Is Being Sustainable Enough for Australian Wine?

Regenerative agriculture can redefine what is best practice viticulture

A report for

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Executive Summary

Sustainability has become a common catchcry for the global wine industry. This is no different in Australia with numerous programs developed to improve the industry's environmental credentials.

Wine grape production faces many challenges. Climatic extremes like heat and declining water resources are already putting pressure on the industry. Rising input costs and consumer concern around how grapes are grown and potential damage to the environment are also putting pressure on growers to improve environmental practices.

The author believes that increasing the capacity of soils through understanding, building and managing soil carbon levels and the soil microbial network with the use of plants and their diversity, is the key to arresting the decline of soils around the world.

Regenerative Agriculture (RA) is a paradigm shift in the way vineyards are viewed and their connection to the broader environment. Its principles are based on mimicking nature by having a diverse range of plant life storing and cycling carbon and increasing soil microbial diversity and activity through interaction with these plants.

The six practices of RA are:

1. Balancing soil nutrition limitations
2. Keeping the soil covered
3. Minimizing soil disturbance (cultivation)
4. Increasing plant and microbial diversity
5. Incorporating living roots into the farming system all year round
6. Integrating and managing Livestock

They give a blueprint to create a healthy, diverse, living soil microbial ecosystem. This over time produces a high functioning soil capable of high productivity and increased quality. Although seemingly straightforward, implementing these practices into a cohesive manageable system will differ from vineyard to vineyard. There is no one size fits all approach and execution will take discipline and patience as meaningful change will take time.

RA is a difficult system to replicate scientifically, with many moving parts and local environmental factors hampering meaningful broad-based evaluation. It has relied on “citizen science” with farmer-driven trial and observation at its core. This does not diminish its potential impact but highlights that no-one understands their farm and landscape better than an observant farmer. With advancements in technology enabling the identification of soil microbes and their role within the soil, this understanding will improve rapidly into the future. Agronomy in the future will increasingly look at biology over chemistry and the role it plays in crop nutrition.

RA could provide the Australian wine industry with a system that increases soil capacity and microbial diversity. This could improve water capture and retention and challenge the reliance on synthetic chemicals and fertilisers and the increasing role of cultivation in organic vineyard systems. This could also be the key to unlocking the individual “terroir” of vineyards and provide a unique environmentally friendly story to consumers.

To give the generations to follow the best opportunity to produce world-class wines the industry must not be content with “sustaining” vineyard ecosystems as they are now. RA shows enormous potential as a farming system to repair damage done to soils and set them on a productive path for generations to come.

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Foreword

From as early as I can remember I have been surrounded by, and interested in, agriculture. I am the third generation of farmers in our family and although there was a switch of States (Central Coast, NSW to McLaren Vale, SA) and crops (citrus to wine grapes) between the first and second generation, the connection to farming has remained.

My family and I own and operate 50Ha of vineyards and a wine business incorporating two brands Hither & Yon and Old Jarvie in McLaren Vale South Australia. I also run a vineyard management business Leask Agri that has a number of clients covering 70Ha.

Vineyards are by nature intensive farming systems with traditionally high amounts of synthetic and chemical inputs. About 15 years ago I started to question the way we were farming. The continual merry-go-round of inputs, the constant battle with nature, and the high amounts of synthetic chemicals being prescribed were starting to take a toll on the land and on me.

I became increasingly conscious of my impact on not only the land we farm but the broader environment around us. The statement "we are leaving the land in a better position than we found it" has been an all too common statement in the wine industry and farming in recent years. I found myself asking "How are we doing this?" and "Is being sustainable from here on good enough?"

I had to admit that the way we have been farming had done some damage to the land and that just being sustainable from this point on was not enough to ensure we stay productive into the future. Some repair and regeneration will be needed to provide a solid platform for the generation to follow.

My Nuffield journey took me to ten countries – Japan, Singapore, Indonesia, France, Canada (twice) Kenya, Zimbabwe, South Africa, New Zealand and nine states in the United States across three visits. These were not constrained solely to the wine industry but included dryland cereal production, vegetables, blueberries, raspberries, grass-fed beef, and sheep production, and tunnel house cut flowers to name a few.

This report sets out to define the key components of a Regenerative Agriculture (RA) system and the potential benefits of implementing RA systems into the wine industry. I hope it complements a number of environmentally progressive systems already being used by producers and perhaps brings new thinking to some old problems.

Most of all it aims to provide some food for thought for our two biggest assets,

- People – questioning our paradigms and biases
  - "the most important piece of land is the six inches between your ears" (Massy,2018)

- Soil – how we restore and nurture it for generations to come
    - “a nation that destroys its soil, destroys itself” (Franklin D. Roosevelt)

Figure 1. 2019 Japan GFP Group (Becky Haddix, 2019)

I am very fortunate to have travelled the world with this great group of people. Friendships that will survive the tyranny of distance, The 2019 ‘Japan’ Global Focus Program (GFP) group with the author far left.

Acknowledgments

I am incredibly grateful to Nuffield Australia and Wine Australia for the once in a lifetime opportunity to travel the world and pursue a topic that I am passionate about.

This report does not exist without the generous support of all the businesses and researchers that I visited and interviewed. I remain humbled at your openness about successes and failures of the systems being implemented. You are all an inspiration, thank-you.

Traveling solo in foreign countries can be a lonely experience at times. Thank you to all the people that welcomed me into their homes to share a meal or put me up for the night, your company and generosity were appreciated more than you will ever know.

To my work colleges, particularly Scott, Wayne and my brother Mal who picked up the considerable slack during my long absences I thank-you. The business couldn't have been in better hands.

Finally, to my family Sharon, Emma, Patrick, and Matthew. Thank you for encouraging me to pursue what is at times a very selfish journey. I will be forever in your debt.

Abbreviations

AWRI – Australian Wine Research Institute

C – Celsius

cm – centimetre

ESR – every second row

GFP – Global Focus Program

Ha – Hectare

mm – millimetre

NSW – New South Wales

OC – Organic Carbon

RA – Regenerative Agriculture

SA – South Australia

SAW - Sustainable Australia Winegrowing

SOM – Soil Organic Matter

SWA - Sustainable Winegrowing Australia

Objectives

The objectives of this project were to research farmers and organisations that were improving resource management and sustainability with a specific focus on:

- Understanding the principles and the key practices of RA systems with particular reference to improving soil health and capacity;
- To investigate how these practices might be practically integrated into wine grape growing systems; and
- To understand the elements needed to make a permanent paradigm shift in a farming system.

