SoilsForLife

Colodan Ecological Report

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Summary

This report on the ecological values of Colodan is based on the responses of the woodland ecosystems to changing land management regimes on the property since 1990. Additional information prior to 1990 is added to provide context.

Much of the information presented in this assessment was compiled by interviewing the land manager, James Henderson. The start date of 1990 for this assessment reflects the period which James has a detailed working knowledge. James's knowledge was used to document the response of Colodan to Soils for Life's 10 standardised ecological criteria for assessing regenerative responses on Colodan.

Colodan is has been managed by the Henderson family as a cattle grazing enterprise since the 1930s. Between the 1930s and 2020 four phases have been defined in the response of Colodan.

Colodan was been conventionally managed cattle breeding property from 1930-1999. It was characterised by set stocking. Paddocks were relatively large and the placement of fences and watering points were traditional. In 1998 the Henderson family started to think about regenerative management regimes when they attended the first field days to learn about how to maximise the matching of available feed with cattle numbers and what is a cattle production cycle.

Between 2000-06 it was largely business as usual however improvements were made in aligning fences with land type and the strategic placement of stock water points.

In phase three regenerative land management regimes were implemented across Colodan. This included introduction of rotational grazing between paddocks combined with a reduction in the numbers of cattle across the property and improved the genetic stock of the cattle. This phase also saw the introduction of fast moving warm season grass fires (cool burns) which promoted pasture productivity.

In phase four (2016 – 2020) the land manager commenced an intensive program of rotating cattle between paddocks to match available feed and cattle numbers. In addition, two carbon projects (Avoided Clearing and Human Induced Regeneration) were initiated. Fast moving warm season grass fires (cool burns) that promote pasture productivity were continued.

Key findings

1. An independent validation of the ecological responses for Colodan shows unequivocally that the property is being managed for ecologically regenerative outcomes. This includes resilience in the face of severe climatic events, ground cover and woody vegetation (woodlands).
2. An independent assessment shows the property maintained a moderate degree of ground cover through the Millennium Drought (1996 – 2009) around 55% ground cover. Between 2010-20 Colodan has averaged around 75% ground cover.
3. Up to 2011 regenerating trees were chemically controlled to prevent thickening and promote pasture production. Since that time trees have been managed for saw log potential and more recently carbon sequestration.
4. An independent assessment shows the extent of woody vegetation (woodland trees) on Colodan has increased since 2011. The extent of woody vegetation has been maintained between 3.75%-4% of the area the property.
5. Four phases in the report document the transformation of Colodan from conventionally managed cattle breeding property to regeneratively managing each land type on Colodan for cattle and timber as well as carbon production.
   a. Phase 1 Colodan was conventionally managed cattle breeding property from 1930-1999.
   b. Phase 2 2000-06 commenced aligning fences with land type and the strategic placement of stock water points.
   c. Phase 3 2007-15 commenced managing Colodan using regenerative land management regimes. introduced fast moving warm season grass fires (cool burns) which promoted pasture productivity.
   d. Phase 4 2016-20 commenced an intensive program of rotating cattle between paddocks to match available feed and cattle numbers. Initiated two carbon projects (Avoided Clearing and Human Induced Regeneration). Continued the use of fast moving warm season grass fires (cool burns) to promote productivity of pastures and assist in managing productivity of trees for saw log production.
6. Colodan's ecological functions, that is land surface condition, have all improved since the implementation of regenerative land management regimes, particularly in phase 4 including:
   a. Status of soil nutrients – including soil carbon
   b. Status of soil hydrology - soil surface water infiltration
   c. Status of soil biology - soil biology
   d. Status of soil physical properties – as a medium for plant growth

Introduction

Colodan was part of the Wuli Wuli people's country with the near neighbours to the east the Waka Waka people. The Gureng Gereng were located to the east of the coastal range and the Yiman people were located to the west.

European settlement of the district commenced between 1848-50. It is most likely that Colodan was part of Rawbelle Station which was established, probably, as a squatters run in 1848.

The area of Colodan is 4660ha, the majority of which in 2020 is dominated by native vegetation. Only small areas have either been converted to non-native pasture types (buffel grass) or have been over-sown with naturalised legumes (stylo).

The pre-clearing land types including the main soil types are as follows:

- About half the area of Colodan (47.6%) is characterised by steep low hills and with shallow rocky soils (rudosols). Narrow-leaved ironbark is the predominant overstorey.
- Almost half the area of Colodan is plains country, with equal areas of alluvial plains (deep black cracking clays -vertosols 24.3%) and non-alluvial plains (texture contrast soils -sodosols, chromosols 22.5%). The overstorey of the alluvial flats are dominated by blue gum / river red gum while the non-alluvial plains are dominated by silver-leaved ironbark woodland.
- A small area of Colodan (5.5%) is characterized by undulating low hills and plateau remnants with eucalypts and bloodwood being the dominant land type.

The main land use limitations of the soil types on Colodan are rudosols with low fertility. Subsoil of sodosols very erosive when exposed. These are highly erodible soils with dispersible subsoils. Chromosols are prone to erosion if disturbed. The main sources of ecological information about Colodan's land types, fire scars and ground cover were sourced from the Queensland Government's Forage Reports. Information about the land use limitations on Colodan was sourced from FutureBeef's Fitzroy Region Grazing Land Management (GLM) land types.

Rainfall on Colodan is approximately 621 mm per annum. Rainfall is dominantly spring, summer and autumn (Figure 1). Patterns of average annual and seasonal rainfall since 1900 are shown in Appendix B. Over the last 10 years, 2010 was a very high rainfall year, while 2019 Colodan experienced a major rainfall deficit (Appendix B). It is interesting to note that during the period of the Millennium Drought (1996 – 2009) the annual rainfall anomaly (Appendix B) showed a reasonably even distribution except there was an obvious rainfall deficit in autumn over this period (Appendix B), however that deficit was compensated by above average rainfall in winter and spring (Appendix B). These changed patterns of seasonal and annual rainfall highlight the need for regenerative land managers to adapt to rainfall variability.

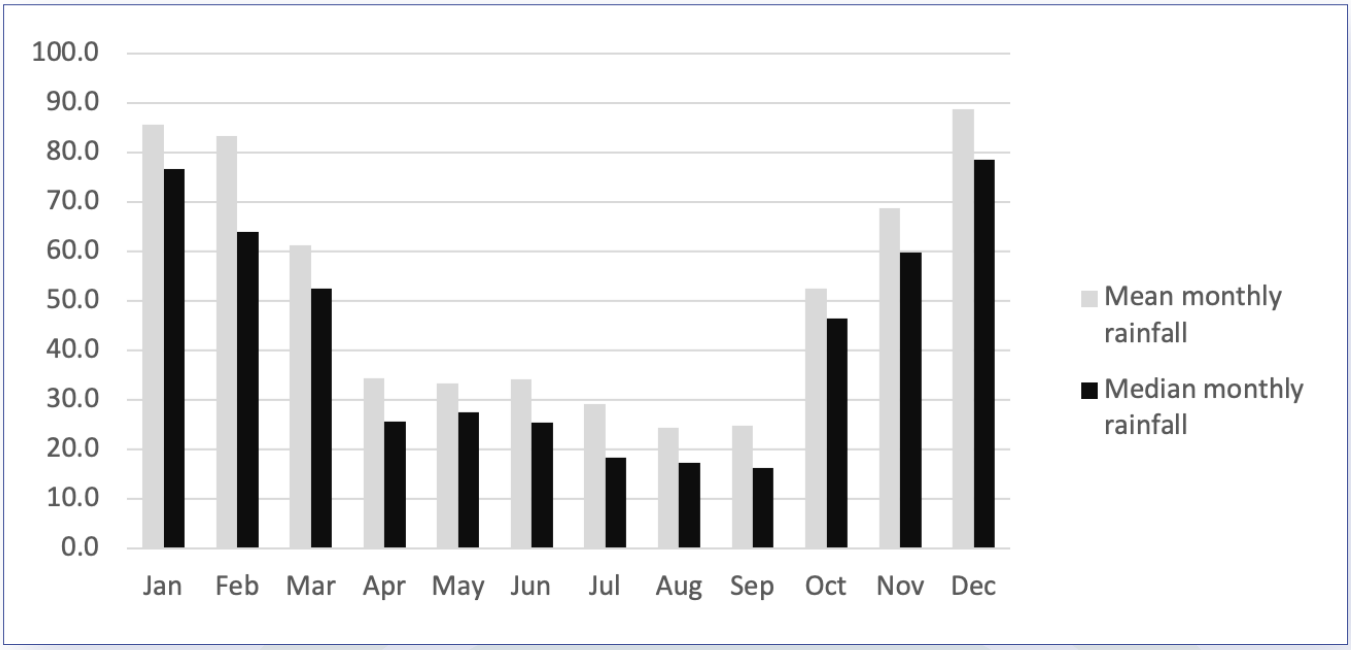
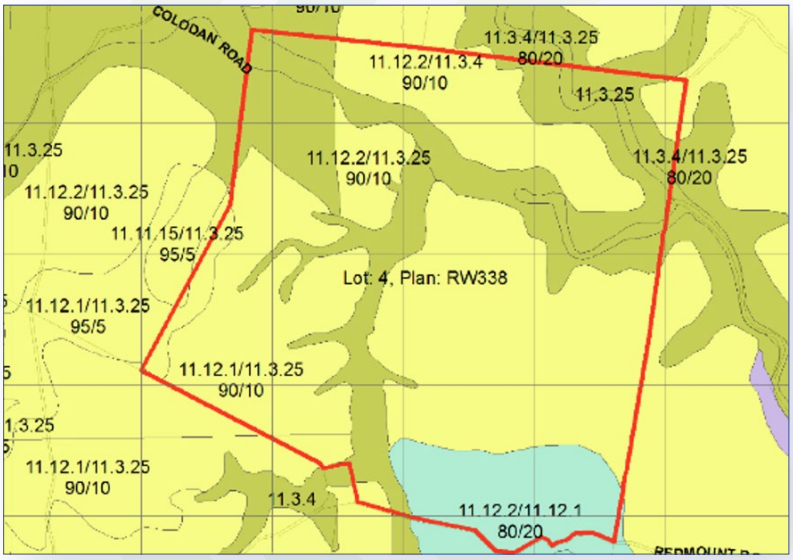


Figure 1. Annual pattern of rainfall including monthly mean and median (mm).

Land types



Colodan has five land types (Queensland Government (2020), the largest of which is Regional Ecosystem (RE) 11.12.1 (2244 ha) (Figure 2). Other large land types are RE 11.12.2 (1146ha) and RE 11.3.4 (961ha). The smallest land types are RE 11.11.10 (251ha) and RE 11.3.25 (94ha). Each of these land types would have had a grassy understorey that was managed by the Wuli Wuli people using fire stick farming.

RE 11.3.4	Blue gum / river red gum woodlands on alluvial plains
RE 11.3.25	Eucalypts and bloodwood woodland fringing drainage lines on clay soils
RE 11.11.10	Silver-leaved ironbark woodland on deformed and metamorphosed sediments and interbedded volcanics
RE 11.12.1	Narrow-leaved ironbark woodland on ranges on igneous rocks
RE 11.12.2	Silver-leaved ironbark woodland on duplex soils with igneous rocks

Figure 2. Pre clearing regional ecosystems for Colodan

Methods

The process used to record changes and trends in ecological functions involved expert elicitation (Hemming et al. 2018; Thackway and Freudenberger 2016) and involved the SFL ecologist working with the land manager to apply a standardized and systematic approach to elicit the land manager's knowledge to generate two products 1) a systematic chronology of land management regimes and 2) 10 ecological response functions that illustrate the land manager's knowledge of how land management regimes over time have changed the condition of the soil and vegetation across the dominant land types.

Chronology of land management regimes and practices

A chronology of land management regimes and practices summarises how the dominant land types have been managed over time for the key agricultural enterprises. Ideally the chronology of management regimes should be documented at the paddock level.

The chronology seeks to document land management regimes before, during and after the adoption of regenerative management regimes and practices.

10 ecological response functions

The land manager's observations of the responses of the landscape over time to land management regimes and practices is documented using 10 ecological response functions including resilience, soil and vegetation condition. The following 10 ecological criteria have been standardised and tested nationally (Thackway and Gardner 2019) and are relevant for any land use type and agro-ecological region.

The 10 ecological criteria are:

A. Resilience of landscape to natural disturbances

B. Status of soil nutrients – including soil carbon

C. Status of soil hydrology

D. Biological activity in the soil

E. The physical properties of the soil

F. Changes and trends in the reproductive potential of plants

G. The extent of tree cover

H. Status of ground cover

I. The diversity of tree and shrub species

J. The diversity of grass species

The process of visually representing the 10 ecological functions elicits the land manager's expert knowledge of ecological changes and trends in ecological function and links this with their land management over time. Information about long term rainfall including monthly, seasonal and annual patterns is integrated with the land manager's knowledge of the 10 ecological responses (Appendix B).

