SoilsForLife

Milgadara Ecological Report

BY RICHARD THACKWAY & KATE TAYLOR

Contents

List of Figures

List of Tables

Case Study	Summary		
Enterprise type	Cereal, canola and legume crops, prime lamb and cattle production, humus compost production	**Location**	20km east of Young, NSW 34°23'20.47"S, 148°28'15.37"E (Google earth)
Property Size	1182ha	**Annual Rainfall**	650 mm
Soil Type	Moderately deep stony soils (Rudosols), deeper uniform earths and sands (Kandosols) and texture-contrast non-sodic (Chromosols) and sodic (Sodosols) soils.	**Elevation**	386 m
Agro-Climatic region	Temperate Cool Season Wet		
Social Structure	Operated by owners Bill & Rhonda and home their children and grandchildren		
Motivation for change	Health concerns and disillusion with 'chemical' farming		
Innovations	• Improving soil condition with a focus on soil structure, microbiology and mineral balance. • Introduction of biological farming practices such as compost, compost teas and Organic Colloidal Concentrate (OCC). • Introduction of multi-species crops for nitrogen fixation and diversity of root exudates. • Tree planting to increase faunal diversity and produce shelter belts for stock. • Conducting site-based bird surveys to measure diversity over time. • Balancing stock nutrition using dry lick minerals and simple sugars.		

Key findings

- Biological farming practices have transformed the soils and landscapes which past conventional agricultural practices had degraded.
- Improved soil fertility has reduced inputs. Crops and pastures are disease-free, and pests are significantly reduced.
- Soils are now less compacted and more alive and fertile with overall farm resilience to severe climate events.
- Regular applications of composts and compost teas and OCC have improved soil fertility. Prior to implementing biological farming SOC was measured in the early 2000s at 1.5 to 2.5%. In 2019 SOC had doubled (3.2%).
- Improved agricultural production and carrying capacity with lambing increases up to 120% and wool staple strength measures of 38 newtons per kilotex (Nkt) or above.
- Crop protein levels are higher than under previous conventional approaches. Canola yields are up to 3t/ha and 47% oil using only 12 units of nitrogen as well as biological nitrogen fixing products. Wheat crops now yielding 5-6 t/ha.

Introduction

Milgadara is a 1182 ha cropping and livestock property located 20 minutes outside of Young, NSW and found within the New South Wales South-western Slopes Bioregion (NSWSWS). The property has a south-westerly aspect and the landscape consists of soft rolling hills. Their north eastern boundary is bordered by the Douglas Range which comprises of well-timbered rocky upper slopes and ridges. Milgadara has been farmed by the Daly family since 1906 making Rhonda and Bill Daly the fourth generation of Daly famers. Milgadara originally totalled 615 hectares. In 1970, Bill co-purchased an additional 324 hectares with family member Jack Daly, which adjoined Milgadara's southern boundary and had notably richer soils. In 1976, Bill and Rhonda purchased an additional 243 hectares which adjoined Milgadara to the east and consisted of some open country and quite a lot of range country.

Milgadara's local average per year is recorded at 650 mm. Monthly average rainfall data (Figure 1) from Bureau of Meteorology (BOM), derived from national modelled data and interpolated to Milgadara homestead area, shows rainfall to be winter dominant with a mean monthly minimum of 42 mm in February and a mean monthly maximum of 62 mm in June. Additional long-term standardised rainfall information including annual and seasonal rainfall since 1900 and rainfall anomalies above and below mean is shown in Appendix B.

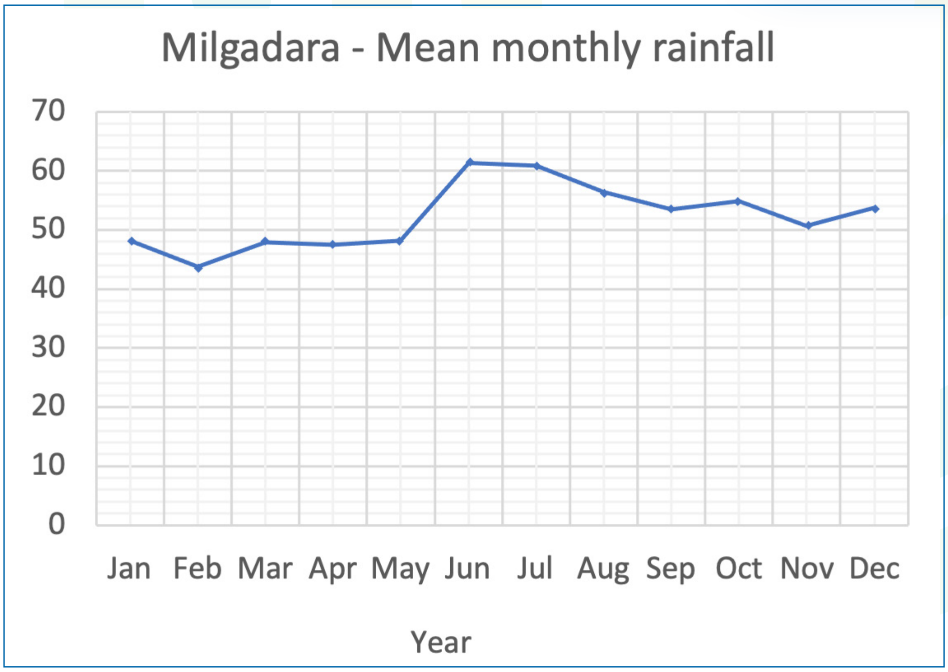

Figure 1. Mean monthly rainfall for Milgadara homestead location taken from national modelled rainfall data (source BOM)

History of landscape transformation

Originally much of the NSWSWS Bioregion was open grassy woodlands, however today, most of this bioregion is now an intensively managed agricultural landscape with most of the native vegetation cleared, modified, replaced and fragmented for agricultural production (Benson, 2008). Naturally, the open woodland country consisted of stringy bark (*Eucalyptus macroryncha*), white box (*Eucalyptus albens*), yellow box (*Eucalyptus melliodora*), red gum (*Eucalyptus blakelyi*) and rough-barked apple (*Angophora floribunda*). Prior to cultivation, the landscape had outcrops of *Eucalptus* overstory with an understory comprised of native species such as red grass (*Bothriochloa macra*) and wallaby grass (*Austrodanthonia spp.*). Pastures were low in species diversity and comprised of annual rye grass (*Lolium multiflorum*), sub clover (*Trifolium subterraneum*) with some Phalaris (*Phalaris aquatica*). There was relatively low weed pressure with only a few thistles, marshmallow plants (*Malva parviflor*a) and cape weed (*Arctotheca calendula*).