Chapter 1: Introduction

The Australian wine industry is the world's sixth-largest producer of wine by volume. The 2019 wine grape crush was estimated to be 1.73 million tonnes. This comes from a total vineyard area of 146,128 Ha. (Wine Australia, 2019)

Figure 2. National Vintage Report (Wine Australia, 2019)

The Australian wine industry has encountered numerous challenges over recent years including oversupply and strong exchange rates that have tested the resilience of grape and wine producers. While some of these challenges have abated recently, the cyclical nature of global wine production requires Australian wine producers to be as nimble as ever given the export orientated nature of the industry.

However, climate variability and its effects on vineyard production, water use, and sustainable vineyard management are other major challenges facing the industry now and into the foreseeable future. Wine Australia sees this as one of its strategic goals stating,

As part of the Wine Australia 2015-2020 Strategy document but not limited to,

1. *Research and Development – climate change and climate variability, water use in agriculture, soil management, education, the efficacy of inputs*

Priority 2 of Wine Australia Strategic Plan 2015-2020 – Increasing Competitiveness. Under this heading, there are a number of key strategies not limited to,

Strategy 4 Improving resource management and sustainability,

- *Climate adaptability*
- *Sustainable resource management*
- *Biosecurity, pest and disease management*

Strategy 5 Improving vineyard performance

- *Efficient and sustainable vineyard management*

(Wine Australia, 2015)

Globally there are a number of wine industry sustainability programs most of which are designed to capture data around vineyard inputs and outputs but add little in the way of educating growers on practices that can improve the vineyard and the ecosystems around them. The development of the Sustainable Australia Winegrowing (SAW) program by Dr. Irina Santiago-Brown for the McLaren Vale Grape Wine and Tourism Association was the first of its kind to integrate data collection and aspirational goal setting to give growers a roadmap for improvement on a number of key areas of vineyard management. This program has been used as a foundation for the development of a new national program, Sustainable Winegrowing Australia (SWA). This new program was developed following a global review of the sustainability landscape. The Australian Wine Research Institute (AWRI), and McLaren Vale Grape, Wine & Tourism Association, with support from Wine Australia and Australian Grape and Wine, worked together to develop this single Australian sustainability program, building on the strengths of the existing Entwine Australia and SAW programs. (AWRI, 2019).

Although this is a major step in reaching the goals of the strategic plan, is this concept of sustainability enough? Should the Australian wine industry be more aspirational and aim to repair the damage done by some of the vineyard practices of the past?

It is through this lens that the author sought to understand the concept of RA and whether it has any potential to deal with some of the above challenges for the Australian wine industry.

Chapter 2: What is Regenerative Agriculture?

Principles

There are many ways to define the principles of what RA is. Terra Genesis International (2020) states, "*RA is a system of farming principles and practices that increases biodiversity, enriches soils, improves watersheds and enhances ecosystem services.*"

It is a system and a way of thinking that asks the land manager to look beyond the singular focus of the crop they are growing and to understand that everything within that localised ecosystem is linked and every action will have consequences be it positive or negative.

In the Preface to Gabe Brown's book Dirt to Soil, Courtney White offers: "*RA is a biological system for growing food and restoring degraded land. Its goal is to continually advance the health of the soil with practices that promote microbial activity, increase carbon cycling and improve plant and animal health, nutrition and productivity*" (White, 2018, Dirt to Soil)

Whereas Regeneration International has even bigger goals in mind stating: "*RA describes farming and grazing practices that among other benefits, reverse climate change by building soil organic matter and restoring degraded soil biodiversity – resulting in both carbon drawdown and improving the water cycle*"

Although slightly different the common theme running through all these statements is the core principle of RA:

- Improve soil health through ecosystem diversity and soil microbial activity.
- Increase soil carbon and soil organic matter (SOM).

It is the authors opinion that the success and long-term viability for most agricultural enterprises ultimately hinges on the health of their soil.

Understanding the principle purpose behind RA is critical in changing a mindset from systems and practices that degrade the soil to developing a system that works with nature and positively contributes to the soil and the local ecosystem. It provides a framework to critically analyse current practices against a known set of RA principles. Only then can a system be developed to match these principles against the long-term requirements of the farming operation.

Chapter 3: Why are Soil Carbon and Soil Microbial diversity important?

The role of plants in improving soil health.

Increasing soil carbon levels and increasing soil microbial diversity and activity are the key principles behind RA, but why are both so important in creating a healthy soil?

Carbon as an organic fraction of soils consists of a large variety of carbon compounds ranging from micro-organisms, plant and animal cells and their residues at various stages of decomposition. The need for complex organic soil carbon is critical for chemically controlling Nitrogen, Phosphorus, Sulphur and macronutrient nutrition to the microbial communities as well as providing better water holding capacity, pH buffering and increasing metabolic activities of microbes. (Brunetti, pp102)

Dr. Christine Jones believes, "*In addition to enhancing nutrient availability, carbon performs many other functions in soil, including the maintenance of soil porosity, aeration and water-holding capacity*" (Jones, 2010).

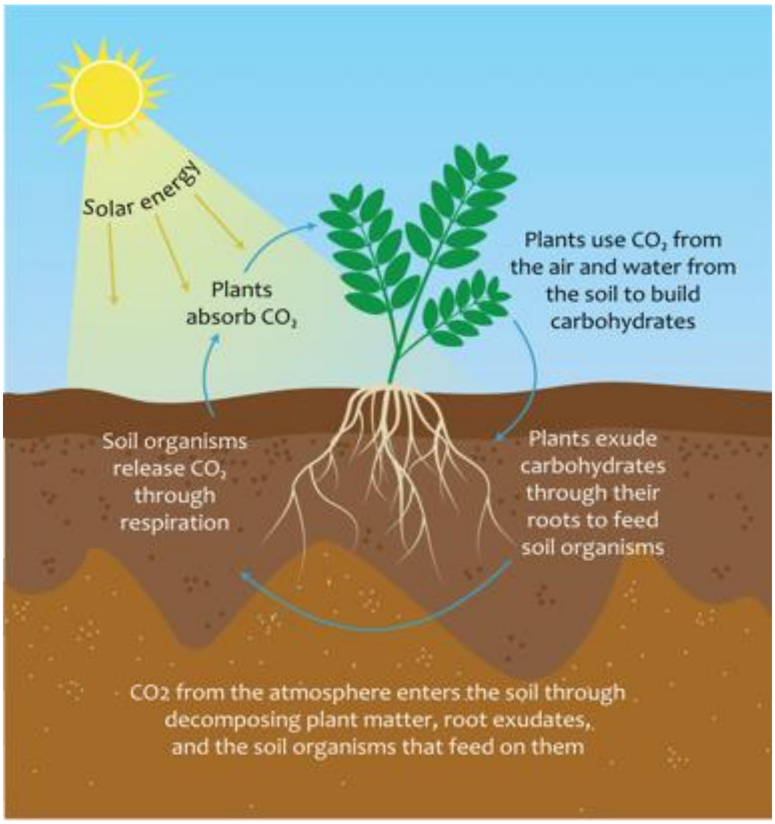

Figure 3. How carbon cycles in and out of the soil. (Lavallee, 2020)

There is no clear guaranteed pathway to locking up carbon for good, instead, we can think of soil organic carbon as an ongoing cycle of carbon gains and losses which we need to constantly manage.

