway and Specht (2011) and Thackway and Freudenberger (2016) show that opportunities exist through changing land management regimes to transition sites 1 and 2 (classified as class III) to VAST class II; this could be achieved through controlling total grazing pressure.

Site No.: vegetation formation, landscape position and land type	Site 1: woodland on mid-slope	Site 2: woodland site on ridge	Site 3: floodplain pasture	Site 4: floodplain pasture	Site 5: floodplain pasture	Site 6: mid-slope or floodplain pasture	Site 7: woodland on mid-slope	Site 8: floodplain pasture
Field-based classification of sites using VAST classes (Table 1)	Class III Transformed	Class III Transformed	Class V Modified and replaced	Class V Modified and replaced	Class V Modified and replaced	Class V Modified and replaced	Class I Unmodified	Class V Modified and replaced
Property name, land manager	Palerang (Sue & Ulli Tuisk)	Duralla (Michael Thomes MCNF CEO)	Duralla (Michael Thomes MCNF CEO)	Mulloon Farm North (Andrew ….)	Mulloon Farm South (Marlene Cantwell)	Mulloon Farm South (Marlene Cantwell)	Mulloon Creek Natural Farms Home Farm (Michael Thomes MCNF CEO)	Mulloon Creek Natural Farms Home Farm (Michael Thomes MCNF CEO)
Field description of the plant community	Closely-cropped low height native pasture. Lots of regrowth E. pauciflora among older mature E. rubida and E. pauciflora. E. dives mainly on upper slopes	Closely-cropped low height native pasture. E. dives and E. mannifera subsp mannifera	Good ground cover exotic pasture with high height (to 20 cm) and a high biomass	Less ground cover and less of biomass than site 2	Closely-cropped low height pasture. Low diversity grass pasture species. No thistles etc. Bare ground; very little litter; patchy cover	Very similar to Site 5. Closely-cropped low height pasture. All grass pasture species. No thistles etc. Bare ground; very little litter; patchy cover	Long unburnt regrowth native eucalypt woodland	Similar to sites 5 and 6

Table 6. Vegetation sites (Figure 15) classified into VAST classes and plant community types.

The assessment of ground cover types recorded at the three native dominated sites 1, 2 and 7, correspond the indicators describes in Table 2.

Function

<u>Litter</u>

Site 7 had the highest relative cover of litter with 81% (Figure 18), followed by site 2 with 73% (Figure 17) site 1 with 45% (Figure 16). Site 7 had the highest tree cover of the three native dominated sites; site 7's tree cover was 87%, followed by site 2 (38% tree cover) and site 1 (13% tree cover).

<u>Wood</u>

All three sites recorded small relative covers of wood in order; site 1 with 6%, (Figure 16), site 7 with 5% Figure 18) and site 2 with 3% (Figure 17).

<u>Bare ground</u>

Sites 1 and 2 were the only sites to record bare ground 11% and 3%, respectively.

Structure and composition

Overstorey

Results of the floristic survey recorded five tree species Appendix 4 including *Eucalyptus dives, Eucalyptus mannifera* subsp *mannifera, Eucalyptus pauciflora, Eucalyptus rossii and Eucalyptus rubida* subsp. *rubida.*

Site 7 had the highest tree cover with 87%, with the dominant species was the E. *mannifera* in association with *E. dives* and *Acacia dealbata*.

Site 2 had 38% tree cover, the dominant species was the E. *mannifera* and the sub-dominant was *E. dives*.

While Site 1 had 13% tree cover, with Eucalyptus *pauciflora* the dominant species with no sub-dominant species present.

Sites 1 and 7 had a predominance of regrowth Eucalypt trees.

Understorey

Site 1, 3 and 7 had the largest number of plant species, 19, 13 and 12 species respectively. It is worth noting that site 3 is a non-native pasture with 12 exotic species. This site receives high nutrient inputs from chicken manure.

Type of species	Site 1	Site 2	Site 3	Site 4	Site 5	site 6	site 7	site 8
Exotic	2	0	12	5	0	1	0	8
Native	17	8	1	3	2	4	12	0
Totals	19	8	13	8	2	5	12	8

Table 7. Species richness for sites 1-8

Site 1, 2 and 7 had the highest number of native species (Table 7). It is noteworthy that sites 1 and 7 had low intensity total grazing pressure. In contrast site 2 showed evidence of high grazing pressure. A detailed list of species, native and exotic for all sites, along with their cover abundance, is presented in Appendix 4.

Of the three sites, Site 1 had the highest frequency of native graminoids with 33% (Figure 16) comprising four species in order of dominance; Themeda spp. Aristida spp., *Microlaena stipoides,* and Panicum spp. This site had the lowest tree cover of the three native dominated sites.

Site 7 had the next highest frequency of native graminoids with 23% (Figure 18), comprising three species in order of dominance; Rytidosperma pallidum, Lomandra spp. And *Gompholobium huegelii.* Site 7 had the highest tree cover.

Site 2 had the least frequency of native graminoids with 14% (Figure 17) comprising three species in order of dominance; *Microlaena stipoides* Lomandra spp. and Juncus.

On non-native sites, native graminoids while present at some sites were nonetheless a rare and uncommon ground cover type (Appendix 4).

It is worth noting that the non-native cover dominated ground layer species i.e. improved pasture sites on the floodplain (i.e. sites 3, 4, 5, 6 and 8) had on average fewer ground layer species (3.5 species), compared to native cover dominated ground layer species (5.9 species); except for site 3 which had 12 species. While native graminoids were present at some of these intensively managed sites, they were a rare and uncommon ground cover type (Appendix 4).

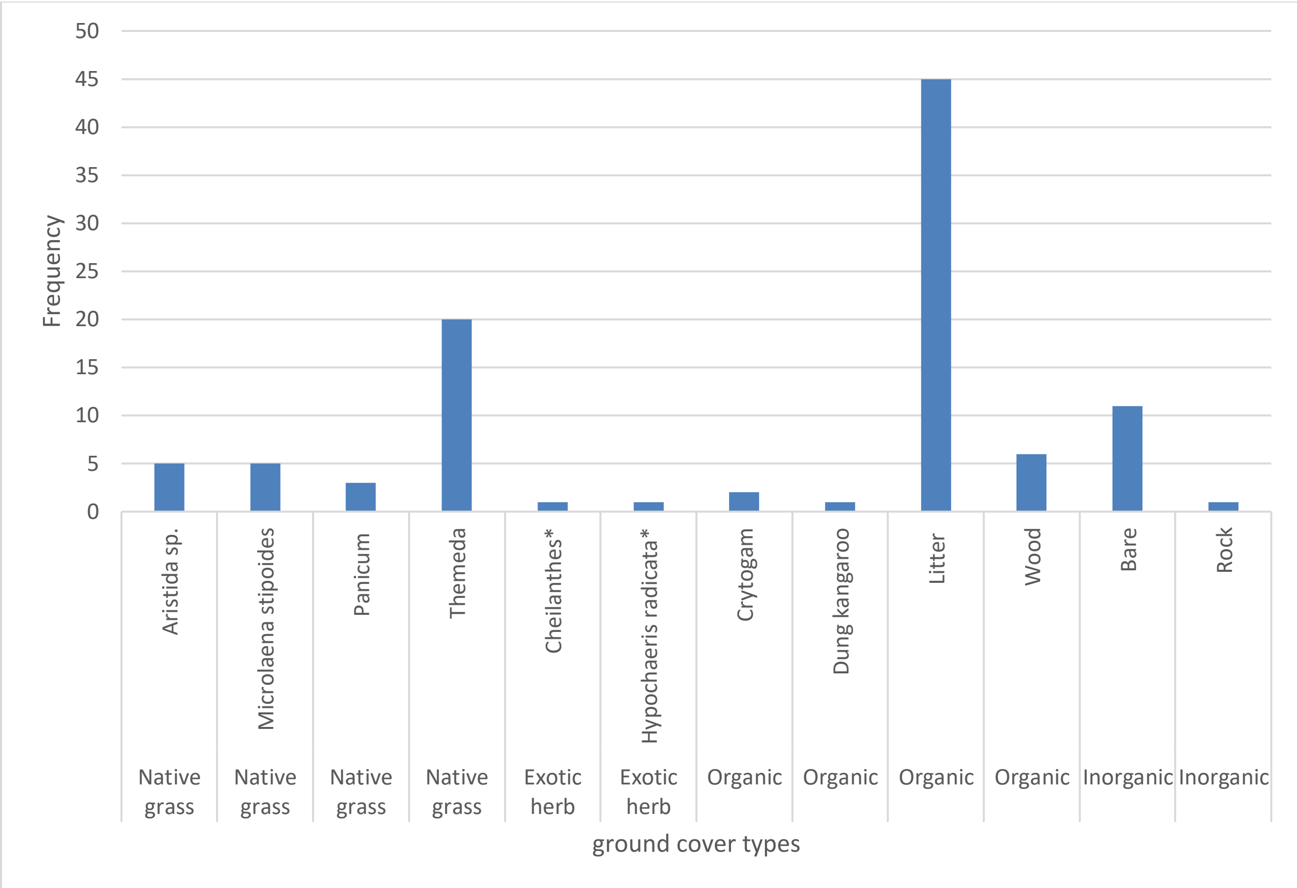


Figure 16. Frequency of ground cover types recorded at site 1.