Prior to 2001, Bill and Rhonda (Figure 2) ran a mixed farming enterprise of a self-replacing merino flock, prime lamb production, backgrounding steers and cropping using conventional management and farming practices. It was during this time the Daly's acknowledged that they were essentially 'reacting' to weed and pest problems, increasing inputs with limited productivity gain while sensing that overall, they were doing more harm than good to their environment and natural capital. Rhonda describes production practices as being highly reliant on "an overuse of chemicals". It was in 2001 that Rhonda was diagnosed with chronic meningitis and heavy metal poisoning which was a pivotal moment in the questioning of their current farming practices. It was at this time that Rhonda had the epiphany "to heal the soil and help others" which was the catalyst for change at Milgadara.

Figure 2: Bill and Rhonda Daly, Milgadara landowners.

After 2001, the Daly's transitioned from a conventional farming system that was well known to them but causing a deal of personal discomfort, to one that was based on building the natural resource base while delivering great personal rewards. Prior to implementing biological farming, Rhonda says that they were essentially "mining our natural resources, as well as destroying wildlife habitat, contributing to climate change and polluting water ways". The Daly's acknowledge that through their conventional agricultural practices they had greatly diminished the soil's capacity to support soil life. Compaction prevented plant roots being able to penetrate and deliver nutrients and the heavy reliance on chemical farming resulted in soil mineral and microbial imbalances. As cropping practices were geared towards production and yield at the cost of our environment and soils, the Daly's adopted a vision and looked for alternatives to ensure a future for the next generation. This saw 350 hectares of cropping land transitioned from monoculture to multi-species cropping, under-sowing legumes such as clover to encourage nitrogen fixation in the soil. The Daly's key innovation in restoring soil biology was made with the transition to shift focus away from chemical soil fertility, to developing humus compost and to building healthy and productive living soils. Bill noted that "while using less soluble fertilisers, crop production provided higher yields of higher quality". Examples of this included:

- Using 'Humus Compost Extract' as a foliar fertiliser instead of the spring application of urea, produced increased crop yields and protein levels than under the previous conventional approaches of the 1990s.
- Canola yields increased up to 3 ton/ha and 47% oil using biological nitrogen fixing products and only 12 units of nitrogen (8 units of Gran-Am and 4 units in the MAP).
- Wheat crops now yielding 5-6 ton/ha with less fertilisers along with a more balanced soil and crop fertility program.

The Daly's have built an extensive understanding of the potential of the landscape and in particular, a profound respect for their soils. By reading their property through the health of their animals, pastures, cropping activity, soil, water courses and vegetation, this information is used to adaptively manage, modify and anticipate what is needed to achieve their ideals.

Chronology of land management regimes and natural events

Milgadara landowners worked directly with the Soils for Life (SFL) Ecologist to collate and compile a chronology of land management regimes, natural events and the effects these had to the ecological functions on Milgadara (Appendix A). The process used standardised and systematic guidelines (Thackway and Gardner, 2019) and was achieved through expert elicitation (Thackway and Freudenberger, 2016; Hemming, et al., 2018). Sources of information included farm journals and notebooks, reports prepared by consultants, photographs, accountant records and land manager discussions. The chronology seeks to document a timeline of land management regimes before, during and after the adoption of regenerative management regimes and practices. Where land management regimes were specific to a land type or group of paddocks this was denoted in the chronology. Ideally the chronology of management regimes would be documented at the paddock level however this has not been achieved in this report. The duration of land management regimes and natural events were recorded either by season, single or multiple year periods. These observations assisted in generating and interpreting the ecological response functions that were deliberately or inadvertently affected by these land management regimes and natural events. This information illustrates the landowner's knowledge of how land management regimes over time have changed the condition of the soil and vegetation across the dominant land types.

Ecological response functions

Landscape responses to land management practices are documented using ten ecological criteria. The process of visually representing these ecological functions elicit the landowner's expert knowledge of ecological changes and trends in ecological function which is linked to their land management practices over time. The landowners are asked to provide a score for the ecological state of the property when it was first acquired; when changes to land management practices commenced; and where they are now. The score is given between 0 (no function) and 1 (total or fully effective function).

10 ecological response functions

A. Resilience of landscape to natural disturbances
B. Status of soil nutrients – including soil carbon
C. Status of soil hydrology
D. Status of soil biology
E. Status of soil physical properties
F. Status of plant reproductive potential
G. Status of tree and shrub structural diversity and health
H. Status of grass and herb structure- ground cover
I. Status of tree and shrub species richness and functional traits
J. Status of grass and herb species richness and functional traits

The four phases of agricultural practice

The land management chronology (Table 1 & Appendix A) and the ten graphically represented qualitative ecological response functions are synthesised and interpreted according to guidelines which are based on the conceptual model outlined by Thackway and Gardiner (2019).