The 10 response curves record change and trend in ecological functions before, during and after the adoption of regenerative management regimes and practices.

Phases of agricultural practice

With the land management chronology and 10 graphical ecological response functions in place, the SFL ecologist synthesised the two knowledges 1) systematic chronology and 2) the 10 ecological response curves to write this ecological report which summarises the ecological outcomes for the property across various phases.

Phases were interpreted according to the following guidelines:

- **Phase 0** - Indigenous peoples' production systems and pre-European ecosystems.
  Phase 0 is not the focus of the Soils For Life case studies.
- **Phase 1** – Conventional agriculture production systems[2]
- **Phase 2** – Initial trialling of regenerative management regimes production systems
- **Phase 3** – Upscaling of regenerative management production systems
- **Phase 4** – Whole farm regenerative management production systems

These phases are based on the conceptual model outlined by Thackway and Gardiner (2019).

Findings

A well-managed native vegetation landscape

The Henderson family has modified the ecological functions of each land type at the paddock level since the 1930s. Over this time the dominant land cover of Colodan has been managed as native vegetation.

The intent of this report is to document changes and trend in ecological functions of land types at the paddock level however, without a documented paddock-level management history over time, the Colodan land management chronology could only be documented at the whole property level. James Henderson's understanding of how land management regimes have modified the natural ecological functions of Colodan is presented at the whole farm level (Figure 3)

The Colodan land management chronology was compiled from published and unpublished sources, with the bulk of the information coming from interviews with the land manager, James Henderson (Appendix A). The chronology represents James Henderson knowledge of land management regimes and practices by the Henderson family and includes three main enterprises: cattle production from mainly native pastures, timber production from native woodland and carbon production.

[2] Across Australia, these practices usually led to diminished or degraded function, structure and composition of the landscape.

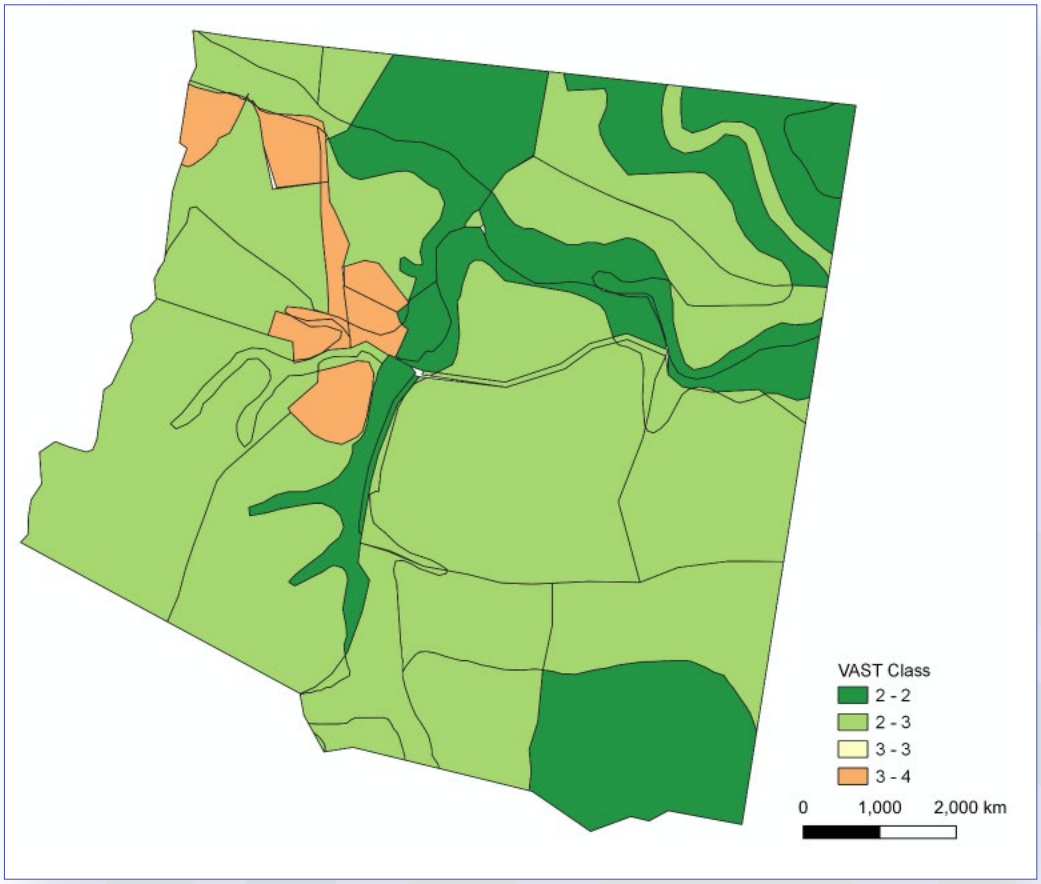


Figure 3. Effect of land management regimes on the natural ecological function of Colodan. Class 2 is least modified and class 4 is most modified.

Over time land management regimes have modified the condition of natural ecosystems of Colodan. The least modified ecosystems (Figure 3, class 2-2) include the alluvial plains and fringing drainage lines (Figure2). Other minimally modified land types are those on steeper rocky landscapes e.g. the south east and the and northern areas of Colodan (Figure 2, RE 11.12.1 and RE 11.12.2). Extensive areas of Colodan are mapped as Class 2-3, where the woody tree cover has historically been ringbarked or chemically treated to reduce the density of woody tree cover and promote pasture production (Figure 2, RE 11.12.1 and RE 11.12.2). The most modified areas (class 3-4) are where intensive land management regimes over time have modified the soil and vegetation condition.

Four management phases

This assessment identified four phases of land management on Colodan (Table 1).

The pre-European indigenous management of the landscape prior to the late 1860s (Phase zero), when the first pastoral settlers established large pastoral holdings in the district.

Conventional management (Phase one) continued until 2001. This phase is characterised by set stocking and the killing of native trees to promote the productivity of the native. Grass fires were also used to promote pasture productivity and control regeneration of eucalypts.

Phase two is characterised by initiating improvements in the cattle water supply and fencing to promote better pasture utilisation, while at the same time continuing with set stocking and killing trees and controlling woody regrowth.

Phase three involved the introduction of rotational grazing between paddocks combined with a reduction in the numbers of cattle across the property and improved the genetic stock of the cattle. Introduction of fast moving grass fires (cool burns) which promoted pasture productivity.

Phase four began in 2016, which involved the development and implementation of an intensive program of rotating cattle between paddocks to match available feed and cattle numbers. Started carbon projects over most of the property with Green Collar as the proponent (equivalent of a sharefarmer).

Table 1. The four management phases on Colodan

	Production Regimes	General Observations
Phase zero: <1870s	Aboriginal people managed the country using fire	Country was a grassy open woodland.
Phase one: 1870s- 1999	Conventional management practices. Ring barking and chemical stem injecting with tordon to killed trees and controlling woody regrowth. Set stocking initially with the sheep and later with cattle. Harvested mature trees for saw logs. Annual grass fires used to promote pasture growth. In 1998 started to think about regenerative management regimes; attended first field days.	Extensive areas of tree died. Increased availability of pasture. Sheet erosion and gully erosion. Green pick contributed to weight gains in cattle.
Phase two: 2000 – 2006	Continued set stocking with cattle. Continued use of injecting trees with tordon to kill trees and control woody regrowth. Initiated improvements in the cattle water supply and fencing to promote better pasture utilisation.	Extensive areas of tree died. Gradual improvements in percent ground cover.
Phase three: 2007 - 2015	Introduced rotational grazing between paddocks. Reduced cattle numbers. Improved the genetic stock of the cattle. Commenced using fast moving grass fires (cool burns) to promote pasture productivity.	Observed minimal regeneration of eucalypts on all land types. Observed improvements in P3 grasses (Productive, Perennial and Palatable)
Phase four: 2016 - 2020	Commenced intensive program of rotating cattle between paddocks to match available feed and cattle numbers. Started carbon projects (Avoided Clearing and Human Induced Regeneration).	Obvious mass regeneration of eucalypts on all land types. Continued improvements in P3 grasses (productive, perennial and Palatable) Introduced urea and molasses to enable better utilisation of the total standing dry matter

Annual Production cycle

Experience gained in Phase four: 2016 – 2020 has enabled the Henderson's to develop an annual production cycle for managing their beef cattle enterprise (Figure 4).

Operation of the annual production cycle is closely linked to the 10 regenerative ecological outcomes i.e. response curves described below.

The cycle summarises "how" the Henderson's cattle management regime operates and underpins their approach as regenerative landscape managers. The cycle also represents the management inputs to the beef cattle enterprise.

The cycle represents a balance between management activities over a year including: breeding and raising cattle, matching herd numbers with feed on offer (i.e. timing of rainfall and its effectiveness, and its links to pasture quality and quantity), herd health and management which is linked to rotating and spelling paddocks and supplementary feeding, and tracking the desired ecological response outcomes i.e. grass and tree balance and links to soil condition.

The cycle provides a measure of predictability and certainty i.e. what practices need to be prepared for and implemented by "when" i.e. which months and seasons. Accordingly, the cycle is also closely linked to the Henderson's social, financial and production outcomes.

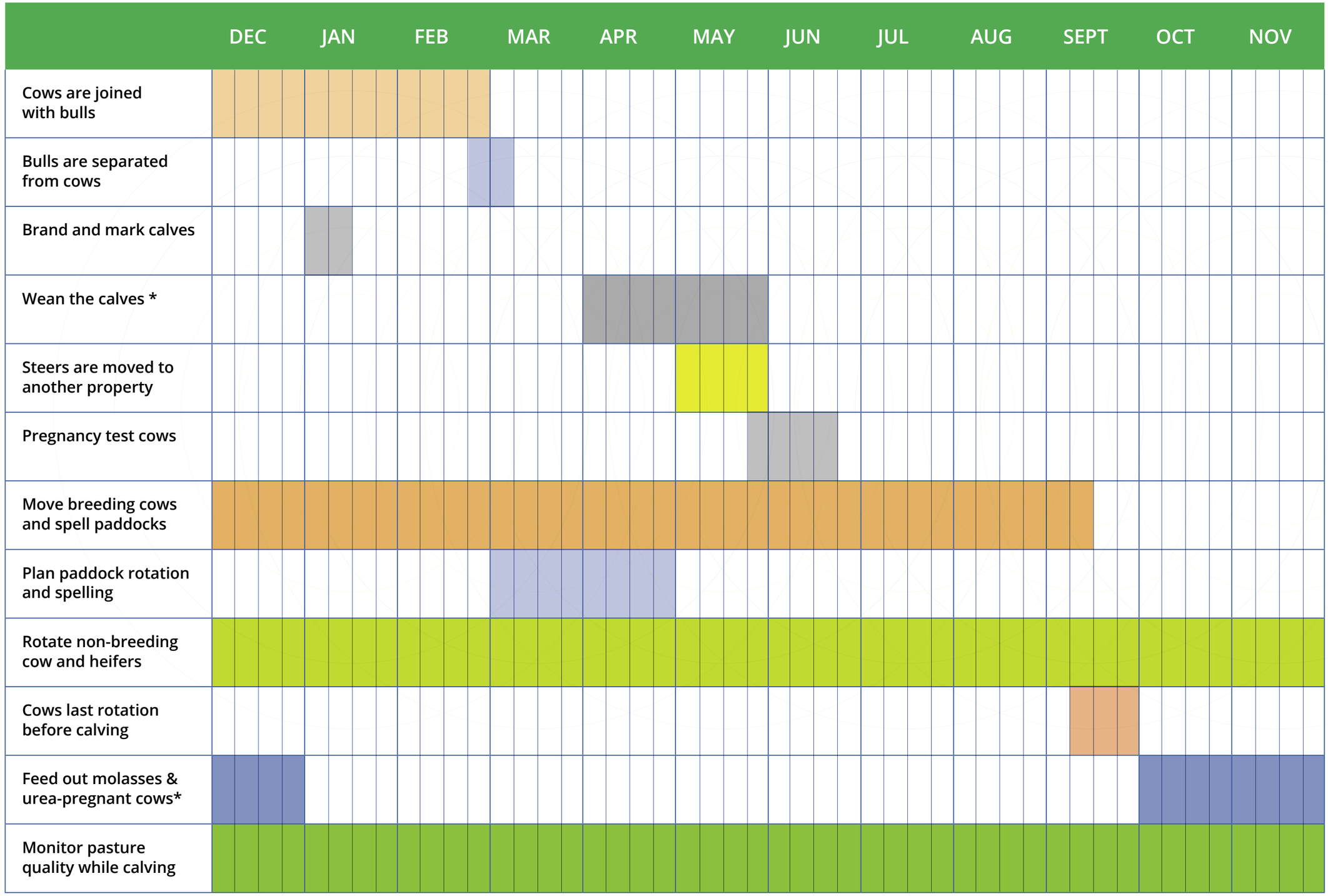


Figure 4. Annual production cycle for managing the beef cattle enterprise at Colodan.