Not all soil carbon is the same. It can be found in two different forms:

1. Particulates, enveloped by soil particles.
2. Bonded to the soil minerals.

Particulate organic matter is the stuff you can generally see. Mineral-associated organic matter consists mostly of microscopic coatings on soil particles, derived mainly from soil microorganisms. They both have different nutrient contents and lifecycles in the soil. (Lavallee, Cotrufo, 2020)

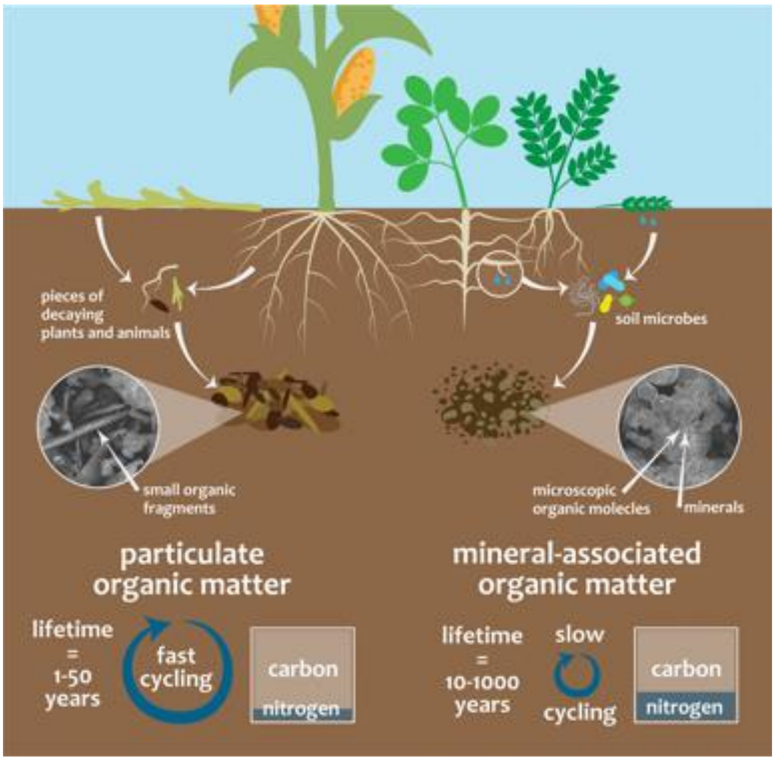

Figure 4. Overview of particulate and mineral-associated OM form and function. (Lavallee, 2020)

Plants are the key part of the soil carbon cycle. RA at its core seeks to mimic the way nature works within the confines of an agricultural production system. Natural systems are diverse ecosystems and generally have a diverse array of plant species. This is in direct contrast to the monoculture row crop agriculture systems that are prevalent in modern agriculture. The key to this diversity is that they are providing an essential function in the carbon cycle and the microbial population they help support.

Photosynthesis is a process that takes place in the chloroplasts of green leaves, where carbon dioxide from the air and water from the soil are combined to capture light energy and transform it into biochemical energy in the form of simple sugars. Significantly, many of the carbon compounds derived from the simple sugars formed during this process are also essential to the creation of well-structured topsoil from the lifeless mineral soil produced by the weathering of rocks. (Jones, 2018)

In other words, the combination of plants (photosynthesis) and soil microbial activity help build SOM and store carbon, thereby increasing soil capacity, one of the key features of RA.

Microbial activity drives the process of aggregation enhancing soil structural stability, aeration, infiltration, and water holding capacity (Jones, 2018).

Not only is this plant-microbial partnership important in building and regenerating soil, it is also critical to feeding both the plant and the microbes through the exudates from living roots.

These exudates are the most energy-rich of these carbon sources. In exchange for ‘liquid carbon’, microbes in the vicinity of plant roots – and microbes linked to plants via networks of beneficial fungi – increase the availability of the minerals and trace elements required to maintain the health and vitality of their hosts (Jones, 2018).

This complex interconnected system is a key aspect of RA and the one that is the most neglected in conventional farming systems. The use of soluble fertilizers has replaced the intricate, diverse plant-microbial bridge and increased inputs and costs into the farming operation.

Synthetic fertilizer inputs interrupt the relationship between microbes and plant roots because the fertilizer gives the plants free nutrients. They do not need to trade carbon for nutrients from microbes. When this happens, the plants retain much of that carbon for themselves, which means the microbes cannot access enough food to grow and reproduce and their populations suffer (Brown, 2018 pp31).

An RA system is therefore based on the cyclical nature of the plant-soil microbe relationship through the “microbial bridge”, “you feed me, and I will feed you”.

In summary, plants take sunlight convert it to simple sugars which allow soil microbes to feed themselves and then help feed the plant. In the process they build SOM and store carbon in the soil, regardless of the plant species being grown. The better the photosynthetic capacity of the soil surface (ground coverage and plant diversity) the greater potential for improved soil health. As Dr Jones argues “*all food and fibre producers are at first and foremost light farmers*” (Jones, 2018).

In modern times, vineyards have been mono-crop environments, with many traditional management practices of the midrow and under vine area detrimental to sustaining a high functioning plant-soil microbe ecosystem. RA is not the only farming system that could improve soil health but through research and personal visits, the author has concluded that this plant-microbe-carbon cycle is the key to the regeneration of degraded soils. Furthermore, the author found that there are six key practices that if implemented will promote and sustain this cycle.