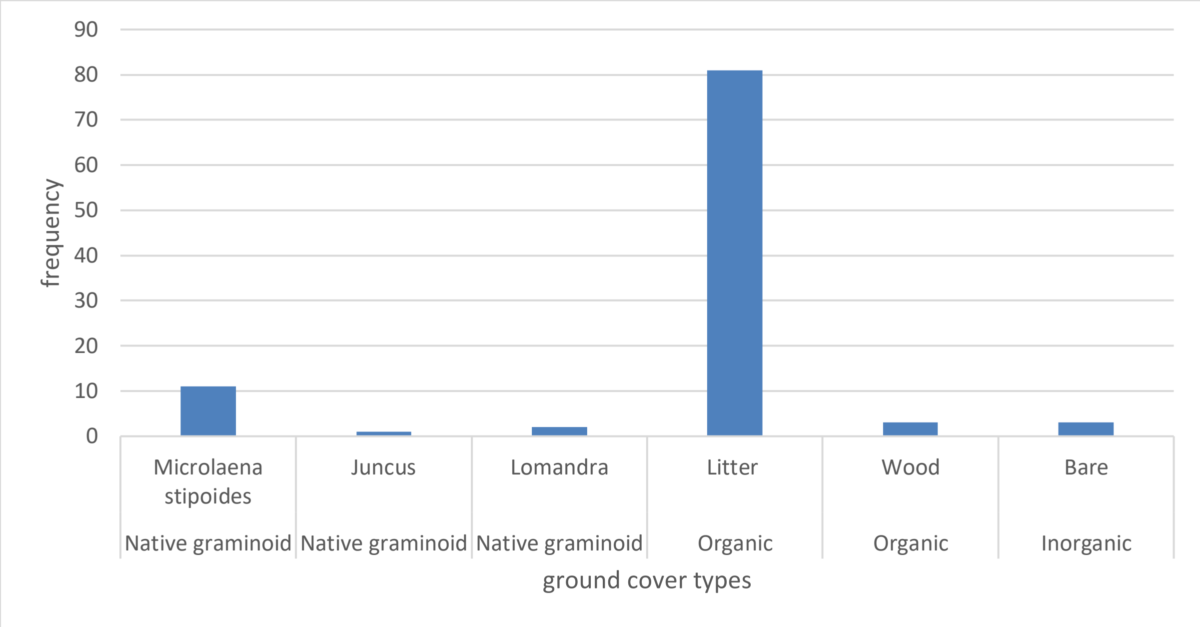


Figure 17. Frequency of ground cover types recorded at site 2.

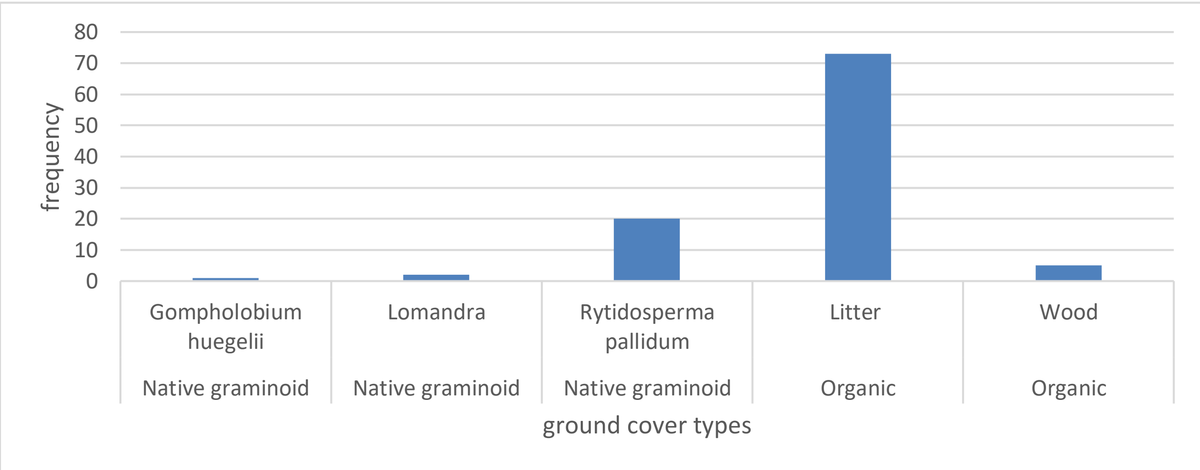


Figure 18. Frequency of ground cover types recorded at site 7.

Discussion

As noted above the soil-landscapes in the intensive land use zone of the MCC are transformed by land management regimes, practices and interventions. In agricultural landscapes inherent natural ecological functions, along with the structure and composition of vegetation are transformed, either deliberately or inadvertently, to enhance the production of various ecosystems goods and services, including agricultural commodities. Monitoring and reporting of indicators of resource condition, function, structure and composition can give insights into the status, changes and trends in vegetation condition (Noss 1990).

The impetus for undertaking this baseline assessment of vegetation condition is the inform and assist decisionmakers associated with the MCC and MCLRP to understand the impacts that land use and land management practices and regimes have on the status, change and trends in ecological indicators of function, structure and composition.

The above graphs (Figures 5-14) provide valuable insights for the land manager as well as other decision makers, however there is a need to independently validate these results. Ideally whole farm monitoring and reporting should be occurring over time i.e. before, during and after the installation of leaky weirs. Each of the land managers involved in the MCLRP should be asked to participate in developing such graphical summaries in a process of self-assessment for each property in the MCC.

Species composition and structural data collected as at geolocated sites will be invaluable for monitoring and reporting as will data of measures of LFA.

The next logical step should be accessing and evaluating time series synoptic data derived from remote sensing including:

1) fractional covers (i.e. photosynthetically active vegetation i.e. green, non-photosynthetically active vegetation i.e. brown; and bare ground)
2) estimated biomass

These data are available at the operational scale of the land manager and relates to indicators of vegetation condition, particularly ecological function (Table 2).

Has vegetation condition changed as a result of installing the leaky weirs?

The data collected and information presented in this report are not sufficient to objectively answer the question “has there has been a recent improvement in vegetation condition in the MCC or the MCLRP”. This has to do with survey design of this baseline project. Ideally a sampling framework would have established in 2002 to measure status and change of key indicators of vegetation function, structure and composition at representative sites in soil-landscapes before any leaky weirs were installed. Ideally that survey design would also have factored in the effects of land use, land management regimes and production systems and had established controls in a comparative catchment. The findings of this report regarding before, during and after the installation of leaky weirs are therefore qualitative and relative.

Figure 3 presented a conceptual model illustrating potential landscape transformation trajectories in response to landscape management interventions. Leaky weirs as one example of an intervention.

The next steps in assessing vegetation condition in the MCLRP and MCC should be to examine time series synoptic data derived from remote sensing including:

1) ground cover
2) fractional covers (i.e. photosynthetically active vegetation i.e. green, non-photosynthetically active vegetation i.e. brown; and bare ground)
3) estimated biomass

This assessment could be applied at the Home Farm to assess the effect of installing the weirs 13 years ago for the ground cover and fractional covers using the Landsat-based image archive (30m resolution 1990-present day) available through Cibo Labs (Phil Tickle pers comm). This would require some on ground assumptions about the status of the ground cover and fractional covers measures 13 years ago. This evaluation will require the TMI to establish a geospatial fabric in order to effectively evaluate the response at the site level and the soil-landscapes level relative to the installation of leaky weirs; before, during and after the establishment. In the context of Figure 3 i.e. whether the responses in different parts of the MCLRP represent a) a very high response, b) a moderate to high response, c) a moderate response, and/or d) a low-moderate response would need information on land management regimes along the lines of that presented in this report.

An assessment of estimated biomass would need access to access a detailed vector dataset of paddock boundaries; the resolution of which would need to closely match that of the Sentinel satellite imagery and be established before, during and after the establishment of planned leaky weirs.

This direction is not to discount the methods and the vegetation condition data collected, compiled and analysed in this report. Rather that data infrastructure, should be evaluated and incorporated in the continuous learning cycle (Thackway et al. 2018) relevant to the scale of land managers and decision makers in the MCC and the MCRLP.

In order to prevent a future loss of ecological function, similar to that which occurred across the MCC in the late 1800s, it will be necessary for the TMI to monitor and report changes in the ecological function, structure and composition. Monitoring and reporting of the subset of 8 VAST sites relative to the 25 LFA sites will be critical to determining the outcome of establishing the leaky weirs across the MCC, not just within the extent of the MCLRP.

Across most soil-landscapes in the MCC and MCLRP there is currently little capacity to readily identify which sites and farms are responding as a result of installing the leaky weirs along the Mulloon Creek. Evidence shows that rehydrating the floodplain at Home Farm produced a moister soil profile and more persistent green vegetation into dry periods (Luke Peel pers comm). However, for monitoring and reporting in the context of the outcomes of the MCLRP it will necessary to work more closely with the land managers to track the installation of weirs and associated land management regimes and practices across the key land types. The current focus of the MCLRP is on assessing the response of the floodplains upstream of leaky weirs that have been, and are to be established.

To assist decision makers, such as the TMI and land managers, in the assessment of the resource condition and to determine whether soil-landscapes are being regeneratively or sustainably managed, Thackway and Gardner (in press) developed the following working definition for landscape management regimes in agricultural landscapes as follows:

> *Regenerative farming and grazing systems are holistically managed landscapes that show a consistent positive response, or a consistent high functioning stable pattern across the 10 criteria (Table 2) over time to landscape management practices and the harvesting of food and /or fibre. By nature, they should require a low level of inputs to do this.*

Conclusions

This report presents a information framework and a baseline assessment of vegetation condition in the Mulloon Creek Catchment and the Mulloon Community Landscape Rehydration Project (MCLRP) area using the VAST framework.

The MCC and its grassy floodplains were managed for millennia by indigenous people (Gammage 2011, Pascoe 2014). The MCC catchment was settled and developed for agricultural production in the late 1800s. Subsequent development of the lower reaches of the Mulloon Creek for agricultural development have transformed the vegetation at landscape and site levels.

The installation of leaky weirs to rehydrate floodplains represents another land management practice and regime in a landscape. There are numerous positive benefits of installing leaky weirs, i.e. once the weirs backup water behind the structure, the floodplain upstream of the weir is stimulated. This in turn stimulates and influences: the resilience of the floodplain soil-landscapes to withstand severe climate events; soil physical properties by reducing soil compaction; soil hydrological properties by promoting soil permeability; soil chemical and nutrient recycling; soil biological activity; enhances plant productivity and plant growth i.e. biomass and photosynthetic material into dry seasons and periods of rainfall deficit.

Results are presented for catchment, property and sites spatial scales. While providing a baseline for 2018 the results provide a temporal context for understanding the impacts that land use and land management regimes and practices have had on status, changes and trends in ecological indicators and criteria.

Because the VAST framework provides standardised geospatial approach to land-based assessments of vegetation condition, it provides a sound basis for ongoing monitoring and reporting of vegetation condition for the MCC and MCLRP that are variously managed for agricultural production and biodiversity conservation.

