2020
SALISBURY CASE STUDY
DETAILED ECOLOGICAL REPORT

Prepared by Mark Parsons and Matthew Bolton

Summary

This report on the ecological values of Salisbury is based on the known history of management of the property since 1972. The earlier history of the Marra Creek district has been inferred from a number of published and unpublished sources on nearby properties with the same land types, including Ditchfield (1996) and R. Thackway, pers. comm. (January 2020).

The ecological values assessed include resilience to disturbance and soil nutrients, hydrology and biology. Because little empirical data was available to the authors at the time of writing, the assessment is necessarily based on observations and a subjective judgement of likely effects of management.

The condition of all values assessed is assumed to be poorer than they were originally in the mid-1880s having declined steeply around the time of the Federation drought when scalds developed on duplex soils in the Marra Creek district. Also assumed is a slow, steady decline during the 20th Century until Salisbury was split off from Womboin in 1972. These assumptions are based on the set stocking strategy used over a long period, leading to loss of soil structure, hydrological function and biological values, combined with negligible fertiliser inputs and limited pasture improvements. This assessment places special emphasis on the reclamation of these scalded areas by a technique known as waterponding.

Information presented in this assessment has been compiled by interviewing the land manager, Will MacAlpine, to document the response of the red duplex land type[1] to these land management regimes over time. Measured data such as soil tests and biodiversity survey data have been referred to where available to the assessors. The ecological responses have been assessed using 10 ecological criteria. However, a time-series of the fractional ground cover of Salisbury was not available at the time of writing this report.

Key findings

This assessment identified four phases of land management on Salisbury (Table 1), which includes production regimes and biodiversity enhancements.

The pre-European Phase 0 (zero) lasted until about 1830 to 1850, when the first pastoral settlers came to the Marra Creek district (Ditchfield 1996). Conventional management (phase one) occurred until about 1972 and included widespread degradation from overgrazing, leading to the formation of

[1] The areas of grey/black clays on Salisbury were not assessed formally, but may be mentioned at times though this report.

hard-packed "scalds", with zero to minimal vegetation cover, on the relict floodplains of Marra Creek and associated tributaries.

After 1972, phase two commenced when Salisbury was split off from Womboin Station, the first owners and then the MacAlpine family (after 1977) began to experiment with reclaiming scalded areas. Some improvements to the scalded areas were apparent, but failures were common and large areas of scalds remained, enabling Grant MacAlpine to land his light aeroplane most places on the property.

After 1999, waterponding work on Salisbury was ramped up. It accelerated even further in 2009 and 2012 using the expertise of Ray Thompson (Thompson 2008), then at the Catchment Management Authority in Nyngan. This comprises phase three and includes additional practices to manage water use, stock health and total grazing pressure.

Phase four is in the future. Further results are expected from completing regenerative projects, such as the wildlife-proof fence to control total grazing pressure, capping the artesian bores and increased areas of improved pasture.

This assessment shows that all functional criteria are considered to have improved, but that there is room for further improvement (i.e. scores between 0.8 – 1.0). For example, since the widespread adoption of regenerative practices in 2009:

- The property is becoming more resilient to drought (Criterion A). A similar conclusion is likely for flood proofing.
- Soil health and function has gradually improved. This summary applies to the following ecological changes: soil nutrients and soil carbon (Criterion B); soil hydrology (Criterion C); soil biology (Criterion D); and soil physical properties i.e. soil as a medium for plant growth (Criterion E).
- Vegetation biodiversity has stayed much the same during the waterponding operations. This summary applies to the following ecological changes: tree and shrub structure (Criterion G) and tree and shrub species richness and functional traits (criterion I).
- Pasture status has gradually improved (from zero) in the ponded areas. This summary applies to the following ecological changes: ground cover/ground layer/grass and herb structure (criterion H) and ground layer/grass and herb species richness and functional traits (criterion J).
- The reproductive potential of the plant species and plant community (Criterion F) was applied to both the tree/shrub and pasture layers and a similar conclusion to the above criteria was found.

More improvement in these values is expected in future, particularly when drought conditions ease. Further rainfall will serve to leach salts from surface layers of the scalds as well as provide an essential input for plant growth.

Table 1. The four management phases at Salisbury

	Production Regimes	**General Observations**
Phase one: 1850- 1972	Conventional management practices were undertaken throughout this phase.	• Large numbers of stock were present in the late 19th century.
Phase two: 1972-1998	During this phase the manager implemented small-scale experiments and interventions with a view to expanding some or most of them in future.	Small scale interventions include: • ponding of scalds in red country • managing stock numbers to prevent overgrazing, especially after the wool crash of 1991.
Phase three: 1999-2019	The manager implemented certain regenerative and sustainability practices.	The land manager has: • capped artesian bores and provided water to each paddock via pipes, tanks and troughs • expanded the area of ponds on red soil scalds • observed "triggers" for stock management • established infrastructure for containment feeding • sown improved pastures on the intact red country • begun erecting a wildlife-proof fence.
Phase four: 2020 and beyond	Further implementation of regenerative practices is expected in the near future.	• Plans to add pasture seeds to both the red and black country, with particular emphasis on the ponds on red soil. • Completion of recent, current and planned work under phase three is expected to pay dividends for the ecology, production and finances, after the current drought breaks.

Salisbury in ecological context

Salisbury is situated on the Marra Creek district approximately 60 km west of Carinda. It was split off from the large Womboin Station in 1972. Present day Salisbury comprises 20,000 ha and supports a self-replacing merino flock totalling about 10,000 dry sheep equivalents of grazing pressure, typically comprising 5000 breeding ewes (1.5 DSE each) and 2500 ewe lambs, on average in the long term (and allowing for the kangaroos!). The property is subdivided into 22 main paddocks and a number of smaller holding yards and transport routes (Figure 8).

Figure 1: Salisbury paddocks superimposed over a satellite image. The dark circles in the central areas are naturally vegetated areas.

