# 2020
# FAIRHALT CASE STUDY
# DETAILED ECOLOGICAL REPORT

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## Key findings

Fairhalt is a 300ha mixed enterprise property which has been managed by Garry Kadwell since the 1970s. The property has been owned by the Kadwell family since 1901. The property is located to the South of Crookwell on top of the Great Dividing Range in New South Wales. This ecological assessment commences in 1980, a date which reflects the time that Garry had detailed knowledge of the management of the property.

Fairhalt is split into 22 paddocks, water supply on the property consists of an ephemeral creek, a number of dams and two large wetlands which Garry constructed to provide a healthy water supply and wildlife habitat. The property sits at an elevation on 1000m above sea level and the average annual rainfall is 813mm. The Crookwell district was first settled in the 1820s, when land was progressively cleared for agricultural purposes. Growing wheat, potatoes and fruit orchards along with producing sheep, cattle and dairy products were the main enterprises of the Crookwell region in the years post-settlement. The production of wheat in the region was slowly phased out and replaced with wide scale production of potatoes by the early 1900s.

Vegetation on Fairhalt is a mix of remnant forest and conservation plantings by the Kadwell family. Dominating the remnant forest is an overstorey of eucalyptus species such as mountain gum *(Eucalyptus dalrympleana)*, broad-leaved peppermint *(Eucalyptus dives)*, ribbon gum *(Eucalyptus viminalis)* and snow gum *(Eucalyptus pauciflora)*. The vulnerable species black gum *(Eucalyptus aggregata)* is present on Fairhalt. Mid and understorey species found within the remnant include acacias, bracken, numerous native grasses and native orchids. The remnant forest areas on the property are fenced and protected from livestock grazing.

Prior to 1980 the main enterprise on Fairhalt was growing apples. In 1980, Garry conducted a trial crop of potatoes and found that they grew well on the property. Over the course of a few years, Garry transitioned from growing apples to growing potatoes and producing fat lambs. Currently seed stock potatoes are the chief product of Fairhalt, accompanied by fat lambs, gourmet potatoes and lucerne hay. A minimum five-year cycle on Fairhalt ensures that potatoes are planted a maximum of one year out of every five. The intervening four years Garry conducts a crop rotation of lucerne for a few years, then pasture grasses for the remaining year. Garry extends the five-year cycle out to 15 years when seasons allow, e.g. a potato crop once every 15 years. The minimum five-year cycle is required when producing seed stock potatoes to ensure the presence of disease in the potato crops is detected and the diseased potatoes removed from production. Adequate rest periods after each potato crop also ensures repaired soil structure and minimal nutrient depletion.

To ensure the health of the soil on the property Garry utilises a “one pass” tilling machine when planting crops to reduce tillage damage. Ten cubic metres of organic compost is applied per hectare annually to provide nutrients and organic matter to promote biological activity in the soil. Lime is applied every ten years at the rate of five tonnes per hectare to ensure pH levels stay within the optimal range for producing potatoes (4.8 – 5.8). Garry also utilises soil carbon content as a measure to determine the health of his soil. Typically, the carbon content on Fairhalt ranges from 2.47% - 5.02% depending on the soil type.

The wetlands Garry Kadwell constructed on Fairhalt provide habitat, resulting in a wide range of biodiversity. Sixty-four species of birds were recorded on one of the wetlands in surveys conducted by the Crookwell Flora and Fauna Club. Garry Kadwell has also observed platypus *(Ornithorhynchus anatinus)* in the wetlands as well as a number of fish species. Many of the bird species observed at the wetlands utilise them for breeding. Vulnerable or threatened bird species seen on the property include: powerful owl (*Ninox strenua)*; white-fronted chat *(Epthianura albifrons*); varied sittella *(Daphoenositta chrysoptera)*; white-bellied sea-eagle *(Haliaeetus leucogaster);* and scarlet robin *(Petroica boodang)*.

This report demonstrates a close relationship between the land manager's goals/ideals and the ecological outcomes in each of four phases.

This assessment identified four phases of land management regimes including production regimes and biodiversity enhancements.

| | **Production regimes** |
|---|---|
| Phase one: 1980-1985 | Trials of potato crops leading to whole scale up take of potato cropping. Farmed conventionally with major focus on production. |
| Phase two: 1986-1997 | Continued farming conventionally with small scale trials of regenerative practices; wetland construction, pasture improvement and the use of lime to regulate pH levels. Synthetic fertiliser application started during this phase. |
| Phase three: 1998-2010 | Started planting large habitat corridors across the property and protecting areas of remnant vegetation. Synthetic fertiliser application ceased, replaced with organic compost. Lucerne cropping started and the landholder gained control of fodder production and storage. |
| Phase four: 2011-2019 | Continued vegetation conservation works and plantings. Maturation of regenerative management principals. One pass tilling adopted to reduce soil damage from crop plantings. Ground cover maintained in pasture paddocks. |

An assessment over time of the responses of ten ecological criteria shows that by phase four, compared to the previous three phases, most ecological criteria have been assessed as nearly fully achieved or having achieved their reference state (i.e. scores between 0.8 – 1.0). For example:

- Minimizing effects of extreme climatic events, which considers the whole property and its place in the broader catchment, including preparedness for drought (Criterion A)
- Maintaining high levels of ground cover across the property (Criterion H) and increasing the number of ground cover species present (Criterion J)

- Maintaining and increasing woody vegetation on the property (Criterion G) and increasing the number of woody vegetation species (Criterion I)
- Improving soil health and function. Ecological changes include: 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).

Transformation of the farm toward a regeneratively managed property has been achieved through deliberate planning and is based on a sound understanding of the links between land management regimes and ecological responses. Consistent implementation of management ideas has enabled the land manager to produce quality potatoes in a healthy soil medium as well as developing high-quality pastures which produce fodder for livestock throughout the year.

## Independent scientific assessment

An independent assessment of the land manager's self-assessment across all ten ecological response criteria supports information presented by the land manager.