To demonstrate the breadth of understandings of vegetation condition, public and private, the VAST framework has been applied at three scales; catchment or landscape, farm or property and site levels.

Large relatively intact areas of the MCC are minimally modified and minimally managed (i.e. VAST class I (Residual or unmodified native) and class II (Modified native). These VAST classes are contributing to biodiversity, water quality and visual amenity and other social values. Most of the mid and lower reaches of the Catchment are variously VAST classes III (Transformed native) and V (Removed and replaced with managed vegetation). VAST classes III and class V are land scapes managed for agricultural production. Small areas of the Catchment are VAST class VI (Removed and replaced); these include infrastructure and intensive production areas.

The current status and change in vegetation condition of the MCC and the MCLRP strongly reflects the land management practices and regimes. The environmental response of floodplain rehydration will continue to evolve. However, the challenge for the TMI and the land managers in the short and medium term (3-5 years), will be to extend the focus on land management regime change away from the MCC floodplains to improved land management of the slopes and ridges in the wider catchment. This will involve active land management to control total grazing pressure.

This baseline report will enable decision makers and land managers in the MCC and MCLRP to evaluate what contributions they are making to healthy and productive landscapes such as; healthy soils, healthy communities, fostering biodiversity, protection of waterways and maintaining clean water. These contributions need to be assessed at various scales, spatial and temporal.

This report has highlighted the need for the TMI assess and evaluate whether the geospatial framework established and the baseline results presented in this report are a valuable contribution to inform decisionmakers on the status and change of vegetation condition on the floodplain in proximity to the installation of leaky weirs through the MCLRP. This report has also highlighted the need for the TMI assess and evaluate whether there has been a commensurate positive benefit in vegetation condition across other soil-landscape types in the intensively managed and extensively managed parts of the MCC. Ideally, lessons about regenerative land management on floodplains arising from installing leaky weirs and the benefits they bring for agricultural production and biodiversity that are learned by land managers on the floodplains through the MCLRP would also become apparent on these same properties on soil-landscapes surrounding the floodplain i.e. on lower, mid and upper slopes of the MCC.

The next steps in monitoring and reporting vegetation condition in the MCLRP and MCC should be to establish a geospatial fabric which includes vector GIS coverages of key landscape and ecological features as well as land use and management and cultural features.

With that fabric in place it should be relatively straight forward to ingest time series synoptic data derived from remote sensing including:

1) ground cover
2) fractional covers (i.e. photosynthetically active vegetation i.e. green, non-photosynthetically active vegetation i.e. brown; and bare ground)
3) estimated biomass

Monitoring and reporting should be done against the geospatial fabric i.e. features that are deemed and recognised as important to inform decision makers, including land managers.

Such monitoring and reporting should be informed by the VAST criteria and indicators presented in this report and be done in partnership with the land managers. LFA site assessments should also be integrated and analysed with the VAST site data and reported using the VAST Integrative report cards. It is expected that will occur in due course, and as noted previously, the LFA site attribute measures compliment those attributes used in a standard site-based VAST assessment.

Applications of remote sensing should aim to simultaneously engage land managers to document changes in land management practices and regimes at the soil-landscape/land type level and be informed by regular measurement of attributes measured from permanent sites.

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Greg Hosking commented on an earlier draft.

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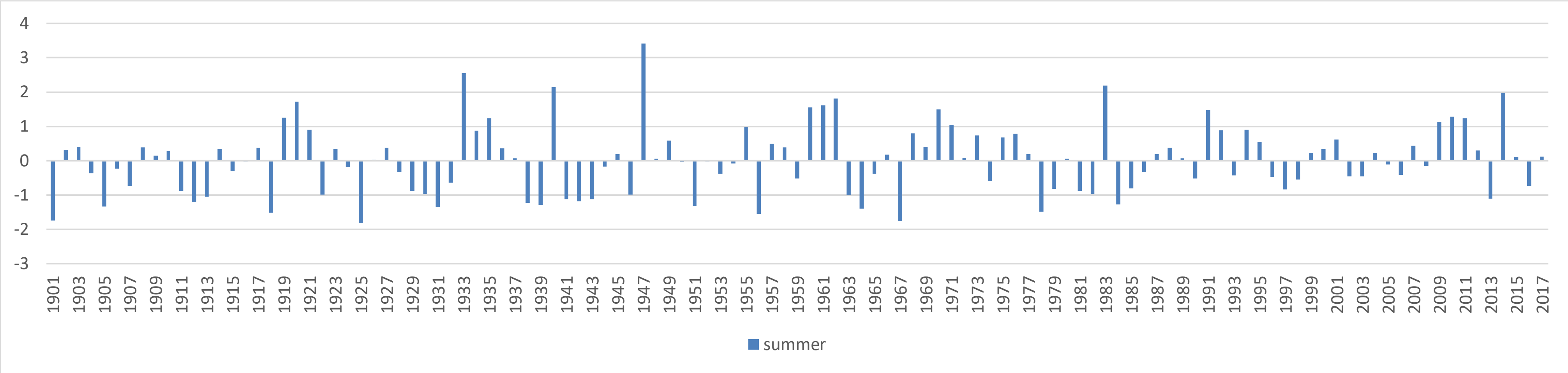
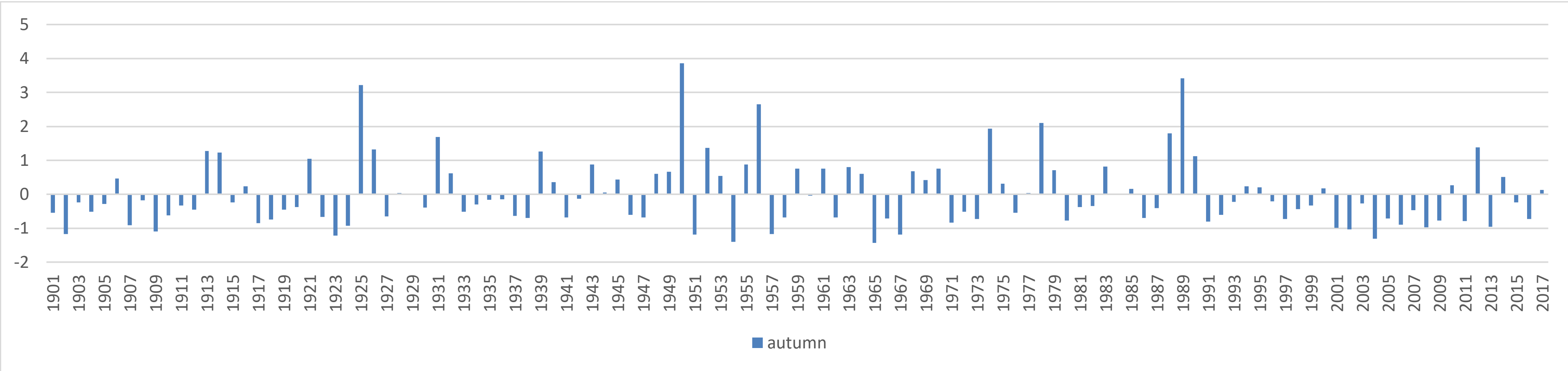
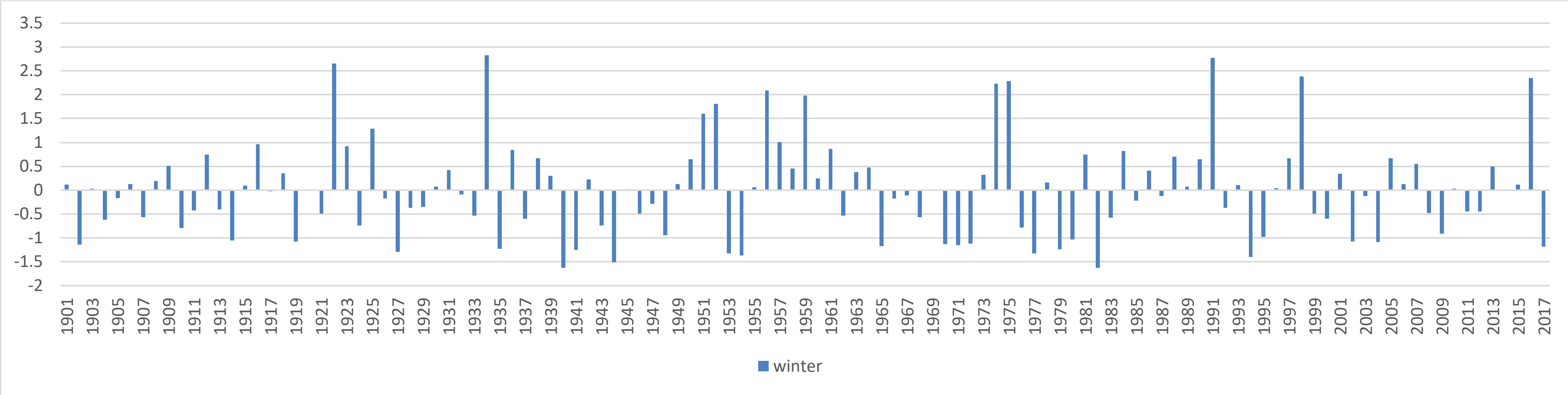
Appendix 1. Patterns of seasonal rainfall derive from modelled monthly rainfall data for the mid to lower reaches of the MCC[2] showing variants around the mean.





