SoilsForLife
AN OUTCOMES AUSTRALIA PROJECT

2018

BROWNLOW HILL CASE STUDY: SUMMARY ECOLOGICAL REPORT

Prepared by Richard Thackway

Key findings

This ecological assessment commences in 1973 when Edgar Downes returned to Brownlow Hill to run the property. Two examples of regenerative landscape management are found, corresponding to two very different land types; river flats and shale hills. Both land types have been managed using separate and distinct land management regimes since European settlement.

Brownlow Hill is located in the mid-reaches of the Nepean River, near Camden. Between 1880 and 1888 the Upper Nepean Scheme was commissioned and completed to provide water for Sydney's growing population. Construction of dams including Nepean, Cataract and Cordeaux Dams, effectively captured peak flows in the Nepean River and prevented flooding along the river flats of the Mount Hunter Rivulet at Brownlow Hill.

Detailed responses to 10 criteria are presented in the Supplementary Ecological report. These responses over time correspond to the following production system phases and land management regimes.

Phases	Irrigated stable waste on the lucerne river flats	BioBanking sites of Cumberland Plain Woodland on the shale hills
Phase 1 - Conventional non-regenerative management	1973-2005	1973-2010
Phase 2 – Small scale treatments mainly non- regenerative management	2006	2011
Phase 3 - Transitioning to broad scale - mainly regenerative management	2007	2016
Phase 4 - Broad scale regenerative management	2008-18	2017-18

This assessment reports on the responses of these two land types since 1973:

Date: 20180523

1. River flats:
The flats were first settled in the 1820 and were converted from native eucalypt woodland to intensively managed crops and pastures. In 2005, due to degraded and declining soil condition, horse stable waste was applied to paddocks. Some paddocks were irrigated with water from the Nepean River, while other paddocks were treated with horse stable waste but with no addition of irrigation water.

   The impetus for trialling and subsequent broadscale implementation of regenerative land management on the flats was an acknowledgement that the soil condition was degraded and declining. The landholders had access to innovative ‘holistic landscape management’ information and to a free source of horse stable waste.

2. Shale hills:
Since1820 the native eucalypt woodlands on the lower and mid-slopes have been converted to native pastures for cattle grazing. The native woodland on upper slopes and ridges were left timbered and used for cattle grazing. Commencing in 2011, several patches of modified Cumberland Plain grassy woodland on the upper slopes and ridges were transformed by removing and treating invasive woody weeds and removing set stocking with beef cattle. This management practice can be compared to the upper slopes and ridges where woody weeds have not been removed and grazing with beef cattle using set stocking has continued.

   Brownlow Hill contained reasonable patches of modified Grey Box - Forest Red Gum grassy woodland on shale on the southern Cumberland Plain. This vegetation type is a component of the Cumberland Plain Woodland EEC as listed on the NSW *Threatened Species Conservation Act* 1995 (TSC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) (ELA 2009). Given its status, patches of modified Cumberland Plain grassy woodland can attract a premium price under the NSW Government’s BioBanking scheme. Commencing in 2008, patches of modified Cumberland Plain grassy woodland were treated to remove woody weeds in exchange for payments for works specified in patch-based conservation management agreements. Under the management agreements, grazing with beef cattle is permitted where it protects, maintains and enhances the function, structure and composition of these nationally significant grassy woodlands.

Introduction

The Downes family arrived in the area in the 1850s and have been managing Brownlow Hill since 1858. They subsequently purchased the property in 1887. The river flats were primarily managed for diary pastures, while hilly shale country has been managed mainly for beef cattle.

Ecological and biodiversity outcomes are a response to implementing regenerative land management regimes. This report describes the ecological and biodiversity outcomes observed by Edgar Downs.

River flats - After decades of managing the river flat for irrigated lucerne production and observing that this intensive land management regime was turning the sandy loam soils to ‘terracotta clay”, Edgar ceased applying superphosphate and began applying chicken manure when preparing the soil to sow lucerne and crops. Due to rising costs of chicken manure and observing the soil condition was not improving, Edgar began an intensive program of soil rejuvenation on the river flats.

In 2005 the land manager commenced regular applications of horse waste from nearby horse stables. Some of the paddocks were irrigated and some were left as rainfed. Application of the stable waste, particularly under irrigation, changed the soil condition from ‘terra cotta clay’ in 2005, to ‘chocolate mud cake' between 2006 and 2018. In those paddocks where irrigation water was applied to the stable waste, this enabled consistently higher annual production of small bales of lucerne hay and to maintain a relatively longer-lived lucerne sward (~11 years), compared to the non-irrigated lucerne paddocks which were treated using the same stable waste but not irrigated. Adding stable waste to a 10 ha paddock to a depth of 20cm and mechanically incorporate that organic matter into the soil takes 4 months.

Shale hills – Decades of conservative rotational grazing of native pastures associated with the mid and upper slopes of the grassy woodlands of the Cumberland Plain Woodland had transformed the vegetation structure and composition at Brownlow Hill. By the 2000s, the woodland, found on the mid and upper slopes, had increased in vegetation cover and density and in places had thickened via regrowth to become a forest, along with the incursion of woody weeds including; boxthorn, African Olive, lantana, privet, melia (white cedar), wild acacia (honey locust/gleditsia, variants) and blackberry. This change in structure and composition meant these mid and upper slopes were of little productive value for beef cattle production.

In late 2009 Edgar began investigating the benefits of accessing public funds under the NSW BioBanking Scheme. That scheme would fund the land manager to remove woody weeds from these mid and upper slope regrowth forests, to change the cattle grazing regime and maintain the integrity of the enhanced woodland under an ongoing financial agreement. In 2011 Edgar signed the agreement for a total of 255 hectares to be managed under the BioBanking Scheme and started removing the beef cattle and treating and removing the invasive woody weeds.

Once the mid-storey of woody weeds was removed, this stimulated natural regeneration of the Cumberland Plain Woodland plant community. Low intensity and infrequent grazing with cattle is now used to maintain an open grassy ground layer structure and composition, along with manual spraying to control the incursion of woody weeds. Funds received by Edgar under the scheme have enabled him to convert more weedy Cumberland Plain Woodland on the mid and upper slopes to BioBanking sites.

Together with ongoing regenerative management of irrigated lucence on the river flats and BioBanking woodland sites on the mid and upper slopes, Edgar Downes has secured a sustainable mix of enterprise on the two main land types at Brownlow Hill.

Assessment of ecological and biodiversity outcomes

Managing soil-landscape types to minimise effects of extreme climatic events

The most likely severe climate event to impact the Brownlow Hills Estate is drought. Access to irrigation water from the Nepean River has obviously improved the resilience of the river flats to prolonged drought compared to the shale hills (Figure 1). Severe floods are not an issue for the river flats because there is no infrastructure built on the floodplain and the last major flood was in 1996 and only caused minimal damage. Because of upstream impoundments, flood waters are slow moving; a narrow gorge downstream causes the flood waters to back up and move slowly. The irrigated stable waste on the lucerne growing river flats achieved the desired full reference state in 2007 and this level has continued to be maintained under the current management regime.

Wildfires are not a problem on the river flats due to the high soil moisture content associated with the irrigated pastures, nor on the shale hills, as the surrounding interface with neighbouring land is either hobby farms (~12 ha blocks) which have predominantly been cleared of native vegetation and converted to open pasture, or mown urban landscapes including the University of Sydney, Camden – May and Mt Hunter Campus.

Scores assigned to the shale hills (Figure 1) show that, compared with the lucerne growing river flats, the mid and upper slopes of the hills are more vulnerable to severe drought. Conservative grazing management, using rotational grazing and resting paddocks following grazing, is used to limit the likely negative impacts of drought associated with bare ground and loss of ground cover. It is expected that the drought resilience of these BioBanking sites will continue to increase as structure and composition of the ground layer develops over time.

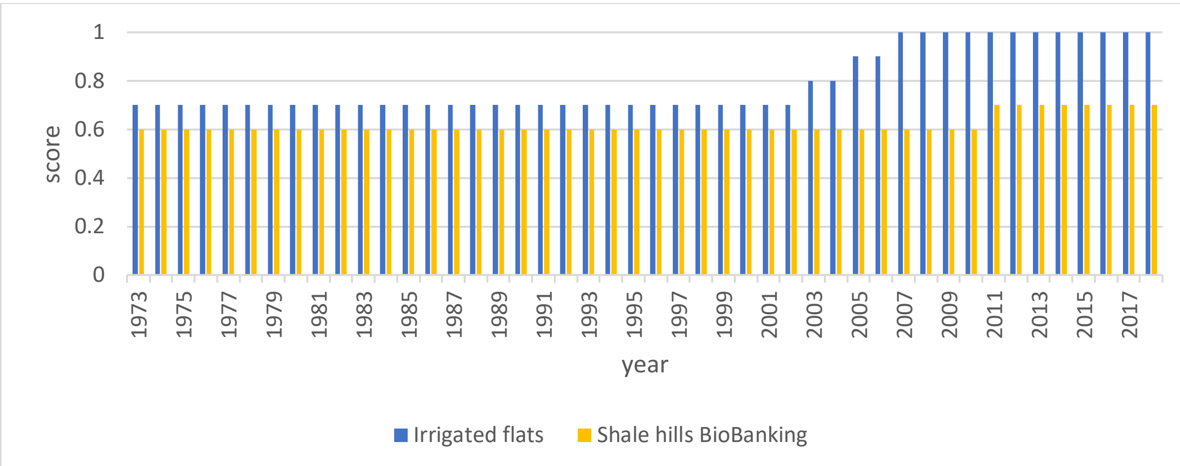

Figure 1. Resilience of the soil-landscape unit/s to severe climate events (drought) for the irrigated stable waste on the lucerne growing river flats and the BioBanking sites on the shale hills.

Managing soils to prevent erosion, restore eroded areas and to maintain ecological health, productive capacity and water quality

Conventional management of irrigated lucerne paddocks on the river flats ceased in 2005 (Fig. 2a). In 2006 experiments with applying chicken manure led to improvements in soil nutrients and soil biology. However obvious gains in soil hydrology and soil physical properties came in 2008 and afterwards, with the addition of horse stable waste on the irrigated lucerne river flats. This addition of organic matter led to obvious changes in the soil condition. Edgar noted that the soil condition changed from ‘terra cotta clay’ in 2005, to ‘chocolate mud cake’ between 2010-18 (Fig 2a).

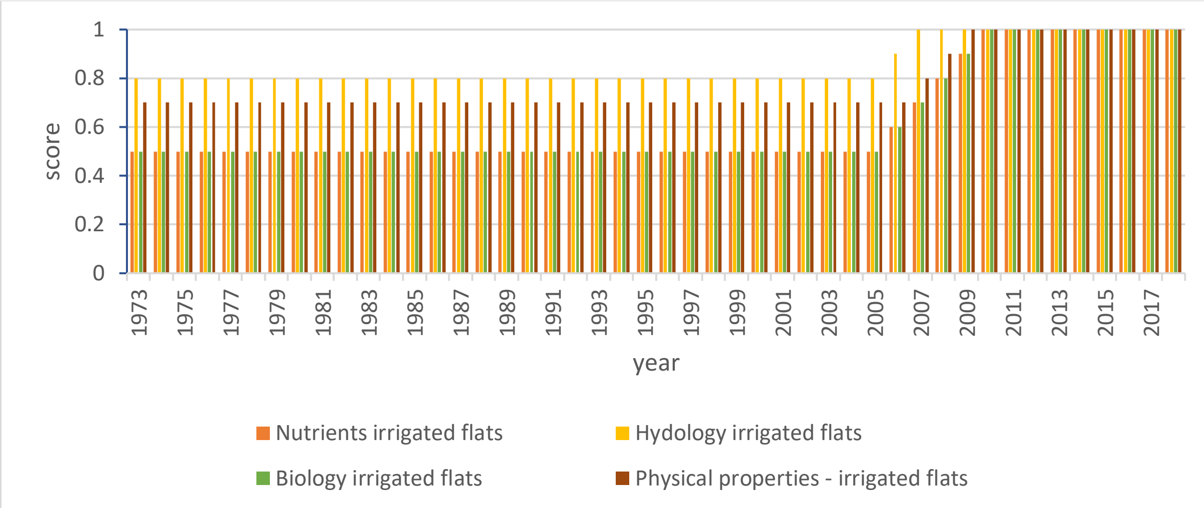

Figure 2a. Status of soil indicators over time at Brownlow Hill with irrigated stable waste on the lucerne growing river flats.