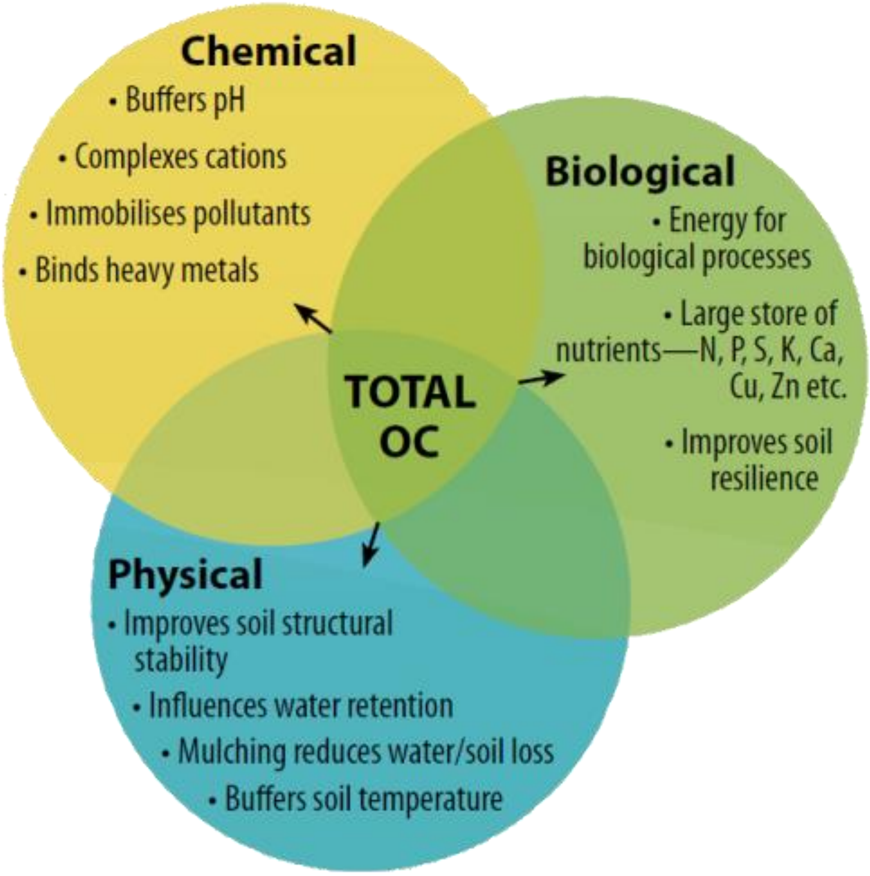

Figure 5. Some of the beneficial physical, chemical and biological processes in soil that total OC contributes to (Carson, 2020)

Chapter 4: The key practices of a Regenerative Agricultural system

The six practices to improve soil health are outlined in this chapter.

4.1 Balanced soil nutrition – without synthetic fertilizers

In a great deal of the literature about RA, the concept of balancing the mineral component of the soil was not seen as one of the key practices to establishing a functioning RA system. Thoughts on this varied across the globe with people falling into two distinct categories, Input Balancers and Plant Balancers.

4.1.1. **Input Balancers**. At various conferences the author attended, many leading soil experts believe that some form of nutrient balancing using inputs, is required to keep the plant functioning at its peak photosynthetic capacity. Without optimum photosynthetic capacity the microbial bridge is weakened, slowing the whole system down. As Garry Zimmer puts it "*do not bring the bulls in (biology) if the cow's not ready"* (minerally balanced soil) (Zimmer, 2018)

The belief of this group is that the right chemistry invites biology into the system, and both ae needed for a high functioning crop. Balance is more important than absolute levels, and the suggestion isn't necessarily to aim for the perfect soil test result. This is generally a process that takes time and requires the farmer to keep at it. Simple targeted changes can produce dramatic results when the right elements are adjusted. In a system that is trying to mimic a natural ecosystem, all nutritional inputs into that system should be organic (non-synthetic) and biological. (Smith, Norwood, Diver, 2018).

4.1.2. **Plant Balancers**. Alternatively, using a diverse group of plants from as many plant families as possible was the best way to balance out any nutritional issues. Arguing that the need for nutritional inputs, even organic ones was not needed if the cover crop mix was as diverse as possible and if needed, continued for more than one year. This is the key component of the nutrient cycling program at Gabe Brown's farm in Bismark North Dakota (ND). It is the same system followed by Peter Barrett at Linnburn Station in Maniototo, Central Otago. After years of synthetic inputs applied to the farm, they were getting extremely poor results and in the case of the final two years of that traditional program, they had almost total pasture failure when seeding. Barrett switched over to Brown's multi-species cover crop system and along with some liquid feeding of the soil microbe populations has what he states, "*woken up my sleepy soils*." He is now growing impressive stands of multi-species cover crops and has seen a regeneration of lucerne where they have been grown without any nutritional input (Barrett, 2019).

The author concedes that there is no right or wrong answer as there are many examples of both management practices being successful. The use of the Albrecht method of soil testing was the preferred method of testing amongst the group that did do soil testing regularly (Zimmer, Smith, Norwood, Zimmer-Durand, 2018).

Even Peter Barrett is not against collecting data to help understand what happened and why. However, he does not believe in "*drowning in data*" just for the sake of it. "*Why spend money off the farm when you can trust your judgment and observe outcomes while developing your own farm-specific system*" (Barrett, 2019).

4.2 Keep the soil covered

In most undisturbed natural ecosystems, the soil has some sort of cover. This could be living plants, or it could be decaying plant material. Either way, the soil's default mechanism is to have some sort of cover. This helps protect the soil structure and particles from physical damage from extreme wind or rain events. Nature does not like bare soil which is why bare soil is such a magnet for weeds (Corfield, 2020). The physical nature of the soil is also prone to change with crusting occurring reducing infiltration and this increases the runoff of water. Ultimately without either a green growing cover or a decomposing litter layer, the "glue" that helps provide the soil structure through the plant-microbe interaction is broken and the soil is susceptible to erosion events and increased water loss through evaporation. When soil is removed from the landscape not only are we removing soil depth and capacity but with it, nutrient that is stored in the soil fraction is also lost.

Another important aspect of maintaining soil cover is to buffer the soil microbe community against temperature extremes (either hot or cold). Temperature, together with moisture are important factors in cultivating and maintaining healthy soil microbial communities. During a study in 2005 researchers found using soil respiration tests bacterial and fungal growth rates had optimum temperatures around 25 – 30 deg/C while at higher temperatures lower values were found (Pietikainen et al, 2005).

This is particularly relevant for vineyards in the Australian summer where prolonged periods of high temperatures are now becoming more common. Cultural practices resulting in bare ground during the summer months such as cultivation or lack of established winter ground cover is likely to have a detrimental effect on soil microbial populations.

Table 1. McLaren Vale vineyard midrow soil surface temperatures taken at 1pm with an ambient air temperature of 42C (source author 30/1/2020)

Bare cultivated soil surface	Rolled cover crop surface	Soil surface underneath 10cm of cover-crop residue
72C	66C	43C

Table 1 illustrates that even a 10cm layer of rolled cover crop mulch can significantly reduce soil surface temperatures. Making the soil less prone to evaporation and more hospitable for soil microbial communities than the cultivated bare soil.