[2] Source: Bureau of Meteorology modelled 5-kilometre resolution rainfall data. Seasons are defined as the standard 3 monthly intervals e.g. summer comprising December, January and February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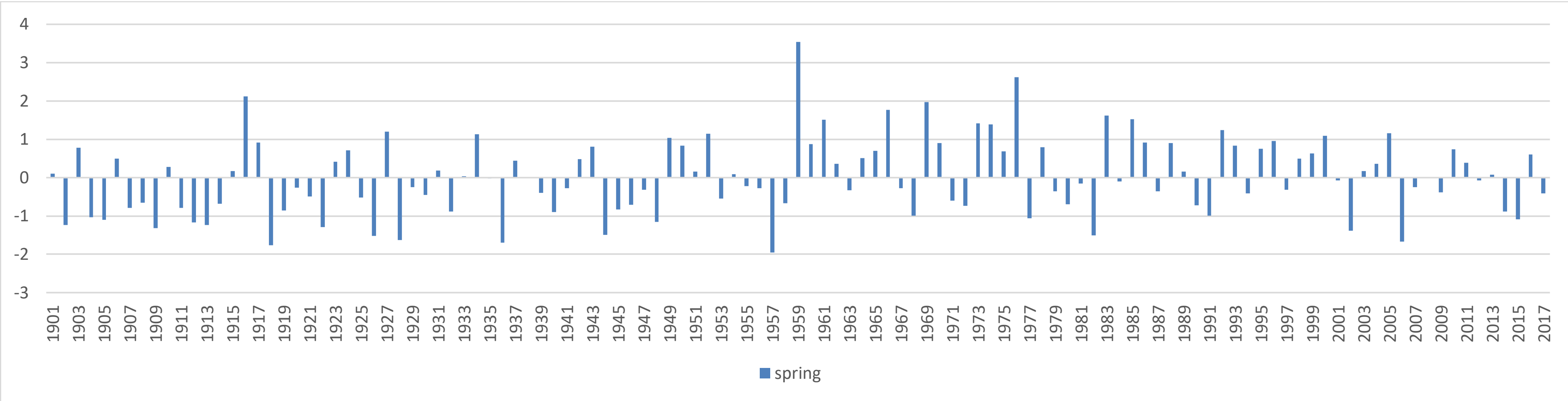
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Appendix 2. Production systems for five properties

Mulloon Creek The Home Farm (Jim Guilfoyle interview)

4440 acres

Interview between Jim Guilfoyle and Richard Thackway (Mulloon Institute). Interview held on 11 March 2017 from 2.00am – 4.00pm at the 'The Home Farm', Bungendore.

Jim Guilfoyle M: 0428 628 342 E: Wjguilfoyle@skymesh.com.au

Mulloon Home Farm and each of the properties which comprise that estate since settlement was always and will always be cattle and sheep country

Jim commenced and farm manager in 1974 and worked until 1997 (period of 24 years). During that time Jim also worked as an Oversee Manager across several other properties in the district in association with Agriculture Investment Australia (AIA).

Each month Jim presented a written report to Tony Coote. These archives should be available somewhere.

Six major acquisitions (portions) comprise the Mulloon Home Farm:

Year acquired	Property name/ Name of section	Acres
1968	Bengwen	660
1969	Robinson 1	925
1970	Greenvale (Managers House end of property)	980
1972	Horton 1	870
2000	Horton 2	360
2010	Lease	645
		4,440

NOTE = individual areas are approx./guestimates however total areas should be correct

Chronology of production systems and management regimes - Robinson 1 paddock

Year	Description of land management regime/practices	Observed effects, description of the country
1968-69	Within this paddock there are variable shale and granites	Erosion gullies were observed to be pre-existing before the block was purchased
1968-69	Originally in Robinsons 1 paddock there was only 3 to 4 smaller sub-paddocks	
1970-71	Hutt Paddock was pasture improved	Timber cleaned up/burnt & sown down to pasture
1974	Robinson 1 paddock comprised four	• West paddock – trees were dead and been

Year	Description of land management regime/practices	Observed effects, description of the country
	paddocks	pushed over and windrowed ready for burning • North central paddock – trees were dead and still standing • Middle paddock – trees had been ringbarked and were long dead. Many dead logs lying on the ground • East 'Range' paddock – trees were alive and standing. No evidence of ring barking
1974-2010	Observations of incursions of regrowth	Re growth is not really a problem
1974	Commenced and completed removing all dead and fallen timber and logs. Timber was windrowed and burnt.	
1974	Bottom paddock was pasture improved	
1974	Observed numbers of deer and the kangaroo	Deer and the kangaroo numbers were not a problem i.e. not even noticed –few kangaroos only
1974	Observed density and distribution of serrated tussock	Serrated tussock was not a problem i.e. not even noticed
1975-2010	Robinsons was set-stocked i.e. continuously grazed	
1975		West paddock was without tree and logs
1975	Soil test were done to assess what complete fertilizer/s were needed to grow and maintain an improved pasture	
1975	Single superphosphate and molybdenum superphosphate was applied (rate? per year/s) to address issues of trace elements and to balance N:P:K. Rye grass, clover and phalaris were sown and fertilized	Generally applied 125kgs/ha each 3 years, 1/3 of the property each year from 1972 to around 1990
1990	Stopped pasture improvement i.e. sowing grasses and clover and nil fertilizer. Stopped for financial reasons.	Some small paddocks on the Mulloon Creek flats were planted to oat crops and sown down to pastures until mid-1990's – fertilizer was used during this time
1990	Below expected rainfall - a very dry year	1982 extreme drought year – dust storms mid-1980's was also dry as were 1994 & 1997
1992-7	The improved pastures reverted to native pastures. During this period rye grass and clover diminished in cover and density	Lack of fertilizer applications
1994	Commenced applications of BD 500 i.e. biodynamics. This involved mixing a 'tea' which was stirred for 60 minutes (30 mins one way and 30 mins the other way). The tea was sprayed over the pasture at a warm temperature and at a low pressure	See attached list
1994	Tony C decided to seek accreditation as an organic and biodynamics producer	

Year	Description of land management regime/practices	Observed effects, description of the country
??	Mulloon Creek Home Farm was certified organic and biodynamic	Biodynamic certification approximately 3 years after first BD 500 application – 1994 – not sure when Organic cert happened
1974-> 2017	Serrated tussock, blown in from the property to the west, became more prevalent as a species of these pastures.	In 1974 scattered serrated was in the valley – in particular Willows, Tombstone paddocks & in the limestone areas of Hortons. Serrated tussock seed was being blown in from the western neighbors. By 1997 the only 2 areas of serrated tussock were – western boundary in Hutt paddock and in the limestone area of Hortons. Lack of attention since then has seen ST establish throughout the property. The inability to use an effective chemical has been a factor in the spread of ST
1974 -> 1997		Soil acidity was noted as higher than desirable. Fertilizer regime probably contributed and maybe clover as well
2009	Re applied BD 500 treatment	Do not have the application list for 1997 -> 2009
	DSE varied on this country under different land management regimes	
1975 vs 2009	Cleared country • 3.0 DSE/ ac on pasture improved and superphosphate added to country • 1.5-2.0 DSE/ac on native pasture with no superphosphate added to country	Note – find attached livestock schedules for April 1997, livestock reconciliations for 1996/97 and a paddock sheet for 3/3/97 Demonstrates past carrying capacity of Mulloon Creek
1975 vs 2009	Thinned country i.e. rung barked • 1.0-1.5 DSE /ac on superphosphate added to country • 0.5-1.0 DSE /ac with no superphosphate added to country	
1975 vs 2009	Timbered country • 0.5 DSE/ac with no superphosphate added to country • 0.5 DSE/ac with no superphosphate added to country	
2010	Cam Wilson and Sue Ogilvy set up exclosures that were monitored to assess the total grazing pressure caused by the addition of deer and kangaroos.	
2010	Commenced rotational grazing – i.e. time-based-cell grazing only implemented on cleared and thinned	

Year	Description of land management regime/practices	Observed effects, description of the country
	country where more fences and water had been added.	
2010-16	Rotational grazing 200 cows and 200 calves. Paddocks rested for nine months before grazing for three days	
2010	Cam Wilson planted native trees into the native pastures in the cleared country because there was no observed regeneration under the grazing regime	
2010-16	Tony does not control the deer or the kangaroos	High numbers of fallow deer and kangaroos observed. High total grazing pressure. Total grazing pressure on cleared country with native pasture estimated to be 0.5 /1.0 i.e. sheep, deer and kangaroos
Future	To remove serrated tussock – this could be done by pasture improvement, but this would void accreditation as an organic and biodynamics producer	Areas of the property could be taken out of accreditation for 1-2 years, treated and then re certified
Future	Under organic and biodynamic certification there is a major reluctance to control weeds and feral animals/vermin	
	When cell-based grazing was adopted electric fencing was introduced resulting in a total of 11 paddocks	

Chronology of production systems and management regimes - Floodplain - Paddocks Flats 1-6

Year	Description of land management regime/practices	Observed effects, description of the country
1974-2010	Sheep and cows were run alternatively when these paddocks were not cropped. Sometimes sheep and cows were run together	
1974 -> 1997	Paddocks were pasture improved with perennial grasses i.e. phalaris and clovers etc. Fertilizer was added at time of sowing including single super phosphate and molybdenum	
1974 to 1994	when not cropped the pastures were treated with fertilizer including single super phosphate every three years and every Fifth application, molybdenum	
1960s to 1970s	soil conservation works were undertaken including dams and levee banks. New South Wales government lent Tony Coote money at 2% for 20 years. This included fencing.	
Mid-	Water recourses commission	

Year	Description of land management regime/practices	Observed effects, description of the country
1970s	straightened the creek and added willows where the creek was incised	
Early to mid 1980s	grew Swedes and pumpkins for Sydney market. Urea and nitrogenous fertilizers were added during this time to produce high-quality even produce.	

Chronology of production systems and management regimes - Willows paddock

Year	Description of land management regime/practices	Observed effects, description of the country
Mid 1960s	Ryegrass and clover	
1970s & 1980s	Tombstone, House, Middle Hill Flats and paddock 57. Sown down to pasture, agi-ash applied	

Chronology of production systems and management regimes - Timbered country

Year	Description of land management regime/practices	Observed effects, description of the country
1974-1997	Lease paddock (900 acres). Horses we used to muster 150 to 200 wethers. Salt blocks were strategically placed in paddocks and the sheep were drawn to them by the smell of the salt licks	
1974-1997	Horton's 1 & 2 was better country than the lease paddock comprising 600 acres. This country ran 100 wethers. In addition, heifers were running this country to toughen them up	
Late 1970s	Kratos paddock patch of pine trees were planted and fenced	
1974-1997	Annually ran between 50 to 80 wethers	
2000 - >2017	No bush/ timbered country is not used for grazing production.	This country now harbors deer and kangaroos

Chronology of production systems and management regimes - North and South Scotts

Year	Description of land management regime/practices	Observed effects, description of the country
Late 1970s -> 1980s	New South Wales Soil Conservation Service bulldozer was used to establish dams and banks and to sow ryegrass and to superphosphate the area.	Pasture improvement was observed as a failure.
2017		These paddocks are now dominated by serrated tussock

Mulloon Creek The Home Farm (Tony Coote interview)

Interview between Tony Coote and Richard Thackway (Mulloon Institute). Interview held on 3 March from 10.00am – 12.45pm at the "The Home Farm"

Biophysical context

- The Home Farm straddles the Great Dividing Range.
- The average rainfall is 660 mm however this is very variable.
- Geomorphology of the area - Peter Hazell has a report. (Johnson & Brierley, 2006)
- Soil and vegetation of the Home Farm - John Field has done a survey and described the results.