By the 2000s the mid and upper slope sites of the Cumberland Plain Woodlands had increased in vegetation cover and density, mainly due to incursions of woody weeds including; boxthorn, African Olive, lantana, privet, melia (white cedar), wild acacia (honey locust/gleditsia, variants) and blackberry. In 2010 these mid and upper slopes were of little productive value for beef cattle production or for biodiversity conservation.

In 2011 Edgar began treating and removing the invasive woody weeds and changed the cattle grazing regime from rotational to planned grazing (Fig 2b.). These interventions stimulated natural regeneration of the Cumberland Plain Woodlands indigenous plant community, resulting in improvements in soil nutrients, soil hydrology and soil physical properties, due mainly to the development of native ground layer of perennial grasses.

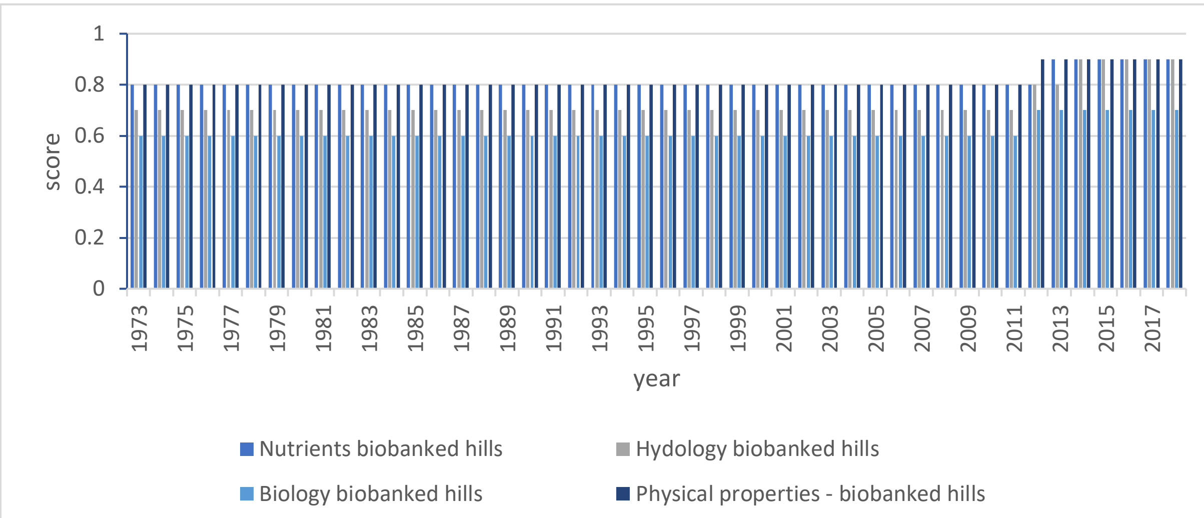

Figure 2b. Status of soil indicators over time at Brownlow Hill, BioBanking sites Cumberland Plain Woodland on shale hills.

Managing native groundcover for production and to maintain ecological health

On the river flat, this criterion has not changed even through there has been a change in the soil condition. A high level of ground cover is characteristic of irrigated lucerne. Species richness in lucerne is maintained at a low level with the aid of mowing and slashing undesirable species of weeds (Fig 3a).

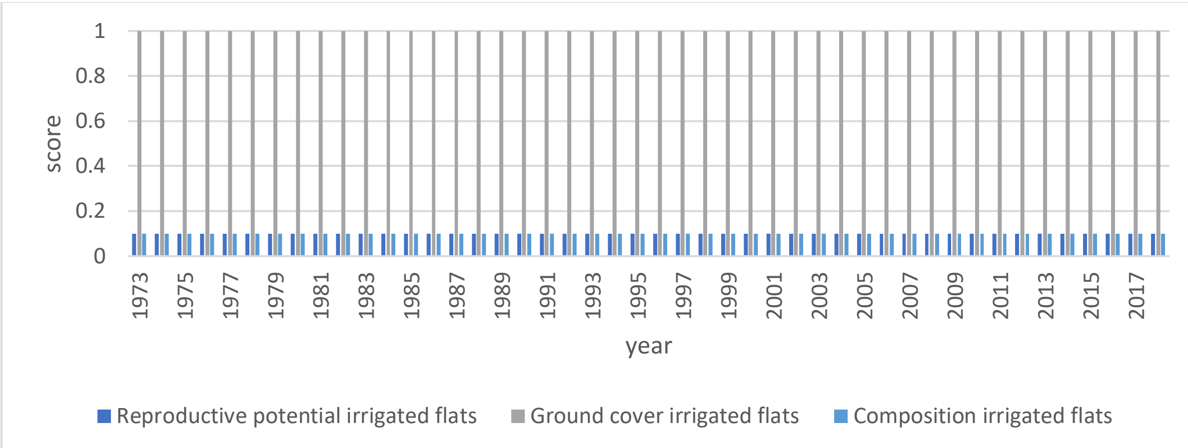

Figure 3a. Status of ground cover indicators over time at Brownlow Hill; irrigated stable waste on the lucerne growing river flats.

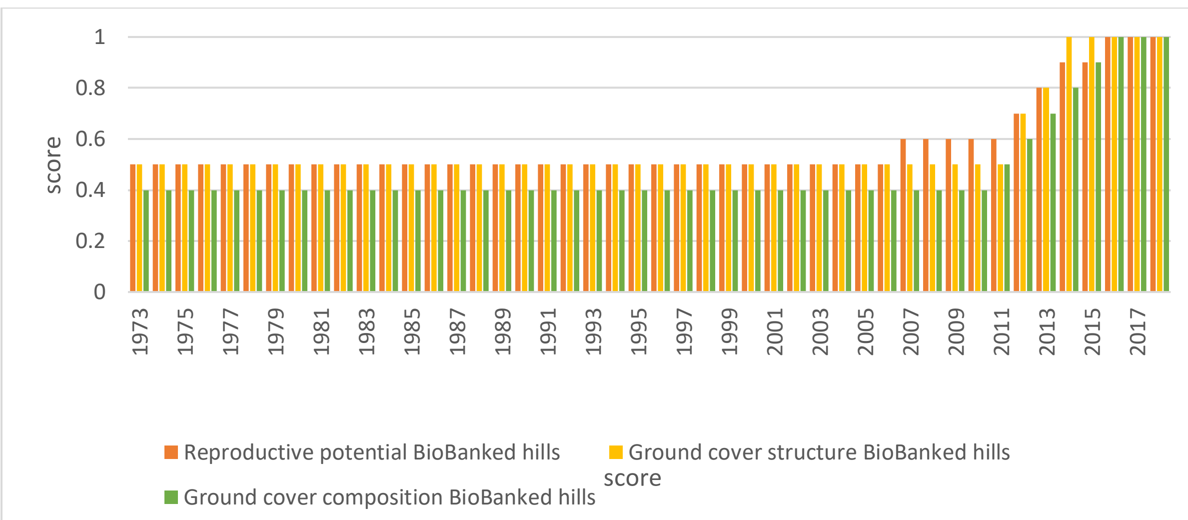

Figure 3a. Status of ground cover indicators over time at Brownlow Hill, BioBanking sites Cumberland Plain Woodland on shale hills.

Removal of woody weeds in the BioBanking sites has enabled natural regeneration of the indigenous ground layer including the reproductive potential of the ground layer, as well as the structure and composition. Perennial native grass tussocks have established in the ground layer, providing microhabitat for germination and establishment of indigenous herbs.

Managing trees and shrubs for production and to maintain ecological health of the property and watershed

Trees and shrubs along the river flats were cleared and converted to crops and pastures in the mid 1800s. The tree and shrub structure and composition on the river flats was not assessed under this criterion. Trees and shrubs are restricted to fence lines and riparian strips adjacent to intensively managed paddocks used for cropping and improved pasture. The land manager noted that these narrow strips carried a high cover of woody weed species.

Figure 4 shows a gradual increase in the composition and functional diversity of trees and shrubs in response to the removal of woody weeds between 1995-2011 in the regrowth woodland and forest found on the mid and upper slopes of the shale hills. In 2010, the implementation of the BioBanking scheme and changing the grazing regime with beef cattle to infrequent seasonal grazing, controlled woody regrowth and maintain an open grassy ground layer. This changed grazing regime has improved the relative structural and compositional integrity of the native trees and shrubs found in the BioBanking sites.

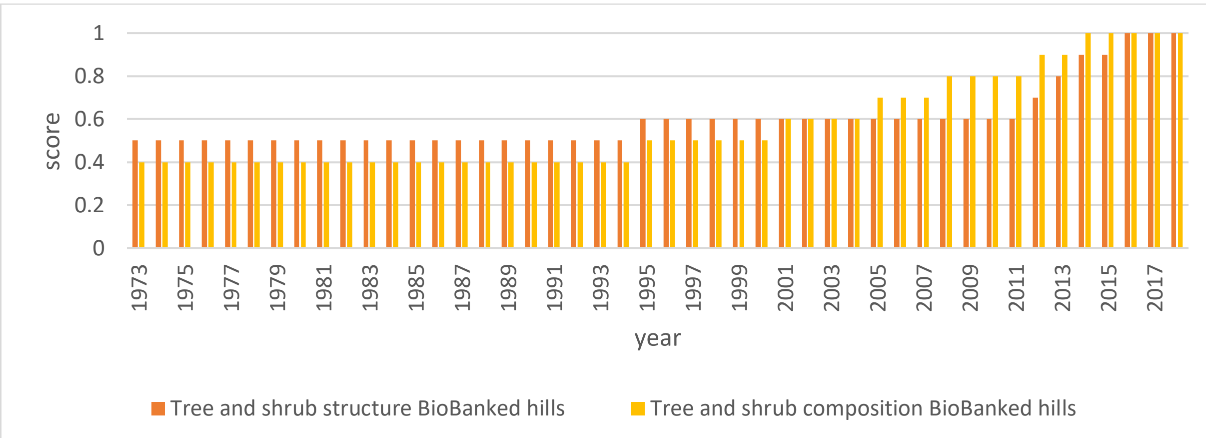

Figure 4. Status of tree and shrub indicators overtime at Brownlow Hill, BioBanking sites Cumberland Plain Woodland on shale hills.

Managing natural watercourses, riparian areas, natural lakes and wetlands, to protect ecosystems that are sensitive to agricultural land management.

All irrigation water is pumped under licence from the Nepean River. While riparian strips are present on the river flats, the land manager noted that these narrow strips carried a high cover of woody weed species. Farm water for cattle in the shale hill country is via rainfed creeks and farm dams. The creeks and farm dams are not fenced to exclude stock access.

2018

BROWNLOW HILL ESTATE CASE STUDY: SUPPLEMENTARY ECOLOGICAL REPORT

Prepared by Richard Thackway

Key findings

This ecological assessment commences in 1973 when Edgar Downes returned to Brownlow Hill Estate to run the property. Two examples of regenerative landscape management are found on Brownlow Hill, corresponding to two very different land types; river flats and shale hills. Both land types have been managed using separate and distinct land management regimes since European settlement.

The area of Brownlow Hill Estate is 720 hectares. Note that an additional 617 hectares is also managed by the Estate (Attachment A).

Two land types are present: river flats and associated tributaries of the Nepean River; mapped as Alluvial Woodland (NPWS 2002) and rolling hills mapped as shale hills Woodland (ELA 2009). The areas of both land types are river flats (~240 ha) and the shale hills (~480 ha).

The main enterprises on each land type are: river flats - Dairying and crops; shale hills: lower slopes beef cattle grazing and mid and upper slopes BioBanking sites.

Detailed responses to the 10 criteria are presented in this Supplementary Ecological report. These responses over time correspond to the following production system phases and land management regimes.

This assessment presents two examples of regenerative landscape management at the Brownlow Hills Estate:

1. River flats:
   The flats were first settled in the 1820 and were converted from native eucalypt woodland to intensively managed crops and pastures. In 2005, due to degraded and declining soil condition, horse stable waste was applied to paddocks. Some paddocks were irrigated with water from the Nepean River, while other paddocks were treated with horse stable waste but with no addition of irrigation water.