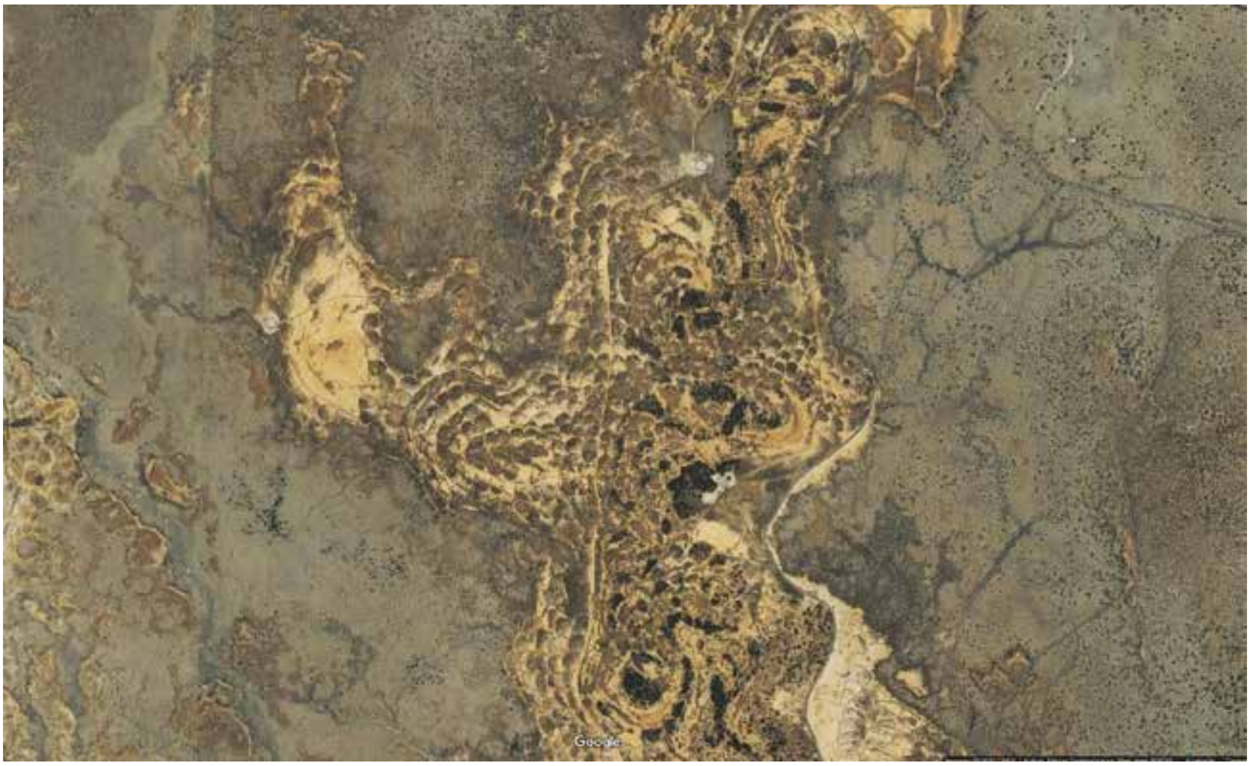


Figure 2: Satellite image zoomed in to show some of the water ponds.

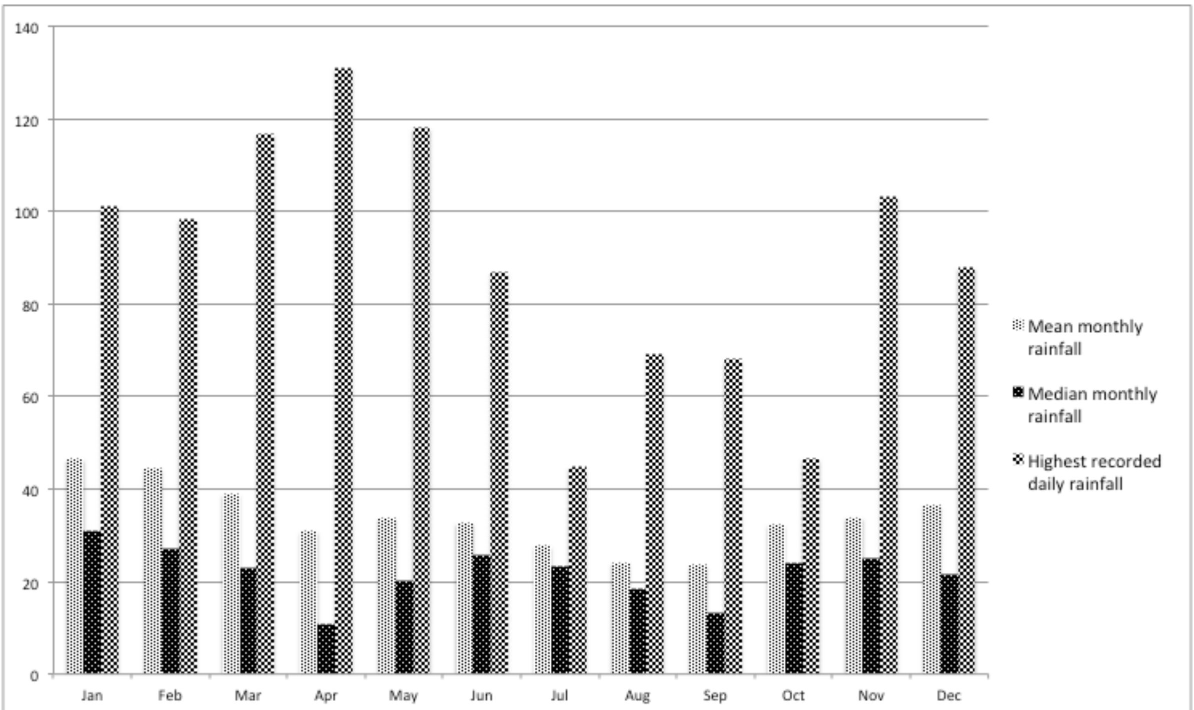


Figure 3: Monthly mean, median and daily maximum rainfall (mm).[2]

[2] Data for Bureau of Meteorology Marra Creek (Wamboin) station; records from 1886 to 2018. http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=051057

There are no permanent watercourses on Salisbury. Water supply is rain and bores that tap the Great Artesian Basin. Average annual rainfall is about 450 mm on the property or 405 mm as measured at the nearest meteorological station, perhaps indicating high local variability. The median annual rainfall is only 263 mm and records of highest daily falls show that rainfall tends to occur in infrequent large falls, commonly exceeding 50 mm/day in winter-spring months and exceeding 100 mm/day in summer-autumn months (Figure 3). In other words, the average and median monthly rainfall sometimes falls in a single day, and conversely very little falls for substantial periods. Levee banks have been constructed around towns in the region, such as Warren, to protect them from floods. As is the case across large areas of Australia livestock production is challenged by the low average rainfall, high rainfall variability and infrequent but intense falls interspersed with extensive dry periods.

There are two general soil types on Salisbury: a dark heavy clay soil that is relatively impervious to erosion and red soils with a highly erodible sandy upper horizon over a finer red clay lower horizon – so-called texture contrast or "duplex" soils[3]. These land types each cover approximately 50% of the area of Salisbury (Figure 1).

The red soil has better natural potential for grazing than the heavy clay, but large areas of it have been degraded by wind and water erosion in the Marra Creek district (Figure 3 and Ditchfield 1996). Texture contrast soils cover about 20% of Australia and may have been formed from one or more of four possible processes (McKenzie *et al*. 2004):

- Formation of a "biomantle" A-horizon by the action of earthworms, ants and/or termites with the loss of fine particles in arid regions by erosion;
- Supplementation of clay in the B-horizon by downward clay movement;
- Differential weathering; and/or
- Sedimentary layering.