Phase 1 – Conventional agriculture production systems

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

Table 1: A chronology of land management practices and qualitative ecological response functions between 2001 – 2020

Period	Practices
Phase one: 1960s- early 1990s	Conventional management practices. Cropping, artificial fertilisers, stubble burning, chemical use and set stocking and regular applications of lime.
Phase two: Mid 1990s -2000	Began searching for alternative land management regimes to suit their enterprise and land types. This included educating themselves on information and practices for managing the physical, chemical and biological condition of their soils.
Phase three: 2001 – 2012	Soil testing commenced and several trials were conducted to determine the effectiveness of biological inputs on soil health, production and productivity. Developed a sound understanding of humus compost production and humus soil fertility as a pathway to amend soils. Commenced biologically feeding the soil using composts and compost teas and commenced sowing crops with liquid injection using humus compost extracted tea. Also changed practices from burning to retaining stubble and using a microbial stubble digestion program applied as a foliar. Changes to grazing management occurred with an emphasis on regular stock movements to maintain ground cover. Practices initiated to balance farm animal nutrition with dry lick minerals and simple sugars. Tree planting occurred to increase diversity in bird life as well as shelter belts for stock. Fencing occurred around an area of 200 hectares of native vegetation to exclude stock grazing and to allow native flora and fauna species to regenerate and re-establish.
Phase four: 2013 - 2020	Continued innovations, refinements and trials including evaluating the performance of liquid compost tea and compost pellets. Continued refinement of grazing systems and soil health for crops and pastures. Including introduction of multi-species crops for nitrogen fixation and OCC. Reintroduced breeding and backgrounding cattle and began grazing regime of running cattle through paddocks before the sheep.

Phase 1 (1960s – early 1990s)

Mixed farming enterprises consisted of a self-replacing merino flock, prime lamb production and backgrounding of steers and cropping. This phase involved a heavy reliance on conventional management practices. Livestock management consisted of set stocking with autumn lambing and early spring shearing. Cropping involved artificial fertilisers, stubble burning, chemical use and were managed as a rotation of oats, wheat, lupins, wheat, and canola, using four passes of cultivation and sowing with a plough fitted with purpose-built tines. Fertiliser programs were based on using 100 kg of mono-ammonium phosphate (MAP), 100 kg of anhydrous ammonia gas and urea per hectare and stubble burning. Regular applications of lime were also used to ameliorate the effects of applying chemical fertiliser during the establishment crops and to improve pasture health and vitality. During this early phase it was noted that soil organic matter was decreasing and there was no sign of soil life or earthworms. Weeds were increasing as well as disease and insect pressure. Calcium was an important input; however, it did not alter the soil structure due to lack of soil biology and it also displaced magnesium from the clay colloids which led to magnesium deficiency.

Phase 2: (mid 1990s – 2000)

In the early 1990s a new seed grain operation was added, growing up to 23 different seed crops. This additional enterprise was introduced to value add and find another market for seed grain. This phase still involved a heavy reliance on conventional management practices however it was during this phase that the Daly's began questioning the conventional farming practices they were using and began searching for alternative options to suite their enterprise and land types. This was a time of education and in 1995, Bill completed a biodynamic course and the Daly's accepted the need to change their farming practices. They began their journey to understand and blend information and practices about managing soil condition (physical, chemical, and biological) and commenced and developed innovations in land management regimes including keeping good levels of ground cover.

Phase 3 (2001 to 2012)

This phase saw learnings from the previous phase implemented with the introduction of biological farming to amend the productivity of soils through humus compost and extracts and sowing crops with liquid injections of compost extracted teas into the rhizosphere. Biological soil amendments were used to feed the soil and assist soil biology and fertility. Over this period several agricultural trials occurred to determine the effectiveness of biological inputs of soil health, production and productivity. Results from these trials were used to gradually transition away from more conventional management regimes. Soil testing commenced and results have been integral for guiding and modifying management actions. During this period, parts of the property transitioned to trialling multi-species cropping, under-sowing legumes such as clover to encourage nitrogen fixation in the soil. Rotational grazing was implemented to better manage pasture health, and the Daly's also developed and implemented practices that balanced the nutrition of farm animals using dry lick minerals and simple sugars.

In 2010, a tree planting program commenced to increase habitat and diversity as well as provide shelter belts for stock. This desire to increase biodiversity also saw an area of 200 hectares native vegetation fenced off from stock grazing to allow native flora and fauna species to regenerate. The Daly's engaged the Canberra Ornithological Group to investigate the responses of bird assemblages to changes in ecological function. Bird counts were conducted between September and October in 2013, 2014 and 2020. A total of 102 species has been recorded for Milgadara over this time, with notable species being the Freckled Duck (Stictonetta naevosa) a vulnerably listed species in NSW and the Crested Shrike-tit (Falcunculus frontatus) (Figure 3). The initial two surveys used an unstandardised approach which allowed for the collection of species occurrence data. Learnings from these surveys occurred and a systematic approach was applied to the last survey (2020) which included explicit fixed spatial and temporal (area and time) effort-based protocols. This will allow for future standardisation and comparison of species population and occurrence trends between surveys. A full site map and species list can be found in Appendix E.

Figure 3: Left: Crested Shrike-tit. Right: Vulnerably listed Freckled Duck. Both species recorded on Milgadara (Source: Wikimedia Commons).

Phase 4 (2013 -2020)

This phase is characterised by continued innovations and refinements including humus extract compost tea as a foliar fertiliser. The Daly's have continued their participation in targeted trials to evaluate the performance of liquid compost tea, rhizosphere injections at sowing time and compost pellets as well as OCC to improve soil condition. Multi-species cropping continued, the use of fertilisers inputs decreased, and paddock trials produced healthy pastures with good ground cover (Figure 4). Soil testing continued and was key in guiding and modifying management actions. This enabled refinement of their grazing systems and soil health management for crops and pastures. In 2016, cattle breeding and fattening was reintroduced as an enterprise. Grazing management consisted of cattle being grazing in front of sheep complementing the current rotational grazing regime.

Figure 4: Contour Paddock on Milgadara. No other fertiliser inputs have been applied to this paddock since 2010. Image taken 11th June 2017. (Source: Rhonda Daly).

Ecological response outcomes

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

Phases 1 and 2 (1991 – 2000)

During the first two phases there were several years of below average rainfall and some severe rainfall events which placed pressure on the productivity of the farm. Severe rainfall events led to the loss of topsoil through overland flows. During this phase, a baseline score of 0.1 was given throughout phase 1. Phase 2 saw a single incremental increase in 1998 and 1999 (Figure 5).