   The impetus for trialling and subsequent broadscale implementation of regenerative land management on the flats was an acknowledgement that the soil condition was degraded and declining. The landholders had access to innovative 'holistic landscape management' information and to a free source of horse stable waste.

   In 2006 the land manager commenced regular applications of stable waste from nearby horse stables. Some of the paddocks were irrigated and some were left as rainfed. Application of the stable waste 'changed the soil condition from 'terra cotta clay' in 2005, to 'chocolate mud cake' between 2008 and 2018'. Those paddocks where irrigation water is applied, the stable waste has enabled consistently higher annual production of small bales of lucerne hay to be marketed to hobby farmers with horses and to maintain a relatively long-lived lucerne sward (~11 years). Noting that it takes 4 months to treat 10 ha patch to a depth of 20cm with stable waste and to incorporate organic matter into the soil.

2. Shale hills:
   Since 1820, the native eucalypt woodlands on the lower and mid-slopes were converted to native pastures for cattle grazing. The native woodland on upper slopes and ridges were left timbered and used for cattle grazing. Commencing in 2011, patches of modified Cumberland Plain grassy woodland were treated to remove woody weeds in exchange for biodiversity payments for works specified in patch-based conservation management agreements. Under the management agreements, grazing with beef cattle is permitted where it protects, maintains and enhances the function, structure and composition of these nationally significant grassy woodlands. Patches of woodland on the mid and upper slopes have been transformed by removing and treating invasive woody weeds and establishing planned grazing with beef cattle.

   Brownlow Hill contained reasonable patches of modified Grey Box - Forest Red Gum grassy woodland on shale hills on the southern Cumberland Plain. This vegetation type is a component of the Cumberland Plain Woodland EEC as listed on the NSW *Threatened Species Conservation Act* 1995 (TSC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) (ELA 2009). Given its status, patches of modified Cumberland Plain grassy woodland can attract a premium price under the NSW Government's BioBanking scheme.

   Decades of time-based rotational grazing, a relatively low intensity form of grazing management regime on the valley floors and lower slopes have largely kept these areas free from the incursion of woody weeds. Since 1973, the regrowth woodland and forest, found on the mid and upper slopes have increased in vegetation cover with the incursion of woody weeds including; boxthorn, African Olive, lantana, privet, melia (white cedar), wild acacia (honey locust/gleditsia, variants) and blackberry. Access to the NSW BioBanking scheme has enabled the woody weeds to be removed from these mid and upper slope regrowth forests and led to a change in the cattle grazing regime.

   Once these changes in the land management regime were established, this enabled the natural regeneration of the shale hill's indigenous plant community's structure and composition. Low intensity and infrequent grazing with cattle are now used in association with the BioBanking scheme to maintain an open grassy ground cover structure and composition along with manual spraying to control the incursion of woody weeds. A total of 255 hectares has been set aside and is managed for BioBanking. This assessment has shown that despite the impacts of these drivers, modified areas of Cumberland Plain Woodland continue to maintain a high level of regenerative potential.

A chronology of production systems was used to generate phases of land management regimes (Attachment A) and corresponding environmental responses (Attachment B). Four phases can be discerned at Brownlow Hill on the two land types:

Phases	Irrigated stable waste on the lucerne river flats	BioBanking sites of Cumberland Plain Woodland on the shale hills
Phase 1 - Conventional non-regenerative management	1973-2005	1973-2010
Phase 2 – Small scale treatments mainly non- regenerative management	2006	2011
Phase 3 - Transitioning to broad scale - mainly regenerative management	2007	2016
Phase 4 - Broad scale regenerative management	2008-18	2017-18

The response criteria are presented in Figures 2-11 and discussed below.

Attachment A presents a detailed description of the Production Systems that have been used over time to transform the original plant communities on the two land types.

Attachment B shows when these responses occurred following the implementation of regenerative landscape management regimes in the two land types over the period 1973-2018.

Attachment C presents the patterns of seasonal rainfall between 1901 and 2017.

Assessment of ecological and biodiversity outcomes

This report assesses ecological and biodiversity outcomes are a response to implementing regenerative landscape management regimes. This report describes the ecological and biodiversity outcomes to 10 ecological criteria observed by Edgar Downs.

Prior to the Soils For Life field visit to the property in April 2018, the land manager was asked to document the production systems (i.e. landscape management regimes) in each land type over time for Brownlow Hill. All information relevant to production systems was sorted by the years when the observation was made and was compiled into a chronology (Attachment A). This included a collation of all available published and unpublished relevant data and information about how the enterprises on Brownlow Hill Estate were managed over time. Information included in this assessment was provided by the land manager and from other publicly available sources. These have included paddock-based photo-points, fertiliser history, paddock-based management histories, rainfall, fauna records (e.g. birds and names) and aerial photos and satellite imagery. In addition, where quantitative soil and water tests are available, these were also compiled.

Apart from soil tests, no new site-based data was collected in order to write this report.

During the on-site visit in April 2018, Edgar Downes completed the ecological assessment using the standardised 10 ecological criteria. This ecological assessment starts in 1973 when Edgar Downes returned from school to take over managing the Brownlow Hill Estate. It is noted that in recent years Edgar's son, Henry, has taken over much of the management of the production systems on the Estate.

Quantitative data had been collected over time by the land manager, and these were used to populate the respective response criteria for this Ecological Assessment. Because of a paucity of quantitative data, expert elicitation was used to assess the ecological effects of implementing production systems on criteria associated with ecosystem function, structure and composition over time. This was done by asking the land manager to self-assess their goals or lifestyle intents, and how these affected their landscape management regimes (i.e. production systems) and the subsequent effects these might have had on the ecological response criteria. Change was assessed graphically relative to the baseline which was defined by the land manager as conventional non-regenerative land management.

This ecological assessment acknowledges that climate variability and drought play major roles in interacting with the land manager's goals and ideals which are expressed in the implementation of landscape management regimes (i.e. production systems). In turn, the effects of climate variability, drought and fire can have major effects on production, ecological, economic and social criteria. A summary of the seasonal rainfall from 1900-2017 for Brownlow Hill Estate is presented in Attachment C. These seasonal patterns are expected to correspond well with the Bureau of Meteorology's monthly rainfall data which have been collected at the Brownlow Hill Estate since 1882 (Attachment A).

Responses of ecological criteria to land management regimes

In the following section, each of the 10 ecological response criteria are shown graphically over four phases.

A. Resilience of the landscape to severe climate events

Why track changes and trends in resilience of the landscape to severe climate events?

Resilience to major severe climate events includes the following factors in the agro-climatic region (wildfire, drought, cyclone, dust storm and flood). Land managed for different enterprises using different land management regimes at the time of a severe climate event may be vulnerable to being degraded.

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 including social, ecological, economic and production. If the structure, composition and function of the landscape is adversely affected, this may require the land to be rested, regenerated or restored.

Assumptions and definitions

This is an aggregate score across all paddocks found in the two land types found on Brownlow Hill Estate. The most likely regular severe climate events are likely to be flood and drought.

Results and Interpretation Fig 2

The most likely severe climate event to impact the Brownlow Hills Estate is drought. Access to irrigation water from the Nepean River has obviously improved the resilience of the river flats to prolonged drought (Figure 2). Severe floods are not an issue for the river flats because there is no infrastructure built on the floodplain. The last flood in 1996 caused minimal damage as the flood waters were slow moving because there is a narrow gorge downstream, hence the water backs up.

Wildfires are not a problem on the river flats due to the high soil moisture content associated with the irrigated pastures, nor on the shale hills, as the surrounding interface with neighbouring land is either hobby farms (~12 ha blocks) which have predominantly been cleared of native vegetation and converted to open pasture, or mown urban landscapes including the University of Sydney, Camden – May and Mt Hunter Campus.

Scores assigned to the shale hills (Figure 1) show that, compared with the lucerne growing river flats, the mid and upper slopes of the hills are more vulnerable to severe drought. Conservative grazing management, using rotational grazing and resting paddocks following grazing, is used to limit the likely negative impacts of drought associated with bare ground and loss of ground cover.

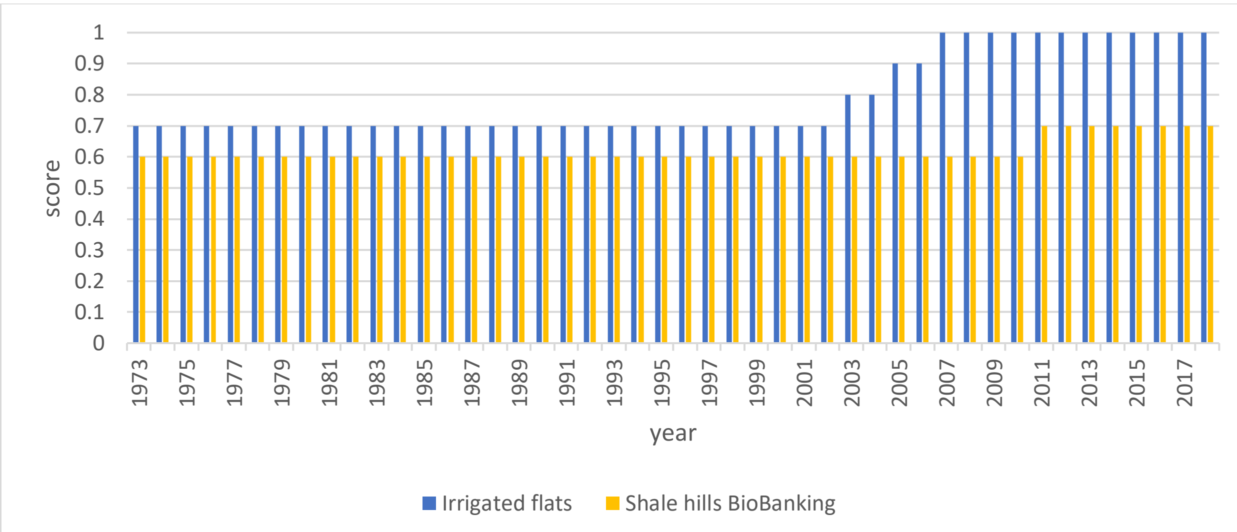

Figure 2. Resilience of the soil-landscape unit/s to severe climate events

B. Status of soil nutrients

Why track changes and trends in soil nutrients?

Differing land management regimes can affect the amount of soil nutrients that are available to maintain healthy soil condition. Various measures of soil nutrients are important to consider over time: nutrients that are held in the soil profile and available to plants for growth and development; nutrients that are leached from the soil via natural rainfall and/or through irrigation; those that are washed off the soil through unimpeded overland surface flows and those that are added to the soil as inorganic solid pellets and liquids, as well as organic solids and liquids. An obvious measure of soil function is the level of soil organic carbon. Soil carbon releases nutrients for plant growth, promotes the structure, biological and physical health of soil, and is a buffer against harmful substances.

Where the soil is regularly and intensively managed to produce pastures and crops, to avoid nutrient deficiencies in the soil, the land manager will replace those nutrients that are removed in biomass e.g. lucence and pastures grazed by grazing animals harvesting and replacement of soil nutrients via animal faeces and urine, trampling and through spelling the land.

Assumptions and definitions

This is an aggregate score of the soil nutrients of all paddocks found in Brownlow Hill Estate. This includes soil carbon and natural levels of major and minor elements and organic matter. A good layer of surface organic matter or humus is indicative of higher levels of soil carbon.

Results and Interpretation Fig 3

Superphosphate has never been added to either the river flats or the shale hills.

On the river flats from 1983, chicken manure was applied when preparing the soil to sow lucerne and crops. Higher levels of soil nutrients were required for winter oats for fodder and summer corn or millet – double cropping. Regular applications of chicken manure were observed to improve the soil condition, however acquiring it as a widely applied source of soil nutrients became unprofitable. Improved pastures are used to feed lactating dairy cows and have a mix of pasture species including; rye, clover, lucerne, cocksfoot.

In 2005, as a measure to improve declining soil nutrients and physical properties on the river flats, the land manager commenced regular applications of horse waste from nearby stables. Some of the paddocks were irrigated and some were left as rainfed. Application of the stable waste changed the soil condition from 'terra cotta clay' in 2005, to 'chocolate mud cake' between 2006 and 2018'. Those paddocks where irrigation water is applied with the stable waste has enabled consistently high annual production of small bales of lucerne hay to be marketed to hobby farmers with horses, and to maintain a relatively long-lived lucerne sward (up to 11 years). It takes 4 months to treat a 10 hectare patch to a depth of 20cm with stable waste, and to incorporate that organic matter into the soil.