Chronology of production systems and management regimes

Year	Description of land management regime/practices	Observed effects, description of the country
1750-1850	Aboriginal people Yuan People travelled from the coast to the Mulloon Creek Farm area. Garry Cook has mapped the aboriginal languages for the area showing the five language groups come together over the Mulloon Creek Farm area. Tony considers that the area was a meeting place for aboriginal peoples. Tony plan is to once again make the area a "meeting place"	
1830	William Scott selected land in the region as a "free settler". Formerly William Scott was an indentured convict selected by Elizabeth MacArthur.	
1850	The upper slopes and ridges are considered to have been eucalypt woodland /open woodland	
~1850s-1860s	Sheep were kept on the smaller farms and were managed by shepherds. There is a relic of wooden fence on the southern section of the Farm which is made of small diameter branches.	
1880s to 1970s	Major loss of ecological function on the smaller farms occurred in the late 1880s which was caused by overgrazing. This was caused by overgrazing and lack of regeneration of the pastures. This led a major dump of colluvium on the floodplains in the area. Subsequently the creek incised through the new bedload lowering the base-flow and causing major erosion. River revetment works were used in the ~1970s to control the loss of productive creek flats and constrain the creek to a narrower channel.	
~1920s	Scott's property supplied cattle that were overlanded to the NT. An aboriginal stockman from the NT, "Black Jacky", lived on, and worked with Mr Scott on Scottsdale.	
1920s-2016	No wildfires have been recorded in the Home Farm area	

Year	Description of land management regime/practices	Observed effects, description of the country
~1920s	Ring barking commenced on various properties on the slopes and ridges. Unproductive country was soon recognised and was left to regrow	
1968	Tony Coote arrived in the district and purchased “Bengwen”	
1968-2006	Mulloon Home Farm was built up as a composite of five previously separate smaller farms: 1. 1968 purchased Bengwen 2. 1970 purchased Robison 3. 19?? purchased Scottsdale 4. 19?? purchased Hortons 5. 2006 purchased Coopers	
1968-mid 1970s	Practiced conventional grazing i.e. set stocking with 60% sheep and 40% cattle. Produced hay and silage when the seasons were good. Drenched regularly and preventatively to control parasites. Chemicals were regarded as fundamental for maintaining and increasing farm production. Production was totally reliant on the use of chemicals to prop up plant and animal yields.	
1970	Robison was one paddock.	Paddock was covered with dead trees and fallen timber. The pasture was native species dominated.
1972	Robison subdivided: one paddock into five paddocks. Timbered country was fenced out. Proceeded to push the dead timber into windrows and burnt it. Ploughed the open country Sowed the paddock to rye corn and clover	
Mid 1970s to early 80s	Production was totally reliant on the use of chemicals to prop up plant and animal yields.	Soil was becoming increasingly acidic and was declining in productivity and the diversity of pasture plants and animals was decreasing - another sign.
1974-95	Jim Guilfoyle (Mulloon Farm Manager) and also manager of other farms in the area and region. Jim has an extensive knowledge of the history of the area and of Mulloon.	
~1980	Robison subdivided: five paddocks into nine paddocks Observed that cattle are preferentially grazing under set-stocking	
Mid 1980s	Tony C and Jim Guilfoyle (Mulloon Farm Manager) agreed to cease using chemicals at Mulloon including drenching animals. Huge numbers of animals died because they were being kept alive by prophylactic drenching.	Reason for going ‘off chemicals’ was because the country was unhealthy and so were the animals.
~1991-92	Honours thesis by Mark Cavicchiolo (1991) ‘An investigation into aspects of the ecological status of the regrowth dry sclerophyll forest at “Mulloon	

Year	Description of land management regime/practices	Observed effects, description of the country
	Creek", a Southern Tablelands grazing property'.	
~2006	All the bush blocks are ascribed as a Wildlife Refuge. NB: Voluntary and non-binding agreement. Bush blocks are currently a regrowth forest and formally these areas were woodland /open woodland.	
~2006	David Tongway did a LFA study of the bush blocks	
After 2006	Results of the changes in the management of the Farm were monitored by Fenner School	
~2010	Since the re-established floodplain hydration there have been fogs in the valley. That fog has been estimated to add an additional __mm of rainfall on the flats	
2011	Mulloon Creek Natural Farms and the Mulloon Institute have been established as a trust in perpetuity comprising around 6000 acres. Mulloon Institute registered as Company Limited by Guarantee	
~2012	Sold all the sheep because it is impossible to do time controlled grazing	
2013-16	Implemented time-based controlled grazing across the whole Farm.	Observing more species germinating and growing in the pastures. Observing more germination, establishment and growth of trees including wattles.
2013-16	Total grazing pressure is a problem with high numbers of kangaroos. Numbers need to be reduced to allow the pasture to fully regenerate before the paddocks are opened up to cattle in the next grazing cycle	
~2013	Larger numbers of environmental plants have established at the break of slope on the downhill slope of a 2 km contour. Trees have been planted in groves on the downhill side of the absorption bank The trees form part of a permaculture plan for the valley. The trees form part of a vision for feeding animals and people. The trees also provide shelter, temperature control, mulch, aesthetic and beauty. Chris Rowlands is responsible for the permaculture plan. Honeybees are part of this permaculture plan for the future.	Trees are vigorously growing and at present are less than 2 m in height.
~2014		Rehydrated creek frontage has seen a 60% increase in productivity. This is based on before after intervention using DSE. It is expected that this figure will be constant even in a dry year.
2015	ABC Interview with Hannah McOwen transcript mid to late February 2016.	
2016	Robison subdivided: nine paddocks into 22 paddocks. Some of the paddocks are temporary and subdivided using electric fences	

Year	Description of land management regime/practices	Observed effects, description of the country
2016 and future	Plan to use the bush blocks for plant and animal production .e.g. time-based controlled grazing of pigs and growing deciduous trees in the regrowth forest. Aim is to improve the social, environmental and economic values of these areas	

Landtasia previously called 'Cinderella' – (Dimity Davy interview)

1000 acres of 3000 acres

Interview between Dimity Davy and Richard Thackway (Mulloon Institute). Interview held on 11 March from 9.30am – 11.00pm at 'Turala', Bungendore

Dimity and her husband were former owners of 'Cinderella'. 'Cinderella' is now owned by Richard Graham and has been renamed 'Landtasia'

Chronology of production systems and management regimes

Year	Description of land management regime/practices	Observed effects, description of the country
1880-1900s	Dimity indicated that the property was mined for copper and maybe gold.	
~1961	Purchased Cinderella 3000 acres because it was flat country with the potential to be cleared of the native timber i.e. open forest and developed for improved pasture and grazed by cattle. Dimity described the country as light sandy. Dimity described the geology as greystone.	
1961-1990	Dimity and her husband did not live at Cinderella however they regularly visited the property	
1961-64	1000 acres of flat country was cleared with a bulldozer. Dimity could not recall the detail of how the 1000 acres were cleared. When the land was cleared and converted to improved pasture, they discovered several mine shafts. Dimity could not recall whether the pasture mix was used to sow down to rye grass, phalaris and cocksfoot. Dimity was not sure whether superphosphate was applied at the time the pasture was sown. A small uncleared remnant of 200 acres was fenced for wildlife protection.	The most likely scenario for how the land was developed is as follows: A bull dozer would have pushed over each tree and a stick rake on the blade would then have pulled out the green roots and any small trees and shrubs. All the woody material including trunks, branches, bark and roots would then have been pushed into piles or windrows and left to dry for a couple of years. Once dry the piles would have been burnt. Small patches of the remnant forest were left uncleared.
1964-1990	Cattle then had free access to the unfenced remnants for rough grazing and shelter.	
1964-1990	Dimity stated that no super phosphate was used on the country after it was pasture improved. She described the improved country as 'good country for cattle production'. Dimity was not sure of the year however she noted that Mulloon Creek was fenced out to	

	prevent the stock gaining access to the banks and water. Dimity recalled her husband say years ago that he was mad to have cleared the light country because it has a lower carrying capacity. They would have better off to have purchased land that was already cleared.	
1970-80s	Dimity and her husband were successful in receiving a grant from the NSW Soil Conservation Service to construct 26 dams, swales/absorption banks. Sydney Water was also involved at that time because Mulloon Creek is a feeder stream catchment for the Sydney water supply. Dimity indicated that the cleared area of Cinderella was run largely as a single paddock. The remaining timbered areas were fenced out. The cattle enterprise was run on the 1000 acres of cleared country and comprised 100 cows and three bulls. Dimity indicated that this was not economically viable. Dimity indicated that she and her husband ran less stock over the period than their neighbours. Their neighbour ran goats because the country was unimproved. When the goats got over the fence they were removed. Dimity recalled initially there were few kangaroos and more wallabies. Over time they observed more kangaroos on the cleared country. Pigs were observed in low numbers and when practical they were removed. In the early years once the trees were removed there was a very damp area which they described as a bog or a swamp. As time went on that area dried out. In the wooded area of Cinderella they gave access to Eucalypt cutters who boiled the eucalypt leaves to extract oil.	
1990s	Cinderella was sold to Richard Graham. Property was renamed 'Landtasia' and Richard built a home on the property	

Landtasia – (Richard Graham and Martin Teece interview)

Interview with Richard Graham (RG) and Martin Teece (MT) (Landtasia) and Richard Thackway (Soils for Life) and Matthew Bolton (Soils for Life) and Luke Peel (LP) (TMI) (Mulloon Institute). Interview held on 5 December from 12.30pm – 2.00pm at the Woodwork's Cafe Bungendore. Landtasia consists of three separated properties: north: Kalbilli; middle: Landtasia Kings Highway "The Swamp" and South: Landtasia. The focus of this interview was Landtasia south (Figure 1).