The native vegetation is sparse woodland with common tree species including poplar box (*Eucalyptus populneus*), leopardwood (*Flindersia maculosa*), wilga (*Geijera parviflora*), rosewood (Heterodendrum oleifolium, also known as bullock bush), warrior bush (*Apophyllum anomalum*) and wild orange (*Capparis mitchellii*). The most widespread low ground cover is old man saltbush (*Atriplex nummularia*) and bladder saltbush (*A. vesicaria*).

The following vegetation types on Salisbury were identified from Keith (2006):

- North-west Floodplain Woodlands;
- Inland Floodplain Woodlands; and
- Western Peneplain Woodlands.

There is a wide range of herbaceous plants and grasses, including Mitchell grass (*Astrebla* spp.). The perennial saltbushes and Mitchell grass give the property a natural resilience to drought when managed well.

Scald rehabilitation by waterponding

The early period of sheep grazing in the arid and semi-arid rangelands of western New South Wales was a disaster for topsoil. Overgrazing encouraged by high wool prices destroyed ground cover, which in dry periods led to widespread wind and water erosion that created 'scalds' where the coarser textured surface material has been completely lost, leaving the finer textured and less permeable subsoil (Figure 4). This was reported as being an extensive problem as long ago as 1901

[3] Now called texture differentiated soils (McKenzie *et al*. 2004)

(Cunningham 1987). By the 1960s, tens of thousands of square kilometres of rangeland sites in western NSW were moderately bare or 'scalded' (Thompson 2008).

Figure 4: Scald at Salisbury showing the hard-packed surface soil and elevated root systems of dead plants, indicating the depth of topsoil lost to wind and water erosion

The natural rate of vegetation re-establishment on these scalds is nil or negligible, largely because the surface seals up to prevent water infiltration and root development. Also, air temperatures are exceedingly high for too long. Lack of seed and abrasion of germinating plants by wind-blown sand also contribute to the problem (ibid). Intervention is required to get re-vegetation started.

Methods for reclaiming scalded soils in Western NSW have been researched since the late 1940s (Cunningham 1987). Rehabilitation work was begun on Salisbury in the 1970s by the previous owners, continued by the MacAlpine family in the 1980s and 1990s, and ramped up in 2009 and 2012 when government grants were available. The previous owners used a 'checkerboard' pattern, dividing the scald into squares by ploughing two sets of furrows, one set perpendicular to the other. However, that method was found to be an ineffective way to enable vegetation to establish and persist (Cunningham 1987).

Surveying and construction methods developed over several decades have made rehabilitation of scalds more and more cost-effective (Rhodes 1987). The methods that have been used for several years on Salisbury involve using a grader to build low ponding banks to hold rainwater to a depth of 10 cm or so. These are circular on flat ground and semi-circular (a 'horseshoe' shape) on scald with a mild slope. The opening of the horseshoe is to the up-slope side, so that run-off collects within the banks. Each pond covers about 0.4 hectares. The grader used to construct the banks is also used to disturb the soil surface within the ponds in strategic locations (Thompson 2008). Saltbush seed – some of it collected on the property – is sown over the disturbed surface. Running cattle over the ponded area after the surface had been softened by rain was used to disturb the soil surface in a previous Soils for Life case study of a property near Brewarrina.[4]

The effect of the ponding banks and disturbance is to hold water from the intermittent heavy falls. This then infiltrates – albeit slowly – to leach salts from the surface and provide moisture down the soil profile. The banks and disturbance within them provide a barrier to wind-blown sediments and plant material, which collects and starts to form an organic-rich surface layer. The saltbush seed, together with whatever other wind-blown or sheep- or bird-delivered seed arrives, then has somewhere to germinate and moisture to tap in the soil profile. The natural processes of ecological succession have effectively been given a 'kick-start' and can take their course.

On Salisbury, several tranches of waterponding works (Figure 2 and Attachment A) cover approximately half of the red country – i.e. about a quarter of the property. Some of the results can be seen in Figures 5 to 7.

Figure 5: A horseshoe pond bank with water ponding in the trenches either side of the bank and across the surface. Regenerating vegetation is evident within the horseshoe.

[4] https://soilsforlife.org.au/bokhara-plains-reaching-the-real-potential-of-the-nsw-rangelands/

Figure 6: Pond created in 2009. Note soil loss from parts of the bank.

Figure 7: Pond created in 2012. Note saltbushes growing in the rip line and posts used for monitoring.

Figure 8: Waterpond established in 2012. From the foreground: scalded area, external borrow trench, pond wall, inner borrow trench, reclaimed area. The water is from 30 mm of rainfall in an overnight storm.

Managing grazing pressure

The accompanying Narrative Report has a discussion of wildlife proof fencing and 'trigger points' in stock management to control total grazing pressure. The authors were unable to detect the presence of rabbits on Salisbury – perhaps because of the absence of deep sandy substrates in the district.

Assessing responses to land management regimes according to the ecological criteria

This detailed ecological report is underpinned by the Soils For Life *Conceptual Model* and *Assessment Framework* that documents the responses of 10 criteria corresponding to ecosystem function, composition and structure.

During the visit to Salisbury in February 2020, Will MacAlpine was asked to represent the responses of all 10 criteria graphically. This ecological assessment[5] commences in 1989, which is an arbitrary date before the "Ginghet" blocks were added in 1999. Will also expects an improved response for most criteria after the drought breaks.

[5] Further context on management regimes is provided in the Chronology at Attachment A.

The graphs for several criteria were considered identical to others at interview and were not hand-drawn separately. However, they are presented in this report. Despite the two major land types, only one land type was considered for the majority of the graphs[6]. The most productive country on Salisbury was considered to be the "lighter, red country" with duplex soils. This responds well to lighter showers of rain compared with the floodplain country with black clay soils. The reclamation of scalded areas back into productive usefulness has been a long-term goal of Grant MacAlpine and his son Will.

Assessment of response criteria

A. Resilience of landscape to natural disturbances – flood, drought and frost

Why track changes and trends in resilience to major natural disturbance/s?

Resilience to major disturbance/s includes the following factors depending on the agro-climatic region (wildfire, drought, cyclone, dust storm, flood, frost). A major natural disaster or natural disturbance event can occur at any time. Some disturbances give a warning, such as a windstorm or electrical storm preceding a wildfire or a flood. Once a disaster happens, the time to prepare is gone. Lack of preparation can have enormous consequences on farm life including social, ecological, economics and production.

Assumptions and definitions

Since the purchase of the property by the MacAlpine family in 1977, several important interventions have been conducted (Table 1). This includes waterponding of the scalded red duplex soils, the success of which has contributed to the overall resilience of the property. Unlike the majority of the criteria, this assessment is of the whole property and enterprise, rather than the red country.