Figure 6. Bare compacted soil, Central Valley California (Author, 2019)

Figure 7. Bare cultivated soil, Central Valley California (Author, 2019)

4.3 Minimize disturbance – cultivation severity and frequency

The severity and frequency of cultivation is one of the major challenges for conventional and organic agriculture. The wine industry has long used cultivation for mid row vegetation control during the growing season. This was a cultural hangover from practices copied from Europe as a way of limiting competition for water and nutrients. Before the introduction of herbicides, it was the primary control of under vine plant material as well. With the current trend away from herbicides, cultivation has again become popular for both mid-row and under vine areas.

The problem with excessive cultivation is that it destroys soil aggregates, significantly decreases water infiltration rates and accelerates the breakdown of SOM. When soil aggregates are split apart and exposed to oxygen particular types of opportunistic bacteria are stimulated and they quickly consume the glue-like carbon When the glues are gone, the silt and clay particles fill the voids which reduces porosity (Brown, 2018 p108, Corfield 2020).

Combined with this that the soil is then generally left bare for extended periods of time increasing the chances of erosion through wind and rain events.

Cultivation also disrupts and diminishes the complex mycorrhizal fungal network. The severed fungal network can no longer deliver the complex amino acids and other complex organic and inorganic molecules that they produce through the microbial bridge. This, in turn, affects the nutrient cycling of the system and impacts on plant growth (Brown, 2018 p108).

Mycorrhizal fungi are extraordinary ecosystem engineers that can access water, protect hosts from pests and diseases and transport nutrients in exchange for liquid carbon from plants. The carbon polymers formed by these fungal networks improve soil structure, porosity, cation exchange capacity, and plant growth (Jones, 2018).

In the opinion of the author there are no impediments to reducing or eliminating the amount of cultivation in the midrow with a great range of mowing and rolling equipment available. The establishment of annual cover crops could be done with a no-till method as used in a great deal of the dryland farming sector. The author saw a mature green cover crop no-till systems in many countries but most notably when he visited Blake Vince, a 2013 Canadian Nuffield Scholar as well as Peter Barrett at Linnburn Station in New Zealand. Both operations use multi-species cover crops to keep the soil covered in winter. They are then rolled and either summer crops or pasture is sowed straight into this thick layer of mulch in spring. The under-vine zone provides a greater challenge with pressure from customers and the wider community to reduce or eliminate herbicides resulting in a return to cultivation for weed control. New equipment such as finger weeders and mechanical cord mowers, like the one the author viewed at Terra Sancta vineyard in Central Otago (See Figure 17), is changing the way this is done and may provide a much less invasive method of weed control.

Figure 8. Soil structure damage by over-cultivation. Davis, California 2019 (Author)

Left - Figure 9. Soil Cultivated eight times during the growing season, McLaren Vale (Author, 2019)

Right - Figure 10. Direct drilled multi-species cover crop with no cultivation, McLaren Vale (Author, 2019)

These images were taken after 25mm of rain over eight hours. Vineyards are 1km apart.

4.4 Increase diversity – above and below the ground

One of the keys to stable and high functioning natural ecosystems is plant diversity and by association soil microbial diversity. In mono-crop farming systems, this diversity has been lost for the simplification and specialisation of the farm system. This simplification has potentially reduced the ability of the farming enterprise to withstand extremes of seasonal weather.

Diversity is important in a farming enterprise and helps to manage risk at all levels of the business, be it people, machinery, grape varieties, buyers, or crop levels. To help build resilience in soil a diverse range of plant species is needed above the ground to cultivate a diverse microbial ecosystem below the ground, Gabe Brown calls diverse cover crop cocktails "*biological primers*" (Brown, 2018). Every plant exudes its own unique blend of sugars enzymes, phenols, amino acids, nucleic acids, auxins, gibberellins and other biological compounds, many of which act as signals to soil microbes. Root exudates vary continuously over time, depending on the plant's immediate requirements. The greater the diversity of plants, the greater the diversity of microbes and the more robust the ecosystem over time (Jones, 2018). The mid-row area of the vineyard provides a great opportunity to experiment with different species of plants to kick-start the microbial diversity required to build resilience into the vineyard system. The physical nature of this plant mix is also important to the vineyard system. A diverse mix of cover crop plants with different flowers and flowering times increases the habitat's for predator insect species. These are beneficial in controlling pest insect species, reducing the reliance on chemical pesticides. As shown in Figure 11, researchers found, insect populations were more than ten-fold higher on mono-culture insecticide treated farms compared to RA run farms with multi-species cover crops, no insecticides, no tillage and animal grazing.

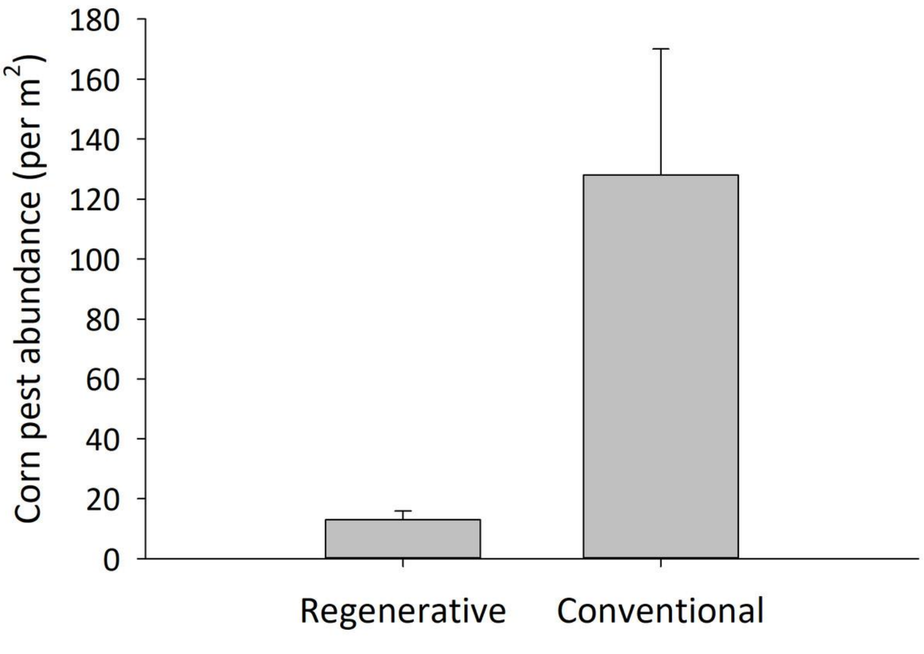

Figure 11. Pest populations in conventional cornfields vs regenerative cornfields (La Canne and Lundgren, 2018)

The root systems are equally important creating pathways at different soil depts for water infiltration, breaking open compaction layers and storing carbon through the plant-microbial bridge network. As 2013 Scholar Blake Vince challenges “*why use all this heavy machinery to prepare our land when we can use roots, not iron, to do all the preparation for us*” (Vince, 2019).