It is noted that the river flats have a much higher score for soil nutrients than the shale hills (Figure 3). The irrigated river flats, on which lucerne and improved pastures are grown, have higher levels of soil nutrients than non-irrigated because of higher biological functioning.

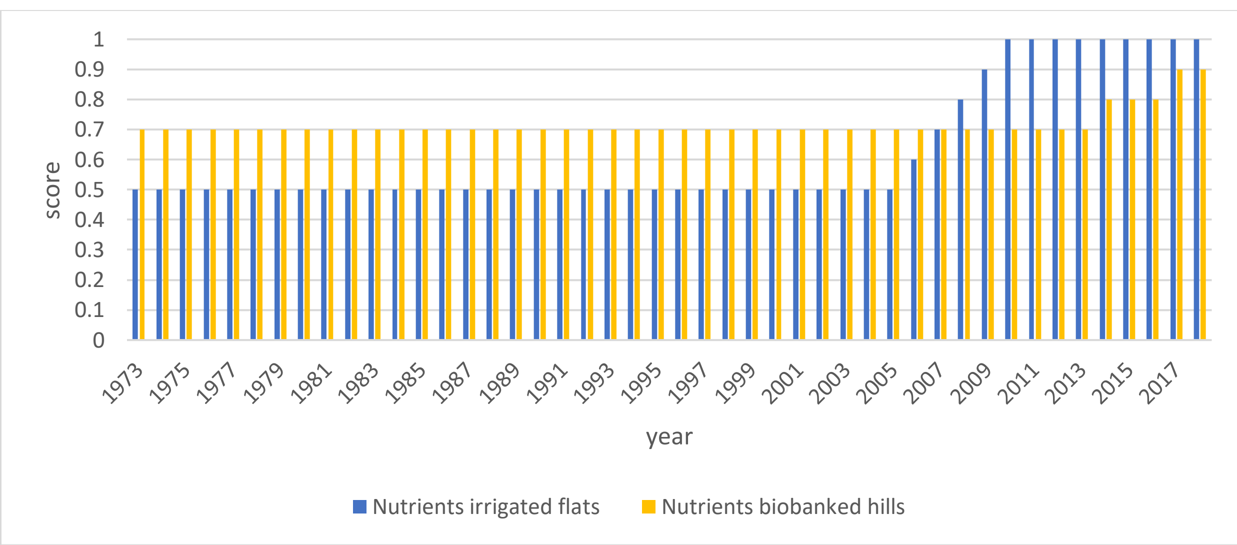

Figure 3. Status of soil nutrients.

Scores assigned to the shale hills (Figure 3) show that, compared with the river flats, these hills have lower and uniform levels of soil nutrients. The grazing management regime on the lower slopes and valley floors of the hills is time-based rotational grazing and resting paddocks following grazing. This is designed to spread cattle faeces and urine onto the pasture and trample the grasses to promote surface organic matter. Long rest periods are used to promote the release of nutrients from deeper in the soil profile. This management regime eliminates the likelihood of bare ground and loss of ground cover.

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. When water enters a soil profile, some will be stored within the rooting zone for plant use, some will evaporate and some will drain away from the plant root zone. In agro-ecological settings, increasing water infiltration, permeability and water-holding capacity will usually act as a stimulus to ecological function.

Assumptions and definitions

Water availability 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 100 cm or maximum rooting depth.

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

Soil water infiltration is observed as rainwater and surface flows resulting from intense rainfall events to be absorbed into the soil rather than wash off a given area.. These observations applied to cropped areas as well as pastures.

Results and Interpretation Fig 4

The land management regimes used on the river flats scores, assigned to the status of soil hydrology scores, are much higher on the river flats than the shale hills (Figure 4). The sandy loam soils found on the river flats, combined with the maintenance of higher ground cover (crops and pastures) and flat terrain are naturally better at soil water infiltration than the shale hills. The addition of waste organic matter from horse stables has further increased the degree of soil water infiltration and water holding capacity.

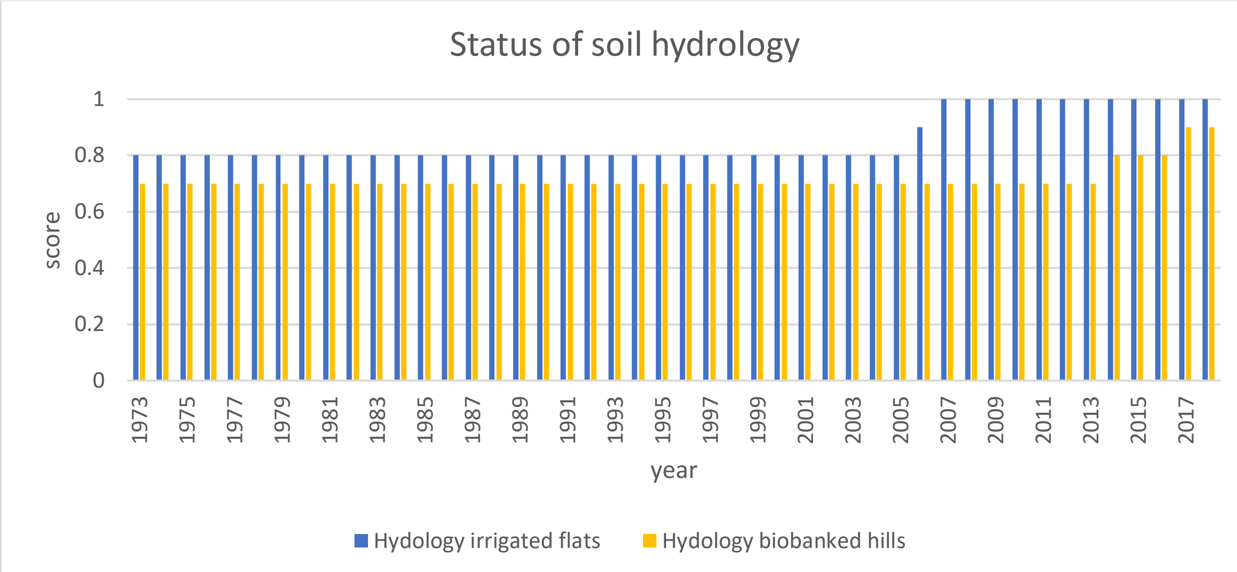

Figure 4. Status of soil hydrology.

The soil water infiltration and water holding capacity of the soils associated with the shale hills has been maintained over the longer term by the grazing management regime on the lower slopes and valley floors of the hills area. This involves time-based rotational grazing and resting paddocks following grazing. This is designed to spread cattle faeces and urine onto the pasture and trample the grasses to promote incorporation of organic matter in the soil surface. This management regime largely eliminates the presence of extensive areas of bare ground and loss of ground cover, and the loss of soil and surface organic matter associated with overland flows during intense storm events. These are soil hydrology problems associated with continuous or set-stocking.

D. Status of soil biology

Why track changes and trends in soil biological activity?

Soil biology affect plant (and animal) production by modifying the soil's 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 much bacteria can indicate an unhealthy and unproductive soil. Soil fungal activity contributes to: 1) natural processes (litter transformation, micro-food web participation and soil engineering), 2) ameliorate the effect of land management regimes on these processes, and 3) the combined effect of the first two on plant health and productivity (i.e. crops and pastures).

Assumptions and definitions

This is an aggregate score of the soil fungal activity of all paddocks found in Brownlow Hill Estate. This includes fungi physically observed in the soil and associated with the roots of plants. Soil fungal activity was observed using a shovel to dig and expose soil, enabling observations of fungal hyphae.

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. The process of converting plant and animal residues into humus is facilitated by enzymes, either contained within the soil organisms or secreted by either living or dead soil organisms into the soil matrix. Each of these processes makes soil nutrients available for plant production (i.e. crops and pastures).

Results and Interpretation Fig 5

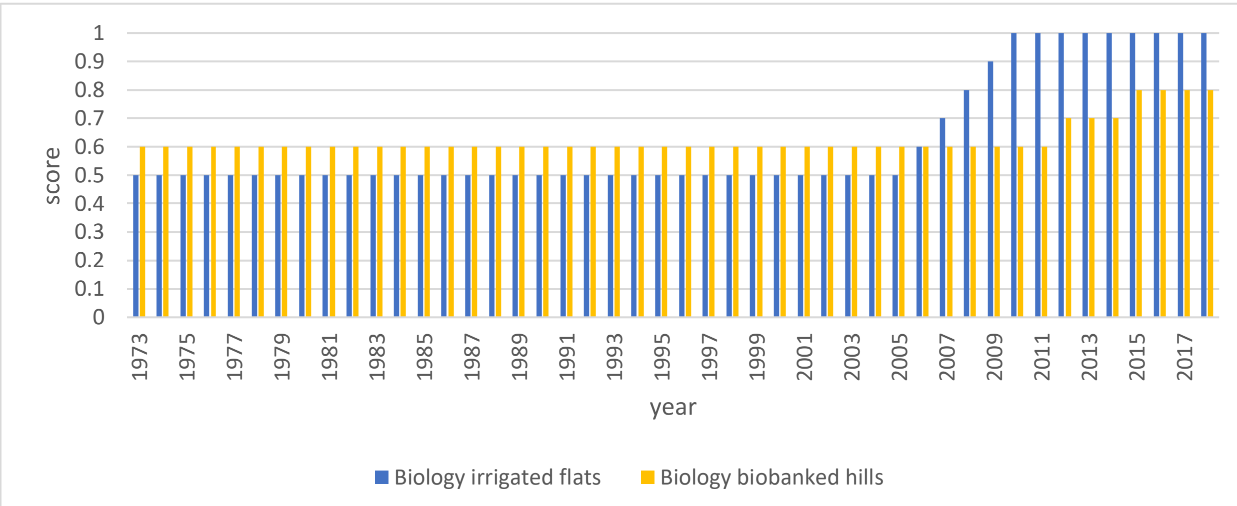

Figure 5. Status of soil biology.

There is an obvious difference between scores assigned to represent the status of soil biology on the river flats compared with the shale hills. From 2006 to 2018, the regular applications of stable waste from nearby horse stables on the river flats with some paddocks irrigated and others left as rainfed, the application of the stable waste ‘changed the soil condition from terra cotta in 2005, to chocolate cake’.

The non-irrigated flats have reached a stable regenerative state but not as high as the irrigated flats. Non-irrigation does not stimulate the presence of fungal decomposition enabling the rapid breakdown of stable waste. Slower rates of decomposition of the organic stable waste occur under rainfed conditions.

The status of soil biology associated with the shale hills has been consistently maintained over the longer term by the grazing management regime used to manage the lower slopes and valley floors. This involves time-based rotational grazing and resting paddocks following grazing. This is designed to spread cattle faeces and urine onto the pasture and trample the grasses to promote incorporation of organic matter in the soil surface. This management regime largely eliminates the presence of extensive areas of bare ground and loss of ground cover, and the loss of soil and surface organic matter associated with overland flows during intense storm events. These are soil hydrology problems associated with continuous or set-stocking.

Soil biology in the mid-upper slopes has improved because of the removal of woody weeds and the promotion of native shrubs and ground covers (herbs and grasses). It is unlikely that the soil biology has changed between the BioBanking and Non-BioBanking sites.

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

Why track changes and trends in soil physical properties?

Declining, or the loss of, soil surface condition involves the depletion of nutrients and soil organic matter. Soil degradation can be observed as water erosion, wind erosion, and chemical and physical deterioration. Soil degradation may be due to unsuitable land management regimes and/or inappropriate land management practices.

Soil provides all necessary things for the plant growth, except light and solar radiation, hence that is why soil is called the natural medium of plant growth. Where land management regimes are too intense e.g. too much cultivation, this can lead to poor soil condition. This will have consequences on production, economic and other ecological criteria and, in turn, have social consequences.

Assumptions and definitions

This criterion relates to landscape function and focuses primarily on the cover of plants and organic matter associated with the soil surface. It includes the A0 as well as plant material (living and dead) found on the surface. Condition was defined as the extent and size of vegetation "patches", where resources accumulate, and bare soil areas ("inter-patches"), where resources may be mobilised and lost. By observing changes and trends in the cover of plants and organic matter over time, this enabled the land manager to assess their success in implementing regenerative landscape management principles and practices.