## Assessing responses to land management regimes according to the ecological criteria

This Supplementary Report is underpinned by the Soils for Life *Conceptual Model* and *Assessment Framework* that documents the responses of ten criteria corresponding to ecosystem function, composition and structure.

Prior to undertaking a field visit in December 2019, the landowner, Garry Kadwell, was asked to document the production systems that have been developed and implemented. This includes land management regimes associated with the following: soil and vegetation condition (pastures, shrubs and trees); weed and pests; surface and ground water; and animal production. That production history aimed to document land management phases which led up to the current regenerative landscape management in this agricultural setting.

This included collation of all relevant available published and unpublished ecological data and information about the farm and how it was managed. It also included paddock-based photographs, fertiliser history, paddock-based management histories, as well as grazing charts, soil surveys and names of interested parties who had visited the farm over time (Attachment A). This 2019 assessment has incorporated information which was compiled in September 2012 as part of the Soils for Life (SFL) Case Study Project.

## Assessment of Response Criteria

This ecological assessment commences in 1980 this year reflects the date that Garry Kadwell had detailed knowledge of the production history.

### A. Resilience of landscape to natural disturbances – drought preparedness

***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). A major natural disaster or natural disturbance event can occur at any time. Some disturbances give a warning, such as a wind storm 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, economic and production.

***Assumptions and definitions***

Drought is the most frequent natural disturbance affecting the property. Drought preparedness is an aggregate score across all paddocks. Appropriate drought management dictates dynamic monitoring of stock numbers and available pasture to avoid groundcover loss and expensive fodder purchases.

***Results and interpretation***

Phase one extended from 1980-1985 and was associated with conventional farming. During this phase, the land manager changed from growing apples to producing potatoes and fat lambs. The focus of the land manager was on production with little regard for soil health or ground cover vegetation species. The ability of the property to cope with drought events was limited due to poor water supply and a soil medium which was not adept at retaining water.

Phase two extended from 1986-1997 and was associated with conventional farming with small scale trials of regenerative practices occurring. The resilience of the property to drought events improved during this phase due to the land manager constructing wetlands on the property. The wetlands provided a year-round water source which could be used to irrigate crops when necessary. During this phase the land manager started applying lime across the property to regulate pH levels. Pasture improvements were also undertaken during this phase.

Phase three extended from 1998-2010 and was associated with large scale adoption of regenerative management practices. During this phase the land manager ceased the application of synthetic fertiliser on pastures and replaced it with organic compost. Further wetlands were also constructed, and habitat corridors were planted across the property linking areas of remnant vegetation. Lucerne cropping was also adopted during this phase to repair soil health post potato cropping. The deep root system on lucerne is known for its ability to repair soil health and fix nitrogen.

Phase four extended from 2011-2019 during this phase the land manager’s regenerative ideals and production systems fully matured. A “one pass” tilling machine was adopted to reduce tillage damage when planting crops. Cropping cycles of potatoes were extended out to give land time to rest and repair between potato crops. The land manager purchased equipment to bail and store fodder enabling the land manager to control feed supply for livestock year-round and through drought periods.

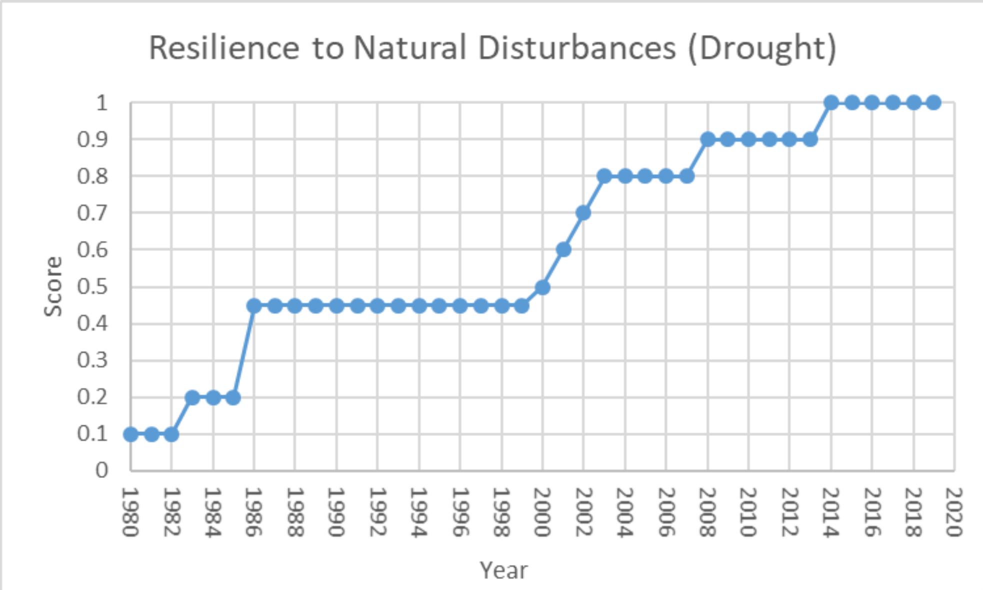



Figure 1. Landholder's graphical assessment of drought resilience change over time.

## B. Status of soil nutrients – including pH level

***Why track changes and trends in soil nutrients – including pH level?***

pH level is an important indicator when producing potatoes. Potatoes grown in a soil medium with a pH level above or below the desired range will be of inferior quality. This occurs due to the plant being unable to absorb nutrients from the soil. When the plant cannot absorb nutrients due to high or low pH levels, it results in poor quality potatoes in terms of size and taste. It is important to regulate and track pH level to ensure the soil medium is kept at the optimum level for producing potatoes.

***Assumptions and definitions***

This is an aggregate score of the soil nutrients of all paddocks found on the property. This includes pH level, soil carbon and a range of plant nutrients.

A typical treatment to regulate acidic pH levels is to apply quantities of lime, as that ameliorates acidity and raises the pH level of the soil.