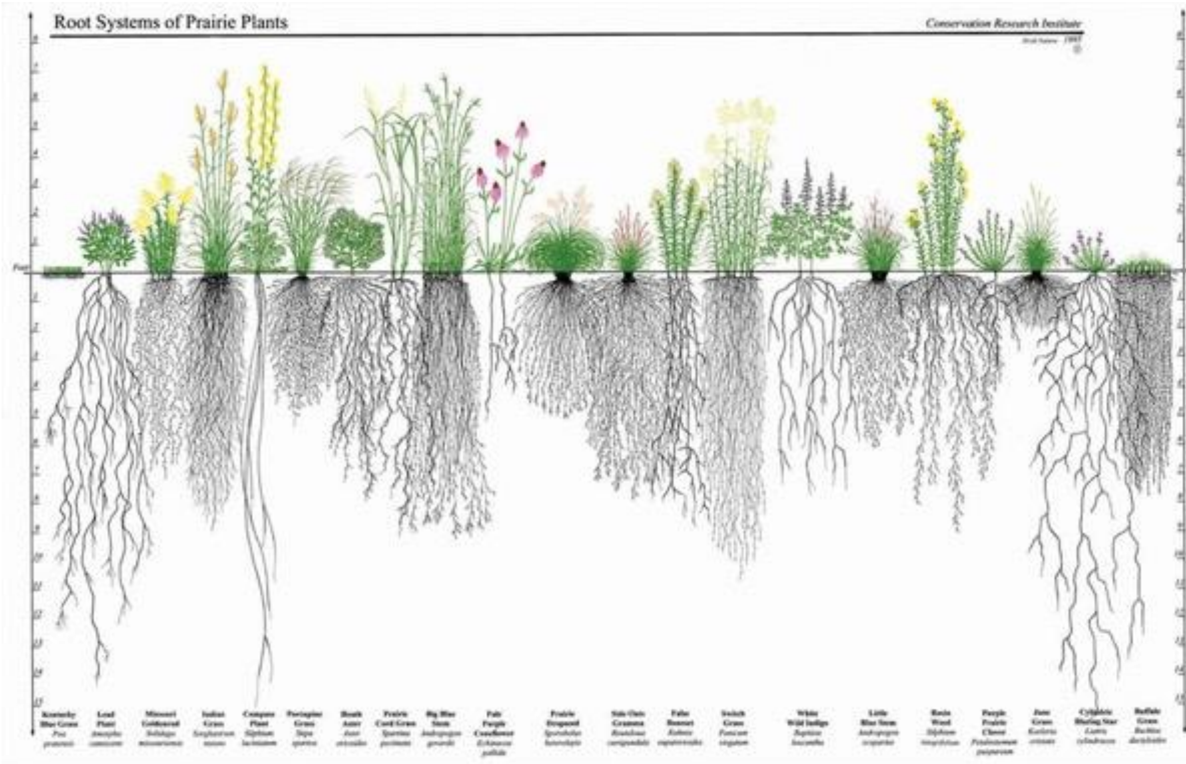

Figure 12. Root Systems of Prairie Plants. (Conservation Research Institute, 1995)

4.5 Living roots all year round – farming sunlight

Living plants are the key to building up the diverse soil microbial community and building soil capacity through soil organic carbon storage. As discussed previously, every green plant is a solar-powered carbon pump. It is the photosynthetic capacity and photosynthetic rate of living plants (rather than their biomass) that drives the bio sequestration of stable soil carbon. To put it simply the conversion of solar energy to biological energy.

Photosynthetic capacity – the amount of light intercepted by green leaves in a given area. Determined by percentage canopy cover, plant height, leaf shape, and seasonal growth cycles (Jones, 2018).

This highlights the need to have a diverse range of plant species with differing heights and leaf shapes. It also requires a range of plants that cover both winter and summer seasons. Vineyards traditionally have little to no mid-row growth during summer due in part to reduced moisture availability. However, quite often the species present has been specifically chosen to be dormant during this period to avoid competition for moisture. Vineyard systems do have living roots in the summer period with the vine itself acting as a carbon pump. There is potential to have companion plantings of various plant species, both in the mid-row and under-vine areas during summer months to increase the amount of green leaf area without a detrimental effect on vine production. Recent research by Penfold and Howie (2019) on under-vine cover cropping concluded but not limited to:

- When well-adapted plant species are used for under-vine cover cropping, grapevine yields be maintained and improved on some soil types compared to the bare earth/herbicide treatment;
- Under-vine management operations can be minimized, and costs significantly reduced; and
- Soil carbon increases, which in turn improve soil structure and water infiltration.

Summer cover crops do not need to reach the same biomass as winter grown cover-crops it's just about having living roots in the system for as much of the year as possible to keep feeding the microbial ecosystem, "*bare soil has zero photosynthetic capacity*" (Jones, 2018).

Figure 13. Diverse multi-species cover-crop, Opus One Vineyard, Napa Valley (Author, 2019)

Figure 14. Diverse multi-species cover-crop, Opus One Vineyard, Napa Valley (Author, 2019)

4.6 Livestock integration and management – more than just mowers

Animals have been moving through the landscape for centuries and we need to mimic the way they grazed plants before human intervention with large herds of animals constantly being moved on by predators (Brown, 2018). There is great potential with animals to accelerate soil health and regeneration through planned strategic grazing management. The way these are managed through the landscape is just as important, if not more important, than having them there in the first place (Gaudin, 2019). The preferred technique in RA is to have high stock numbers per hectare (Ha) and move them frequently. This concentrates the manure onto smaller parcels of soil increasing nutrient availability for the pasture. It also reduces the threat of overgrazing and selective grazing leaving behind larger vegetative biomass which recovers more rapidly due to a larger leaf area being left behind (Lonborg, Barrett 2019). This continuous light grazing keeps plants in a vegetative state and promoting root growth that produces root exudates and feeds soil microbes and pumping carbon into the soil profile (Nichols, 2019).