Notes: * weaning is season and cow condition dependent. *Note – Supplementary feeding is cattle condition dependent. The aim is to keep > 50% of breeding cattle in condition score 3 or higher. Depending on the severity of the seasons, supplementary feeding program will be bought forward to start in September and can go through until " Bulls out" in late February.

Ecological response outcomes

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

Figure 5 presents the resilience of Colodan to major climatic events. The main assessment here is in relation to drought and extreme rainfall events.

In phase one, the Henderson family practised conventional grazing land management and established legume based pasture by direct drilling of fine stem stylo Stylosanthes guianensis var. intermedia. This included a 69 year period (1930 – 2001) of grazing cattle using set stocking. During this period most of Colodan was treated to kill and control trees and woody regrowth. Initially this involved ringbarking and then stem injections of tordon. During this phase the placement of stock water points and the alignment of fences were not strategically placed to maximise matching of available feed with cattle numbers or cattle production cycle.

Figure 5. Resilience of Colodan to major climatic events.

During phase two improvements were made in the placement of stock water points and the alignment of fences to promote better pasture utilisation, while continuing the manage the cattle using set stocking. In this phase trees density and woody regrowth continued to be controlled using stem injections of tordon. This management regime promoted greater ground cover.

In phase three paddock rotation were initiated combined with resting the paddock allowing the pasture to regenerate. Fast moving grass fires (cool burns) enabled higher productivity from the otherwise rank pasture grasses. Obvious mass regeneration of eucalypts was observed as a result of increased rotation and paddock rests. During this phase, the property experienced a major rainfall event and received 450 mm in December 2010 (Appendix B). Minimal sheet erosion was observed however there was obvious stream bank erosion. This high rainfall event was associated with a La Niña weather pattern, which caused prolonged and heavy rainfall over Queensland river catchments and lead to major damage and disruptions in low lying rural and urban areas. At the time grazing operations on Colodan were minimally inconvenienced.

Phase four saw the resilience of the paddocks increase as observed by greater amounts of total standing dry matter (biomass), less bare ground and increased levels of regeneration of eucalypts.

Improvements were observed in the condition of naturalised legumes (various types of Stylo) including increasing in height and available forage.

B. Status of soil nutrients – including soil carbon

Figure 6 presents the Status of soil nutrients – including soil carbon.

During phase one the pastures were heavily grazed due to set stocking. Under this management regime much of the standing biomass was consumed by cattle and minimal grass cover would have trampled and returned to soil as nutrients available to plants. Annual grass fires in the warm season were used to promote pasture growth associated with the summer monsoon rains.

In phase two set stocking continued however strategic improvements were made in the placement of stock watering points and fencing which enabled better pasture utilisation. As with phase one much of the standing biomass was consumed by cattle and little was returned to the soil except through dung and urine.

In phase three set stocking ceased and rotational grazing was introduced, where the cattle were moved between paddocks. Introduced resting paddocks after they had been grazed. Observed pasture was trampled by the cattle and this trampled grass formed a layer which began to decompose. The land manager began to observe a slight decrease in bare ground because the cattle were moved to other paddocks before the too much of the pasture was consumed. The land manager observed improvements in indicators of pasture condition i.e. P3 grasses (Productive, Perennial and Palatable).

In this phase the land manager in 2011 reintroduced a warm season fire regime to Colodan (Appendix C). This comprised using fast moving prescribed fire with a low flame height. This warm season fire regime burns off grass (cool burns) by removing dead rank grass and promotes pasture productivity over the summer rainfall period (Appendix C).

During this phase cattle numbers were reduced and improvements were made to the genetic stock of the cattle.

In phase four the land manager commenced an intensive program of rotating cattle between paddocks to match available feed and cattle numbers, combined with longer recovery times to enable the pasture to regenerate. Continued improvements were observed in the condition of the pasture. Introduced urea and molasses to enable better utilisation of the total standing dry matter.

In this phase despite improved pasture condition cattle numbers were kept as there were in phase three.

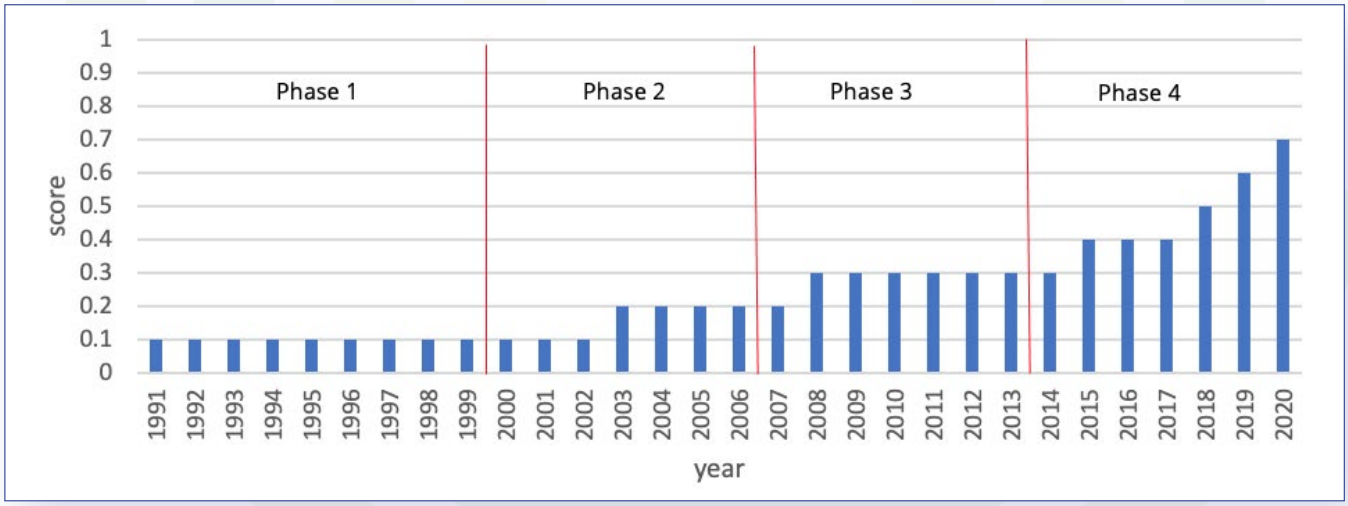


Figure 6. Status of available soil nutrients

C. Status of soil hydrology - Soil surface water infiltration

Figure 7 presents the status of available soil moisture to plants.

In phase one set stocking with cattle and running higher numbers of cattle would have reduced water infiltration. The grazing regime would have contributed to the development of sheet erosion and gully erosion on Colodan, particularly during intensive summer monsoonal rainfall on dry soils, which would have sheeted-off the steeper country as over land flows. In this phase set stocking would have limited the capacity for native grasses to slow such over land flows and would have limited the capacity capture rainfall where it fell.

In addition, efforts to transform the woodland, by killing and removing the trees, into grassland would have enabled higher numbers of cattle to be run on Colodan using set stocking.

In phase two the land manager continued to set stock with relatively high numbers of cattle, which reduced the capacity of native pasture to slow over land flows associated with summer monsoon rainfall events. This grazing regime would have limited the capacity for native grasses to slow such over land flows and would have limited the capacity capture rainfall where it fell.

In this phase the land manager initiated improvements in the cattle water supply and fencing to promote better pasture utilisation.

In phase three the land manager ceased set stocking, introduced rotational grazing and reduced cattle numbers, combined with resting pasture after it was grazed. Adoption and implementation of regenerative grazing land management resulted in greater standing biomass and greater capacity for the native grasses to slow over land flows associated with intensive summer rainfall events and improve the capacity to capture rainfall where it fell.

In phase four the land manager continued to run fewer cattle and introduced an intensive program of rotating cattle between paddocks to match available feed and cattle numbers, combined with longer resting of the pasture. This had the effect of generating higher levels of total standing dry matter (biomass) which again improved the capacity to capture rainfall where it fell especially during intensive summer rainfall events.

During this phase the land manager continued to use a warm season fire regime to achieve a balance between sustainable total standing dry matter (biomass) and improved pasture productivity. It is worth noting that the land manager observed mass regeneration of eucalypts on all land types, combined with continued improvements in P3 grasses (Productive, Perennial and Palatable).

In addition, during this phase the land manager observed improved clarity of the water in the creeks and water holes over and above that which was observed in phases two and three.

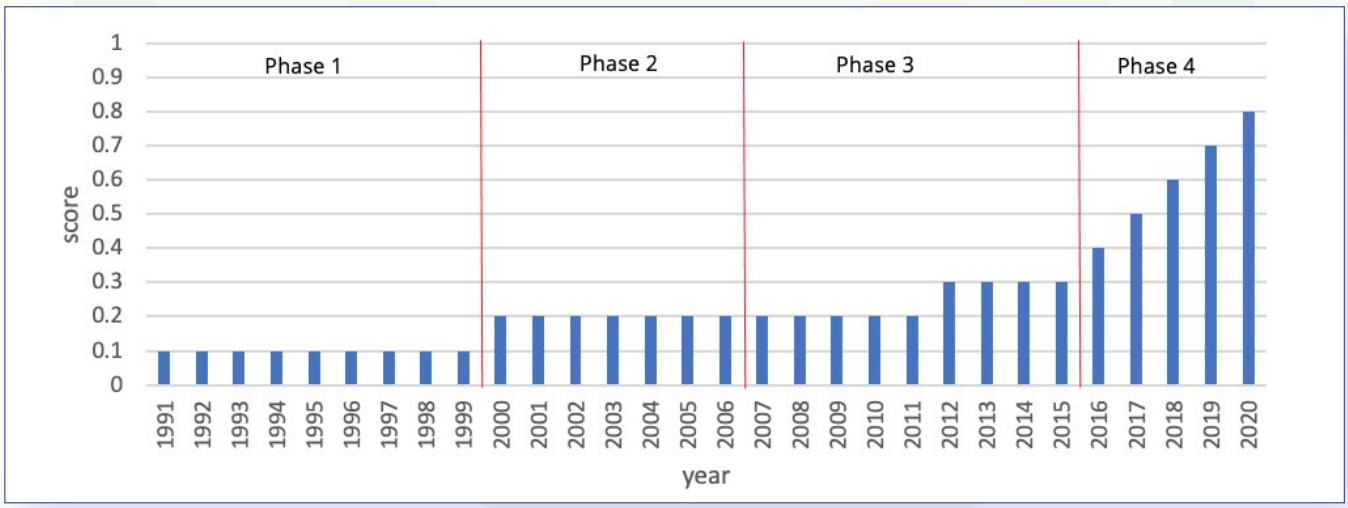


Figure 7. Status of available soil moisture to plants.

D. Status of soil biology - Soil biology

Figure 8 presents the status of available soil biology.

The observed trend in soil biology of the four phases is associated with available pasture biomass and changes in pasture condition.

In phase one a decrease in the function of soil biology is associated with decreased autumn rainfall (Appendix B).

The steady increasing trend in soil biology over the phases two, three and four reflect changed land management regimes including improvements in pasture utilisation (phase two: fencing and watering points), decreasing cattle numbers (phase two) and implementing

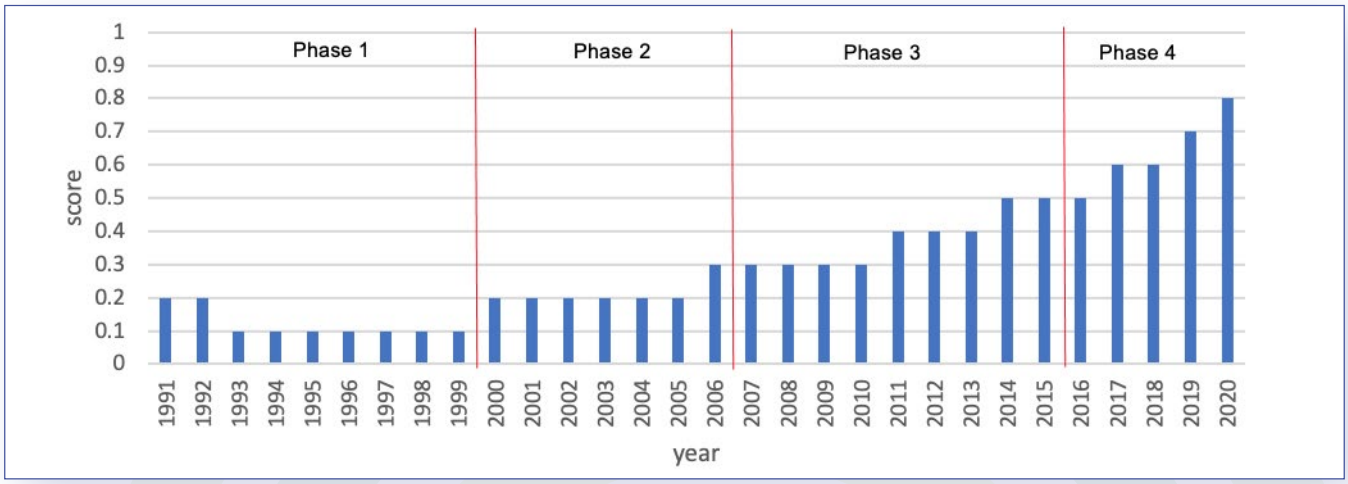


Figure 8. Status of available soil biology.