Table 1. Classification of pH levels.

| Classification | pH range |
|---|---|
| Ultra acidic | < 3.5 |
| Extremely acidic | 3.5–4.4 |
| Very strongly acidic | 4.5–5.0 |
| Strongly acidic | 5.1–5.5 |
| Moderately acidic | 5.6–6.0 |
| Slightly acidic | 6.1–6.5 |
| Neutral | 6.6–7.3 |
| Slightly alkaline | 7.4–7.8 |
| Moderately alkaline | 7.9–8.4 |
| Strongly alkaline | 8.5–9.0 |
| Very strongly alkaline | > 9.0 |

***Results and interpretation***

Within phase one, pH levels on Fairhalt were between 4.1-4.2, meaning the extremely acidic soil was not optimal for producing potatoes. The potatoes produced during this phase were missing nutrients provided from the soil during the growth stage. Fertiliser application during this time was minimal, as the landholder was focused on small scale production of potatoes.

During phase two, the landholder started applications of lime to regulate pH level. This resulted in minor improvements of pH. Synthetic fertiliser application increased during this phase.

At the beginning of phase three, the landholder started to focus on improving pH levels across the property as he gained knowledge relating to nutrient uptake from soil in plants. The pH level across the farm in 1999 was 4.8. The landholder increased the application of lime across the property. The landholder also ceased applying synthetic fertilisers on the property in 2002. The landholder started crop rotations including lucerne and mixed grass species after potatoes. Lucerne was utilised due to its deep roots which are known to repair soil and fix nitrogen.

During phase four, the landholder started applying compost at the rate of ten cubic metres per hectare per year. Lime is now applied every ten years at the rate of five tonnes per hectare. The current pH level is 5.5-5.6. This falls within the optimal range for producing potatoes. Post-potato planting and harvest ground cover levels are maintained across the property. The land holder currently runs 1800 fat lambs on the property which are rotated around paddocks when ground cover is reduced. The landholder also has the capacity to cut and bail fodder to feed the lambs during the non-growing seasons. Soil carbon levels on the property vary between soil types. The red basalt soil contains 5.02% total carbon and the grey loam soil contains 2.47% total carbon.

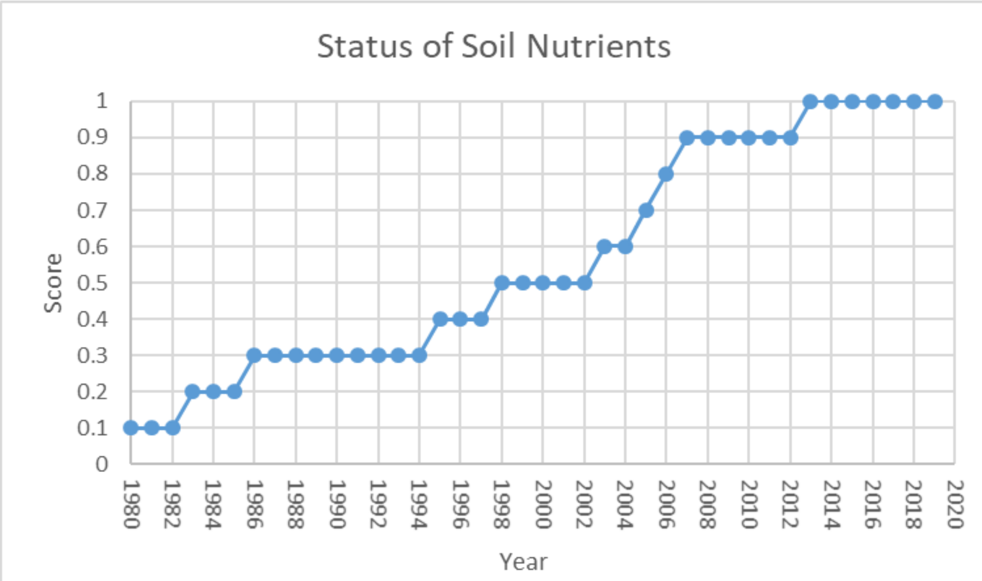



Figure 2. Landholder's graphical assessment of soil nutrients change over time.

## C. Status of soil hydrology

***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 ecological function.

***Assumptions and definitions***

This is an aggregate score of the soil surface water infiltration and water holding capacity across all paddocks found on the farm.

Plant available water is the difference between field capacity (the maximum amount of water the soil can hold) and the wilting point (where the plant can no longer extract water from the soil) measured over 100cm or maximum rooting depth.

***Results and interpretation***

Phase one as seen above in Criteria A and B.

Phase two as seen above in Criteria A and B.

Phase three as seen above in Criteria A and B.

Phase four as seen above in Criteria A and B.

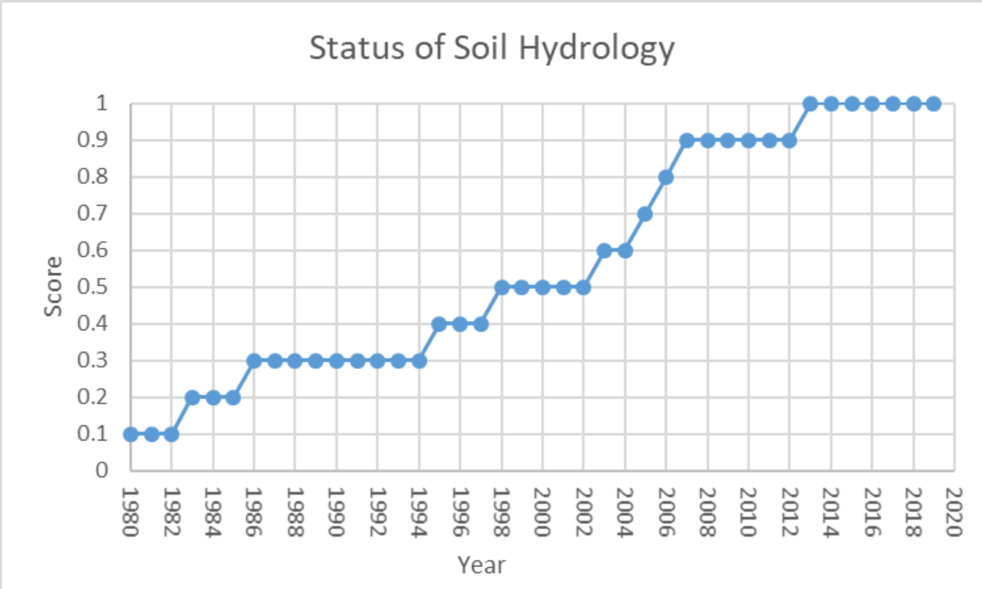



Figure 3. Landholder's graphical assessment of soil hydrology change over time.