Results and interpretation

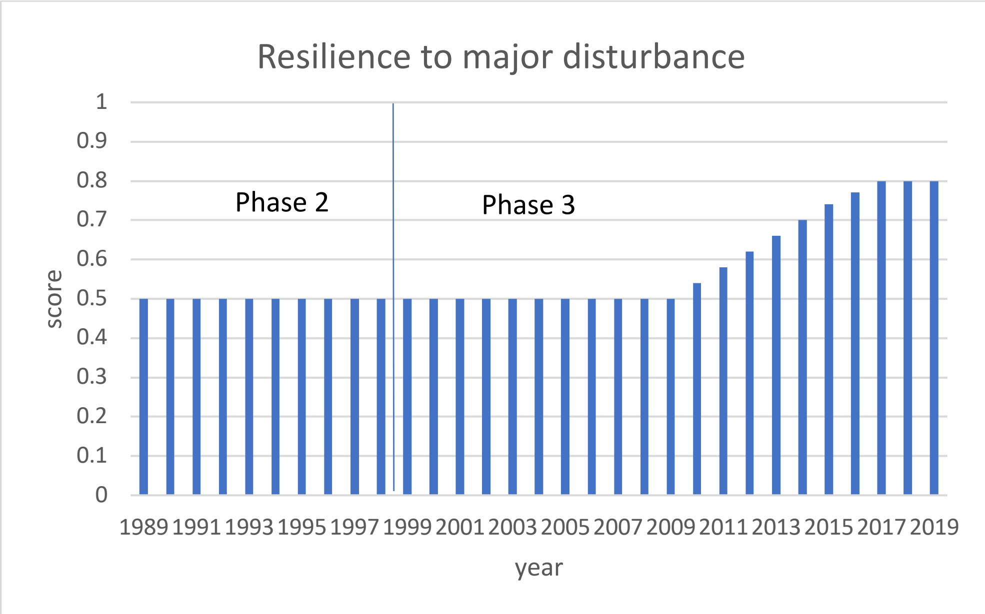
In phase one, the current land manager regards the previous resilience to be generally good, where perennial pasture components (saltbushes and/or Mitchell grass) remained intact. However, the scalded country did not contribute to drought resilience at all.

In phase two, the land manager implemented a series of trials and experiments to reclaim the scalded areas of red country, but only small areas had beneficial effects.

In phase three, after ramping up the area of waterponding in 2009 and 2012, the MacAlpines noticed an improvement in drought resilience.

---

[6] Except Criterion A, below.



B. Status of soil nutrients – including soil carbon

Why track changes and trends in soil nutrients – including soil carbon?

Soil organic matter (SOM) plays a vital role in soil fertility. As a general rule-of-thumb, for every tonne of carbon in SOM about 100 kilograms (kg) of nitrogen, 15 kg of phosphorus and 15 kg of sulphur become available to plants as the organic matter is broken down. SOM therefore releases nutrients for plant growth, promotes the structure, biological and physical health of soil, and is a buffer against harmful substances.

Assumptions and definitions

The following figure is an aggregate score of soil nutrient status for the red country on Salisbury. It represents the observed and inferred changes in status with changes in land management practices.

Soil organic carbon accounts for less than 5% on average of the mass of upper soil layers and diminishes with depth. According to the CSIRO, in good soils soil organic carbon can be greater than 10%, while in poorer or heavily exploited soils levels are likely to be less than 1%.

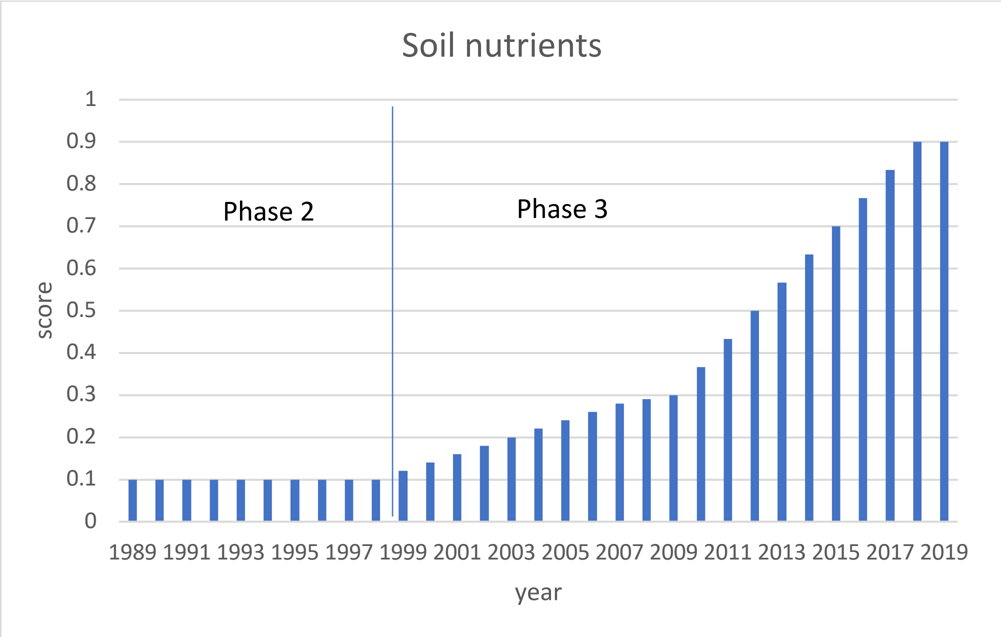
Results and interpretation

In phase two, the following graph shows a very low status of soil nutrients on the red country because of the large scalded areas compared with intact pastures.

In phase three, interventions to reclaim the scalds by waterponding after 2000 (and certainly after 2009) showed marked improvement in soil nutrient status. Read *et al.* (2014)[7] show an approximate 29% increase in carbon density to 30cm within five years of establishment when compared with the scalded soils.

Further improvement is likely in the future. However, achieving a status of “1” on the graph does not necessarily imply that the reclaimed land will be as productive as undisturbed red country.

[7] Including sample sites apparently on Salisbury.



C. Status of soil hydrology - Soil surface water infiltration

Why track changes and trends in soil surface water infiltration?

Soil physical properties have a direct relationship to soil moisture. Soil texture and structure greatly influence water infiltration, permeability and water-holding capacity. Of the water entering a soil profile, some will be stored within the root zone for plant use, some will evaporate, and some will drain away. In agro-ecological settings, by increasing water infiltration, permeability and water-holding capacity this will usually act as a stimulus to improve ecological function.