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

Figure 9 presents the status of soil physical properties.

Across the four phases, the function of soil physical properties has shown the least improvement of all 10 criteria. The land manager observed improvements in soil condition in phases three and four i.e. soil as a medium for plant growth.

These recent changes observed in Figure 9 are a response to changed land management regimes including implementing of rotational grazing combined with resting of the pasture after grazing (phases three and four). In addition, the use of a warm season (cool) fire regime has seen improvements in health and vitality of pasture grasses and legumes and observed mass regeneration of eucalypts.

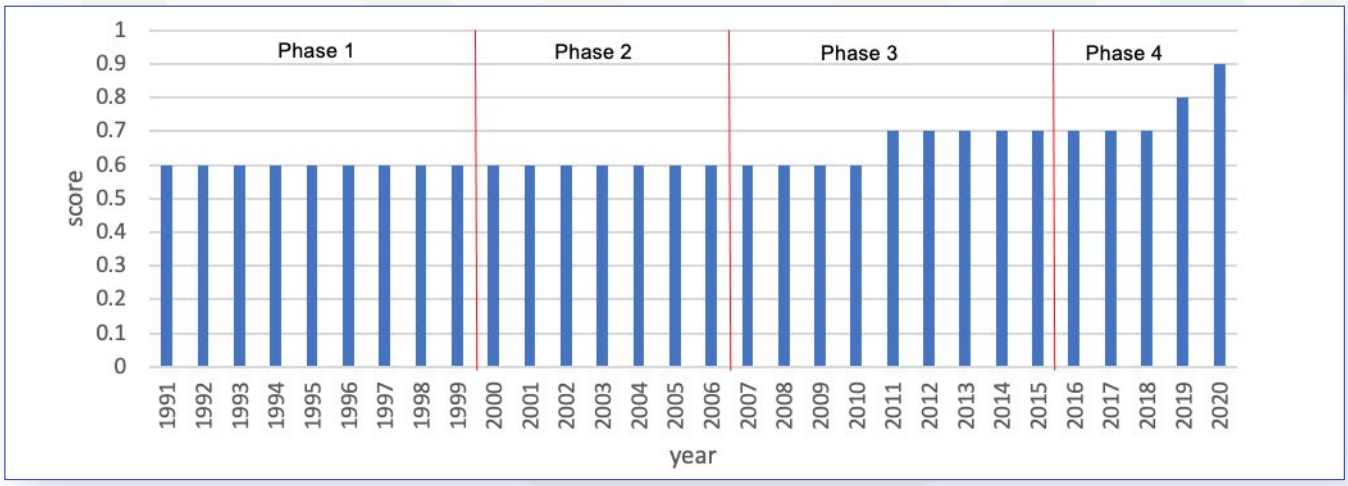


Figure 9. Status of soil physical properties

F. Status of plant reproductive potential

Figure 10 presents the status of pasture reproductive potential including that of introduced legumes as well as native and naturalized grasses.

In phases one and two Colodan had a long history of grazing land management and transforming the landscape from a woodland to a grassland. Despite repeated attempts to kill and remove trees from Colodan to promote pastures for grazing, most of land types have retained their regenerative potential of the tree layer. Changes in the overstorey structure is discussed below under criterion G 'Status of tree and shrub structural diversity and health'.

Legumes were established on Colodan by preparing the ground with a disc plough and seeding naturalised legumes with a combine seeder. Initially fine stemmed stylo (Stylosanthes guianensis var. intermedia) was established. Set stocking with relatively large numbers of cattle limited the productivity and reproductive potential of the stylo.

In phase three in response to changed land management regimes including implementing of rotational grazing combined with resting of the pasture after grazing the reproductive potential of the stylo was observed to be greater than that of native grasses. In addition, the use of a warm season (cool) fire regime has seen improvements in health and vitality of stylo and pasture grasses.

In phase four in response to changed land management regimes the reproductive potential of the fine stemmed stylo (Stylosanthes guianensis var. intermedia) was observed to be greater than native grasses. Noting this improved performance of stylo compared to grasses the land manager introduced an additional three species of stylo to Colodan's pastures: seca or shrubby stylo (Stylosanthes scabra); Amiga stylo (Stylosanthes hamata); and Progardes® Desmanthus (Desmanthus virgatus). Stylo pastures are a deep rooted protein rich fodder, which grow later into the dry season and can produce significantly more feed than normal native pastures. Stylos introduced to Colodan vary in growth form from a prostrate to semi-erect, herbaceous, annual or short-lived perennial to erect perennial herbs or small shrubs. The land manager uses a small electric seed spreader mounted on quad bike to distribute the stylo seed into the ash bed of the pasture grasses burnt using a warm season (cool) management regime.

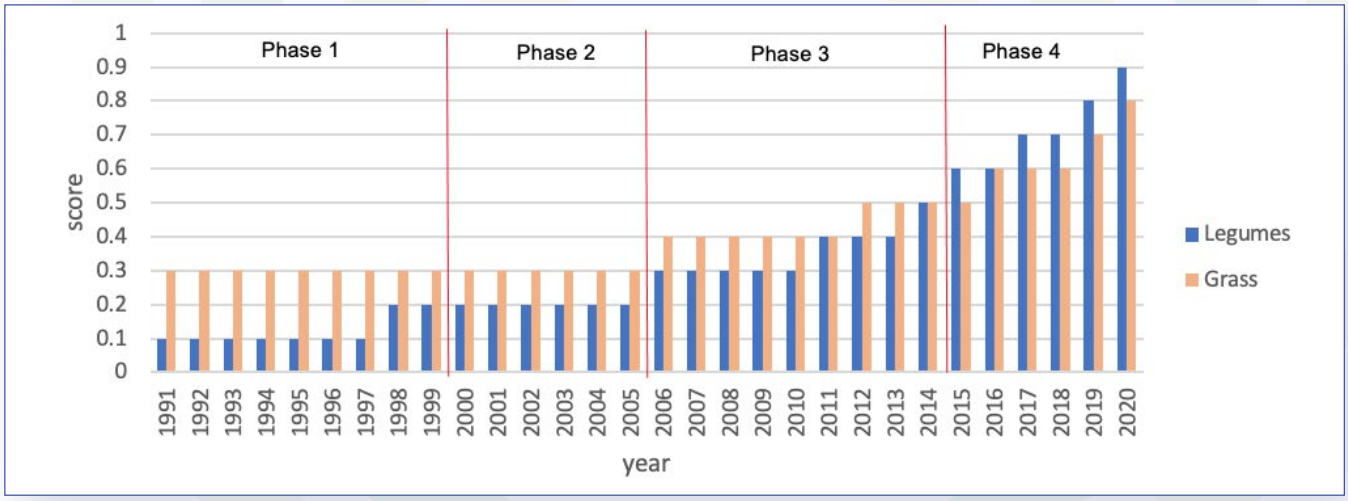


Figure 10. Status of pasture reproductive potential of legumes and grasses

G. Status of tree and shrub structural diversity and health

Figure 11 presents the status of the structure of shrubs and trees.

In phase one the passing of the Upper Burnett and Callide Land Settlement Scheme in 1923 was instrumental in transforming the woodlands in the Colodan district https://queenslandplaces.com.au/monto. Critical to the scheme was a railway through the Monto district where large pastoral leaseholds established in the early 1950s would soon expire.

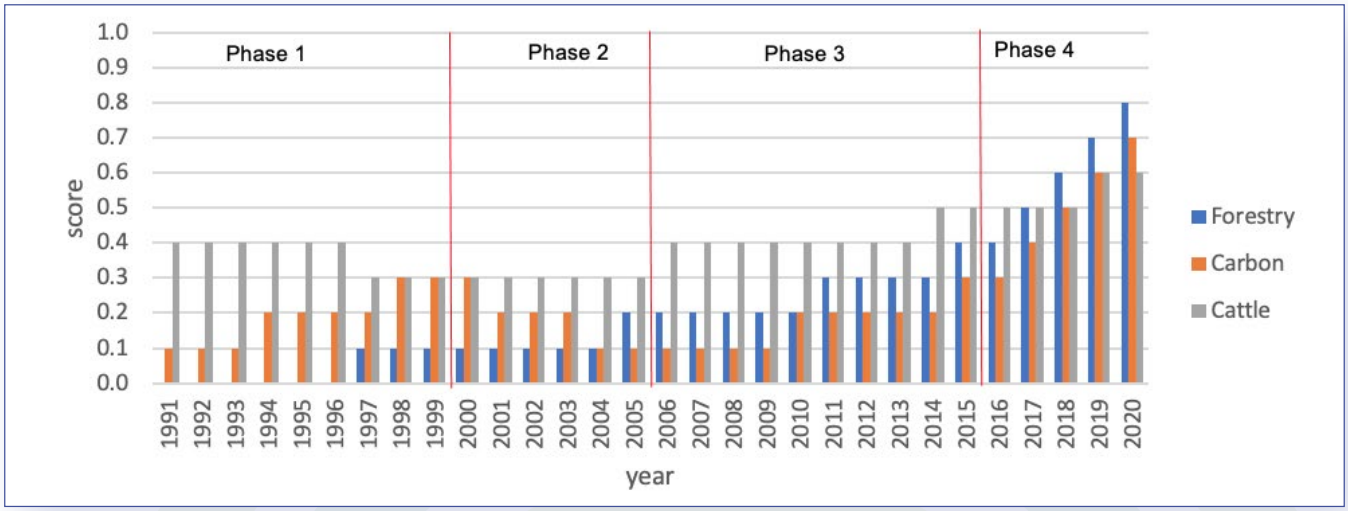


Figure 11. Status of the structure of shrubs and trees for the three main enterprises cattle, forestry and carbon

In this phase trees were seen as an impediment to pastoral development and when considered as timber, the resource was thought of as virtually inexhaustible (Powell 1998). Ringbarking was used as a quick and cheap method of clearing pastures of timber without the costs of cutting and removing timber (Powell 1998). The effect of ringbarking was to increase the quantity of grass available for grazing animals (sheep and cattle).

In the 1930s James Henderson's grandfather commenced ringbarking the trees on Colodan as part of the Upper Burnett and Callide Land Settlement Scheme.

In this phase selected large mature trees mainly blue gum (*Corymbia tessellaris)* were harvested and sold as saw logs.

By the 1960s chemical stem injecting trees with tordon was introduced to kill trees and to control the subsequent woody regrowth. The effect of this repeated killing and controlling of regrowth was that large areas of Colodan's original woodlands were converted to open woodland and grasslands.

In phase two the land manager continued injecting trees with tordon to kill trees and control woody regrowth. Killing trees and controlling of regrowth in this phase maintained Colodan as a transformed landscape of open woodland and grasslands.

In phases three despite changes in land management regimes including implementing of rotational grazing combined with resting of the pasture after grazing the land manager observed minimal regeneration of eucalypts on all land types.

In phase four it is estimated that almost 80% of the area of Colodan has been cleared or thinned of its original woodland cover (Table 2). The largest land type found on Colodan is Narrow-leaved ironbark on ranges (2216 ha), by 2014 almost 2100 ha (95%) had been treated to control and remove trees with only 117 ha (5%) remaining unmodified as a woodland.

Table 2. Reductions in the extent of tree canopy cover on Colodan that has been modified from a pre-clearing reference state.

	Reference state	Reductions from reference state		Unmodified in 2020	
Woodland land types	**Total (ha)**	**ha**	**%**	**ha**	**%**
Narrow-leaved ironbark on ranges	2216	-2099	-94.7	117	5.3
Silver-leaved ironbark on duplex	1134	-756	-66.7	378	33.3
Blue gum / river red gum flats	1050	-609	-58	441	42
Eucalypts and bloodwood on clay	256	-181	-70.7	75	29
Narrow-leaved ironbark woodlands	4	-3	-75	1	25
Totals	**4660**	**-3648**	**-78.2**	**1012**	**21.7**

The areas of modified woodland area and percentages shown in Table 2 were calculated from Table 3. Table 3 shows the Foliage Projective Cover reference state for each land type as it would have been in its pre-clearing state (i.e. grey shaded cells). For example, the pre-clearing area of Narrow-leaved ironbark on ranges was 2216 ha. Over phases one, two and three this woodland land type has been transformed for grazing land management with around 94% of the area now present as <30% FPC; the majority of which is <15% FPC (61.2% of the area).