## D. Status of 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, invertebrates including arthropods and worms also form a vital part of the soil food web.

***Assumptions and definitions***

This is an aggregate score of the soil surface condition properties of all paddocks found on the farm.

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 (detritivores), other residues have already been sequestered by soil microflora, which are in turn consumed by microfauna predators.

***Results and interpretation***

During phase one, the landholder applied minimal fertilisers and the property was in transition from an apple orchard to producing potatoes and fat lambs. Minimal pest spraying occurred during this phase. The landholder remembers worms being fairly present in the soil during this phase suggesting that the soil biology was relatively healthy.

Within phase two, the landholder started applying synthetic fertilisers to boost production of potatoes. Pest sprays were also adopted and used regularly to reduce pest damage on crops. The application of chemicals on the property damaged soil biology and worms were observed less often.

During phase three, the landholder recognised the damage synthetic fertilisers were causing the soil and the biological life within it. The landholder ceased the application of synthetic fertilisers and reduced the number of pest sprays each year.

Within phase four, the land holder started the application of compost and only sprays for pests when absolutely required, typically once per year. As a result of the land holder's management strategies during this phase, biological life within the soil has greatly improved. Worms are now commonly observed across the property at all times of the year.

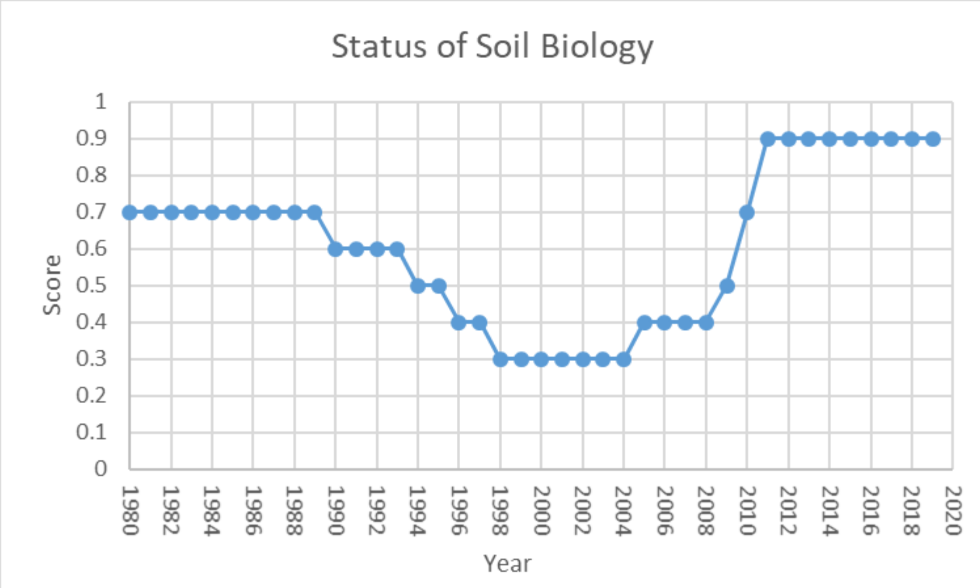



Figure 4. Landholder's graphical assessment of soil biology change over time.

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

***Why track changes and trends in soil physical properties?***

Declining soil surface condition involves the depletion of nutrients, soil organic matter and of key elements of the soil biology. Soil degradation is the result of high levels of bare ground, water erosion, wind erosion, chemical and physical deterioration. It is often associated with unsuitable land management regimes. Over time loss of soil physical properties will have consequences on production, as well as other ecological criteria and economic and social outcomes.

***Assumptions and definitions***

This is an aggregate score of the soil physical properties of all paddocks found in the farm. This includes effective rooting depth of the soil profile and bulk density of the soil through changes to soil structure or soil removal.

The rooting depth of plants was observed by the landholder over time when the soil was ploughed or dug with a shovel. Under more intensive management involving continuous grazing, grass tussocks were observed to be low in height and relatively shallow rooted.

Indicators of landscape function over time include soil surface rain-splash protection; cryptogam cover; soil surface erosion (type and severity); washed/deposited materials; physical features on the soil surface to retain resources during surface flows; and ground cover complexity, which influences permeability.

***Results and interpretation***

The landholder observed that the physical properties of the soil on Fairhalt did not change between phases 1-3. The landholder based this assumption of the quality of the soil structure.

Within phase four, the land holder observed that the application of compost increased the carbon content in the soil and improved water holding capacity.