Phase 3 (2001 to 2012)

During this phase, the Daly's observed improvements to landscape resilience particularly in regard to withstanding climate variations while achieving higher quality production outcomes and improving soils and ecological outcomes. In this phase the Millennium Drought occurred, and below average rainfall placed pressure on the productivity of the farm. Due to the changes in management practices during this period, Milgadara was the only property on Moppity Road that continued to harvest crops each year whilst maintaining stock numbers and ground cover. No wind erosion from Milgadara was recorded unlike neighbour's properties and while rainfall was low, resilience scores continuously increased from 0.2 in 2002 to 0.6 in 2010 – 2012 (Figure 5).

Phase 4 (2013 – 2020)

Improved farm resilience continued. Rainfall penetration and infiltration into the soil profile increased with water being retained in the soil for longer, and excess water now flowing through the soil profile without removing nutrients from the system. Together with reduced run-off and evaporation, this demonstrates increased water conservation and therefore landscape resilience. Scores increased from 0.7 in 2013 to 0.9 in 2019 – 2020 in line with increases in landscape resilience, even with below average rainfall years during this period (Figure 5).

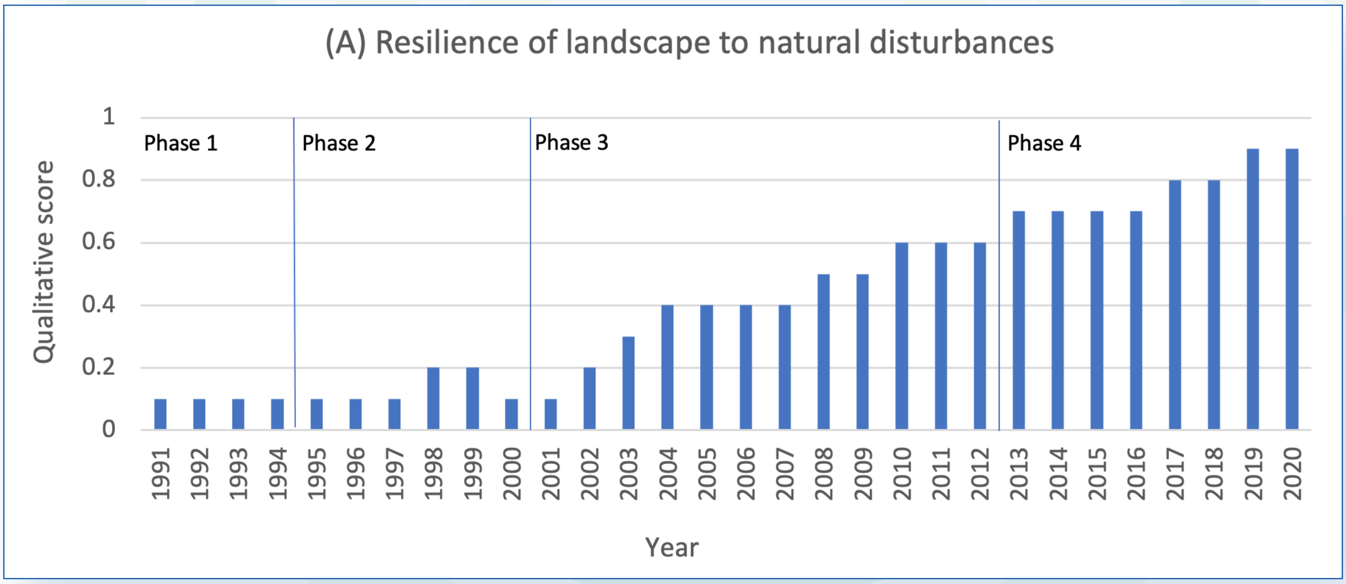

Figure 5. Status of landscape resilience to disturbance (such as flood, drought and frost)

B. Status of soil nutrients – including soil carbon

Phase 1 and 2 (1991 – 2000)

The lack of diversity due to previous land management regimes, did not allow for natural cycles and there was a high reliance on artificial fertilisers. This led to 'watery' plants which increased both pest and disease susceptibility. Low soil organic matter and declining fertility parameters was noted, particularly soil humus, and ever-increasing reliance on soluble minerals inputs occurred. Soil life was deficient with no sign of earthworms or soil life. Insect pressure was noted as increasing as was weeds and prevalence of plant diseases. The reliance on chemical fertiliser inputs, particularly nitrogen and phosphorus, were increasing problems with more weeds, diseases and pests and consequently, offered low yields and profitability outcomes.

Phase 3 (2001 – 2012)

At the beginning of this phase, soil fertility testing, including soil carbon, commenced to track changes of soil health in each paddock. Testing has occurred between one and five times across 23 paddocks (Appendix D). Data were independently analysed with results used to monitor changes and trends in soil physical, chemical and biological condition within each paddock allowing management to be adapted accordingly. Initial results indicated soil nutrient imbalances with low levels of calcium, magnesium, phosphorus, zinc, copper, boron and sulphur and high levels of potassium, iron, aluminium, and hydrogen. By the end of this phase, positive outcomes were already being observed due to changes to management practices. Milgadara was noted to have softer, well-structured soils with no hard pans, a higher diversity of groundcover and pasture species and less weeds. This led to further increases in exudates, microbial activity and nutrient cycling.

Phase 4 (2013 – 2020)

During this period, the focus was on increasing groundcover with the overall aim of improving the soils physical, chemical and biological condition. Soil tests results revealed noticeable increases in soil organic matter. In addition, obvious improvements in soil structure occurred showing good soil tilth, increasing humus levels and visible earthworm and fungal activity. Independent soil tests indicated improvements to previous mineral imbalances which was further validated with minerally and nutritionally dense sown pastures with improved root systems. The reintroduction of cattle into the rotational grazing system during this phase provided a different and complementary effect to the land and pasture with cattle introduced to paddocks prior to the sheep coming through. In addition, the introduction of OCC showed beneficial outcomes by boosting the plant's vascular system and passive immunity. The latest soil tests showed minerals in pasture soils to be more balanced and plants also showed further improvements to their root system in both crops and pastures. Cation-exchange capacity of the soil also increased creating a greater store for positive minerals such as calcium (Ca), magnesium (Mg), potassium (K) and ammonium ($NH4^+$). Figure 6 presents the Daly's understanding of the status, change and trend of soil nutrients – including soil carbon between 1991 and 2020. Scores increased overtime from 0.1 in 1991 – 1994 to 0.9 in 2019 and 2020.