Table 3. Foliage Projective Cover (FPC) for Colodan showing the reference state foliage projective cover for each land type (green shading)

Source: http://www.longpaddock.qld.gov.au/forage

Expected land type (for land types > 1 hectare)	Code	Land type area (ha)	FPC <15: ha & (%)	FPC 15-30: ha & (%)	FPC 30-50: ha & (%)	FPC 50-70: ha & (%)	FPC >70: ha & (%)	Reference state/ Benchmark (FPC%)[3]
Narrow-leaved ironbark woodland on ranges RE 11.12.1	FF20	2216	1356 (61.2)	743 (33.5)	117 (5.3)	< 1(<1)	< 1(<1)	35
Silver-leaved ironbark woodland on duplex RE 11.12.2	FT28	1134	599 (52.8)	378 (33.3)	152 (13.4)	6 (<1)	< 1(<1)	20
Blue gum / river red gum woodlands on flats RE 11.3.4	FT02	1050	520 (49.5)	441 (42.0)	88 (8.4)	< 1(<1)	< 1(<1)	17
Eucalypts and bloodwood woodland on clay RE 11.3.25	FT13	256	177 (69.3)	75 (29.1)	4 (1.6)	< 1(<1)	< 1(<1)	22
Narrow-leaved ironbark woodlands RE 11.7.6	FT22	4	**< 1 (<1)**	1 (29.3)	3 (70.7)	< 1(<1)	< 1(<1)	50
Total		**4659**	**2653 (56.9)**	**1638 (35.1)**	**363 (7.8)**	**6 (0.1)**	**0 (0)**	

[3] Queensland Herbarium (2019a) https://www.qld.gov.au/__data/assets/pdf_file/0026/67391/brb-benchmarks.pdf

In phase four the priorities of the land manager involve managing the transformed woodland landscape on Colodan for multiple benefit outcomes; forestry, carbon and cattle. In addition, where practical, the land manager also manages the regenerating woodland as habitat for arboreal mammals. Fenced riparian strips have been modified by replacing the two top wires from barbed wire to plain wire to minimise harm to greater gliders.

In phase four based on a knowledge of how and where the landscape has been transformed from the former woodland (Table 2 and 3 and Figure 12) James Henderson's has embarked on managing the thinned and cleared woodlands as a carbon sequestration project under scheme titled Human Induced Regeneration. This involves legally binding agreements for a 25 year period under the Australian Government's Carbon Farming Initiative. In addition, James is also managing another area of Colodan as another carbon project: Avoided Clearing. Both carbon projects involve Green Collar as the proponent.

An additional carbon project is being investigated which involves rehabilitating small areas where the soil condition was historically degraded in phase one through the grazing habits and movements of sheep. The aim of this soil carbon project is in the longer term to promote the reestablishment and natural regeneration of trees. Currently trees do not readily re-establish on these areas.

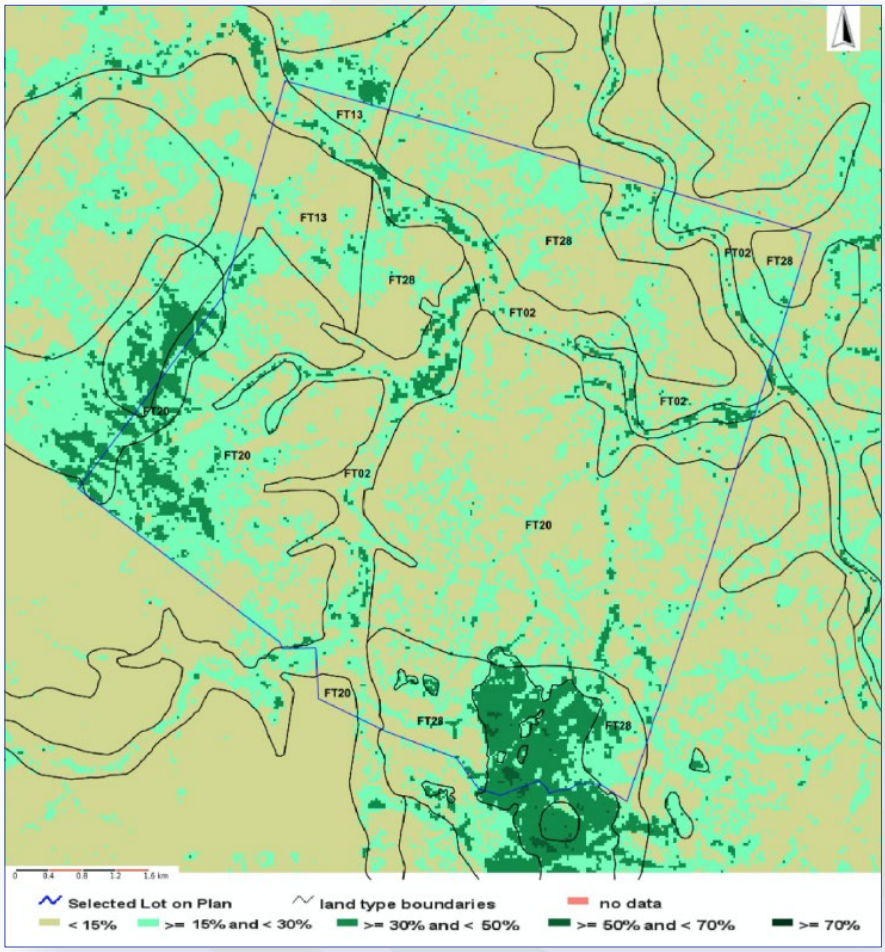


Figure 12. Extent of Foliage Projective Cover (FPC) class interval found on Colodan in 2014.

H. Status of grass and herb structure - ground cover

Figure 13 presents the status of ground layer structure.

The observed trend in grass and herb structure - ground cover over the four phases reflects available pasture biomass.

In phase one a decrease in the function of soil biology is associated with decreased autumn rainfall (Appendix B, Graph 4).

The steady increasing trend in ground cover over the phases two, three and four reflect changing land management regimes including improvements in pasture utilisation (phase two: fencing and watering points), decreasing cattle numbers (phase two) and implementing of rotational grazing combined with resting of the pasture after grazing (phases three and four).

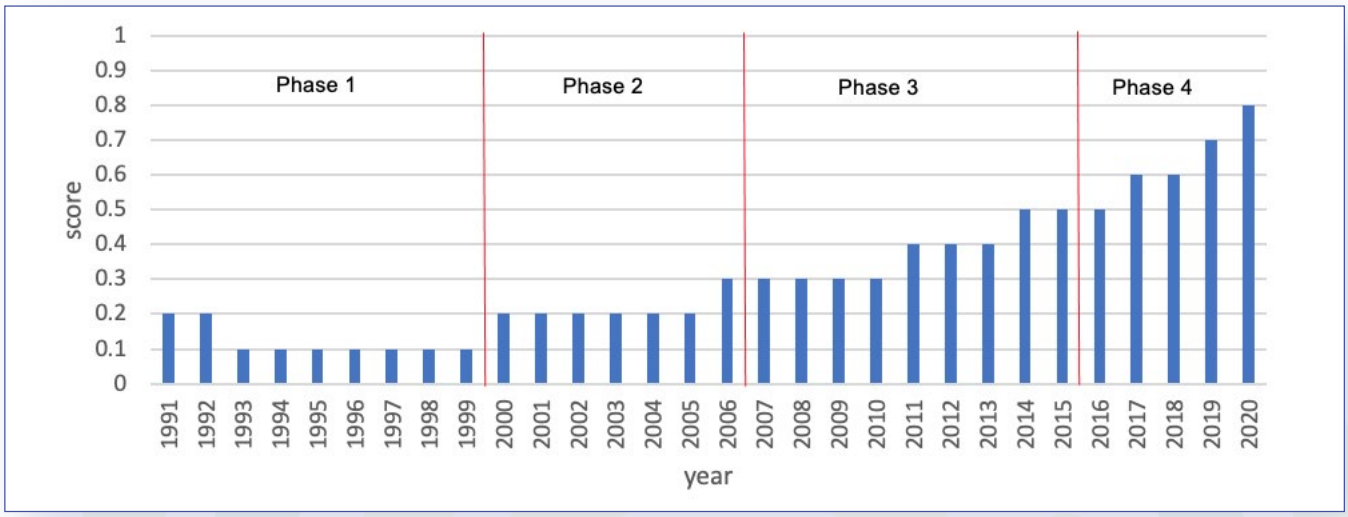


Figure 13. Status of ground layer structure

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

Figure 14 presents the status of shrub and tree composition regeneration.

The observed trend in tree and shrub species richness and functional traits over the four phases reflects changes in the way trees and valued across Colodan.

The steady increasing trend in species richness and functional traits over the phases two, three and four reflect changing land management regimes including improvements in pasture utilisation (phase two: fencing and watering points), decreasing cattle numbers (phase two) and implementing of rotational grazing combined with resting of the pasture after grazing (phases three and four). Under these changing land management regimes the richness and functional traits shrubs and trees across Colodan has been able to improve.

Achieving the balance between trees and pasture is James Henderson's the overarching vision.

Where historically woodland trees were undesirable and largely incompatible with pasture productivity (phases one, two and three) James Henderson's management of Colodan is showing that rotational grazing, combined with longer paddock rests, is enabling a rapid transition from a grass dominated ecosystem with few trees, to a landscape where eucalypt regeneration is being enabled as an integral part of regenerative land management. Promoting structural diversity is a key component of how the regenerating trees on Colodan are being managed.

In phase four the land manager is actively managing the natural richness and functional traits of the former woodland to promote a balance between multiple benefit outcomes; forestry, carbon and cattle. In some areas of Colodan this involves reset harvesting (selective thinning) to promote the goals of forestry and carbon. The timeframe for achieving both these goals is 25 years. This period reflects both the time it takes to grow a millable tree and the contracted period for a carbon project.

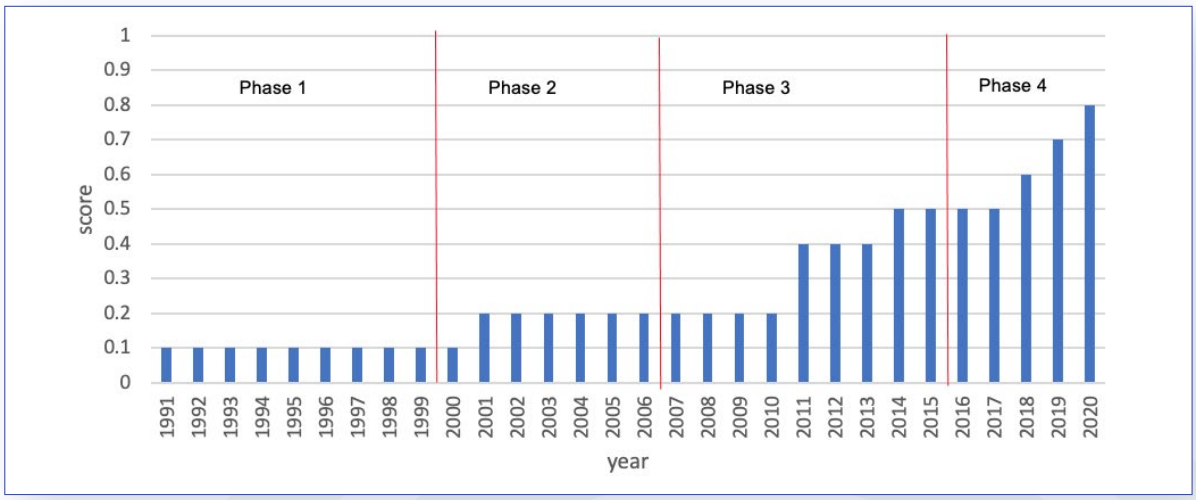


Figure 14. Status of shrub and tree composition regeneration

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

Figure 15 presents the status of the ground layer composition.

In phases one and two the land management regimes resulted in relatively low responses for grass and herb species richness and functional traits which is largely a reflection of the set stocking of Colodan.

Commencing in phase 3 and continuing into phase 4 there is a relatively rapid increase in responses for grass and herb species richness and functional traits reflecting changing land management regimes. These changes include implementing rotational grazing combined with resting of the pasture after grazing (phases three and four) and the re-introduction of a warm season fire regime. This regime burns off dead rank grass and promotes pasture productivity over the summer monsoon period (Figure 1 and Appendix C). Such warm season (cool) fires create an ash bed, do not kill the perennial grass plants and promote the germination of native herbs and forbs. Importantly this fire regime does not scorch tree crowns or adversely impact to the soil biology.