Animals are potentially the most difficult of the principles to bring into a farming system that traditionally has not had a livestock component. Livestock has become increasingly popular in vineyard operations in Australia. With the move away from herbicide use, many vineyards are using livestock to reduce midrow and under vine vegetation over winter making management during spring easier and more cost-effective. There is more potential than just cost reduction, and although it can add costs to the vineyard initially with fencing, the author observed the benefits of this intensive rotational grazing across a number of different farming systems with obvious benefits to soil health. In these well-managed systems, the key was to keep stock moving regularly to ensure soil is not compacted or pasture overgrazed.

Figure 15. Intensive grazing trial, Hither & Yon Wines, Sand Rd Vineyard, McLaren Vale (Author, 2019)

Bringing it all together – an integrated system

The six practices described in this chapter are designed to be used together as an integrated system with each one connected to the others. RA systems are theoretically designed to work with minimal inputs compared to conventional synthetic farming systems, therefore, increasing overall profitability to the farming enterprise.

In a recent study by LaCanne and Lundgren 2018 across 40 corn fields in the northern plains of the United States, evaluated the overall profitability of conventional and regenerative production systems. The RA cornfields implemented three or more practices such as planting a multi-species cover-crop mix, eliminating pesticide use, abandoning tillage and integrating livestock. The conventional fields used fewer than two of these practices. The RA systems had 70% higher profit than the conventional systems.

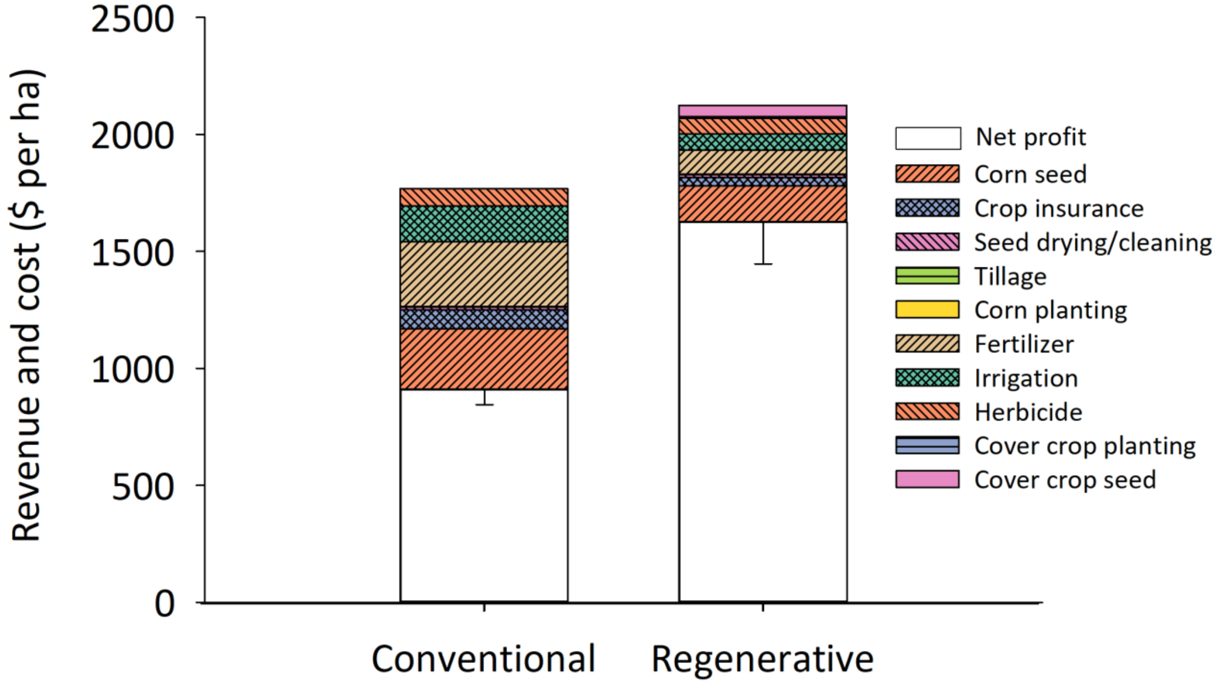

Figure 16. Regenerative corn fields vs conventionally managed corn fields overall profitability (LaCanne and Lundgren, 2018)

This may be true of mature RA farming enterprises but before they get to this stage there is trial and error, observation and manipulation to meet the individual requirements of each farm business. A significant number of new skills are needed along with new systems to be implemented at achieve a mature RA farming system. As Gabe Brown states "*Failure is important, fail at several things a year. Without failure, you do not move forward, and you do not learn, just make them small failures!*" (Brown 2018).

Land managers, need to read their landscapes, understand paradigms and biases. RA is not a recipe card; it is unique to each individual, farm enterprise and surrounding landscape. Experimentation, innovation, and diversity are all keys to having and transitioning to a functioning RA system (Brown, Massy, 2018).

These systems are at times far removed from the simplified nature of conventional systems. They are at times complex and difficult to manage, especially in the formative stages (Lonborg, 2019). It can take time to adapt to the new way of thinking and not do what has been done before. This is where keeping perspective on the bigger picture is important and being clear on the system you are trying to implement (Foster, 2019).

Patience is needed during the conversion process - there will be things that go wrong and are unexpected. Start small and be observant as the outcome may not be what was hoped, but that does not make it a failure. This style of farming puts decision-making back in the hands of the farmer as they are the ones that know their landscape the best (Barrett, 2019).

It was this last point that resonated with many of the enterprising farmers the author met around the globe, bucking the trend of conventional farming systems willing to experiment and try something different. All were refreshed and energized by developing a system on their farm that was specific to them and what they were trying to achieve. There was an overwhelming sense of camaraderie and collaboration to share successes and failures to help others find their system without some of the hardships that they had encountered.

Chapter 5. Global Case Studies

It is all good in theory, but can it work in the real world? This chapter focuses on case studies as part of the research.

5.1 Terra Sancta – Bannockburn, Central Otago, New Zealand

RA practices implemented:

- Total soil cover
- No cultivation
- Diverse cover crop
- Living roots all year
- Livestock integration

This 34Ha vineyard is situated in Central Otago which has an annual rainfall of 340mm. The author met with vineyard manager Conal Wattam to discuss his regenerative approach to vineyard cover-crop management. Wattam uses several different species in both the midrow and under vine areas. Every species has been selected for a specific purpose.