Assumptions and definitions

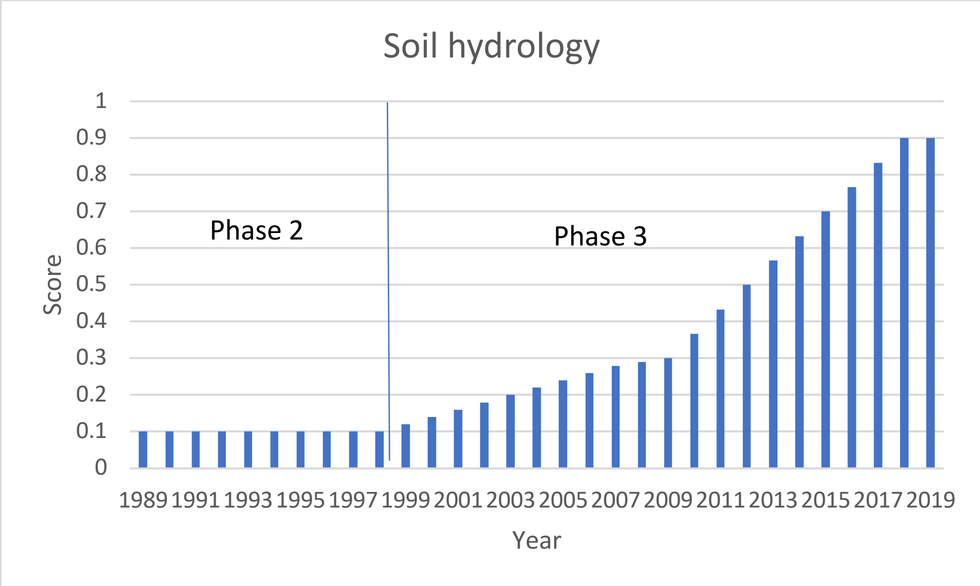
The following figure is an aggregate score of soil hydrology for the red soil country on Salisbury. It is identical in shape to the soil nutrient status outlined above in that it represents the observed and inferred changes in status occurring with changes in land management practices.

Results and interpretation

In phase two, the following graph shows a very low status of soil hydrology on the red country because of the extremely poor infiltration on large scalded areas compared with intact pastures.

In phase three, the waterponding (and other interventions listed in Table 1) have begun to improve the soil hydrology, including a dramatically improved infiltration rate (Ringrose-Voase et al. 19898).

[8] Working on a nearby property



D. Status of soil biology - Soil biology

Why track changes and trends in soil biological activity?

Soil biology affects plant and animal production by modifying the soil physical, chemical and biological environment within which plants grow and persist. The ratio of fungi to bacteria is important for land managers to understand - too many bacteria can indicate an unhealthy and unproductive soil. Soil fungi contribute to:

- natural processes (litter transformation, micro-food web participation and soil engineering)
- the decomposition of organic material resulting from compost applications and disturbance from cattle grazing
- enhancing nutrient distribution for plant health and productivity.

In healthy soils, there is a good balance between fungi and bacteria, and invertebrates including arthropods and worms are usually present. Collectively these form a vital part of a plant nutrient supply web.

Assumptions and definitions

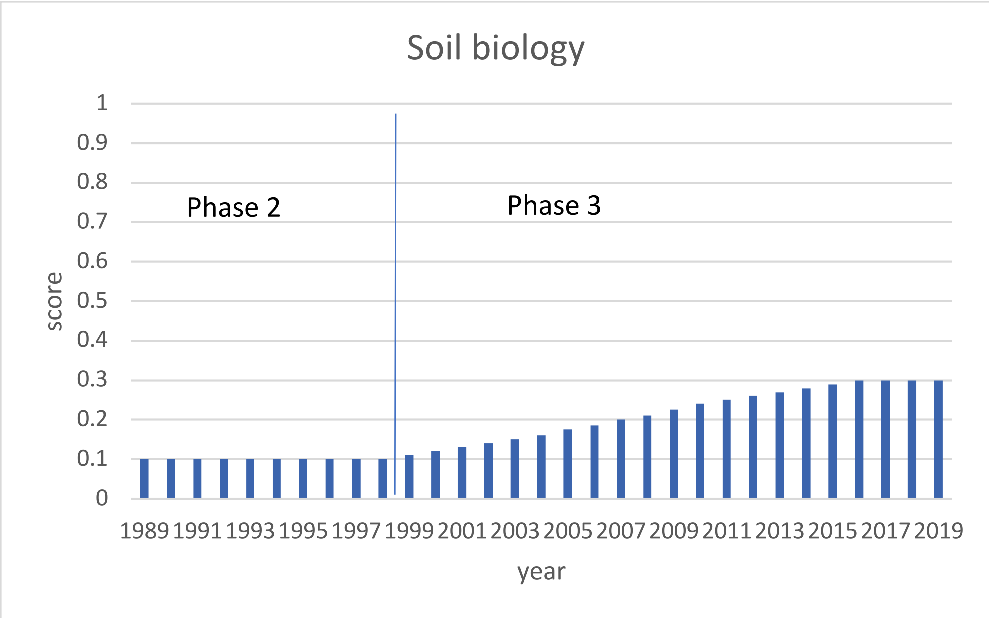
Decomposition of plant and animal residues is a dynamic process involving trophic levels. While some of the residues are being broken down for the first time by the litter transformers called detritivores, other residues have already been sequestered by soil microflora, which are in turn consumed by microfauna predators.

The following figure is an aggregate score of soil biology for the red country paddocks on Salisbury. It was considered by the land manager to be identical in shape to the soil physical properties (below) in that it represents the inferred changes in status in relation to changes from the waterponding work.

Results and interpretation

In phase two, the following graph shows a very low status of soil hydrology on the red country because of the extremely poor infiltration on large scalded areas compared with intact pastures.

In phase three, the waterponding (and other interventions listed in Table 1) have begun to improve the soil biology in line with increases in soil organic carbon (Read et al. 2014).



E. Status of soil physical properties – as a medium for plant growth

Why track changes and trends in soil physical properties?

Soil is a medium for plant growth, given the right environmental conditions.