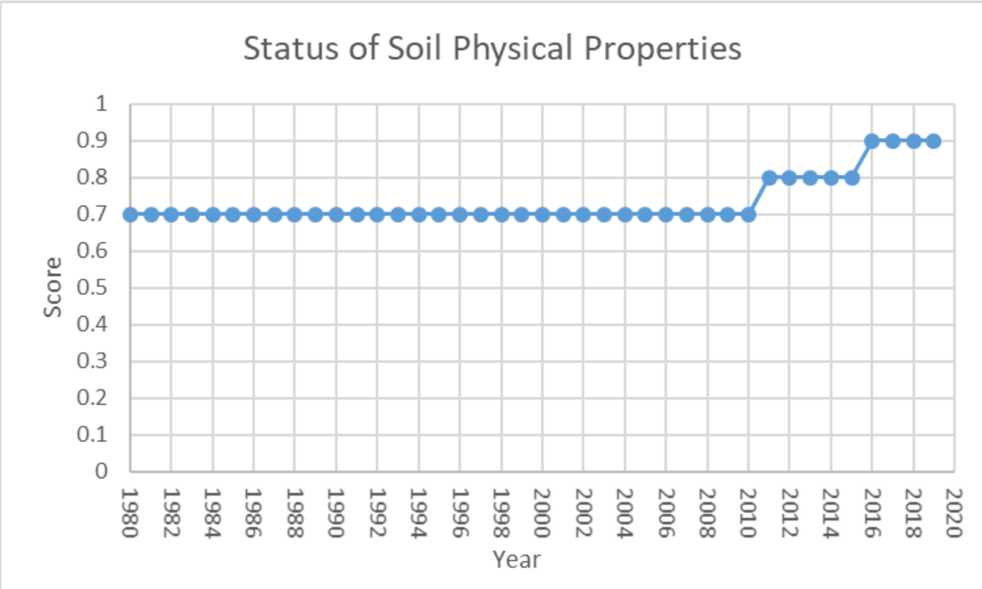



Figure 5. Landholder's graphical assessment of soil physical properties change over time.

## F. Status of plant reproductive potential – reproductive potential of pastures

***Why track changes and trends in reproductive potential of pastures?***

An understanding of successful reproduction, germination, establishment and development of plants is important in managing agro-ecological ecosystems. This understanding of successful plant reproduction is vital in the manipulation of planned production outcomes - e.g. grazing regimes can prevent seed-setting by undesirable or invasive plants and for increasing the longevity of perennial pastures before they need to be resown.

***Assumptions and definitions***

Reproductive potential is the relative capacity of a species to reproduce itself under optimum conditions including trees, shrubs and grasses. In the context of grazing land management regimes, this is an aggregate score assigned across all pastures found on the farm.

Where continuous grazing is the preferred grazing management regime or where total grazing regimes limit or prevent reproductive success of a species mix in pastures, this can lead to bare ground and to the dominance of some species which may have low feed value for grazing animals.

***Results and interpretation***

The reproductive potential of grasses on Fairhalt has not changed across the four phases. The landholder observed that this was due to the production systems implemented on the property.

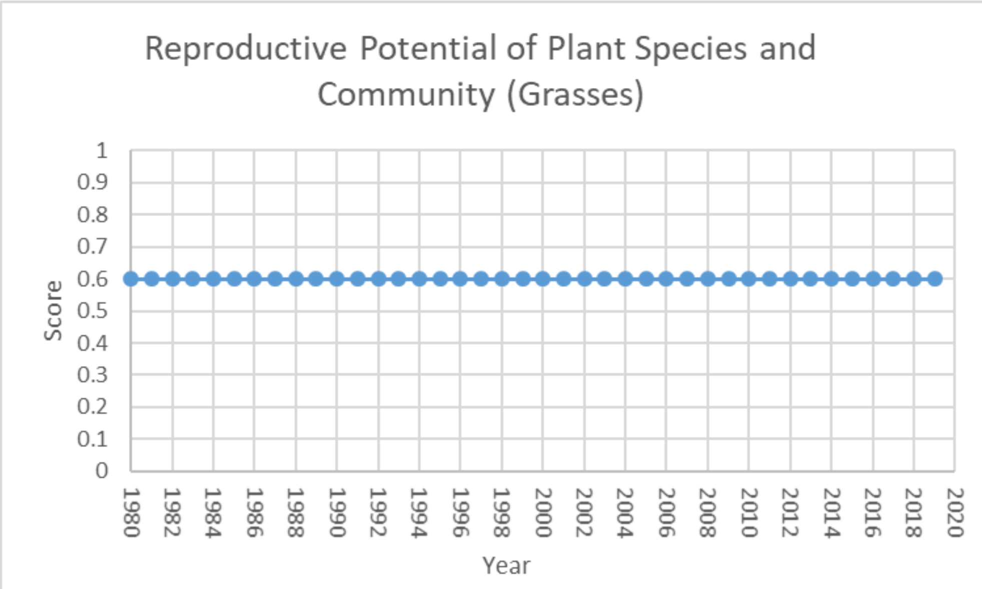



Figure 6. Landholder's graphical assessment of reproductive potential of grasses change over time.

## 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 and improved animal welfare. This enables 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.

***Results and interpretation***

Prior to phase one the landholder remembers planting trees on the property with his father and grandfather. During this phase, the landholder did not conduct any extra tree plantings.

Within phase two, the landholder conducted a few small scale tree plantings and fenced off the existing remnant patches of vegetation from livestock.

During phase three, the landholder conducted widespread plantings of habitat corridors linking patches of remnant vegetation across the property. Green Australia assisted the land holder with selection of species and plantings.

During phase four, the landholder continued further plantings of trees and conducted fencing work around existing woody areas to protect them from livestock grazing.

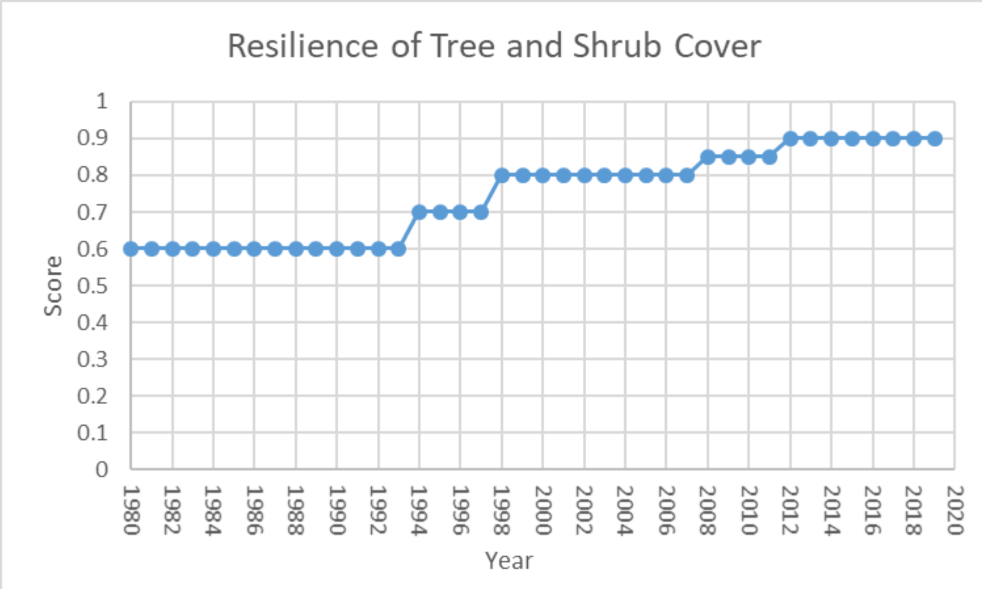



Figure 8. Landholder's graphical assessment of tree and shrub cover change over time.