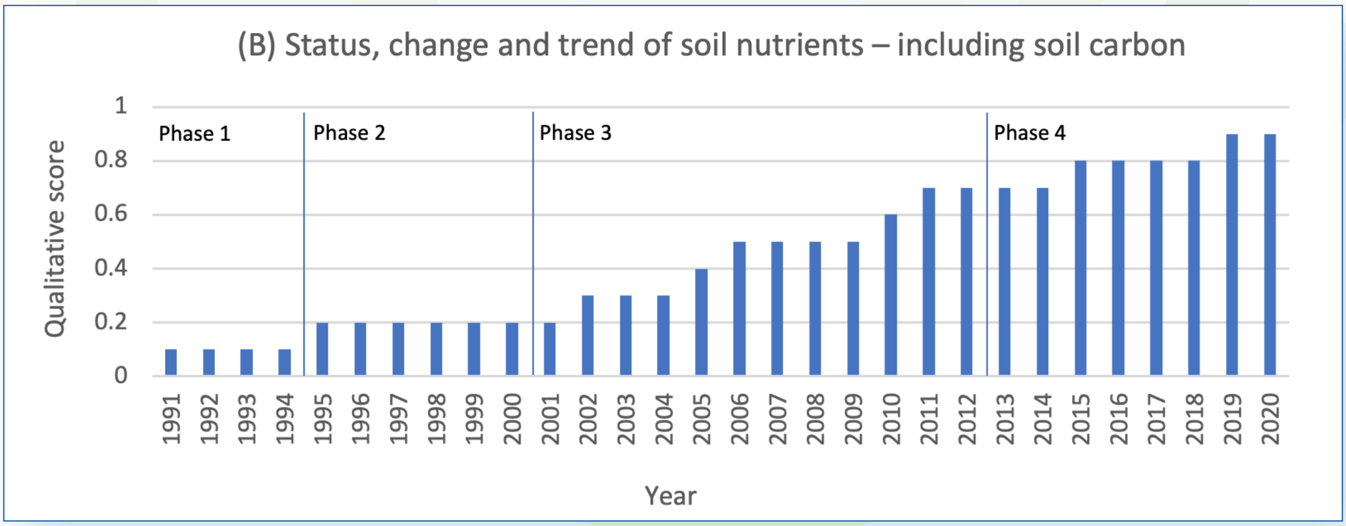

Figure 6. Status of soil nutrients including soil carbon level.

SFL analysed previously collected soil carbon (%) data from 2010 -19 (Phases 3 & 4). Each year, at least three samples were taken from each paddock and data was used to derive the average estimated Organic Matter (% OM) over time. Figure 7 shows the positive trend in SOM (%) over time. The Daly's believe this trend is in response to the changes to land management practices on Milgadara.

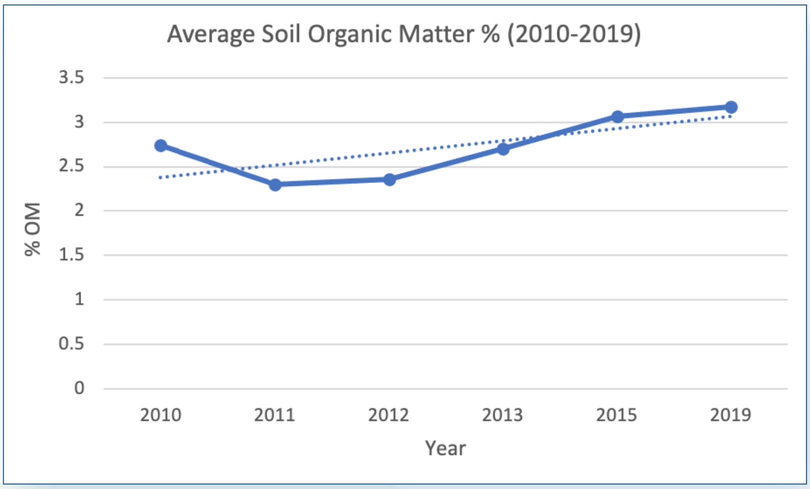

Figure 7: Average soil organic matter % (calculated from soil carbon %) across nine paddocks from 2010-2019 on Milgadara.

C. Status of soil hydrology - Soil surface water infiltration

Phase 1 and 2 (1991 – 2000)

Soil surfaces were hard and sub-surface hardpans were observed in the open farming country. In this period, intense rainfall events meant little water infiltration and excess water flowed across the soil surface and quickly disappeared into the gullies and creeks. Baseline scoring provided during this period was 0.1 between 1991 – 1997 and was increased to 0.2 in 1998 -2000 (Figure 8).

Phase 3 (2001 - 2012)

Since 2002, Milgadara saw a significant soil structure improvement with soil now well-aggregated with good tilth and higher humus levels. Improvements to soil structure has also improved the ability for rainfall to penetrate and infiltrate deeper into the soil profile maintaining soil moisture and nutrients and thus reducing the amount lost to run off or evaporation. The score increases seen in Figure 8 are indicative of the changes to land management practices with the introduction and application of humus compost, extracted compost tea and prescription mineral blends together with retention of pasture ground cover.

Phase 4 (2013 – 2020)

Soil water infiltration benefits continued with rainfall now being essentially "banked" within the soil profile, assisting the property through times of rainfall deficit. This was seen in 2017-19, where rainfall sharply declined and under conventional farming would have placed considerable stress on the plants and animals. However, the provided scoring increased during this time (Figure 8).