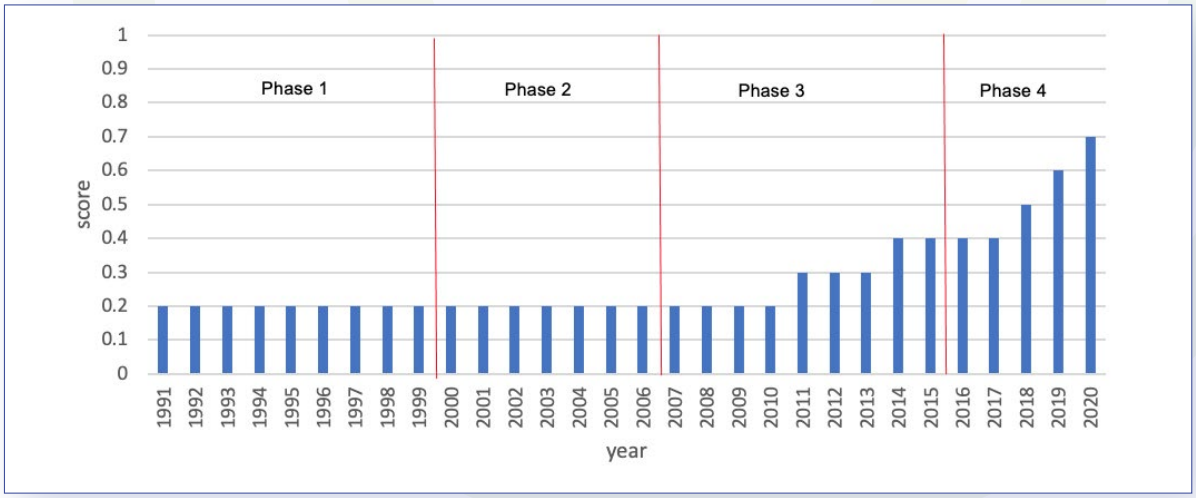


Figure 15. Status of ground layer composition regeneration.

Independent Scientific Assessment

An independent assessment was used to validate the land manager's self-assessment of the graphical ecological responses derived using the structured expert elicitation approach. This involved comparing pattern and trend from the land manager's graphical ecological responses against almost 30 years of Landsat satellite derived land cover metrics within the property and compared to the surrounding district (Appendix D).

A. Ground cover

It is widely accepted that changes and trends in per cent ground cover is a response to rainfall patterns as well as land management regimes (Thackway et al. 2013). The annual rainfall anomaly for Colodan is shown in Appendix B. That shows well-below average rainfall occurred in the following years: 1991, 1993-94, 2001-02, 2006, 2009, 2014, 2016 and 19. Where well-below average is defined as greater than 0.5 standard deviation below the mean.

Ground cover within Colodan was compared to the surrounding properties for the years 1991-2019 using the method outlined in Appendix D. Over this period ground cover on Colodan remained predominantly above 50% (Figure 16). During the period of the Millennium Drought (1996 – 2009) ground cover in the period 1996-1999 averaged around 65% and between 2000-09 ground cover average around 50.6%. As noted above, during this period the annual rainfall anomaly showed a reasonably even distribution (Figure 16) except there was an obvious rainfall deficit in autumn over this period (Appendix B), however that deficit was compensated by above average rainfall in winter and spring (Appendix B).

Figure 16 shows that in the years after the Millennium Drought, ground cover has averaged 74.8%. This period coincides with the Phases 2-4 in the land management chronology (Appendix A) when the land manager was implementing regenerative land management regimes including:

- Initiating improvements in the cattle water supply and fencing to promote better pasture utilisation;
- Reducing cattle numbers per hectare in each paddock; and
- Implementing an intensive program of rotating cattle between paddocks to match available feed and cattle numbers.

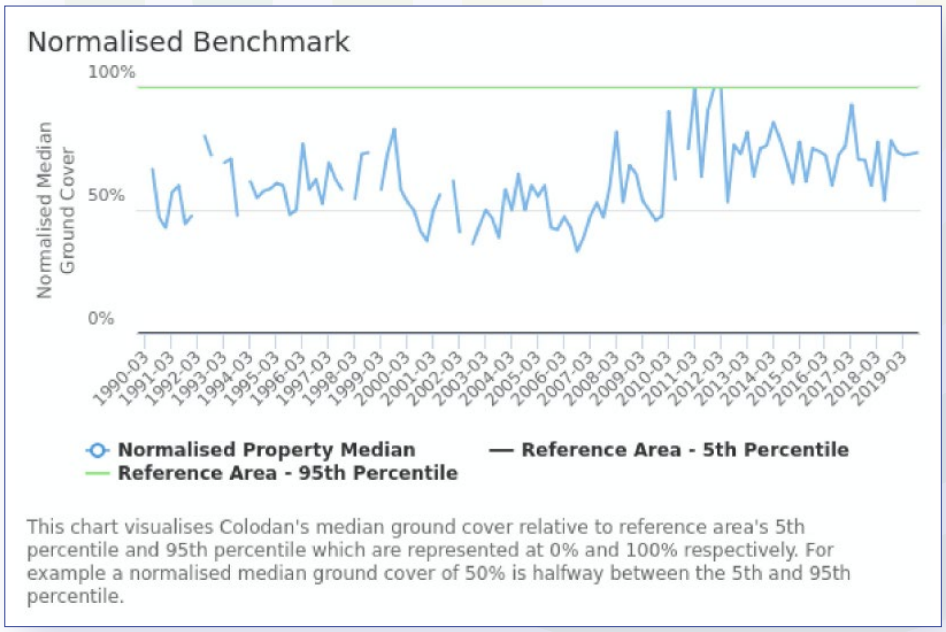


Figure 16: Colodan 's median ground cover relative to reference area's 5th and 95th percentile which are represented at 0% and 100% respectively. For example, a normalised median ground cover of 50% is hallway between the 5th and 95th percentile.

This analysis confirms that the 'Status of ground cover (Figure 13), supplied by the land manager, is regeneratively managed. It is also worth noting that the amount of ground cover and its persistence over time affects the performance of several other functional ecological criteria. This includes the first five criteria discussed above:

- Resilience of landscape to natural disturbances (Figure 5)
- Status of soil nutrients – including soil carbon (Figure 6)
- Status of soil hydrology (Figure 7)
- Biological activity in the soil (Figure 8)
- The physical properties of the soil (Figure 9)

B. Woody plant cover

An independent assessment of the extent of woody plant cover on Colodan was assessed relative to 1990 using the method outlined in Appendix D. Figure 17 shows the area of woody vegetation on Colodan since 1991. In the 11 years commencing in 1992 the total cover of woody vegetation on Colodan decreased from 1547ha to 1043ha. This was in response to the use of tordon (picloram), a land management practice, that was used to kill regrowth eucalypts (Appendix A).

Since 2010 the area of woody vegetation has increased from 1062ha to 1990ha in 2019 (Figure 17).

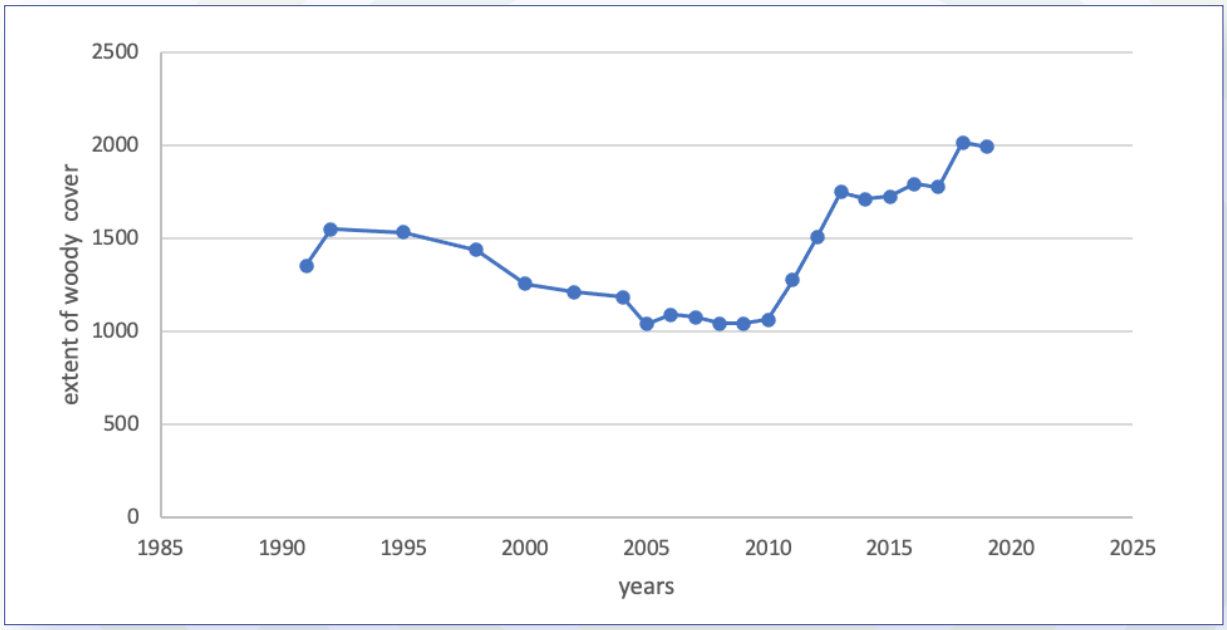


Figure 17. Area of woody vegetation recorded on Colodan using Landsat imagery and Montreal definition of a forest.

This analysis confirms the land manager's assessment of 'The extent of tree cover' Figure 11 that tree cover on Colodan is gradually increasing in line with the management of woody cover for multiple benefit outcomes including forestry, carbon and cattle production. Increases in total woody vegetation is made up from a natural process of thickening and infilling i.e. the conversion of extant native woodland to open forest. In addition, this increase of woody cover is a natural process of incursions of new trees into areas that previously managed as open pasture. It is important to note that at the time of European settlement the whole of Colodan was a grassy woodland landscape (Figure 2).

Future enterprise opportunities

With cattle, timber and carbon enterprises in place the Henderson family are looking for future enterprise opportunities. They have a vision to build on the condition, natural beauty and biodiversity values of Colodan's native vegetation as a business potential. Armed with an understanding the condition of ecosystems across Colodan (Figure 3), the Henderson's are seeking strategic investment opportunities and partners to invest in the potential of well-managed natural landscapes. Independent field surveys (Knott 2020) have confirmed that the Regional Ecosystems 11.3.4 Blue gum / river red gum woodlands on alluvial plains and RE 11.3.25 Eucalypts and bloodwood woodland fringing drainage lines on clay soils (Figure 2) have high potential for attracting biodiversity credits.

Conclusions

In the years prior to 2000 Colodan was managed by the Henderson family using conventional land management regimes. During phases one and two the extent and density of tree cover on Colodan was actively reduced, by chemically killing trees. The intent was to promote the productivity of pastures on Colodan and improve cattle production.

Commencing in 2000, in phase, two the Henderson family commenced implementing regenerative land management regimes in managing Colodan. This involved making improvements in the water supply and fencing to promote better pasture utilisation. During phase three the Henderson's gained a knowledge of pasture utilisation and cattle weight gain and as a result James Henderson began reducing cattle numbers per hectare in each paddock. Commencing in 2016, phase four, an intensive program of rotating cattle between paddocks to match available feed and cattle numbers was implemented.

James Henderson's journey on Colodan shows that regenerative landscape management is a continuous learning process where engaging with other innovators is key. Examples of this include; 1) seeing trees as an asset rather than a liability – James Henderson changed his understanding of trees precisely because he realised that trees effectively managed represent profitable income streams, both as saw log production and carbon sequestration. As a keen naturalist James Henderson has begun to see and appreciate the benefits of maintaining trees as habitat for the diverse range of reptiles and mammals found on Colodan. 2) recognising the benefits that fast moving grass fires (cool burns) provide multiple benefits outcomes for his three enterprises; forestry, carbon and cattle.

An independent ecological assessment has highlighted the importance of a local land manager understanding, planning for, and implementing well-informed land management regimes that aim to achieve sustainable ecological outcomes. This assessment supports the conclusion that Colodan is an outstanding example of regenerative landscape management.