Soil degradation can be defined as a process by which one or more of the potential ecological functions of the soil are harmed. This process lowers the current and/or future capacity of the soil to produce goods and services.

This is an aggregate score of the soil physical properties of all paddocks found in Brownlow Hill Estate. 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, which included cropping and continuous grazing, grass tussocks were observed to be low in height and relatively shallow rooted.

Results and Interpretation Fig 6

In 2005 the land manager commenced regular applications of organic waste from nearby horse stables. Some of the paddocks were irrigated and some were left as rainfed. Application of the stable waste 'changed the soil condition from terra cotta in 2005, to chocolate cake between 2006 and 2018'. Those paddocks where irrigation water is applied the stable waste has enabled consistently high annual production of small bales of lucerne hay to be marketed to hobby farmers with horses and to maintain a relatively long-lived lucerne sward (~11 years). It takes 4 months to treat a 10 hectare patch to a depth of 20cm with stable waste and to incorporate organic matter into the soil.

Figure 6. Status of soil physical properties.

In those paddocks on the river flats where stable waste was applied, but not irrigated, there was a slower response in soil physical properties i.e. effective rooting depth of the soil profile and bulk density than the irrigated paddocks.

Scores for soil physical properties in the shale hills have remained unchanged between 1973 and 2011 because there had been no change in the grazing land management regime. A slight change in effective rooting depth of the soil profile and bulk density is expected in the BioBanking areas because of the removal of regular grazing by beef cattle. However, no change was scored for these areas of woodland and forest regrowth where there has been no change in grazing regime since 1973.

F. Status of plant reproductive potential

Why track changes and trends in reproductive potential of pastures?

An understanding of successful reproduction, germination, establishment and development of plant and animal life cycles are important in managing agri-ecological ecosystems. An understanding of successful plant and animal development and reproduction is vital for developing planned production outcomes. Land management regimes can hinder or even prevent life cycles e.g. using planned grazing to interrupt the life cycle and eliminate undesirable pest plants.

Assumptions and definitions

Reproductive potential is the relative capacity of a species to reproduce itself under optimum conditions. In the context of land management regimes, this is an aggregate score assigned across all pastures found on Brownlow Hill Estate.

Too much cultivation and relatively high stocking rates managed under continuous grazing, was leading to poor soil structure and farming was reducing the amount of organic carbon to the advantage of exotic annual herbs and grasses.

With the advent of smaller paddocks, after they were grazed and the stock excluded, it was realised that plants that reproduced and set seed and were allowed to germinate, develop, establish and develop, resulting in an obvious improvement in the resilience of pastures to grazing.

Results and Interpretation Fig 7

Lower scores for reproductive potential were assigned to the river flats, denoting that crops and improved pastures, including lucerne, need to be repeatedly replanted. This is in contrast to native vegetation in the shale hills, which, when managed to promote regeneration, i.e. setting of seed, germination, establishment, development and maturity, is assigned a higher score for reproductive potential.

Between 1973 and 2018, time-based rotational grazing, a relatively low intensity form of grazing management regime on the valley floors and lower slopes have largely kept these areas free from the incursion of woody weeds.

Since 1973, the shale hill regrowth woodland and forest, found on the mid and upper slopes have increased in vegetation cover with the incursion of woody weeds including; boxthorn, African Olive, lantana, privet, melia (white cedar), wild acacia (honey locust/gleditsia, variants) and blackberry. The scores in the shale hills woodland and forest regrowth stands remained unchanged between 1973 and 2006 because there had been no removal of woody weeds or any change in grazing management regimes.

Commencing in 2007, higher scores for reproductive potential in the shale hills depict removal of woody weeds in the woodland and forest regrowth. From 2010, the establishment of BioBanking sites at Brownlow Hill also led to the removal of the former time-based rotational cattle grazing regime. Areas of regrowth woodland and forest not currently the subject of BioBanking are being prepared for that purpose. However these regrowth stands of woodland and forest continue to be managed using the long standing time-based rotational cattle grazing regime, hence their lower scores over the period 2015-2018.

Changes in the scores for reproductive potential in the BioBanking sites reflects the removal of woody weeds from these mid and upper slope regrowth forests and a change in the cattle grazing management regime. These changes in land management regimes have enabled regeneration of the indigenous plant community's structure and composition.

Funding conditions under the BioBanking scheme require judicious and low intensity and infrequent grazing with cattle combined with manual spraying to control the incursion of woody weeds. These practices are being used to maintain an open grassy ground cover structure and composition along a maturing regrowth stand of native indigenous trees. Shrubs, while present, are no longer a dominant feature of these BioBanking sites. 255 hectares are managed as BioBanking sites.

This assessment has shown that the Cumberland Plain vegetation types (Attachment A) continued to maintain a high level of reproductive potential.

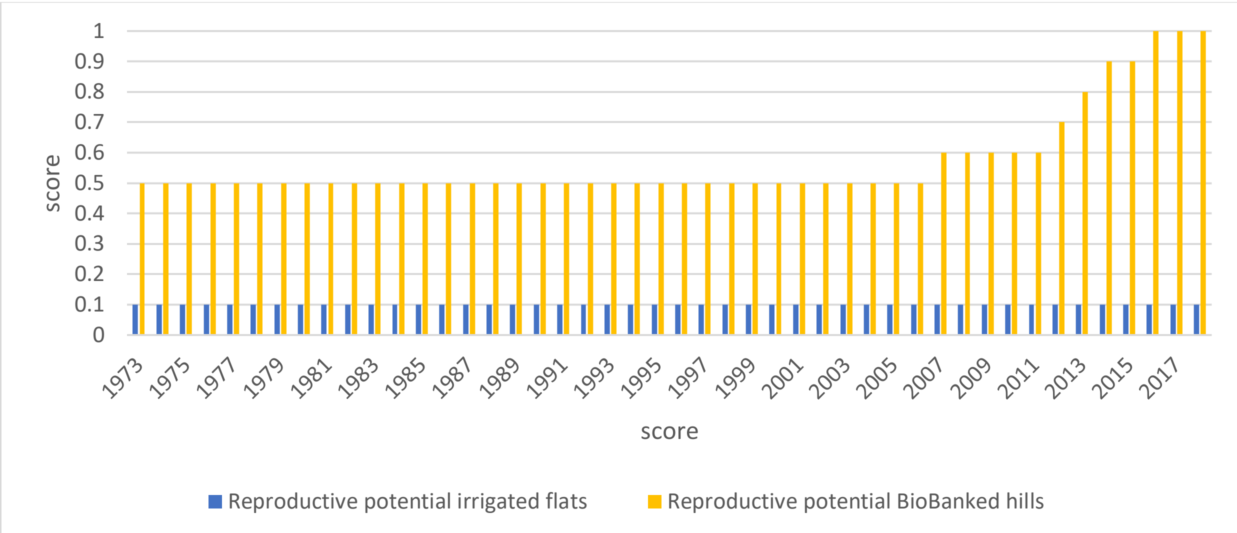

Figure 7. Reproductive potential of the plants.

G. Status of tree and shrub structure

Why track changes and trends in tree and shrub structure?

The extent and structure of trees and shrubs in working agricultural landscapes provides important ecosystem benefits including: mitigation of soil erosion, shelter for pastures and crops, improved animal welfare; 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

By enhancing the tree and shrub cover of the regrowth stands of woodland and forest on Brownlow Hill Estate, the landholder can be expected to benefit in terms of improvements in stock health, pasture productivity, improved habitat, shelter, breeding sites and food for native wildlife. This would also lead to improved visual amenity of the formerly heavily weed covered gently rolling shale hills.

Results and Interpretation Fig 8

Figure 8 did not score the status of tree and shrub structure on the river flats because tree and shrub cover there is restricted to fence lines surrounding the intensively managed paddocks used for cropping and improved pasture. While riparian strips are present on the river flats these were not assessed under this criterion. The land manager did note that such riparian areas carried a high cover of woody weed species.

Figure 8 shows the response of the regrowth woodland and forest found on the mid and upper slopes of the shale hills to the removal woody weeds between 1995-2011. With the implementation of BioBanking in 2010, on some of these regrowth sites, which also included changing of the grazing regime with beef cattle, the regenerative response of the BioBanking sites shows a difference to the Non- BioBanking sites that are yet to be managed under the same management requirements as the BioBanking sites. This involves removal of regular rotational grazing with cattle and implementing infrequent seasonal grazing with cattle to maintain an open grassy ground cover structure and composition.

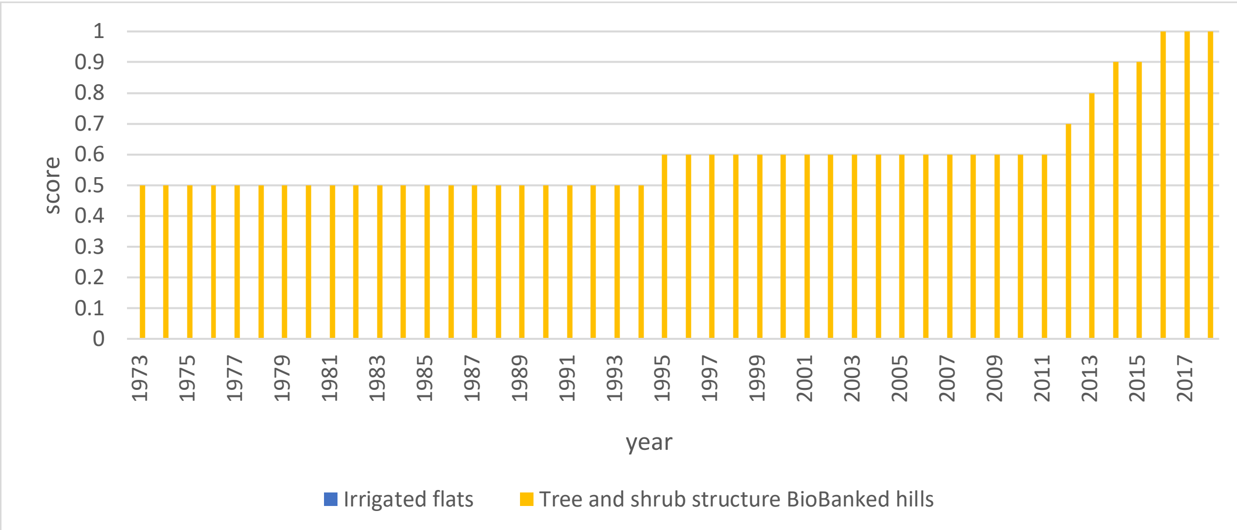

Figure 8. Status of tree and shrub cover and structure.

H. Status of ground cover grass and forb structure and biomass

Why track changes and trends in ground layer vegetation cover and biomass?

Year-round grazing is an important management consideration in landscapes that are managed for livestock production. With proper pasture management including protein and mineral supplementation, livestock can be successfully grazed on dormant winter forage without the need to invest in high inputs of harvested feeds (grains and hays).

Saving forage on pastures for use during winter months can provide a valuable source of feed. Additionally, if precipitation is adequate, and the temperatures suitable for pasture growth, this provides opportunities to use regrowth on pastures that were grazed earlier in a grazing cycle.

The extent of ground cover is important for forage. Ground cover in summer also provides essential protection to keep the soil cool against direct searing summer heat by slowing the degree of evaporation, by protecting bare soil against rain splash, and from wind erosion. The presence of ground cover in summer also slows the rate of overland flow of storms and assists with infiltration of intense rainfall events, thus mitigating water erosion.

Native plants are adapted to local environmental conditions. They require far less water, saving time, money, and perhaps the most valuable natural resource, water. In addition to providing vital habitat for birds, many other species of wildlife benefit as well.

Many indigenous native grasses and forbs are adapted to climate variability and droughts and have proven to be a valuable production system for grazing regimes associated with holistic management.

Definitions and Assumptions

Ground cover is an aggregate score across the total area of Brownlow Hill Estate and is estimated in summer (Dec-Feb). The areal extent of ground cover is estimated and is a relative area defined as a per cent. These relative estimates are scaled up to the paddock level and then scaled up to the whole farm.

Ground cover is defined as green and brown (dead) grasses and herbs as well as other organic matter including litter from grasses, herbs and fine and course woody debris.