## H. Status of grass and herb structure - Ground cover

***Why track changes and trends in ground cover?***

The quality of ground cover in summer 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. Good summer pastures also slow overland flows during the storm season and assist with infiltration of intense rainfall events, thus mitigating water erosion and replenishing soil moisture.

Winter grazing is an important management consideration in landscapes that are managed for livestock production. Conservative grazing land management is both ecologically and economically sensible.

***Definitions and assumptions***

This is an aggregate score across all pasture production paddocks on the farm.

The commonly espoused grazing land management regime in the district is that of continuous or set stocking throughout the year with two growing seasons and two feed gaps between the growing seasons. Typically, landholders cut and harvest pasture during the growing seasons to later feed out to livestock during the feed gap seasons.

In contrast to continuous or set stocking, holistic grazing of pastures involves short duration grazing followed by a relatively longer duration of pasture resting.

***Results and interpretation***

During phases one and two, the landholder utilised continuous set stocking. Pasture improvements were conducted slowly over the course of the two phases. The landholder did not plan ahead for feed gaps during this phase.

Within phase three, the landholder commenced mixed cropping. The mixed crops provided the land holder with the ability to plan ahead for future feed gaps. Maintaining ground cover levels across the pasture paddocks became a significant component of the landholder's management regimes.

Within phase four, the landholder adopted rotational grazing. The landholder assesses when ground cover levels reach a certain point before moving livestock to a different paddock. This ensures that ground cover levels are maintained. The landholder also purchased equipment which enables him to cut and bail fodder. The landholder now has the ability to plan ahead to control feed gaps on the property.

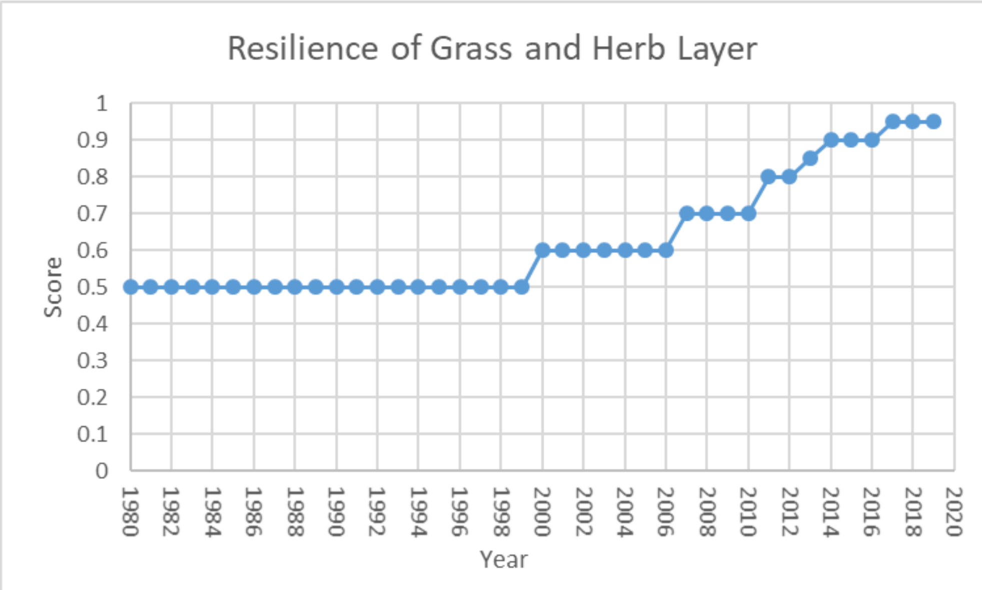



Figure 8. Landholder's graphical assessment of ground cover change over time.

## 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?***

Functional richness refers to the number 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. How an ecosystem is managed in an agricultural setting will determine its productivity and stability.

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 shrub species.

***Definitions and assumptions***

This is an aggregate score across all paddocks.

***Results and interpretation***

During phase one, tree and shrub species composition on the property did not alter.

Within phases 2-4, the landholder planted different species of trees and shrubs and constructed fences around the vegetated areas. Within the vegetated areas, natural regeneration of species also occurred due to the exclusion of livestock from the vegetated areas. The overall number of tree and shrub species on the property has increased due to the conservation management ideals and practices of the landholder.