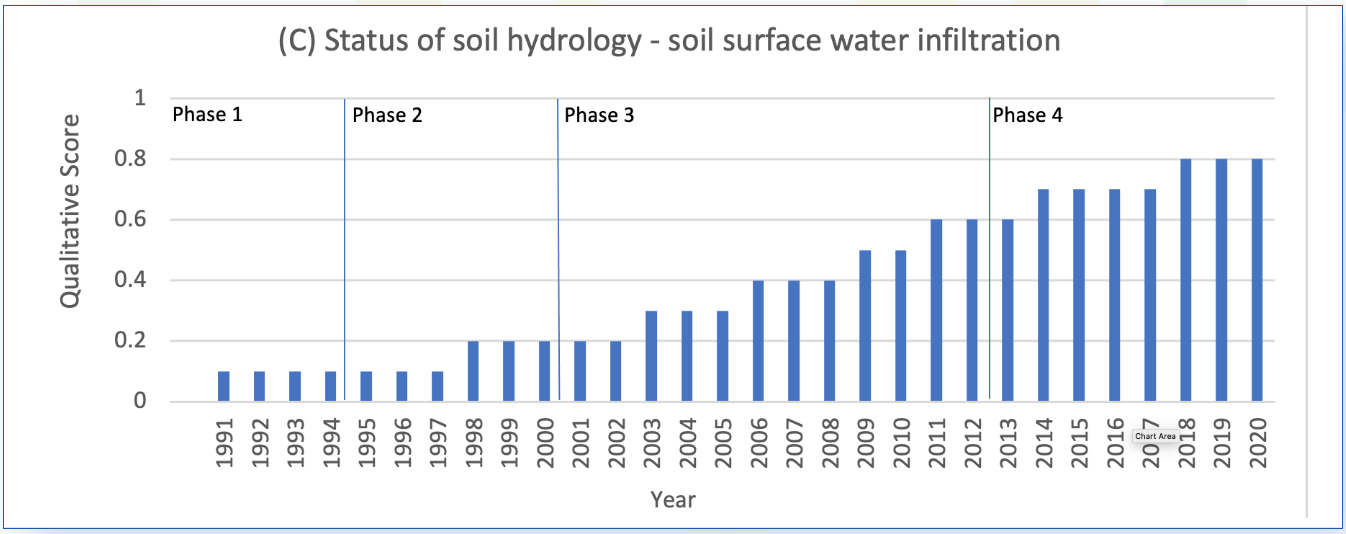

Figure 8. Status of soil hydrology - soil surface water infiltration

D. Status of soil biology

Phase 1 and 2 (1991 – 2000)

During the early phases, conventional practices such as tillage, artificial fertilisers and chemical use, along with stubble burning and set stocking were all decreasing soil biology and soil carbon. Baseline scores provided during this period began as 0.1 between 1991 – 1996 and increased to 0.2 in 1997 (Figure 9).

Phase 3 (2001 - 2012)

The hardpan areas in the open farming country began to breakdown as the soil biology began to respond to the applications of composts and compost teas. In this phase, the Daly's developed a sound understanding of humus compost production and humus soil fertility as a pathway to amend production soils. Rhonda describes the humus compost as being "packed with a diverse range of soil microbes" and with a little encouragement, the soil microbes perform a wide range of functions that improve crop and pasture health including nutrient availability, nitrogen fixation, disease suppression and increased humus building. Crops were sown with Humus Compost Extracted Tea into the plant's rhizosphere. and several trials commenced to determine the effectiveness of biological inputs on soil health, production, and productivity. The Daly's used information gathered during these trials to gradually transition away from past conventional management practices. Animal health also began to improve with provision of dry lick minerals and simple sugars. By the end of this phase, scoring had increase from 0.2 in 2001 to 0.6 in 2010 (Figure 9).

Phase 4 (2013 – 2020)

Soil biology continued to improve with observations of increased earthworm activity and visible signs of soil fungi presence. Soil aroma had become "sweet-smelling" and stubble residues were observed to be breaking down rapidly increasing organic matter levels. In 2017 tillage radish was sown, which not only provided additional livestock fodder but also increased soil function through aeration and root exudates. In 2020, multi-species sowing of crops including legumes to encourage nitrogen fixation occurred in two paddocks. This practice allowed for ground cover retention and pasture conservation while still producing enough feed for livestock. While it was noted that the multi-species crop produced lower yields than a regular single species crop, the benefits outweigh the production of grain only. For this period, scoring began at 0.6 and increased to 0.7 in 2018 (Figure 9).

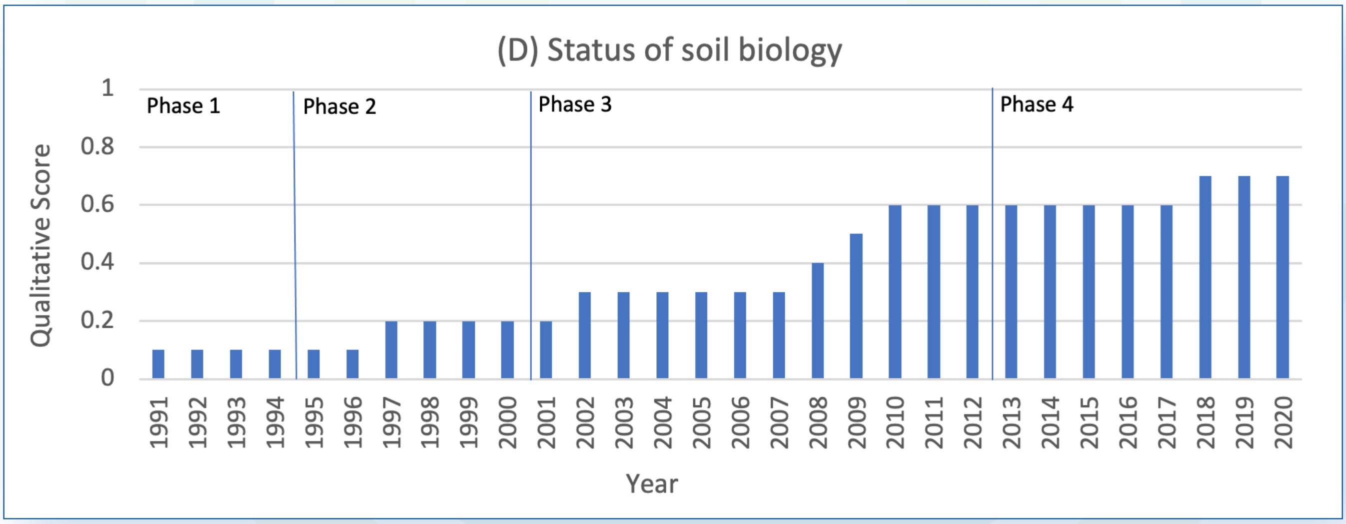

Figure 9. Status of available soil biology.