An area of native grass is defined as native grass, where the number of native species found on a site is 50% or greater than the total number of all species found in the patch.

The commonly espoused practice of continuous or set stocking throughout the year means that the height or the biomass of pastures in winter is generally low to very low. During this critical period land managers have a feed deficit which generally requires supplementary feeding with pasture hays that were harvested as bales during the summer.

Results and Interpretation Fig 9

Figure 9 shows that ground cover on the river flats is maintained close to 100% year round except where the crop or pasture is being replaced. This has been the case since 1973.

In the case of the regrowth woodland and forest found on the mid and upper slopes of the shale hills, Figure 9 shows the response of the ground cover and biomass to removal of woody weeds between 1995-2011. With the implementation of BioBanking in 2010 on some of these regrowth sites, which also included changing the grazing regime with beef cattle, the BioBanking sites shows a different response to the Non- BioBanking sites that are yet to be managed under the same land management requirements as the BioBanking sites. This involves removal of regular rotational grazing with cattle and implementing infrequent seasonal grazing with cattle to maintain an open grassy ground cover structure and composition.

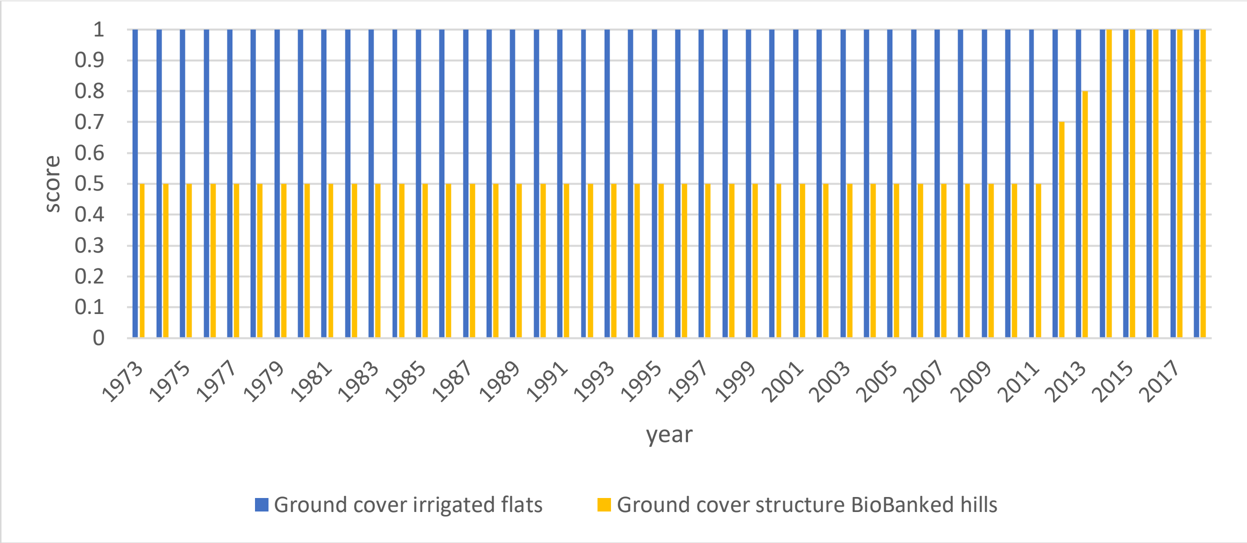

Figure 9. Status of grass and herb cover and structure and biomass.

I. Status of tree and shrub composition and functional diversity

Why track changes and trends in soil surface condition?

Functional diversity refers to the number of species inhabiting a place, their roles in that place and how evenly the species are distributed in an area. A decrease in functional diversity and evenness is usually associated with decreases in an ecosystem's productivity and stability. How an ecosystem is managed in a production setting will determine its productivity and stability.

Assumptions and definitions

This is an aggregate score across all tree and shrub species found on Brownlow Hill Estate.

Results and Interpretation Fig 10

Figure 10 shows no scores for the status of tree and shrub composition and functional diversity on the river flats. This because the tree and shrub composition and functional diversity on the flats is restricted to fence lines surrounding the intensively managed paddocks used for cropping and improved pasture. While riparian strips are present, these were not assessed under this criterion. The land manager noted that such riparian areas carried a high cover of woody weed species.

Figure 10 shows a gradual increase in the composition and functional diversity of trees and shrubs in response to the removal of woody weeds between 1995-2011 in the regrowth woodland and forest found on the mid and upper slopes of the shale hills.

With the implementation of BioBanking in 2010 on some of these regrowth sites, which also included changing of the grazing regime with beef cattle, the BioBanking sites shows a different response to the Non- BioBanking sites that are yet to be managed under the same land management requirements as the BioBanking sites. This involves removal of regular rotational grazing with cattle and implementing infrequent seasonal grazing with cattle to maintain an open grassy ground cover structure and composition.

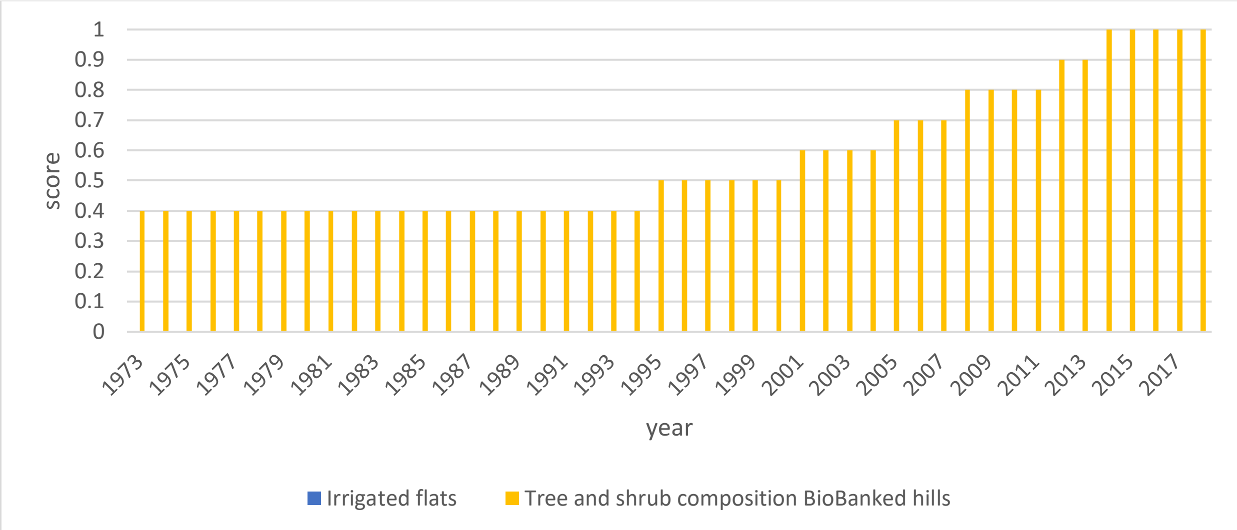

Figure 10. Status of tree and shrub composition and functional diversity.

J. Status of the ground layer composition and functional diversity

Why track changes and trends in perenniality of pastures?

In many farming and grazing settings, perennial pastures (plants that live for more than two years) such as lucerne, warm season grasses and fodder shrubs 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 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. Legume species in particular are valued for their high-quality feeding value and ability to improve soil fertility through the natural fixation of nitrogen.

Assumptions and definitions

This is an aggregate score across all pasture species found on Brownlow Hill Estate.

Results and Interpretation Fig 11

Figure 11 scores the status of the ground layer composition and functional diversity on the river flats as low, because this land type is intensively managed for cropping and improved pasture. The river flats are managed to minimise the species composition and functional diversity of the ground cover i.e. crops and improved pastures. While riparian strips are present on the River flats, these linear and irregular strips were not assessed under this criterion. The land manager did however note that such riparian areas carry a higher cover of ground layer weed species.

Figure 11 shows a rapid increase in the composition and functional diversity of grasses and forbs in the ground layer in response to the removal of woody weeds between 1995-2010 in the regrowth woodland and forest found on the mid and upper slopes of the shale hills. This increase may also be due in part to changes in the grazing regime in the BioBanking sites compared with the non- BioBanking sites. This involves removal of regular rotational grazing with cattle and implementing infrequent seasonal grazing with cattle to maintain an open grassy ground cover structure and composition.

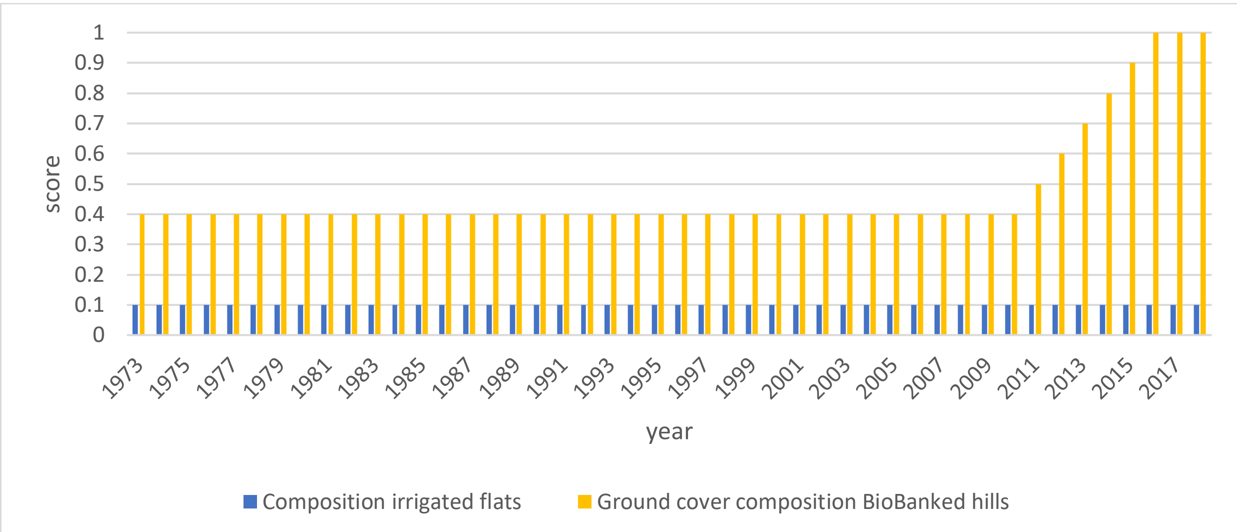

Figure 11. Status of the ground layer composition and functional diversity.

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Attachment A - Production Systems

Original plant communities on the two land types

In the chronology of production systems (below) it shows that various landscape management regimes and their constituent land management practices have been developed for, and tailored to, Brownlow Hill Estate's two land types over time - the river flats and shale hills.

These two land types correspond with the following original vegetation types (in ELA 2009, p8):

river flats	Alluvial Woodland (NPWS 2002)	Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin (HN 526) (DECC 2008)
shale hills	Shale hills Woodland (NPWS 2002)	Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin (HN 529) (DECC 2008)

HN = Biometric vegetation type ID

River flats: Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats

Today the extent of this vegetation type is restricted to small areas because historically the land type has been predominantly converted for cropping and intensive pasture production. Where present this vegetation type exhibits the structure of a forest with native overstorey dominated by *E. amplifolia* (cabbage gum) and *Casuarina cunninghamiana* (river oak), with other tree species present including, *E. crebra*, *E. molluccana* and *E. tereticornis* (ELA 2012). The shrub stratum was dominated by *Olea europaea* subsp. *cuspidata,* with other native shrub species present including, *Acacia floribunda* (white sally wattle), *Breynia oblongifolia* (coffee bush), *Bursaria spinosa* subsp*. spinosa, Clerodendrum tomentosum* (hairy clerodendrum), *Eustrephus latifolius* (wombat berry), *Rubus parviflorus* (native raspberry) (ELA 2012).

Whilst the proportion of exotic species recorded in this vegetation type is low compared with natives, due to the fertile soils of the alluvial flat, it has a high relative proportion of weeds found in the mid and understorey (ELA 2012).

There has been a long history of intensive management of the river flats that are associated with the Nepean River, dating back to the early 1800s. Almost all the alluvial woodland on the river flats was cleared in the early to mid-1800s. Over much of this time the land use on the river flats was cropping and perennial pastures and dairying. In recent decades this land type has been irrigated with water pumped from the Nepean River with an important crop of irrigated lucerne. In order to maintain productivity of the crops and pastures on the river flats, in 2005 the land manager changed to applying organic stable waste as an organic fertiliser.