Assumptions and definitions

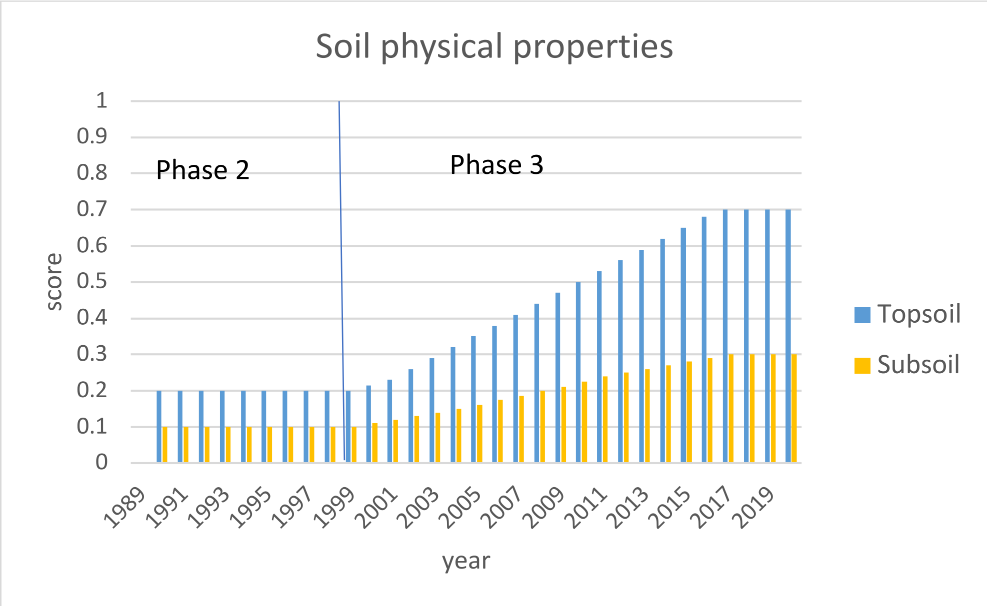
Indicators of improving landscape function over time include soil surface rain-splash protection, cryptogam cover; reduction in soil surface erosion type and severity, reduction in washed/deposited materials, presence of biological structures, e.g., perennial tussocks to intercept and retain resources during surface flows; and ground cover complexity which influences permeability.

The following figure is an aggregate score of soil physical properties for the red country on Salisbury. It represents the inferred changes in status in each of topsoil and subsoil with changes in relation to changes from the waterponding work.

Results and interpretation

In phase two, the following graph shows a very low status of soil physical properties on the red country because of the extremely poor infiltration on large scalded areas compared with intact pastures.

In phase three, the waterponding (and other interventions listed in Table 1) have begun to improve the soil physical properties. Work by Ringrose-Voase et al. (1989), including sites on Salisbury, showed that highly beneficial, deep cracks in the soil resulted from the ponding.



F. Status of plant reproductive potential

Why track changes and trends in reproductive potential of plants?

An understanding of plant reproductive potential leads to managing plant reproduction, germination, establishment and development of plants.

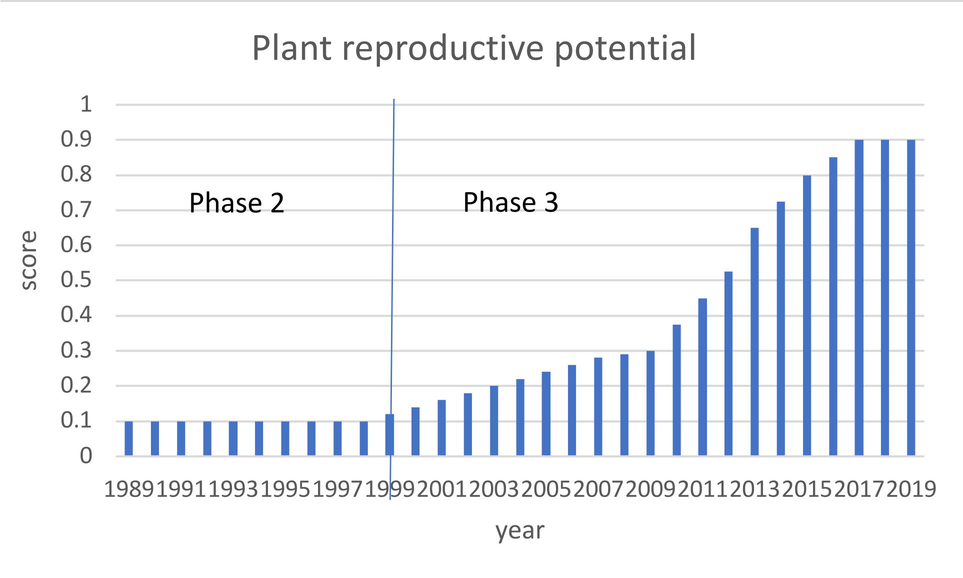
Assumptions and definitions

Development of regenerative land management regimes leads to lower costs of production over time.

Results and Interpretation

In phase two, the following graph shows a very low status of plant reproductive potential on the red country because of the extremely poor regeneration on large scalded areas compared with intact pastures.

In phase three, the waterponding (and other interventions listed in Table 1) have progressively improved the plant reproductive potential. The pond ecosystems are now less reliant on seeds from external sources for regeneration, although further seeding with improved pastures is envisaged. Monitoring ponding works on nearby properties demonstrate improved conditions for plant growth over nine years (Thompson 2008, 2012).



G. Status of tree and shrub structural diversity and health

Why track changes and trends in extent of tree cover?

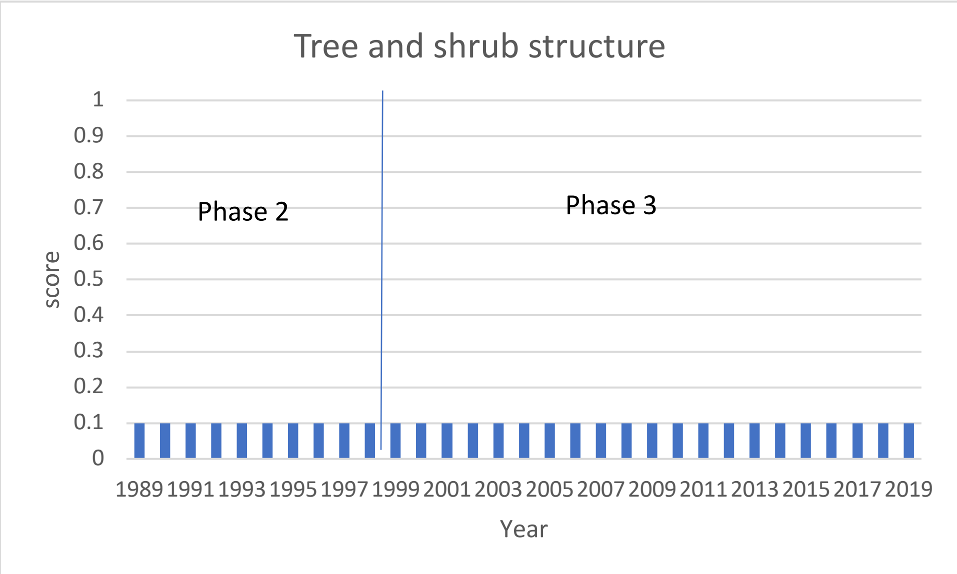
Tree cover in agricultural landscapes provides important ecosystem benefits, including mitigation of soil erosion; shelter for pastures; improved animal welfare; enabling added revenue from stacked enterprises; habitat and breeding sites for pollinators and predatory insects birds and animals; improved salinity management; improved interception of rainfall; and improved aquifer recharge management.

Assumptions and definitions

Trees and shrubs are largely intact as open woodlands on some of the unscalded red and black country on Salisbury. However, the graph below is focused on the scalds. For the purposes of the assessment, chenopod (saltbush) shrubs are considered separately as part of the ground layer in Criteria H and J, below, because they generally grow below the browse line.