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

Phase 1 and 2 (1991 – 2000)

During the early phases, conventional practices such as tillage and the use of artificial fertilisers and chemicals caused compaction creating hardpans. Root development of pastures and crops was poor and there was no observed presence of earthworms or fungal activity. Baseline scores provided during this period began at 0.1 between 1991 – 1997 and increased to 0.2 in 1998 (Figure 10).

Phase 3 and 4 (2001 - 2020)

During this period soil structure improved on Milgadara. By balancing soils with humus compost mineral blends, the overall mineral balances had nearly reached an ideal balance, creating aggregated living soils. Rhonda noted that "using minerals blended with humus compost, nutrients do not leach or lock up but stay available for plant uptake. The addition of trace minerals is essential for enzymatic reactions in the soil". Qualitative scores provided during this period began at 0.2 in 2001 and had increased to 0.7 by 2018 (Figure 10).

Further, in 2020, soil test results from samples taken from a 135-acre area and presented in the Milgadara Soil Report (2020), reported favourable soil depth (90 cm+) with no obvious physical limitations and moderate subsoil structure allowing for water and nutrient movement and good root depths.

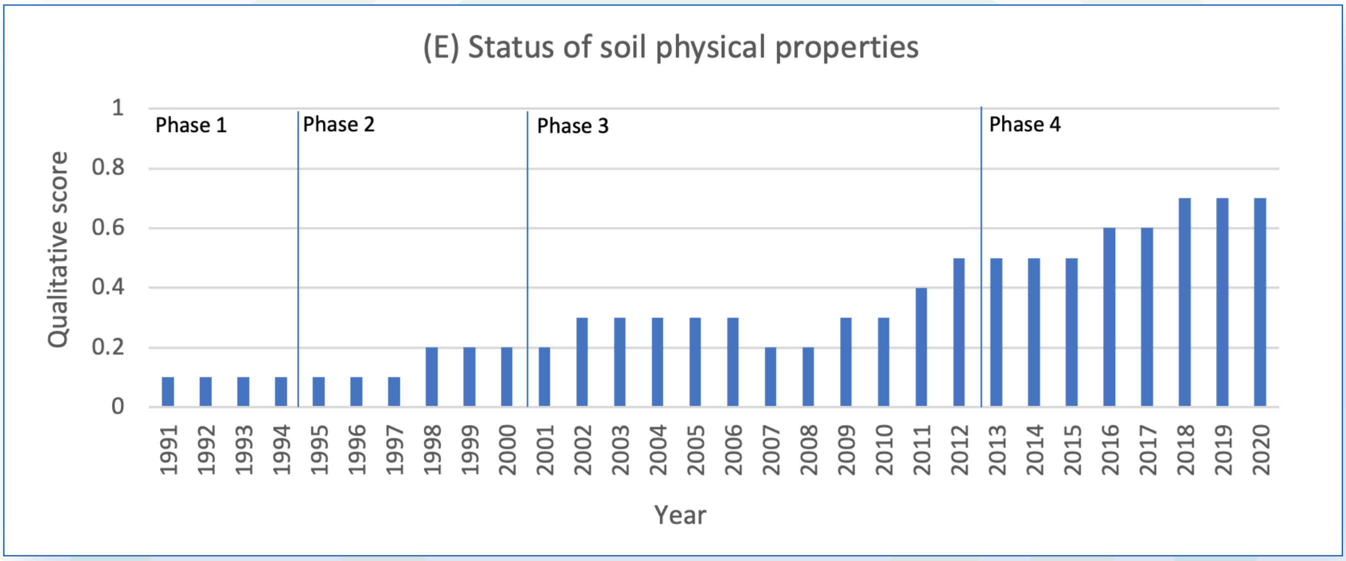

Figure 10. Status of soil physical properties

Figure 11: Oat plant root system with a noticeable amount of soil aggregates in the rhizosphere- where interaction between roots, soil and soil microbes occurs (Source: Rhonda Daly).

F. Status of plant reproductive potential

Phase 1 and 2 (1991 – 2000)

Pastures during this period were reliant on regular applications of chemical fertilisers and treatment for pests and diseases. Baseline scores provided remained at 0.2 across phases 1 and 2 (Figure 12).

Phase 3 and 4 (2001 - 2020)

Over this period, the implementation of regenerative land management regimes including regular applications of composts, compost teas and OCC had improved the vascular system, passive immunity and reproductive potential of plant species. Perennial and bi-annual pasture species diversity increased, and with rotational grazing management practices, pastures grew stronger with less weed species present. During this period, scoring steadily increased from 0.3 in 2003 to 0.9 in 2019 (Figure 12).