Key Learnings

- Establish fencing and water points to best utilise the feed on offer in each paddock
- Gain a knowledge of pasture utilisation and cattle weight gain and begin to reduce cattle numbers per hectare in each paddock; maintain high levels of ground cover
- Establish an intensive program of rotating cattle between paddocks to match available feed and cattle numbers; maintain high levels of ground cover
- Recognise trees as an asset rather than a liability. Appropriately managed, trees can provide two additional income streams; saw log production and carbon sequestration
- Recognise that fast moving grass fires (cool burns) provide multiple benefits outcomes for forestry, carbon and cattle production

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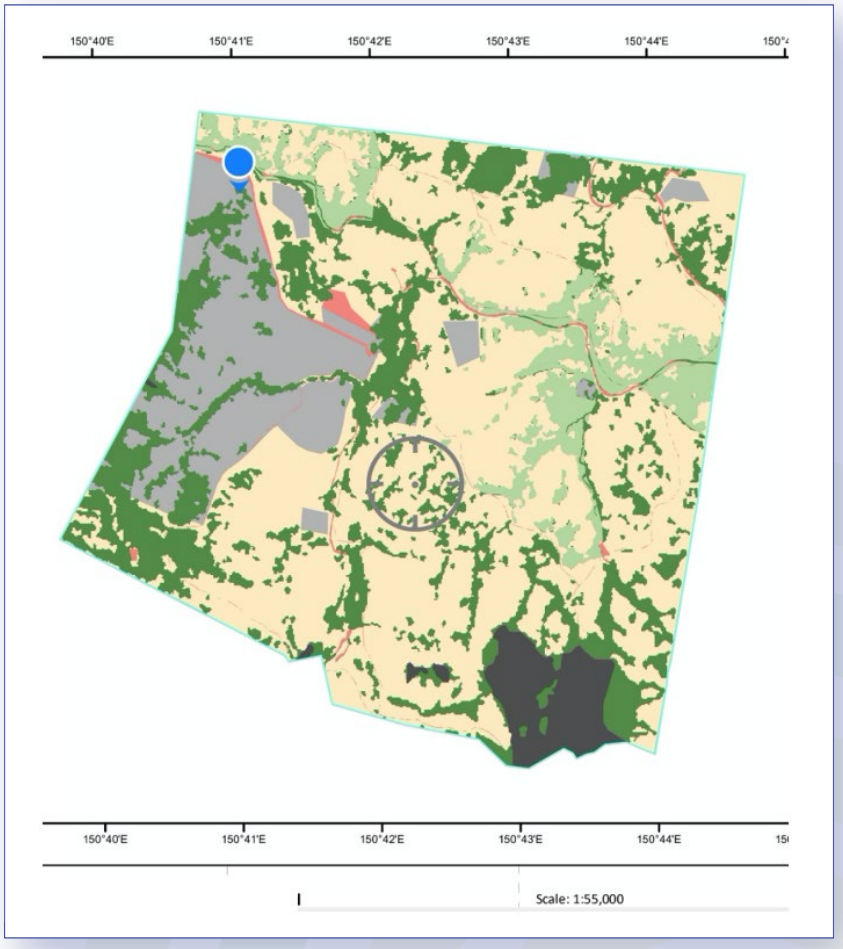
Appendix A

Chronology of land management regimes and practices

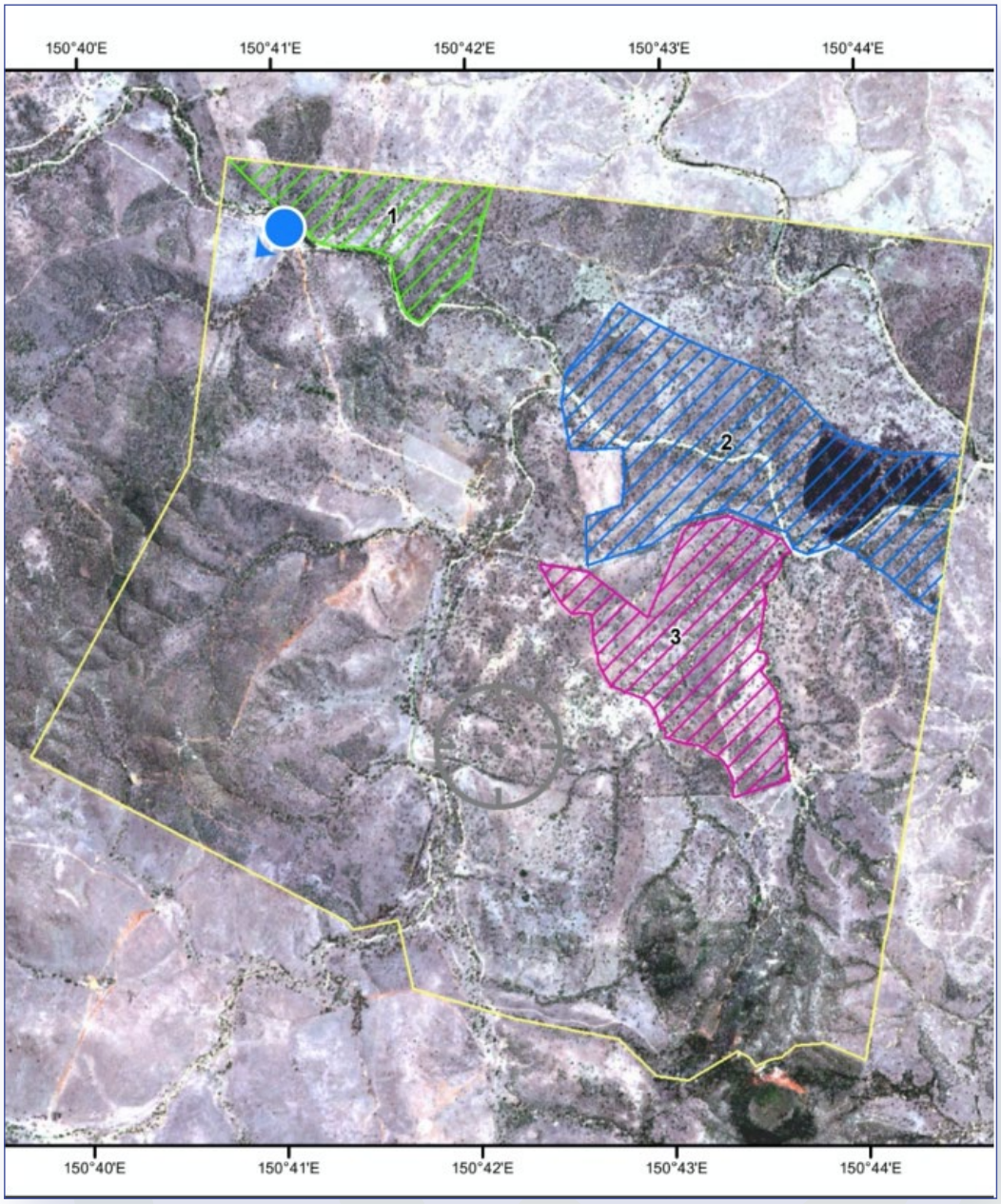
The following chronology was developed in discussions with the land manager: James Henderson.

The Phases of agricultural production were added after the chronology was completed.

Phase one: 1870s- 1999
• Conventional management practices.
• Ring barking and chemical stem injecting with tordon to killed trees and controlling woody regrowth
• Harvested mature trees for saw logs
• Set stocking initially with the sheep and later with cattle
• Annual grass fires used to promote pasture growth
• Before 1991 tordon (picloram) was used to successfully kill regrowth eucalypts
• 1994 a major drought. Was using urea and set stocking. Major effect on the condition of the pasture
• 1994-2010 ceased using fire to manage the pasture quality
• mindset shift management burns (controlled fire) was used to manage the pasture quality
• 1998 started of mindset shift looking for different approaches and solution with Resource Consulting Services (RCS) and Meat and Livestock Australia (MLA) and attending field days
• 2000 Purchase of new property disjunct from Colodan
• 1999-2006 continued to use tordon (picloram) to kill regrowth eucalypts
Phase two: 2000 – 2006
• Continued use of injecting trees with tordon to kill trees and control woody regrowth
• Initiated improvements in the cattle water supply and fencing to promote better pasture utilisation
• John Henderson maintained low debt
• James Henderson started to work at Colodan
• James Henderson becomes a partner in Colodan
• James becomes the senior partner in James and Kylie Cattle become partner in Colodan
Phase three: 2007 - 2015
• Reduced cattle numbers per hectare in each paddock
• Improved the genetic stock of the cattle
• Commenced using fast moving grass fires (cool burns)
• 2010 began to implement the mindset shift
• 2011 wildfire?? impact the property
• Obvious mass regeneration as a result of increased rotation and long paddock rests
• Reintroduced low intensity cool burns to manage the pasture quality
Phase four: 2016 - 2020
• Commenced intensive program of rotating cattle between paddocks to match available feed and cattle numbers
• Started two carbon projects (Avoided Clearing and Human Induced Regeneration) with GreenCollar as the project proponent (akin to a share farmer)
• Pasture dieback possibly caused by mealy bug



LEGEND	PRIMARY LAND MANAGEMENT REGIMES	DESCRIPTION	COMMENT RE CARBON PROJECTS
	Cattle grazing + Timber harvesting of lower value wood products and Low volume Niche species.	Forest (70% original height and 50% of original cover) NCAS 20% canopy and more than 2m in height	Outside the carbon footprint project areas
	Cattle grazing + Carbon sequestration (trees)	Forest (70% original height and 50% of original cover) NCAS 20% canopy and more than 2m in height	Avoided Clearing project (GreenCollar Proponent)
	Cattle grazing +Future Timber harvesting + Carbon sequestration (trees)		Human Induced Regeneration (GreenCollar Proponent)
	Cattle grazing + areas removed from carbon project, creeks, roads, biosecurity zones etc.		Outside the carbon foot-print projects
	Cattle grazing + + Potential soil carbon sites ie number of small areas suitable for WASCA		Outside the carbon foot-print projects
	Cattle grazing + Protection of remnant vegetation + Timber harvesting of high value wood products	Forest (70% original height and 50% of original cover)	Outside the carbon foot-print projects



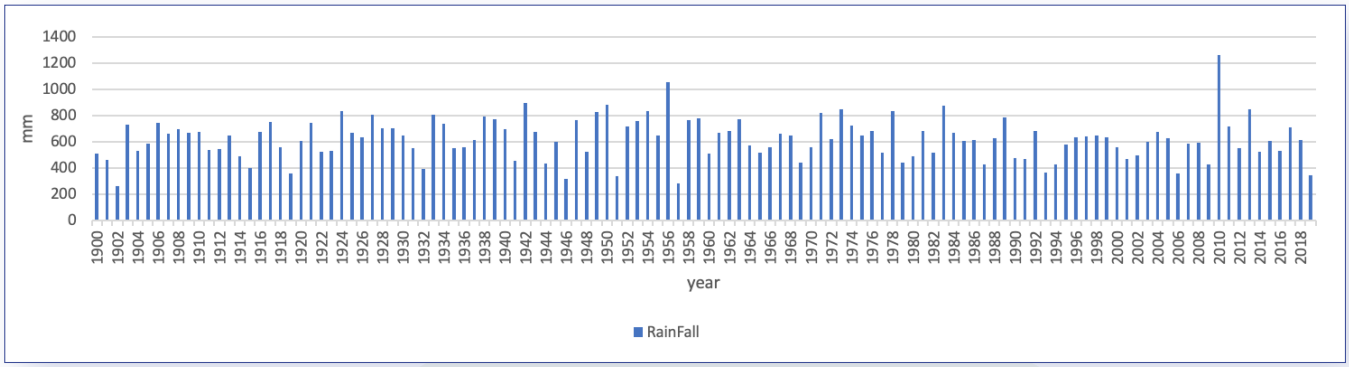
Scale: 1"55,000

Coordinate System: GDA 1994 MGA

LEGEND	PRIMARY LAND MANAGEMENT REGIMES	DESCRIPTION	COMMENT
Zones 1-3	Cattle grazing + Carbon sequestration (trees)	Avoided Clearing project areas (GreenCollar Proponent)	Mapped areas for potential Avoided Clearing from historical records. Dating back to 1986 where a cycle of clearing is clearing demonstrated.

Appendix B

Colodan rainfall information[5]



Source: Bureau of Meteorology

Figure 18. Annual modelled rainfall for Colodan.

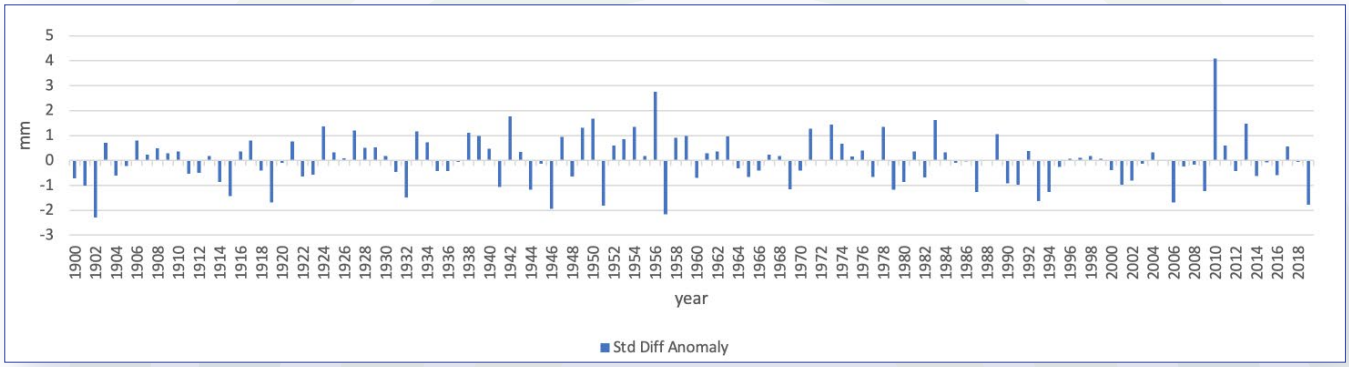


Figure 19. Annual rainfall anomaly above and below the mean for annual rainfall.