Shale hills: Grey Box - Forest Red Gum grassy woodland on shale

Since the 2000s this vegetation type has been in three states: remnant open forest, woodland or cleared. Intact and contiguous stands of trees are predominantly remnant open forest dominated by regrowth *Eucalyptus tereticornis* (forest red gum) and large remnant *E. crebra* (narrow-leaved ironbark), *Corymbia maculata* (spotted gum) and *Eucalyptus molluccana* (grey box). This vegetation type is found in three broad condition classes: open forest with dense exotic mid-storey and no understorey (Olive Rainforest); open woodland with dominant exotic mid-storey and native dominated ground layer (*Olea europaea* subsp. *cuspidata* (African olive) with *Bursaria spinosa* subsp. *spinosa* (native blackthorn); and derived native grasslands (ELA 2012).

The ground layer is dominated by a mixture of native grasses typical of the Cumberland Plain such as *Themeda australis* (kangaroo grass), *Aristida ramosa* (purple wiregrass), *Microlaena stipoides* (weeping grass) *Eragrostis leptostachya* (paddock lovegrass), *Panicum simile* (two-coloured panic), *Sporobolus creber* (rat-tail grass) and *Bothriochloa macra* (red grass). Common native forbs included, *Brunoniella australis (b*lue trumpet), *Desmodium varians* (slender tick-trefoil), *Dichondra repens* (kidney weed), *Galium propinquum* (Maori bedstraw), *Hypericum gramineum* (small St. John's wort) and *Oxalis perennans*. Other common ground layer species include the fern, *Cheilanthes sieberi*, the sedges, *Carex inversa, Cyperus gracilis* (slender flat-sedge), *Lomandra filiformis* (wattle mat-rush), and the vine *Glycine tabacin* (ELA 2012). Flora surveys showed a relatively high ratio of native to exotic species in the ground layer including 63 native species (64%) and 35 exotic species (36%).

A low intensity grazing management regime on the shale hills over many decades has minimally modified the ecological function, structure and composition of the native vegetation, making this land type ideal as offset sites under the NSW BioBanking scheme. Field surveys between in 2009-14 by Eco Logical Australia (ELA 2009, 2012 and 2014), associated with Brownlow Hill Estate initiating several BioBanking sites, shows that the shale hills woodland is equivalent to the Revised Biometric Vegetation Type (RBVT) HN529: Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin. This vegetation type is also a component of the Cumberland Plain Woodland EEC as listed on the NSW *Threatened Species Conservation Act* 1995 (TSC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act) (ELA 2009).

About Brownlow Hill Estate Fig 1

Area of the Brownlow Hill Estate is 720 hectares (Figure 1). An additional area of 630 hectares is not part of this ecological assessment.

Rainfall

The average annual rainfall is 715 mm. The distribution of the rainfall is primarily in summer. The seasonal anomaly for rainfall is shown in Attachment C.

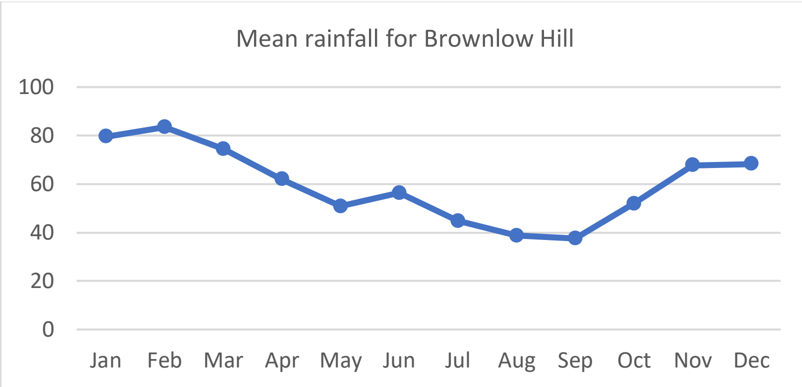


Figure 1. Mean monthly rainfall. Derived from modelled monthly rainfall data obtained from the Bureau of Meteorology.

Water supply

Farm water is rainfed into creek and farm dams on the hill country and irrigation water comes from the Nepean River

Land types

1. River flats: 240 ha
2. Shale hills: 480 ha

Domestic stock

Dairy and beef cattle

Pest Animals

Pest animals: Pigs, deer, rabbits, goats, foxes, cats and dogs.

Weeds

The following weeds including Boxthorn, African Olive, lantana, privet, melia (white cedar), wild acacia (honey locust/gleditsia, variants) and blackberry are managed on shale hills.

Chronology of land management regimes or production systems

Home and environs

1859	The property was leased by Jeremiah Downes.
1999	Sydney Gas Co acquired all the petroleum exploration licences in the Sydney basin. Drilled 26 holes (down 800m) around Camden/Campbelltown and proposed to use fracking to extract the gas. To halt this project on Brownlow Hill, Edgar had it listed as a Heritage site in the Land & Environment Court and the listing came through protecting BH from both coal seam gas drilling and extraction and rural-urban subdivision.

2008	Commenced Annual Music Festival
2018	Completed renovations to the main house

River flats – land type (~240 ha)

Years	Production systems – land management regimes
1788-1850	Property played a role in convict period in NSW relating to incarceration, transport, reform, accommodation and working
1800-present	All watercourses are open to stock – none are fenced off
~1800s	The entire floodplain was drained by Edgar's ancestors with the obvious result that the water table dropped and the watercourses became incised.
1810s	Construction of the Round House is popularly believed to have been one of the government herdsmen's' huts built by Macquarie
1828-37	The amalgamated Brownlow Hill and Glenderual estates were managed as a whole by Colonial Secretary Alexander Macleay's sons George (1805-1891) and James Robert (1811-1892) from 1828 and by George following James Macleay's departure for England in 1837
1820s	Property was originally called Lowe's Hill. Governor Macquarie renamed it to Brownlow Hill at the request of Commissioner Bigge, in honour of his friend Lord Brownlow.
1829	Fanny Macleay reported on her brother George's departure on Sturt's expedition along the Murray and Darling Rivers (a blazed tree near the Round House commemorates the starting point for this expedition), adding 'Poor James is the farmer now at the Cowpastures and a more busy time he could not have had ...He is now engaged with sheep sheering ... then Hay making and harvest immediately follows ... But to what use is all of this but to chain my Father's pockets? since the wool fetches no price, and when we have anything to sell we find its value has fallen 70 per cent since we purchased ...'
1832	Records held by the Botanic Gardens indicate that G. Macleay Esquire was sent a number of horticultural and garden plants
1850s	The property was leased for pig raising when much damage was done to the surrounding growth.
1850-1900	The Round House was known as Monk's Cottage by c1900, having been home to one or two generations of tenant dairy farmers
1858	Jeremiah Downes came to manage Brownlow Hill
1859	The property was leased by Jeremiah Downes.
1862	Brownlow Hill was sold to Severin K Salting and was again leased to Downes.
1862-75	The property was managed as a series of tenant farms

Years	Production systems – land management regimes
1875	Jeremiah Downes purchased the property from Salting.
1882	Commencement of a family tradition of collecting and monthly rainfall measurements for the Bureau of Meteorology.
1947	Four dairies operated on the property
1969	Four dairies operated on the property
1969-2017	Western portion of the property used for grazing only and the alluvial flats for cropping.
1960s	A quarry was established on the western extremity on the property with minimal impact on the working farm.
1800- 1920	Varying degrees of dairy management – initially with herdsmen moving the cattle, and with fencing and gradually improved (exotic) pastures, supplementary forage for the animals. Probably some cropping for flour.
1920 – 1950	Used irrigation to increase the carrying capacity (interrupted by the war); 5 dairies on the farm each with a dairyman. Supplied milk to Camden factory (?) for whole milk into Sydney, butter and cream derived from numerous dairies in the district.
1950 – 1970	Improved dairy genetics, particularly Friesian cattle with large production. Quota milk valuable and farmers doing very well. More improved pastures, including rye, clover, lucerne, cocksfoot. Winter oats for fodder and summer corn or millet – double cropping. Haymaking of improved pasture hay and probably pit silage.
1970 – 1990	More intensive dairy farming and stud breeding. 60 ha are irrigated. Improved irrigation, seed genetics and herd genetics – assume the five small dairies still functioned (including family next door at Aston).
1973	Edgar came to the farm after school and started to double crop – oats, Italian rye, (winter) corn, sorghum, millet (summer). Was losing nutrients, running over clods with the tractor. Used gypsum to break up the compacted soil.
1973-75	Used the Yeoman's Plough and visited Yobarnie at North Richmond.
1979	More lucerne planted and perennial pasture growth replaced annual cropping with oats, corn and millet
1983	Chicken manure replaces chemical fertiliser
1985	Started to think about change – planted more lucerne (as a full perennial); increased this and ran more irrigation – but time-consuming system with pipes, shifted by hand. Continued to add chicken manure to help with nutrients and compaction.
1985-present	Pasture weeds are not sprayed but managed through fallows and tillage – for lucerne to get established 3 or 4 tills are required to clean the paddock. Couch is the main competitor for young lucerne – same growth cycle. If couch becomes too dominant the lucerne is renovated.

Years	Production systems – land management regimes
1985-90	Installed sub-soil drippers (manufactured in Israel – Netafim). Couldn't use pivots as no paddocks have straight sides (because of the watercourses). BUT the drippers blocked up after 5 years. 1 foot underground and a worry with pasture work.
1990 onwards –	Started with K-Line, easy shift behind the motor bike.
1990 – 2005	Dairy deregulation and concerns over the viability of the property. Challenges included CSG exploration, encroachment of urban development, low milk prices, etc. Real belief that farming at Brownlow might cease and the land sold. Believe that 2/3 dairies closed.
1996	Last large flood. There is a narrow gorge downstream, so the water backs up and moves slowly.
2000- to present	Wildfires are not a problem – plenty of water, neighbouring land is cleared open pasture and the rural urban interface surround the property incl. University next door. Neighbours on nearby blocks stop the fires.
2000	One of the diaries converted to beef cattle
2005- 2018	Accidental and intentional impacts. The quarry provided income, stable waste became available at no cost, BioBanking provided cash injections and heritage listing stopped the threat of petroleum licenses and urban development. Better irrigation, more lucerne for sale, less dependence on dairy, etc. Milk market in Picton via Country Valley.
2005	Heard about Peter Andrews, how to get water moving with nutrients.
2005	Ceased to apply chemical fertiliser
2005-2018	Stable waste added to lucerne paddocks. Rate: 4 months to treat 10 ha at a depth of 20 cm.
2012	Aston purchase 120ha
2011-12	Hunter Nepean CMA installed the Weirs in Mt Hunter Rivulet – cost $500,000 for 5 weirs. 2 kilometres of watercourse treated.
2017-18	Now nearly fully organic although not certified. Totally absorbed with the soil.
2017-ongoing	The whole farm supplied with water from the River via a 50 hp pump driving the spraying system – supplies 2 inches of water along each line per day. Move all sprays once daily with the quad bike. The electric pump is 15 years old and has worked non-stop
2018 and future	Looking at branding of milk and value adding. Have funds to redevelop dairies (when staff agreeable). More technology – soils, scanning of cattle, new genetics for milk composition etc.

Shale hills – land type (~480 ha)

Years	Production systems – land management regimes
1800s	Cattle have access to all streams and dams for grazing
1970s-2018	Ongoing control of woody weeds with chainsaws, bulldozer and tritter – also uses basal bark treatments. Species controlled include boxthorn, African Olive, lantana, privet, melia (white cedar), wild acacia (honey locust/gleditsia, variants) and blackberry.
1975	Pest animals: Pigs, deer, rabbits, goats, foxes, cats and dogs are all present.
1990	Film crews operated in the sandstone quarry
2010	Commenced BioBanking sites by reinstating Cumberland Plain Woodland (stage 1) 25 ha
	BioBanking site Cumberland Woodland (stage 2) 50 ha
2010-18	BioBanking sites are grazed infrequently to reduce fuel load and keep cover at threshold level. Only uses the beef cattle on the BioBank sites
2012	Purchased Ashton 120ha
2016	Purchased Ashton 140ha
2018	BioBanking sites Cumberland Woodland (stage 3/4) 40 ha
2018	Total area of BioBanking sites Cumberland Woodland 115 ha
2018-ongoing	Aim to increase area of BioBanking Cumberland Woodland by an additional 250 ha

Attachment B Phases in regenerative landscape management

The table below shows the turning points for each of the ecological criteria over time which has been compiled from Figures 2-11. A summary of this table was used to generate Table 1.