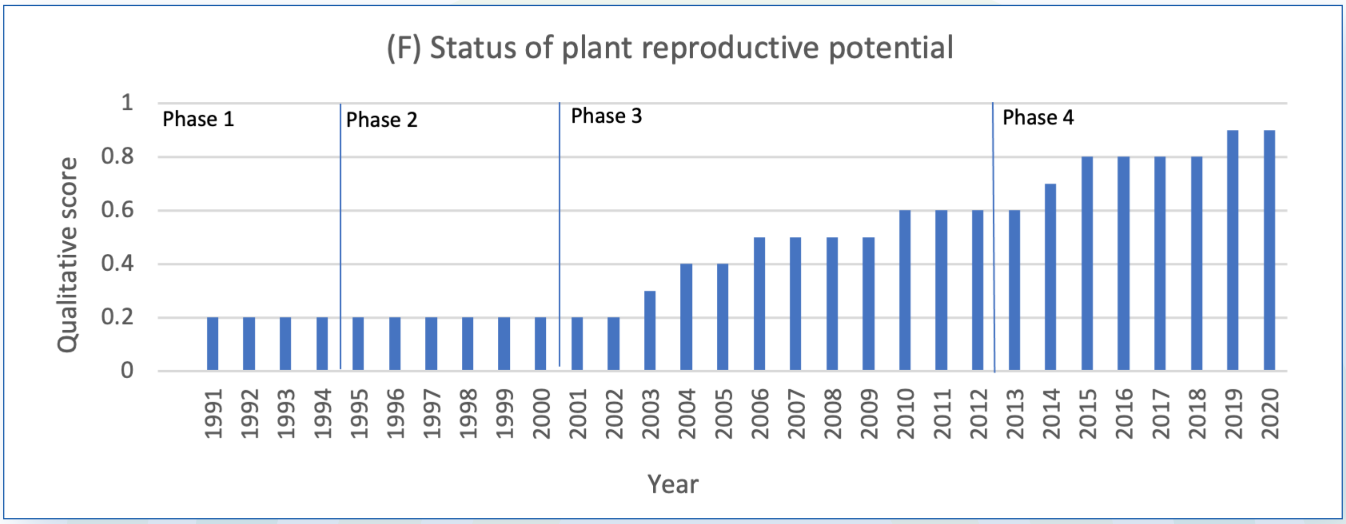

Figure 12. Status of pasture reproductive potential of legumes and grasses

G. Status of tree and shrub structural diversity and health

Phase 1 and 2 (1991 – 2000)

In this period, the open country was lightly timbered comprising of mixed Eucalyptus and rough-barked apple (*A. floribunda*). During this time, the Daly's observed minimal regeneration of the overstorey trees species, both in the open farming country and the timbered hilly country. Baseline scores provided remained at 0.2 across phases 1 and 2 (Figure 13).

Phase 3 and 4 (2001 - 2020)

During 2005, winter and spring rainfall was above average which created good conditions for tree and shrub recruitment. This increase from 0.2 – 0.5 can be seen in Figure 13 between 2005 to 2007. In 2010, thirty hectares were revegetated to increase biodiversity of native fauna and to form shelter belts for stock. Over this period, natural regeneration of the overstorey trees was observed both in the open country and in the timbered hilly country. From 2007, scoring increased from 0.5 to 0.6 by the end of Phase 3 (Figure 13). By the end of Phase 4, scoring reached 1.0 indicating tree and shrub structural diversity and health was at 'total or fully effective function'.

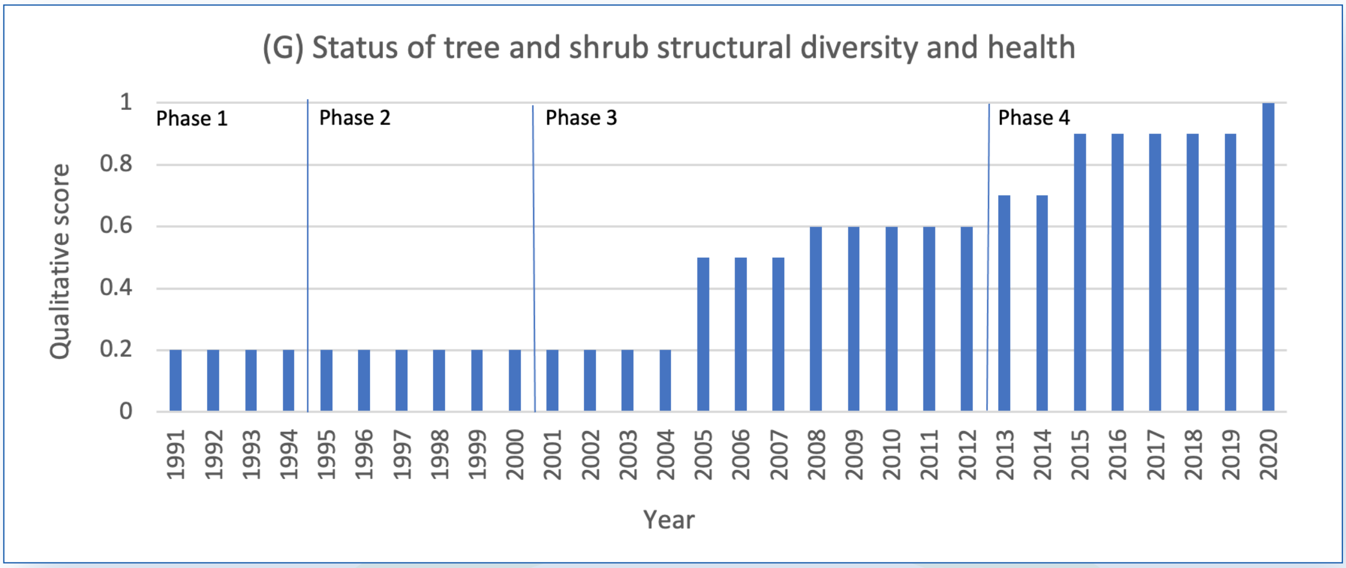

Figure 13. Status of tree and shrub structural diversity and health

H. Status of grass and herb structure - ground cover

Phase 1 (1960s – early 1990s)

Under conventional set-stocking practices, times of low rainfall saw a reduction in ground cover. Further, during rainfall events, water quickly dispersed off the ground layer. Baseline scores provided for this period were low and remained at 0.1 across phase 1 (Figure 14).

Phase 2 (mid 1990s – 2000)

During this period, a key focus was to build ground cover and improve soil organic matter with the aims of increasing the capacity of the soils to supply and retain both water and nutrients. Increases in groundcover demonstrated the soil and land's ability to recover more quickly and retain moisture. From 1998, ground cover scoring increased from 0.1 to 0.2 in 2019 (Figure 14).

Phase 3 (2001 - 2012)

During this phase, pastures were maintained with a greater diversity, including bi-annual and perennial species including cocksfoot, fescues, perennial rye, lucerne, clover, plantain, and chicory. With rotational grazing management and long recovery times, ground cover continued to increase and weed species decreased.

Phase 4 (2013 – 2020)

Rotational grazing practices, combined with long recovery times contributed to further increases to ground cover. During the drought in 2017-19, ground cover levels showed increased resilience under the Daly's 'biological farming' practices. Ground cover scoring increased to 0.3 in 2010 and again to 0.4 and 0.5 during 2011-12 respectively (Figure 14).