Results and interpretation

There are few trees and shrubs on scalded areas before or after reclamation, so no changes have been recorded in the graph below.



H. Status of grass and herb structure - ground cover

Why track changes and trends in ground cover?

The quality of ground cover provides essential protection to keep the soil cool against direct, searing summer heat by reducing evaporation, protecting bare soil against raindrop splash and wind erosion. A dense, matted ground layer of pasture grasses slows overland flows during the intense rainfall events and assists with infiltration of rainfall, thus mitigating soil erosion and replenishing soil moisture.

Assumptions and definitions

For the purposes of this criterion, chenopod (saltbush) shrubs are considered part of the ground layer.

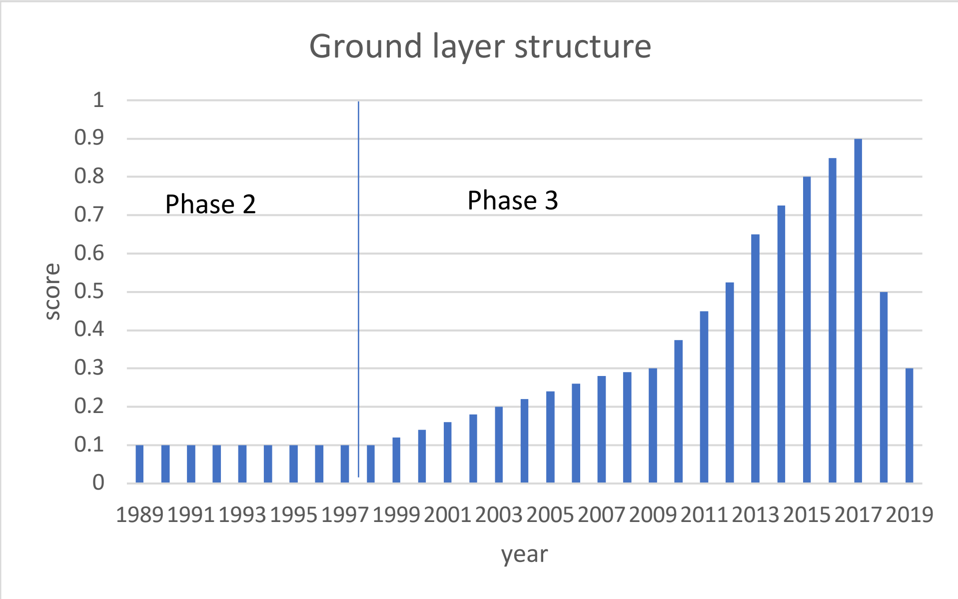
Results and interpretation

The following graph shows a very low status of grass and herb structure on the red country in phase two because of the extremely poor natural vegetation regeneration on large scalded areas compared with intact pastures.

In phase three, the waterponding (and other interventions listed in table 1) have progressively improved the ground layer structure over many years. Monitoring of the 2009 ponds on Salisbury show an increase in vegetation cover from zero to 60% (plus 7% litter cover) in five years[9]. Monitoring ponding works on nearby properties demonstrate improved pasture cover over nine years (Thompson 2008, 2012). The recent drop in ground layer structure is attributable to severe drought.

---

[9] Extract from Project Monitoring Annual Survey (2014) Central West Catchment Management Authority, Nyngan, NSW.



I. Status of tree and shrub species richness and functional traits

Why track changes and trends in the status of tree and shrub species richness?

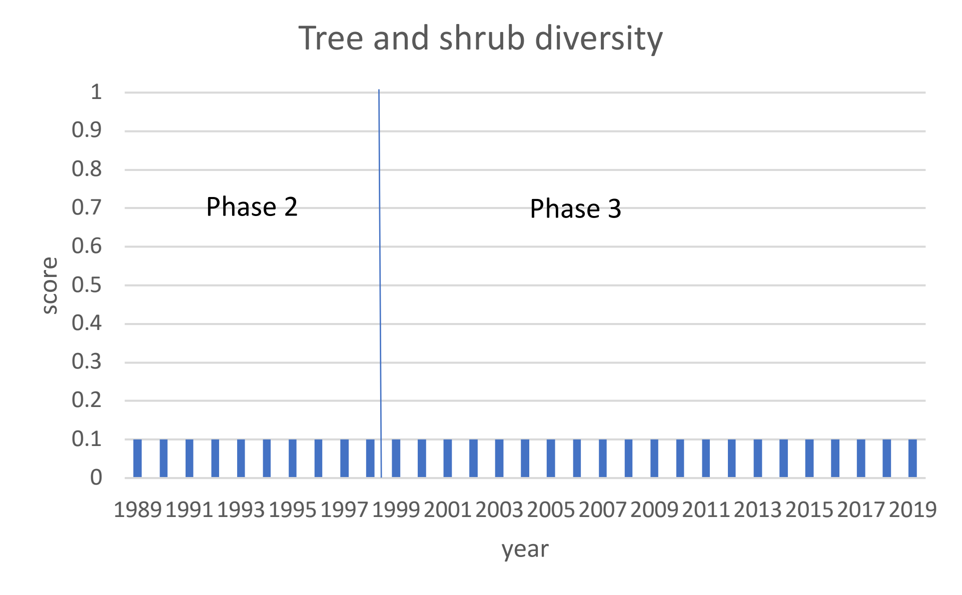
Grazing land management regimes typically result in a reduction in the numbers of species of trees and shrub species as the landscape is modified for pasture production. Grazing animals can inhibit the regeneration of trees and shrubs species.

Definitions and assumptions

Functional traits refer to the types of species inhabiting a place and what is/are their roles in that place. Functional diversity reveals how evenly the species are distributed in an area. A decrease in functional richness and evenness decreases an ecosystem's productivity and stability. As a general rule, the more functional traits of plants found in an area indicates an area is not intensively managed.

Results and interpretation

As per Criterion G (above) trees and shrubs are not a feature of the regenerated vegetation of the water ponds. Thompson (2012) makes some suggestions for regenerating trees for conservation purposes.



J. Status of grass and herb species richness and functional traits

Why track changes and trends in grass species diversity?

In many grazing land management regimes, the variety of pasture plants (annuals and perennials) can improve production, protect natural resources (soil and water) and build the capacity of farming systems to adapt to future production and environmental challenges. The intensity of the grazing management system will determine the health and vitality of pastures and their longevity.

The selection of the perennial pasture species for a grazing production system should be based on considerations of climate, soil conditions and performance of pasture species under different management regimes.