Phase	Component s	Ecological criteria	River flats		Shale hills	
			Irrigated	Non- irrigated	BioBanking	Non-BioBanking
1	Soil function	A	1973-2002	1973-2002	1973-2010	1973-2018
		B	1973-2005	1973-2005	1973-2018	1973-2018
		C	1973-2005	1973-2005	1973-2018	1973-2018
		D	1973-2005	1973-2005	Nil	Nil
		E	1973-2006	1973-2008	1973-2011	Nil
	Reproductive potential	F	Nil	Nil	1973-2006	1973-2006
	Tree structure and composition	G	Nil	Nil	1973-2006	1973-2006
	Ground structure and composition	H	Nil	Nil	1973-2011	1973-2013
	Tree structure and composition	I	Nil	Nil	1973-1994	1973-1994
	Ground structure and composition	J	Nil	Nil	1973-2010	1973-2016
2/3	Soil function	A	2003-2007	2003-2007	2010-2018	2010-2018
		B	2006-2007	2007-2014	Nil	Nil
		C	2006-2007	2006-2007	Nil	Nil
		D	2006-2010	2006-2014	Nil	Nil

		E	2007-2009	2009-2014	2012-2018	Nil
	Reproductive potential	F	Nil	Nil	2011-2016	2007-2017
	Tree structure and composition	G	Nil	Nil	2007-2016	2007-2018
	Ground structure and composition	H	Nil	Nil	2012-2014	2014-2018
	Tree structure and composition	I	Nil	Nil	1995-2008	1995-2014
	Ground structure and composition	J	Nil	Nil	2011-2016	2016-2017
4	Soil function	A	2008-2018	2008-2018	Yet to reach reference	Yet to reach reference
		B	2011-2018	2015-2018	Yet to reach reference	Yet to reach reference
		C	2008-2018	2008-2018	Yet to reach reference	Yet to reach reference
		D	2011-2018	2014-2018	Yet to reach reference	Yet to reach reference
		E	2010-2018	2014-2018	Yet to reach reference	Yet to reach reference
	Reproductive potential	F	Nil	Nil	2017-2018	Yet to reach reference
	Tree structure and composition	G	Nil	Nil	2017-2018	Yet to reach reference

	Ground structure and composition	H	Nil	Nil	2015-2018	Yet to reach reference
	Tree structure and composition	I	Nil	Nil	2008-2018	2014-2018
	Ground structure and composition	J	Nil	Nil	2017-2018	Yet to reach reference

Nil means no change and trend over the time

Legend for the four phases:

Phase 1 - Conventional non-regenerative management

Phase 2 – Small scale treatments mainly non- regenerative management

Phase 3 - Transitioning to broad scale - mainly regenerative management

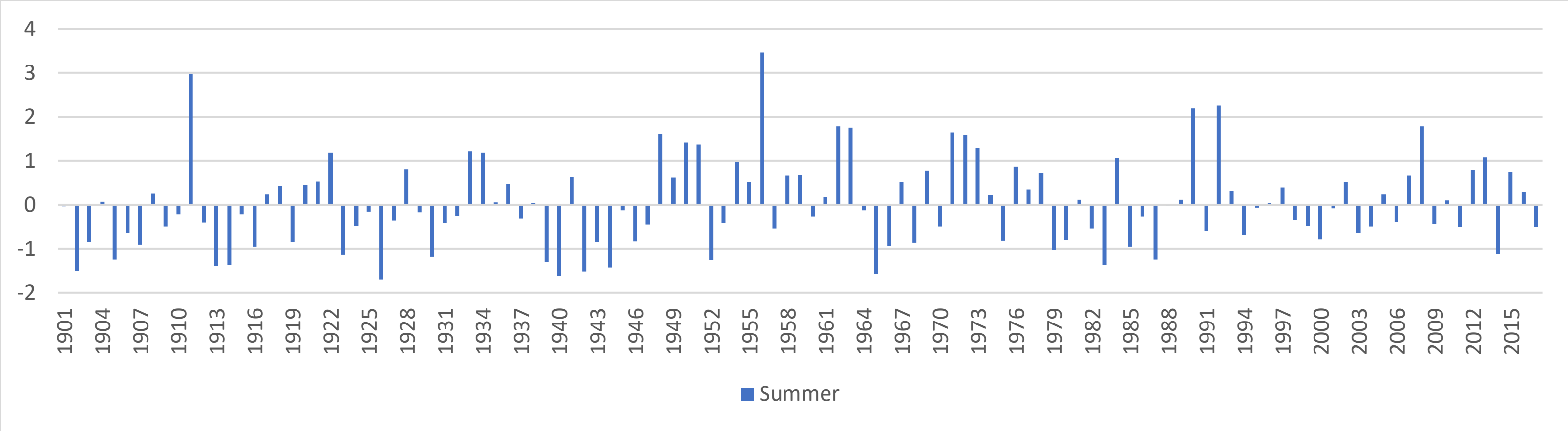
Phase 4 - Broad scale regenerative management

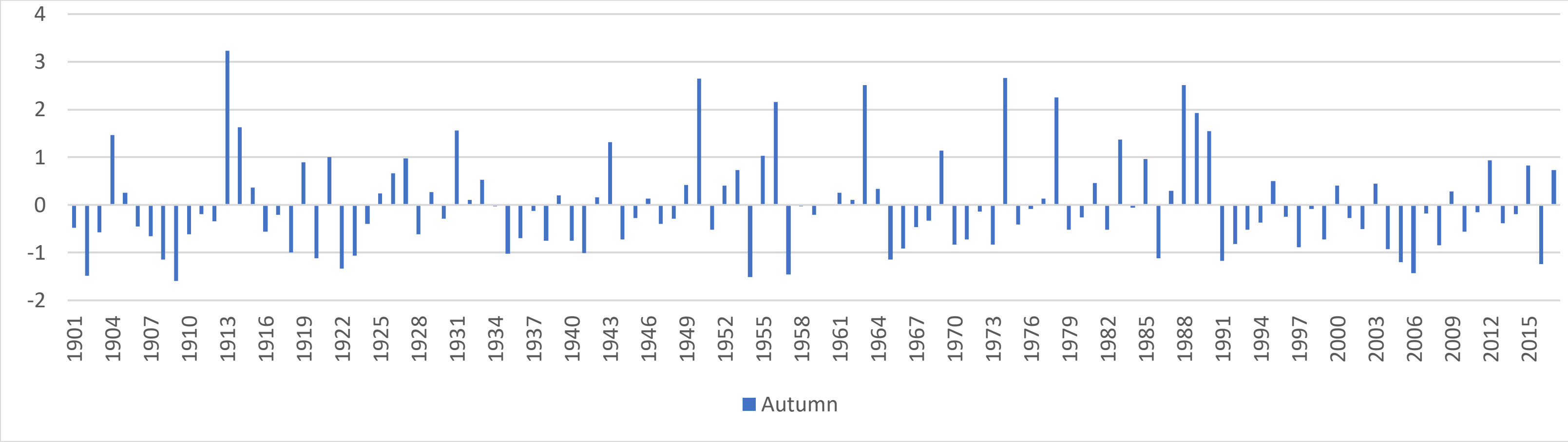
Legend for the 10 ecological criteria

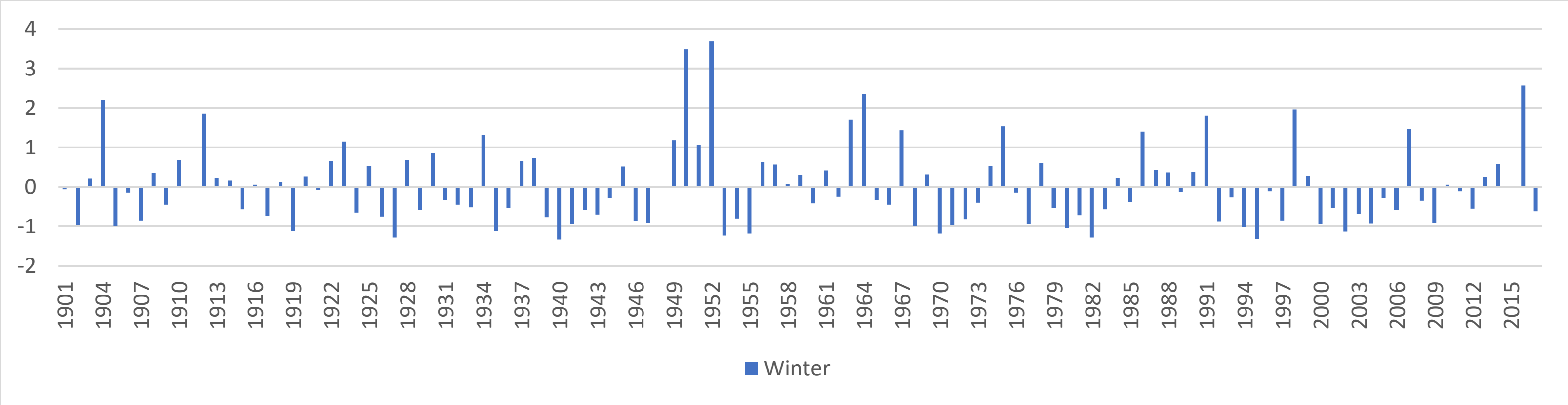
A. Resilience to severe climate events i.e. natural major disturbance/s (cyclone, flood, drought, fire)
B. Status of soil nutrients
C. Status of soil hydrology
D. Status of soil biology
E. Status of soil physical properties -As a medium for plant growth
F. Status of plant reproductive potential
G. Status of tree and shrub structure
H. Status of ground cover grass and forb structure and biomass
I. Status of tree and shrub composition and functional diversity
J. Status of the ground layer composition and functional diversity

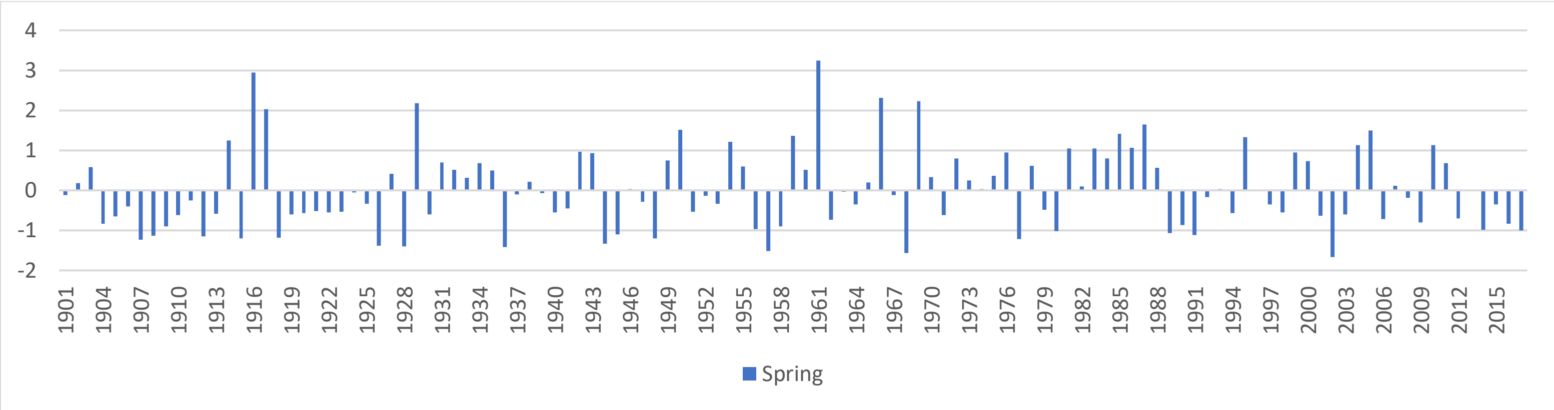
Attachment C – Seasonal rainfall patterns

Patterns of seasonal rainfall derive from modelled monthly rainfall data for Brownlow Hill Estate [i] 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.