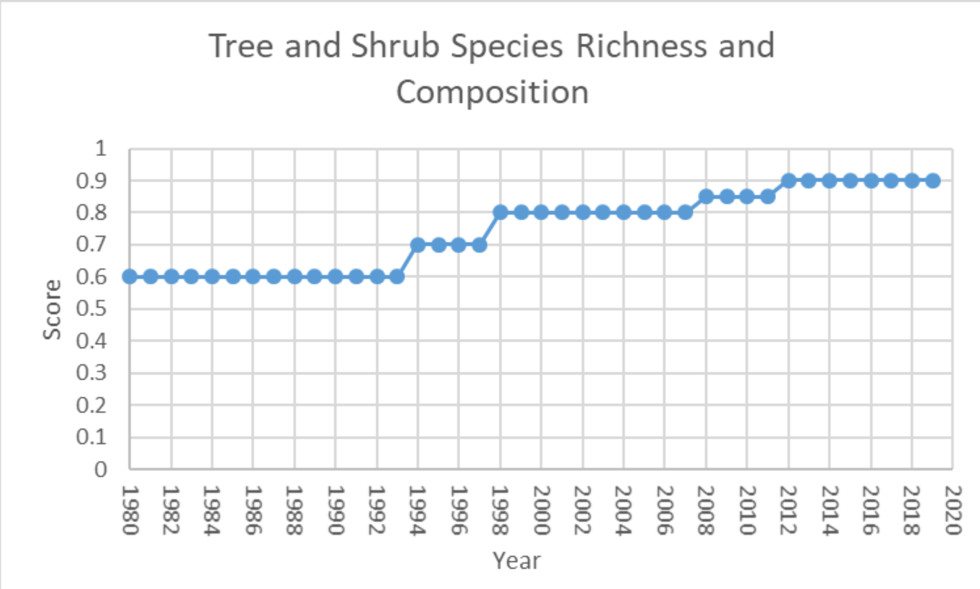



Figure 9. Landholder's graphical assessment of tree and shrub species richness and composition change over time.

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

***Why track changes and trends in grass species diversity?***

Functional richness refers to the number of species inhabiting a place and 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. How an ecosystem is managed in a production setting will determine its productivity and stability.

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 which perennial pasture species on which to base 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***

This is an aggregate score across all pasture species found on the farm.

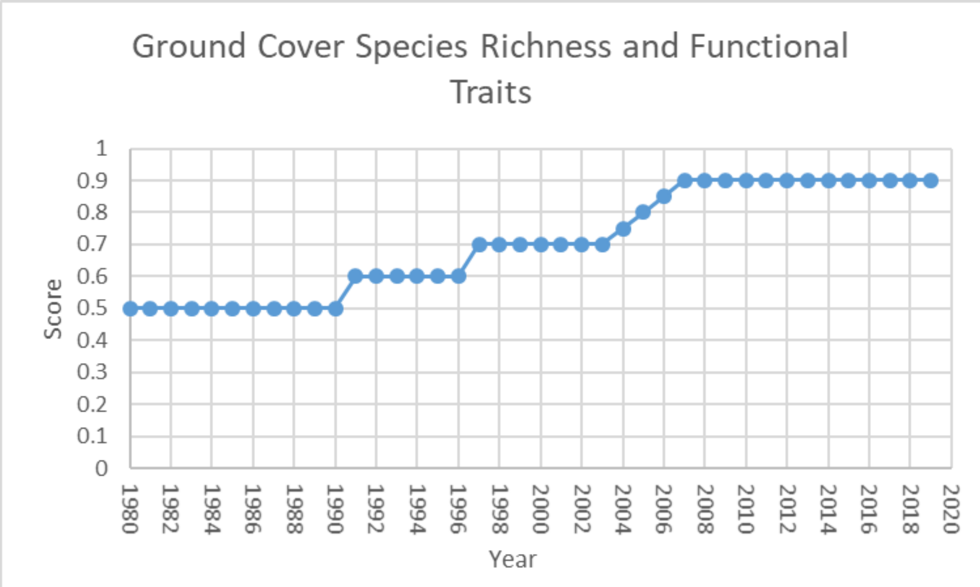
***Results and interpretation***

Phase one as seen above in Criteria H and I.

Phase two as seen above in Criteria H and I.

Phase three as seen above in Criteria H and I.

Phase four as seen above in Criteria H and I.

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## Attachment A

### Production systems

Information below describing land management regimes or production systems was compiled from a field visit and interview with Garry Kadwell, conducted December 2019.

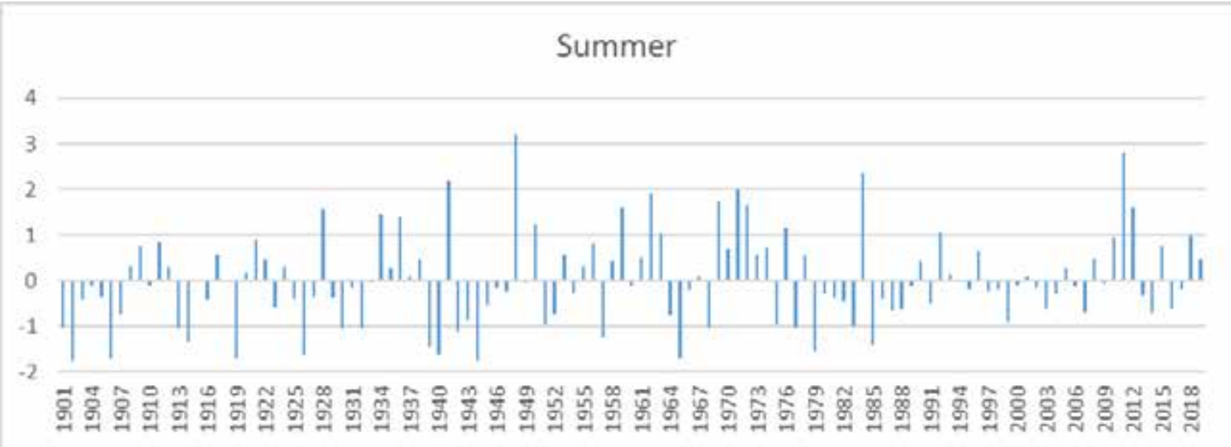
The following chronology was established as a partnership with the land manager for each of the phases 1-4:

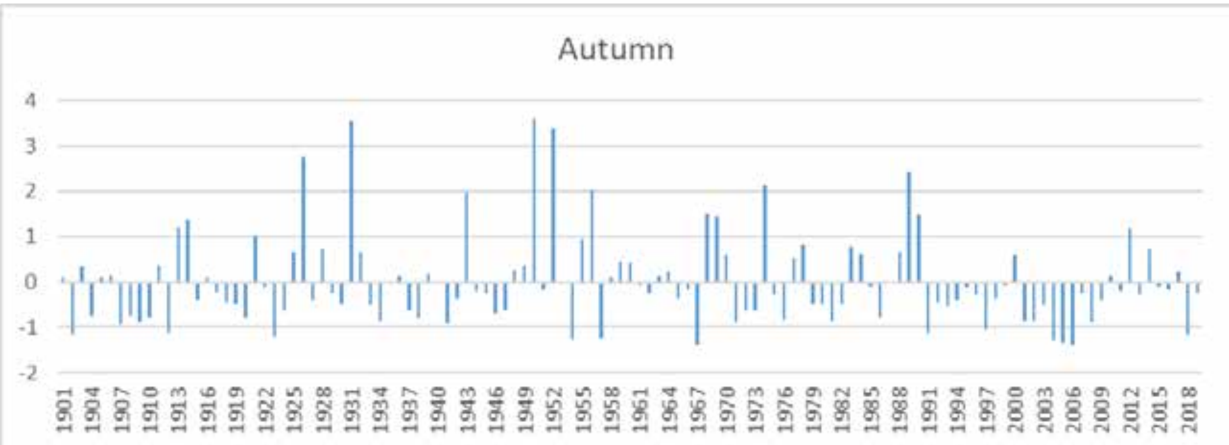
| Date | Action |
|---|---|
| 1901 | Kadwell family purchased Fairhalt |
| 1901-1980 | Fairhalt was utilized to grow apples |
| 1960's-70's | Garry Kadwell planted trees with his Grandfather and Father |
| 1980 | Garry Kadwell started managing Fairhalt |
| 1980 | Small scale trials of potato crops |
| 1980-85 | Switched main enterprise of Fairhalt to potatoes and fat lambs |
| 1985 | Constructed the first wetland on Fairhalt |
| 1985 | pH level of 4.1-4.2 |
| 1990's | Pasture improvements commenced |
| 1990's | Lime applications commenced |
| 1995 | Synthetic fertiliser applications commenced |
| 1990's | Commenced fencing off remnant vegetation |
| 1999 | pH level of 4.8 |
| 2001 | Commenced planting tree corridors across the property |
| 2001 | Commenced Lucerne cropping |
| 2001 | Fenced off the wetlands |
| 2002 | Ceased synthetic fertiliser application |
| 2002 | Constructed the second wetland on Fairhalt |

| | |
|---|---|
| 2003 | Mixed cropping of grass species commenced |
| 2011 | Commenced compost application |
| 2013 | One pass tilling machine adopted |
| 2015 | Started producing gourmet potatoes |
| 2015 | Purchased fodder harvesting and bailing equipment |
| 2010's | Continued to conduct conservation plantings |

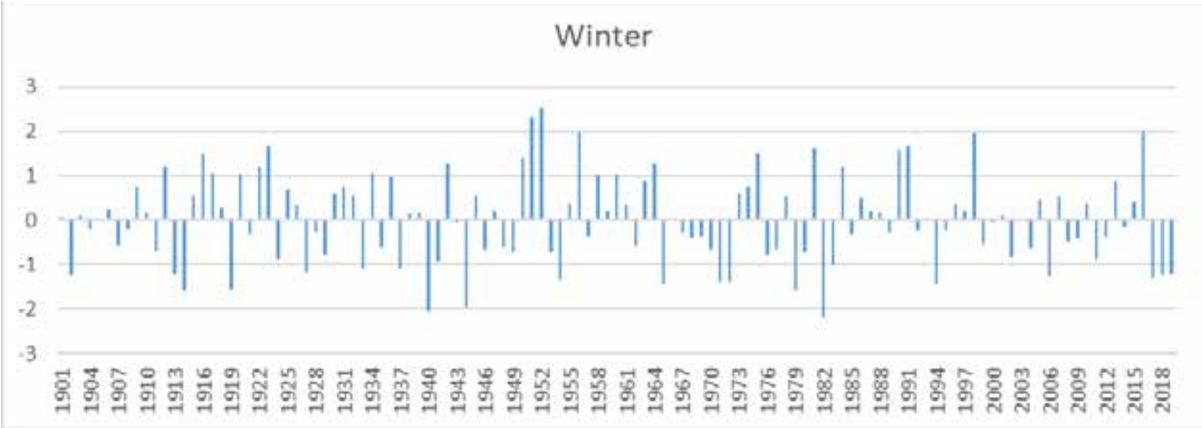
## Attachment B

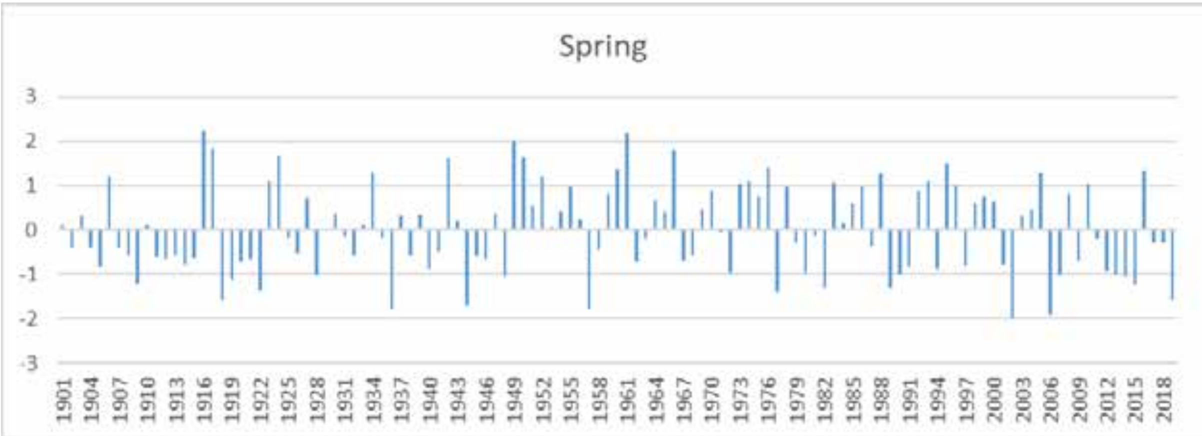
### Patterns of seasonal rainfall derive from modelled monthly rainfall data for Fairhalt[1] showing variants around the mean.




[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

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