Assumptions and definitions

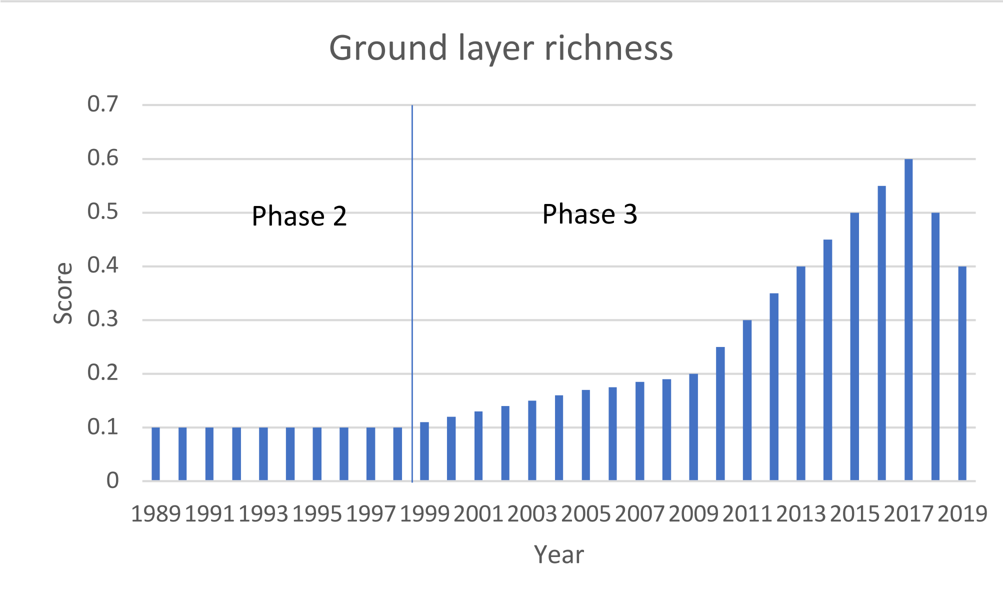
Functional traits refer to the types of species inhabiting a place and what is/are their roles in that place. Functional diversity reveals how evenly the species are distributed in an area. A decrease in functional richness and evenness decreases an ecosystem's productivity and stability. As a general rule, the more functional traits of plants found in an area indicates an area is less intensively managed.

In an agricultural setting, functional traits refer to the diversity of plant species found in an area and this is closely related to productivity and stability.

Results and interpretation

The following graph shows a very low status of grass and herb species richness on the red country in phase two because of the almost complete absence of plants on large scalded areas compared with intact pastures.

In phase three, the waterponding (and other interventions listed in Table 1) have progressively improved the ground layer species richness over many years. Monitoring ponding works on Salisbury and nearby properties demonstrate improved species richness after five to seven years (Thompson 2012). The recent drop in ground layer species richness is attributable the temporary loss of annuals in the severe drought.


Ground layer richness
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Score
Phase 2
Phase 3
1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015 2017 2019
Year

References

Cunningham, G.M. 1987. Reclamation of scalded land in western New South Wales – a review. Journal of Soil Conservation New South Wales 3: (2): 52-61. Soil Conservation Service of NSW, Sydney.

Ditchfield, R. (1996) The effect of waterponding on the reclamation of degraded scalds in the semi-arid rangelands of NSW. B.Sc. Hons Thesis, Dept of Forestry, Australian National University, Canberra.

Greenslade, P.J.M. (1987) Ants and scald reclamation by waterponding. . Journal of Soil Conservation New South Wales 3: (2): 78-79. Soil Conservation Service of NSW, Sydney.

Keith, D.A. (2006) Ocean Shores to Desert Dunes: the native vegetation of New South Wales and the ACT. NSW Dept of Environment and Conservation, Hurstville, NSW.

McKenzie, N., Jacquier, D., Isbell, R. and Brown, K. (2004) Australian Soils and Landscapes. An illustrated companion. CSIRO Publishing, Melbourne.

Read, Z.J., Murphy, B., Greene, R.S.B. (2014) Soil carbon sequestration potential of revegetated scalded soils following waterponding. Report prepared for: Central West Catchment Management Authority, NSW, October 2014.

Rhodes, D. 1987. Waterponding banks – design, layout and construction. Journal of Soil Conservation New South Wales 3: (2). Soil Conservation Service of NSW, Sydney.

Ringrose-Voase, A.J., D.W. Rhodes and G.F. Hall (1989) Reclamation of scalded red duplex soil by waterponding. Aust. J. Soil Research 27: 779-795.

Ringrose-Voase, A.J. and McClure, S.G. (1994) Fabric changes during reclamation of a scalded, red duplex soil by waterponding. In: A.J. Ringrose-Voase and G.S. Humphreys (Editors) Soil Micromorphology: Studies in Management and Genesis. Proc. IX Int. Working Meeting on Soil Micromorphology, Townsville, Australia, July 1992. Developments in Soil Science 22, Elsevier, Amsterdam, pp. 777-786.

Robinson, H.E.C. (1923) Map of New South Wales showing pastoral station &c. HEC Robinson Ltd. Accessed March 2020 at URL: https://nla.gov.au/nla.obj-234025958/view

Thompson, R. (2008) Waterponding: Reclamation technique for scalded duplex soils in western New South Wales rangelands. Ecological Management and Restoration 9: 170-181. https://onlinelibrary.wiley.com/doi/10.1111/j.1442-8903.2008.00415.x. See also 2019 update at: https://site.emrprojectsummaries.org/2019/10/21/waterponding-the-marra-creek-nsw-rangelands-update-of-emr-feature/

Thompson, R. (2012) Waterponding the rangelands. Proceedings of the 17th Biennial Conference of the Australian Rangeland Society, Kununurra, WA.

Attachment A

Chronology, Salisbury, NSW

The following chronology was established by discussion with the land manager and from unpublished sources for nearby properties on Marra Creek.

1830s to 1850s	First European settlers in the Marra Creek district
Mid to late 1800s	High stocking rates over much of NSW rangelands
Late 1890s -1902	Federation drought
1923	Map of the area shows "Booka", "Ginghet" and "Trialgara" blocks. Womboin station is further South.
1972	Salisbury block split off from Womboin station.
Mid 1970s	Chequerboard ploughing trials
1977	Salisbury purchased by the MacAlpine family. Added the "Booka" block. Apart from the scalds, the country was described by the MacAlpines as 'pristine'.
1984	Ponding first trialled on "Booka" block. Marra Creek waterponding demonstration: Four year program (Thompson 2008)
1991	Australia's wool crash caused the family to 'batten the hatches' including: • flock reduction (paid to shoot the sheep - never restocked to the same levels) • let go staff that were employed.
1994	Rest of family bought out by Grant and Cathy MacAlpine
1999	"Ginghet" blocks (NE of main property) purchased
2009 & 2012	Significant waterponding areas established on Salisbury
2020	Well below average rainfall for the previous three years[10]

[10] Monthly rainfall for Marra Creek (Womboin), Bureau of Meteorology (http://www.bom.gov.au/climate/data/) station number 51057.