Chronology of production systems and management regimes

Year	Description of land management regime/practices	Observed effects, description of the country
1800s	Extensive areas of Silver top ash (*Eucalyptus sieberi*) are located on the southern higher elevated land. On the mid-slopes snappy gum (*E. mannifera*).	
Mid to late 1800s	There is evidence on the hilly areas of Landtasia of the copper mining in the mid-slopes snappy gum (E. mannifera).	These hilly areas were probably cleared during the mining activities.
1960s	Pastured areas of much of Landtasia south with cleared by Dimity Davies' husband	
early 1990s	RG began to aggregate properties as part of Landtasia south. RG's management goal over time has been to regenerate the landscape and to make parts of it productive for agricultural production. Where the land was not suitable for agricultural production it was fenced out and maintained for biodiversity conservation. Those areas that have been fenced for biodiversity have not been covenanted and that any public or private scheme.	As an aggregate of former multiple properties, the forest and woodland extent on Landtasia has not changed.
1990s	RG and MT fenced out Mulloon Creek	
1990s	Initially when Landtasia south was formed up as a single property there were 4 to 5 paddocks each with their own dam.	
1998-2018		Pastures within the 26 paddocks are now self-sustaining and self-feeding as a result of short rotation long recovery. The pastures on Landtasia include microlaena, cocksfoot for phalaris and ryegrass. Pastures are 75 to 80% cover including litter.
1998-2018	The beef cattle herd on Landtasia has been locally breed and developed over some decades and are suited to their local agri-climatic setting. The herd is marketed as organic beef. At times when there is	

Year	Description of land management regime/practices	Observed effects, description of the country
	observed to be sick animal it is sold at the saleyards.	
Late 1990s	RG began work on a series of erosion control structures to stabilise a “monster” 6m deep erosion galley which persisted for several hundred meters. These structures have reduced the erosive power of water that previously scoured out the gully. The cause of the galley was cattle grazing, trampling and accessing a nearby cattle yards “Windbone Flat”. The soil profile is inherently shallow and skeletal derived from shale. RG contracted DPI to do the work to establish a chain of ponds under a special environmental water license. RG note these structures are 6 to 12 m deep and are not leaky weir ponds.	
1998-2018	Cattle grazing has been excluded from chain of ponds	
2002-04	Commenced managing Landtasia as an organic beef enterprise.	
2002-04	Internally fencing increased the number of paddocks from 4-5 to 26 paddocks. Surface water were added into each paddock	
2002-04	Chicken manure is/was added to the soil	
2003	The area formerly known as “Towamree” around about 1000 acres at the time of acquisition, a former sheep property. This area is located west of the Mulloon Creek.	
2004-18	The area formerly known as “Towamree” has been destocked because it was highly degraded with little topsoil and little grass cover.	
2005-18	The main agricultural enterprise on Landtasia is beef cattle. A few sheep are kept for weed control	
2005	Peter Andrews came to Landtasia was espousing opportunities for rehydrating the Mulloon Creek Catchment	
2006-18	RG has a long-standing interest in having a stream gauge established upstream of Landtasia.	No on ground rehydration works were implemented on Landtasia by the Institute
2006	1.8m high exclusion fences were erected around the forest and woodland areas. The fence consists of three plane wires high up on the fence and ring lock on the lower section.	

Year	Description of land management regime/practices	Observed effects, description of the country
2006-18	Maintained the 1.8m high exclusion fences	Fence excludes kangaroos and wombats although wombats are a cause of continual fence repairs.
2006	Mulloon Creek RG observed water in the creek during raging torrents was cream in colour from erosion gullies.	
2007-18	Smaller erosion gullies have been filled with rocks. Fencing of Mulloon Creek and broader pasture management	Now Mulloon Creek during raging torrents i.e. heavy rainfall events the flow is far more sedate and water colour is clear.
2008-18	The area formerly known as “Towamree” was re-seeded.	This area has not appreciably improved in pasture condition
2010-18	Groups of fallow deer and sometimes red deer are seen. Sometimes groups up to 30 animals are seen but quickly move on when disturbed	
2017	January major wildfire “flaming crow” fire. Fire destroyed fences and homestead	
2018	Rabbits are observed their numbers are not a big issue at present.	
2018	There is currently no surface water in the dams on Landtasia which can be accessed by cattle. RG is now gearing up to access water from bores which were dug some years ago.	

Resulting from the wildfire on Kalbilly, RG estimates that Landtasia has lost somewhere in the order of $150,000 profit. Because of the drought there has been no obvious recovery of the pasture. RG observed couch grass is more prominent now after the fire. There has been no alternative other than to dramatically reduce the number of stock that the property can carry. RG estimates that Landtasia has lost 11 years of pasture development.

Landtasia Kings Highway “The Swamp” middle Landtasia has been the focus of revegetation activities in the scoured out Mulloon Creek just to the north of the bridge. A small triangle on the west side of the creek and north of the Kings Highway has been fenced out from cattle and revegetated. The cost of this work estimated to be $10,000s was a private investment made with the consent of authorities. The value of this work was recognised with Landcare. Water flowing through the creek in peak flow periods is now clean. The streambank is steep but is now stable.

Manar Creek (Forbes Gordon interview)

Interview between Forbes Gordon and Richard Thackway and Peter Hazell (Mulloon Institute). Interview held on Tuesday 1 December 2015 in Braidwood from 9.30-12.00pm at Forbes' home in Braidwood.

Chronology of production systems and management regimes

Year	Description of land management regime/practices	Observed effects, description of the country
~1835	Matthew Anderson was granted the land for surgical services rendered during the voyage of first fleet. The name of the original property was Madbury Creek.	
1841	Hugh Gordon family purchased the property from Matthew Andreson and changed the name to Manar Creek. The name Manar Creek comes from Scotland. The Gordon family have owned the property since 1841.	
1846	pencil drawing of Manar Creek homestead and shearing shed show the surrounding vegetation to be mixed age eucalypts and some shrubs.	
1842-1860	Shepherds managed sheep on grassy open woodland and grassy woodland	
~1850s – 60s	Likely that ringbarking was used to remove and thin trees on the lower slopes and flats. Soil was observed to be thicker and held water for longer than skeletal soils on the mid and upper slopes and ridges. Most soil on the slopes was 3-4" thick.	
~1860	Soil was very badly eroded. Evidence of major soil deposit on the floodplain of Manar Creek. NB: This period coincided with the transition from shepherds to set-stocking in small paddocks leading to exposed soil/ severe bare ground and high risk of erosion following the breaking of the drought. This period coincided with the introduction of barbed wire fences and removal of wooden post and rail 'A frame' fences which were easily destroyed with grass fires	

1860-2008	After the erection of wire fences the Gordon family managed Manar Creek paddocks using set stocking or continuous grazing. Stock were moved between paddocks when there was more feed observed in some paddocks. Stock ate the regenerating eucalypts. Forbes acknowledged that this style of pasture management resulted in less standing biomass and left the soil vulnerable to water erosion i.e. overland flow during heavy rainfall. Overland flow further carried a higher capacity to erode the soil and the creek channels. Where gully erosion was observed these areas were fenced out and planted to trees to try and stop the erosion. A Landcare grant was used to fence out the Manar Creek and gullies.	
1890s-1960s	Rabbit were not regarded a major problem compared to the experiences of those who managed grazing land near Harden. Nevertheless a rabbiter who used dogs was employed on Manar Creek in the 1940s-50s. Forbes had no recollection that larvicide was needed or used on Manar Creek. Forbes noted that there is a photo of rabbits taken near Braidwood and the photo was used in the book “Braidwood dear Braidwood”.	
~1950s	In Forbes’ father’s day, Manar Creek was 10,000 acres.	
1955	A bad bushfire burnt large area of Manar. Hessian bags were used to try and control the fire	
~1960s	The NSW government forced the sale of 4,000 acres of Manar Creek under the program of “closer settlement”. A further 2,000 acres was sold to settle family inheritance matters	
1962	Forbes father died	
1965-67	Forbes commenced managing Manar Creek when he was ~22 years old.	
1965-2008	During drought Manar was destocked. At different time the stock (cows and calves) were sent on adjistment to Victoria, upper	

	Shoalhaven River catchment, Singleton.	
1966-67	Drought in 1966 a semi-trailer delivered wheat to feed the stock. 1967 Forbes took the stock out on the long paddock, travelling to Tumut and Adelong. Later the stock were adjisted near Hoskington until the end of the drought	
~1970s-2008	Manar Creek was 4,000 acres during the time that Forbes' was owner and manager. Forbes managed mainly native pastures for wool production and calves/weaners cattle. This form of land use was regarded the best use on 'light country'	
~1950s – 1970s	Forbes father build a large bulk superphosphate shed and bought in bulk fertiliser to lift the nutrient levels of the soils. Tractors pulled super spreaders were used to spread the fertiliser and pasture seed comprising exotic grass seed. Pasture establishment was various. Most attempts to establish improved pasture failed because of drought.	
~1950s	In the district native pasture tussocks were managed using a periodic winter fire management regime. Low intensity fires to promote 'green pick' in spring. This was used as an alternative to super applications. This practice was not used on Manar Creek in Forbes lifetime	
~1970	Forbes sought recognition for Manar Creek as a Wildlife Refuge under the NSW NPWS.	
2001-2008	Forbes brought drought feed for the stock and used silage which had been harvested in ~2000 by cutting and bailing in silage bails native pasture from the alluvial flats.	
1967-2008	Blackberry and broom were major pasture weeds. Birds spread the blackberry and stock spread the broom. Both weeds were controlled by regular spraying with weedicides. Serrated tussock was present and was relatively easily controlled by always digging it out when found with a mattock.	
~1841 to 2008	rainfall records are available as are account books showing the stock numbers	

1967-2008	in dry times Forbes would use a tractor to dig out the creek bed to find water for the stock to drink	

Mulloon Farm (North) – (Marlene Cantwell (nee Cooper) and Ruth Cooper interview)

Interview between Marlene Cantwell (nee Cooper) and Ruth Cooper and Richard Thackway and Peter Hazell (Mulloon Institute). Interview held on Wednesday 19 August 2015 east of Bungendore from 10.00 am -12.00 pm at Marlene's home formally Ruth's home.