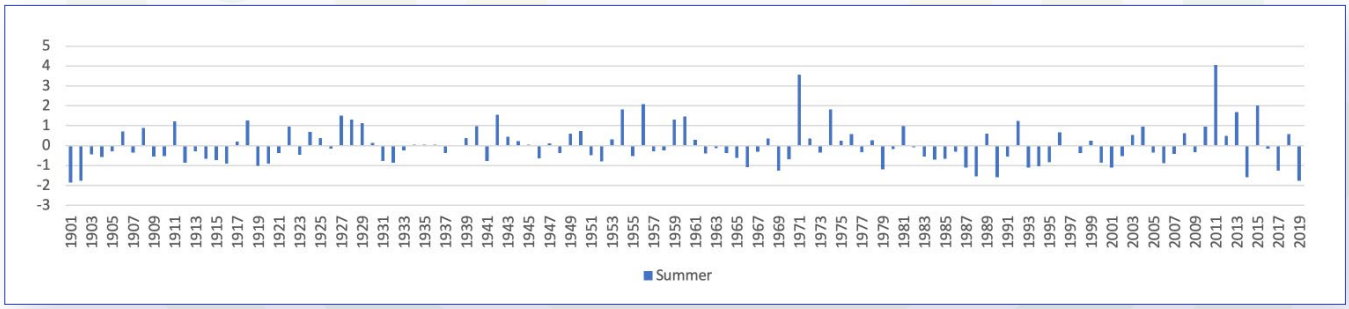


Figure 20. Seasonal rainfall anomaly above and below the mean for summe

[5] (BOM modelled rainfall) 5km x 5km national grid

Appendix B

Colodan rainfall information[5]

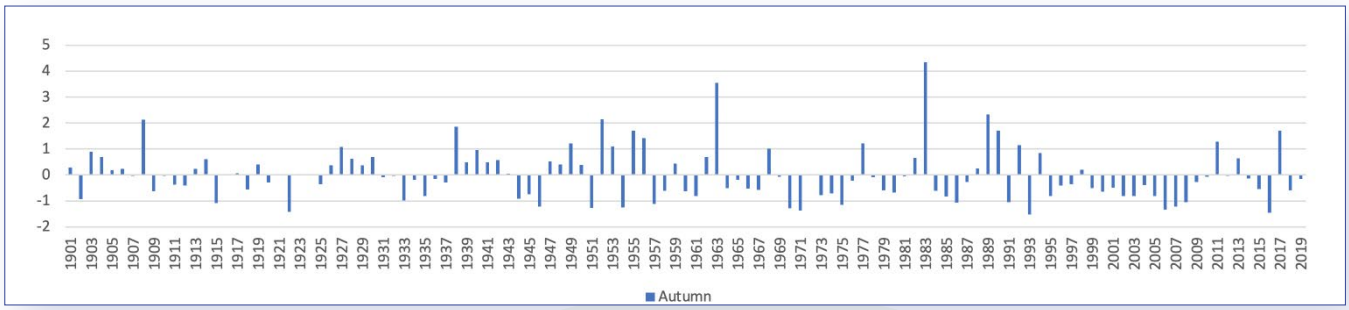


Figure 21. Seasonal rainfall anomaly above and below the mean for autumn

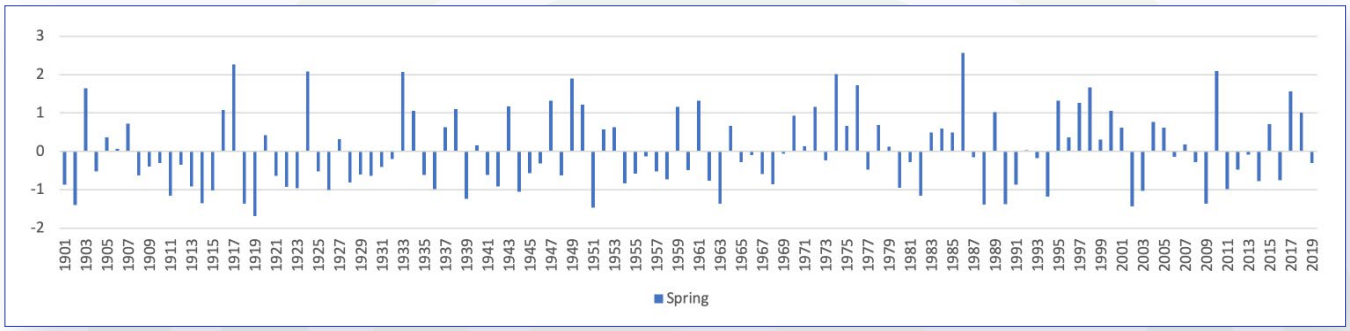


Figure 22. Seasonal rainfall anomaly above and below the mean for winter

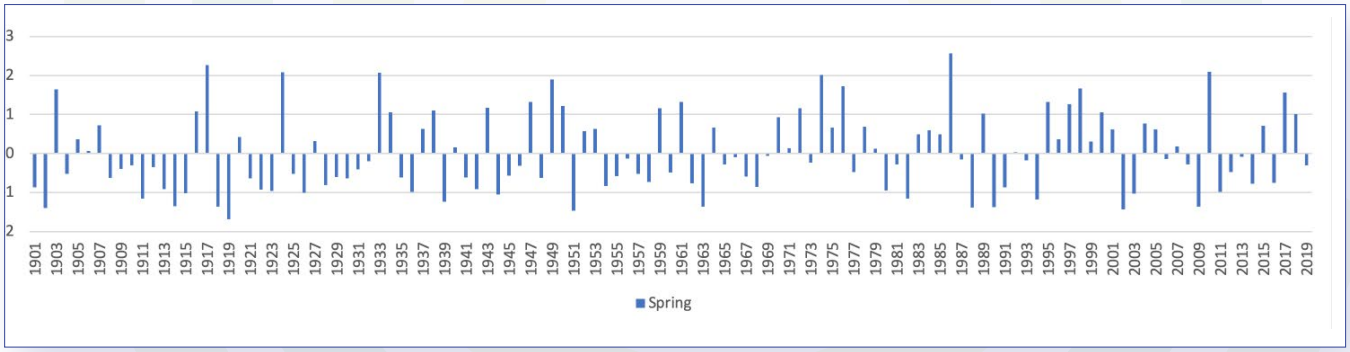
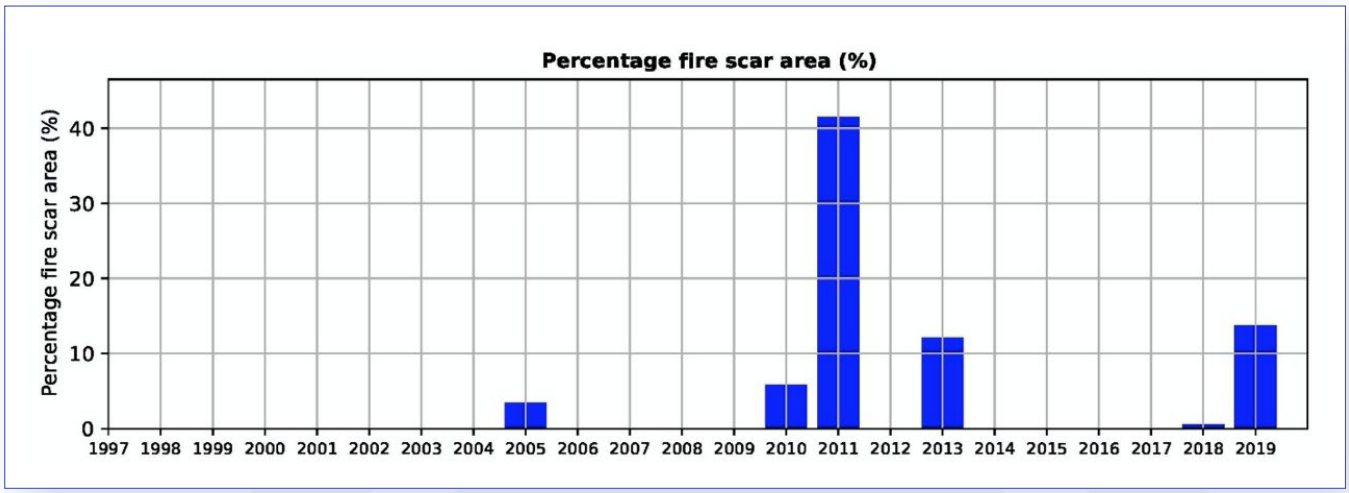


Figure 23. Seasonal rainfall anomaly above and below the mean for spring

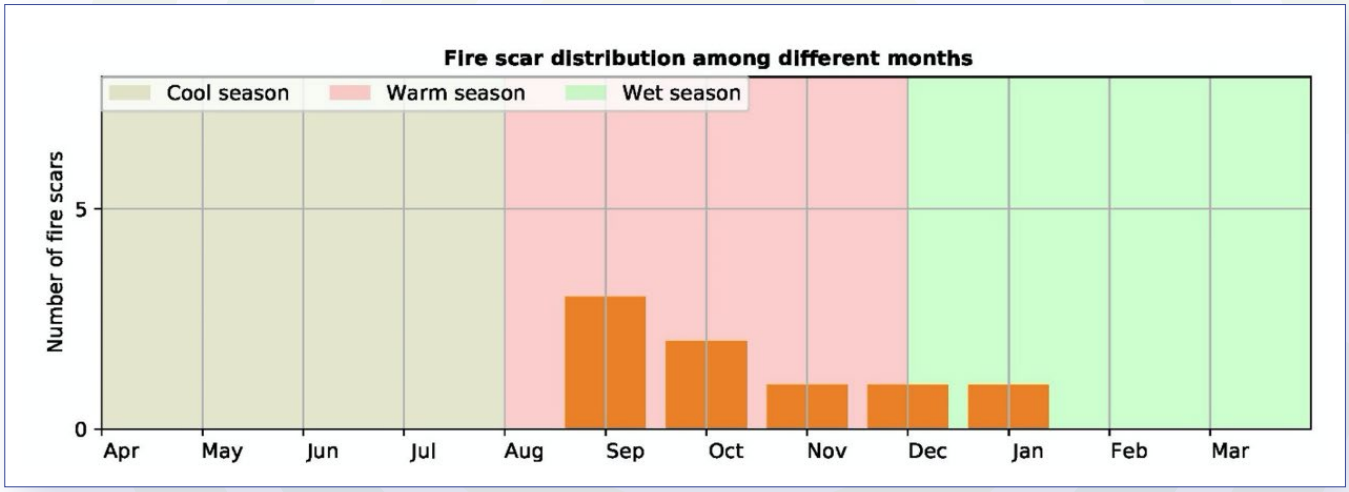
Appendix C

Aspects of the fire regime for Colodan including extent of burnt area in each year (Figure 21) and the number of fires recorded in each season (Figure 22).



Source: http://www.longpaddock.qld.gov.au/forage

Figure 24. Percent area of Colodan burnt in each year from 1997 to 2019.



Source: http://www.longpaddock.qld.gov.au/forage

Figure 25. Seasonal burning on Colodan for all years.

Appendix D

SFL used an online subscription-based service developed Cibolabs Pty (Myfarmkey) to assess the land manager's self-assessment of the response s of the ecological criteria discussed above. This method is presented below.

Myfarmkey is a toolkit for rapidly characterizing and benchmarking the performance of a property or land parcel/s. The Myfarmkey online toolkit integrates several national geospatial datasets including current high resolution visual satellite imagery, national land parcel cadastre, cartographic map, time-series ground cover and woody plant cover, property names, land types, bioregional coverages (sub-IBRA regions).

The Myfarmkey online toolkit utilises ground cover and woody plant cover data and information products derived from time-series Landsat satellite data 1990 to the present time using widely accepted standardized and calibrated land cover metrics. These time-series products are regularly updated for the whole of Australia. These information products include ground cover (e.g. pastures and crops) and woody plant cover (woodlands and forest). The resolution of these information products is 30mx30m. The time-series commences in 1990 and represents the baseline and extends to the current year. The information products use national standardized definitions for ground cover (Stewart et al. 2011; Thackway et al. 2013) and forest (Montreal Process Implementation Group for Australia and National Forest Inventory Steering Committee 2018).

It should be noted that young shrubs and trees cannot be detected using Landsat imagery until these growth forms reach around 10 years old, i.e. when the projective foliage cover is greater than the understorey ground cover.

The geographic footprint of the property was saved within the Myfarmkey online toolkit. The property footprint was then benchmarked against selected land parcels in the neighbourhood and district. In the case of Colodan we used a fixed buffer surrounding the property (5 km). Where land parcels did not share the same broad land cover classes i.e. pasture and cropping these land parcels were deleted from this fixed width buffer.

The Colodan property footprint and the reference land parcels was saved within the Myfarmkey online toolkit and a report was generated. The report includes GIS coverages of the land parcels within the property footprint and the reference land parcels, ground cover and forest cover response curves for the property, response curves for ground cover showing the property compared to the reference land parcels and the performance of the property compared to the responses of all land parcels within the sub-IBRA region. QGIS is used to import the GIS coverages and prepare figures for use in reports.

Separately, long-term standardised rainfall information for the property were generated from a Bureau of Meteorology (BOM) rainfall database http://www.bom.gov.au/climate/history/ . Information about Colodan includes monthly, seasonal and annual rainfall patterns and anomalies. The BOM data are modelled monthly rainfall for each 5kmx5km grid cell across Australia.