Chronology of production systems and management regimes

Year	Description of land management regime/practices	Observed effects, description of the country
1934	Map Parish of Mulloon 21 June 1934 5th edition. Name is listed for the area re the focus of the interview was William Scott.	
1937	Convicts built the now shearing shed. Licensed premises 1937 Stage Coach Inn. Built by convicts. Cobb and Co. change station for the horses. Half way between Sydney and Melbourne. Mulloon road is possibly the old Sydney - Melbourne Road. Why convicts were in the district is not clear.	
1938	Map Parish of Fairy Meadow. 28 Dec 1938. 5th edition. Name is listed for the area re the focus of the interview was William Scott.	
1927	Ruth's husband's grandfather bought Mulloon Farm in 1927. 1927 the Coopers family started purchasing land to establish a pastoral company. Various purchases included: 640 acres, 1000 acres, 1000 acres the "bush block"; and 2000 acres purchased by Coote family. In total Coopers owned 5000 acres. The blocks were bought in stages. Not all blocks were contiguous.	
<1927	Before 1927 the Coopers lived in Bungonia. The Gordons owned the country to the north of Mulloon Farm.	
1927	1927 Ruth's husband's aunty was 12 when the property was bought. 2015 aunty now lives in Wagga Wagga.	
1935	Family home was built. Site of house was built this side of the creek because of flooding and difficulty in accessing the eastern side of their block. Originally lived where the shearing shed is located on the eastern side of the creek and was accessed via a swing bridge upstream of the current crossing.	

1965	Ran sheep on around 3000 acres. 245 cattle poll hereford.	
1968	Ruth was married to Geoff Cooper and came to live at Mulloon. Ruth's Maiden name is Southwell and she came from Wattle Park near Hall in the ACT.	
1968	Rabbits were a major problem in 1968, much less so after the 1974 floods.	
1968	Commenced documenting sheep numbers in a stock book.	
1968-2015	Annual Kangaroo culls. Periodically Kangaroos were also controlled using professional shooters. National Parks 100 tags. Nooses were set in holes under netting fences to snare kangaroos for dog food. Kangaroos were also regularly shot for dog food.	
1968	Farm rainfall records date back to 1968. Gave them to neighbour, Gerry Carroll.	
1968	Combined farm running 2546 sheep	
1969	154 cattle. Pastoral company and property were split between two brothers.	
1970	1000 sheep were run on Ruth's farm i.e. # of sheep half that before the farm was split.	
1974-2015	Rabbits were a major problem in 1968, much less so after the 1974 floods.	
1978	Wild pig drive. Pigs driven out of Cinderella, owned by Davy's (now owned by Richard Graham and renamed the property - Landtasia), onto Mulloon Farm.	
1985	Major drought in 1985	
2000s	Major drought in the 2000s	
2002	459 mm (low rainfall)	
2006	518 mm (low rainfall)	
2009	490 mm (low rainfall)	
2012	Creek almost stopped running	
2012-15	Pigs are a problem on the lighter country currently.	
2012-15	Wombats are a problem on the flats and river terraces. This is particularly after the 2000s drought. Pasture and good soil for digging.	
2012-15	increasingly wild deer are observed.	

2012-15	Serrated tussock on the lighter country. Blows in from Bungendore. Blackberry in the creek. Some up in the paddocks. Constant control over the years. Told not to worry about blackberry in the creeks so much because it holds the banks together. Scotch thistle are regularly sprayed. Some saffron thistle. Sometimes Patterson's Curse. Tea tree from the hills. White flowering type is most common, but also purple flowered. Six types of tea tree. Controlled. Patches are maintained. Sprayed, trittered, slashed and ploughed.	
2015	The creek is not fenced because of the need for stock shelter.	
2015	Soil has eroded in the Crimonses paddock where the lambs and sheep spend lots of time. 40 acres. Called Crimonses because they could have owned that land before Scott's. Side of western hills suffering from drought. Soil eroded around native tussocks on slope.	

Bush block - 1000 acre

Year	Description of land management regime/practices	Observed effects, description of the country
1960s	The block is light country. In parts the soil surface is rocky. Geology is very mixed. Tertiary and meta-sediment. The terrain is rolling.	These characteristics in part explain why in the late 1960s the block was predominantly native vegetation. The bush block was scrub i.e. tea tree growth and gum trees.
Late 1960s	Merino weathers were grazed on light country. Grazing was via continuous grazing.	
1970s	Commenced harvesting timber which was cut from dead and fallen eucalypt trees for fire wood. Harvesting and felling was done with chainsaws. The timber was used on the farm and was sold in Bungendore.	
1970	The pastoral company was split between the two brothers	
1970s	NSW Soil Conservation Service put dams as part of a soil erosion control program in the catchment stabilization program Welcome Reef Dam. Dams and banks were constructed to protect the	

	catchment for the Sydney Water board.	
1970s	A couple of blocks were cleared but most not.	Too costly to clear and maintain.
1978	The bush block was sold by Uncle Ken	
1982	Subdivided into 11 smaller blocks. 3 x 13 acres blocks and rest were 100 acre blocks. Each block was numbered 1-11	
1980s	Block 10 in part was cleared for Lucerne. One or two crops of Lucerne were grown. Preferred management of the blocks in that country was running Merino weathers i.e. rougher lighter country.	
2001	Ruth's husband died.	
2015		Dominant vegetation is native on the smaller blocks. Most of the blocks are a mix of uncleared native trees and cleared cover types.

Mid slopes below the steeper wooded slopes.

Flats were for the cattle and lighter country was for the sheep.

Year	Description of land management regime/practices	Observed effects, description of the country
1969	Burning tussocks for green feed	No obvious fires across the landscape. A small fire came over the hill because the neighbour (now Mulloon Creek Natural Farm) was burning tussocks around 1969. 40 acres burnt on Mulloon Farm.
1970s-80s	Cross breeds were grazed off the flats Applied regular top dressing of superphosphate using aerial spreading	
Mid 1980s	Ceased top dressing of superphosphate	

River terraces and valley flats.

Cross breeds were managed for prime lambs on the river flats.

Year	Description of land management regime/practices	Observed effects, description of the country
1968		The river terraces and valley flats looked much the same as it is today
1968		There were more willows in the creek than today

1970	The pastoral company was split between the two brothers	
1970s		Present valley flats were sown down to Phalaris, clovers and grasses. Bailed hay. Lot of super was aerially spread. Dept of Ag was asked to do soil testing as a guide to super applications
1970s	Native pasture management - Tussocks on the flats were burnt. Tussocks were removed for green growth and before ploughing. Poa tussocks do eventually return in the absence of digging/grubbing out the tussocks and ploughing	
1970s-80s	Air strip at Mulloon Farm (North). Applied regular top dressing of superphosphate using aerial spreading	
1970s	1000 square bales of pasture hay was harvested as winter feed per year. Most years did not need to buy in hay. Set stocked – slopes for sheep, flats for cattle.	
1974	River flooded over bank. Recorded 8 inches in three days.	
1977 - 78	NSW Soil Conservation Service commenced planting willows, installing rock sausages and erecting fences to slow the sideways progression/erosion of the Mulloon Creek. Creek flats were never woody.	
1982	Feb another flood but not a large as 1974. Did not over-top the bank.	
2001-15	Have hardly supered since 2001.	
2015		The river terraces and valley flats looked much the same as it is was in 1968

Palerang – (Sue and Ulli Tuisk Tuisk)

Interview between Sue and Ulli Tuisk <Email: Palerang@tuisk.com> and Matt Bolton (Soils for Life) and Luke Peel (Mulloon Institute). Interview held on Wednesday 5 December 2015 at the Palerang Homestead from 10.00-12.20pm.

The Tuisk's have searched the archives for the early history of the property. However, during the interview it was agreed to focus on the details of management and changes over the past 20 years, since the Tuisk's purchased Palerang (2200 acres or 890 ha) in 1998. The Tuisk's are confident in their recollections over that period.

Palerang has two land types:

- The Mulloon creek floodplain and associated flats (about 1/3 of productive country on the property (726 acres) with silty clay (A horizon) and clays (B horizon); and
- Lighter, undulating hilly country – some of which is cleared or thinned (about 2/3 of productive country (1232 acres) with sodic soils[3], plus circa 200 acres of uncleared, unstocked bushland[4] with a gorge on a tributary creek.

Chronology of production systems and management regimes

Year	Description of land management regime/practices	Observed effects, description of the country
~1830s/1840s	Original settlement "Hazeldell"– i.e. Quite early in Australia's European history.	
Later in the 1800s	Homestead originally an inn – Highlands Retreat - on the Cobb & Co route between Goulburn and Cooma.	
1912	Change to Torrens Title in the archives.	
1920s-1950s	Mary Moore lived on (& owned?) the property and farmed sheep on 3000 acres.	
~1960s to ~1990s	Lots of fertiliser used on the property. Some improved pastures on the flats.	
1996-1998	Unmanaged and probably unstocked while for sale.	
1998	Tuisk's purchased Palerang: 2200 acres. Grass quite high (knee/thigh). Described as a wet farm by the real estate agent.	
1998-2000	Began a cattle trading operation and share-farmed sheep (including "first cross lambs").	

[3] Boggy in the wet.

[4] Kangaroo grass is on the edges, but otherwise dense, woody bush with little pasture. The bush block is not included in the graphs.

	Cut hay for 2 years, but none since – decline in pasture productivity without fertiliser noted. Worked off farm to help pay off some debt. Hares but no rabbits seen.	
~2000	Fertilised 2 paddocks only one in each land type – totalling 40-60 acres.	
~2002	Start of millennium drought. Finished with sheep, because of foxes and workload. Sold 700 acres to Tony Coote to retire debt. Leaving 1500 acres (or perhaps only 1300 acres with a proper survey) for Palerang. Started breeding cattle (Angus). Intention to conduct rotational grazing.	
2002 to 2010	Severe drought. Creek dried up. Cattle destocked, esp. those born in 2007-9 all sold, so a gap in the multi-age herd. Weeds: Serrated tussock. The worst weed, appeared from West and on West-facing slopes; minimal success, despite repeated control efforts; now appearing on other aspects. Patterson's curse appeared on flats West of Mulloon Creek after sheep removal. Controlled by spraying and biocontrol bug over several years and now not a problem. Thistles – as per Patterson's curse. Cape Daisy very dense on Ti Tree paddock	
1998-2018	Ferals & wildlife: Kangaroos have increased in 20 years, despite employing a shooter for 15 years @ 150 killed per annum. Expect to increase that from now on, with new laws/regs. Pigs & dogs – nil. Deer – fallow, some red. Herd of ~30 moves on when challenged. Foxes – present – driven away from neighbours who have fox-proof fences. Wombats – present and severely mangy. Rabbits – see elsewhere. Birdlife – noticeable increase after 2008 weirs, esp. water birds.	
2002-2018	Gradually splitting paddocks on both land types as new watering points created – dams on hilly country and reticulated	

	concrete troughs or dams on flats. Always aim to keep grass >5cm high to avoid overgrazing but have gone past that point in 2018.	
2007-2008	2007: Signed contract (with NSW Land Services?) to add 7 weirs, each 300mm high. 2008: Installation of weirs.	
2013	Fire in some of the hilly country. The only one in 20 years.	
2016-18		Rabbits have noticeably increased; no plans yet to control.
2008-2018	Closed Angus breeding system for the past 10 years. Only new bulls introduced. Lactating mothers put on flats, but not fattening, which occurs on the better hilly country.	
2018	Rainfall deficit. Supplementary feeding with high quality lucerne and clover/rye from Kerang, Vic since May to keep breeding stock; but financial penalty for partly emotional decision. No sign of weed introduction. At other times, always keep some hay as a stand-by. One third of stock sold off for low prices.	

Appendix 3. Baseline monitoring sites - description and geocodes

Table 2. Locations of the baseline monitoring sites Mulloon Creek Catchment, showing that eight vegetation sites, which are LFA sites. Sites are sorted alphabetically by TMI Site #.

Property name	TMI Site #	Longitude	Latitude	LFA site	VAST site
Birkenburn	BKBN1	149.564122	-35.201158	Yes	
Duralla	DLA1	149.617258	-35.201498	Yes	2
Duralla	DLA2	149.622215	-35.204018	Yes	
Duralla	DLA3	149.630674	-35.200951	Yes	3
Duralla	DLA4	149.629161	-35.181923	Yes	
Kalbilli	KLB1	149.637739	-35.176506	Yes	
Kalbilli	KLB2	149.645195	-35.162078	Yes	
MCNF	MCNF3	149.585195	-35.273174	Yes	
MCNF	MCNF4	149.587992	-35.267491	Yes	
MCNF	MCNF6	149.587552	-35.281092	Yes	8
MCNF	MCNF7	149.585296	-35.260873	Yes	7
MCNF	MCNF8	149.589269	-35.28507	Yes	
MCNF	MCNF9	149.591558	-35.289192	Yes	
Mulloon Farm North	MFN1	149.607486	-35.246047	Yes	
Mulloon Farm North	MFN2	149.612445	-35.245227	Yes	4
Mulloon Farm North	MFN3	149.618476	-35.2488	Yes	
Mulloon Farm South	MFS1	149.602281	-35.274952	Yes	
Mulloon Farm South	MFS2	149.613061	-35.266528	Yes	
Mulloon Farm South	MFS3	149.60741	-35.2603	Yes	5
Mulloon Farm South	MFS4	149.606329	-35.263218	Yes	6
Palerang	PLG2	149.628039	-35.218787	Yes	1
Palerang	PLG3	149.62167	-35.211385	Yes	
Palerang	PLG4	149.622062	-35.212945	Yes	
Kalbilli	KLB3	149.6399385	-35.1680561	Yes	
Mulloon Farm North	MFN4	149.6194075	-35.2588041	Yes	
Caroola	CLA1	149.613344	-35.23606157	Yes	
Palerang	PLG1	149.6177555	-35.22108698	Yes	

Abbreviations: LFA (Landscape Function Analysis) VAST: (Vegetation Assets States and Transitions)

Description of sites

Site 1. Palerang (Sue & Ulli) woodland site (8:30am)

Site 2. Duralla, (Michael) woodland site on ridge (10:30am) – site has a slightly challenging access uphill but provides a very good outlook across the floodplains and broader landscape, site is representative of remnant woodland in upper slope.

Site 3. Duralla (Michael) floodplain pasture site (12:30pm) – easy to access.

Site 4. Mulloon Farm North (Andrew) floodplain pasture site (2pm) – relatively easy to access, although may not be able to drive right up to site, with a small walk to access.

Sites 5 and 6. Mulloon Farm South (Marlene) mid-slope or floodplain pasture site (8:30am to 11:30am) – we may do one or both of these sites, site near homestead easy enough to access on floodplain terrace, other site is a small drive and located about mid-slope

Site 7. MCNF Home Farm (Michael) woodland site (12:30pm) – site located off the main driveway into farm (good array of natives)

Site 8. MCNF Home Farm (Michael) floodplain pasture site (2pm) – reasonably good access (park at Hay shed), although will have to walk across paddock (150m) to access site

Appendix 4. Sites and plant species matrix

NOTE: A = Abundant; C = Common; O = Occasional; R = Rare

Exotic species	**Scientific Name**	**Common Name**	Site 1	Site 2	Site 3	Site 4	Site 5	site 6	site 7	site 8	Totals of spp for all sites		
	? Dipsacus fullonum / ? Scabiosa atropurpurea	Wild Teasle / Pin Cushion			O						1		Forb
	Chondrilla juncea	Skeleton Weed			O						1		Forb
	Cichorium intybus	Chicory			R						1		Forb
	Cirsium vulgare	Spear Thistle			O	O				O	3		Forb
	Conyza bonariensis	Flaxleaf Fleabane			R					O	2		Forb
	Hypochaeris glabra	Smooth Catsear	O								1		Forb
	Hypochaeris radicata	Catsear / Flatweed								O	1		Forb
	Onopordum acanthium	Scotch Thistle			O						1		Forb
	Plantago lanceolata	Lambs Tongues			O	O					2		Forb
	Polygonum aviculare	Wireweed			R					R	2		Forb
	Sisymbrium officinale	Hedge Mustard			O						1		Forb
	Sonchus oleraceus	Sow Thistle								R	1		Forb
	Taraxacum officinale	Dandelion								O	1		Forb
	Tragopogon ? porrifolius	Salsify			R						1		Forb
	Trifolium sp.	A Clover								O	1		Forb
	Dactylis glomerata	Cocksfoot			C	O		O			3		Graminoid
	Panicum sp.	A Panic	O								1		Graminoid
	Phalaris aquatica	Phalaris			C	C				A	3		Graminoid
	Rubus fruticosus sens. lat.	Blackberry				O					1		Shrub
Totals			2	0	12	5	0	1	0	8			
Native species	*Euchiton involucratus*	Star Cudweed	R								1		Forb
	Geranium solanderi subsp. *solanderi*	Native Geranium			O	O					2		Forb
	Gompholobium huegelii	Pale Wedge Pea							R		1		Forb
	Goodenia hederacea var. *hederacea*	Forest Goodenia		O					O		2		Forb
	Hibbertia obtusifolia	Hoary Guinea Flower	O						O		2		Forb
	Hovea heterophylla	A Hovea							O		1		Forb
	Hypericum gramineum	Small St. John's Wort	O								1		Forb
	Hypoxis hygrometrica	Weather Grass	R								1		Forb
	Astroloma humifusum	Native Cranberry	R								1		Graminoid
	Caesia sp.	A Grass-lily	O								1		Graminoid
	Juncus sp.	A Sedge		O		O		O			3		Graminoid
	Lomandra filiformis subsp. *coriacea*	Wattle Mat-rush		O					C		2		Graminoid
	Lomandra longifolia	Spiny-headed Mat-rush							O		1		Graminoid
	Microlaena stipoides	Weeping Grass	O				O	A			3		Graminoid
	Poa labillardierei var. *labillardierei*	Tussock				O		O			2		Graminoid
	POACEAE	Unidentifiable Grass(es)					C				1		Graminoid
	Rytidosperma pallidum	Red-anther Wallaby Grass		O							1		Graminoid
	Rytidosperma sp.	A Wallaby Grass						O			1		Graminoid
	Themeda triandra	Kangaroo Grass	C								1		Graminoid

Exotic species	Scientific Name	Common Name	Site 1	Site 2	Site 3	Site 4	Site 5	site 6	site 7	site 8	Totals of spp for all sites		
	Acacia gunnii	Ploughshare Wattle		R							1		Shrub
	Acrotriche serrulata	Honeypots	R								1		Shrub
	Aristida sp.	A Three-awned Speargrass	Upslope A								1		Shrub
	Daviesia mimosoides subsp. *mimosoides*	Bitter Pea	R	R							2		Shrub
	Dillwynia sericea	Showy Parrot-pea	R						O		2		Shrub
	Leucopogon virgatus	A Beard Heath							R		1		Shrub
	Melichrus urceolatus	Urn Heath	R						O		2		Shrub
	Pultenaea subspicata	A Pultenaea							R		1		Shrub
	Eucalyptus dives	Broad-leaved peppermint	Upslope C	O					C		3		Tree
	Eucalyptus mannifera subsp *mannifera*	Brittle Gum		C					C		2		Tree
	Eucalyptus pauciflora	Snow Gum	C								1		Tree
	Eucalyptus rossii	Scribbly Gum	Upslope O								1		Tree
	Eucalyptus rubida subsp. *rubida*	Candlebark	O								1		Tree
Totals			17	8	1	3	2	4	12	0			