1 A mixture of flower colours – for predatory insect attraction
2 Differing root systems – soil tillage and carbon storage at various depths
3 Large amounts of biomass – SOM building and surface cover
4 Species diversity – for microbial diversity and nutrient scavenging and cycling

Wattam manages this cover crop in quite a unique way for a vineyard operation by drawing on a controlled traffic type system. He manages the mid rows over a two-year rotation with almost all tractor passes confined to every second row (ESR) allowing the non-traffic rows to be rested from machinery compaction. The cover crop in these rows is allowed to reach full maturity and go to seed allowing it to self-seed the following year without mechanical intervention. The traffic rows are mown and dropped when necessary during the growing season leaving a thick mulch on the soil surface. Before it goes to seed the crop is intensively grazed by 200-plus sheep at least twice during the season to help concentrate manure additions to the soil and to promote rapid vegetative growth of the cover crop. In the traffic rows cover crop is direct drilled twice during the year. Once for a winter species crop and once for a summer species crop to give living roots all year round. There is no under vine cultivation undertaken with grass cut with an over-row cord mower that can be set to varying heights depending on how much vegetation is required to be left. Chickens are used to control insect pests throughout the vineyard and no synthetic chemicals are used. Any other soil nutritional requirements are handled by compost made on site. Wattam is seeing the benefits of this system with input costs reduced and soil structural conditions improving, while soil carbon levels have risen over 2% in the last two years (Wattam,2019). The author noted the soils had a very spongy feel to them compared to other vineyard sites visited in the area and that there was no water runoff or soil erosion after a heavy rain event just before the visit, unlike the neighbouring cultivated vineyard.


Left - Figure 17. New over-row cord weeding machine. Terra Sancta Vineyard, Central Otago. (Author, 2019)

Right - Figure 18. Non- traffic row with different multi-species cover-crop sown in early spring and diverse under-vine mix. Terra Sancta Vineyard, Central Otago. (Author, 2019)

5.2 Longridge Wines – Stellenbosch, South Africa

RA practices implemented:

- Total soil cover
- No mid-row cultivation – limited under vine cultivation
- Diverse cover crop
- Living roots all year
- Livestock integration
- Mineral balancing

Located at the foot of the Helderberg mountains this 30Ha vineyard is run by Jasper Raats who explained that they started using biodynamic methods from 2011 because of frustration over the endless cycle of chemical inputs doing damage to vineyard environment and the people who worked in it (Raats, 2019). Raats had also come to the realization that their soils were particularly degraded from chemical use and cultivation. In 2012, they started to balance their soil nutrition with blended organic compost and introduced multi-species cover crops by direct drill method into the vineyard and ceased all cultivation. These were then rolled green with a crimp roller to give a good thick surface cover over the hot summer period. During this period cows were introduced into the vineyard using a planned rotational grazing system. The vineyard did not respond favourably to the system change at first with reduced crops in 2014 due to competition for water and nutrient, particularly in the shallower soil areas. During this year Raats also started to introduce beneficial fungi (Trichoderma) into the soil via the drip irrigation system to help increase vine vigour. The benefits of this system change were evident during the 2015 to 2018 drought where Raats explained: "*our independently monitored soil moisture probes were showing a 30% increase in available soil moisture compared to neighbouring vineyards and we have had a 50% reduction in water use from our pre-2012 records*" (Raats,2019). The author also observed multi-species cover crops being used as companion plantings within a newly established vineyard. A diverse plant mix with lucerne being the dominant ground-cover plant was according to Raats "*providing nitrogen to the young vines and keeping the soil cool during the warm summer growing season*" (Raats,2019). This had removed the need for any synthetic fertiliser to be applied, with no detriment in vine growth.

Figure 19. View from cellar door with insectary native planting in the foreground. Longridge Wines, Stellenbosch, SAF (Author, 2019)

Figure 20. Young Merlot with companion planting of Lucerne. Longridge Vineyards, Stellenbosch. (Author, 2019)

5.3 Tablas Creek Vineyard – Paso Robles, CA USA

RA practices implemented:

- Total soil cover – mid-row
- No mid-row cultivation – limited under vine cultivation
- Diverse cover crop – permanent pasture
- Living roots all year
- Livestock integration
- Ecosystem services for pest control

This 44ha vineyard is situated in the Adelaida sub-region of Paso Robles with rolling hills, proximity to the coast and 600mm of annual rainfall. The primary purpose of this visit was to observe the high-intensity rotational grazing system they have developed. Vineyard manager Jordy Lonborg explained that the vineyard had been certified organic in 2003. In 2010, they started using biodynamic techniques and became certified in 2017 (Lonborg,2019). Lonborg stated that "*they had had sheep on the property for ten years but increased the herd size to 200 in 2016 after becoming interested in what intensive rotational grazing could do for the vineyard system*" (Lonborg,2019). The 200 sheep are moved every day into a fresh 2ha area secured by a temporary electric fence. This co-ordinated schedule is based on pasture growth and ground conditions where wet areas are avoided after heavy rainfall. The sheep are removed at budburst and run on a neighbour's property during the summer months. Lonborg explained that "*they had been able to graze all of the vineyards at least once and areas of good pasture re-growth had been grazed twice*" (Lonborg, 2019).

Over the three-year period, Lonborg estimated they have removed two spring tractor passes over the entire vineyard, and soil nutrition is now managed by the concentrated manure resource and compost made on site. Lonborg has also observed a reduction in their invasive weed species because the sheep are more concentrated, they cannot afford to be picky and therefore eat everything and secondly, the pasture growth is more vigorous, and this is outcompeting the weed species (Lonborg, 2019). Lonborg has a very ecologically minded approach to pest control with the use of predators a key to the system. There are 30 owl boxes scattered around the vineyard as well as a number of raptor perches control their problem ground pests particularly squirrels. They have also planted over 100 different flowering fruit trees to provide food for their own beehives and attract predator insects into the vineyard system.

Figure 21. Dry grown Bush Vine Grenache with grazed cover-crop and owl box. Tablas Creek Vineyard, Paso Robles. (Author 2019)

Figure 22. 200 head sheep herd intensively grazing cover-crop. Tablas Creek Vineyard, Paso Robles. (Author, 2019)

5.4 Paicines Ranch – Paicines, CA USA.

RA practices implemented:

- Total soil cover
- No soil cultivation
- Diverse cover crop – permanent pasture
- Living roots all year
- Livestock integration
- Innovative vineyard design

Paicines Ranch is a diverse organically certified farm business located in San Benito County CA. It compromises of 2,800 Ha of pasture rangeland used to grow grass-fed beef and sheep, 200 Ha of row crop production land and 12 Ha of newly established vineyard. The ranch also has an event centre that is used regularly for events and workshops around RA systems. Kelly Mulville is ranch manager with a specific focus on the innovative vineyard design. Mulville explained that "*the entire ranch is managed with RA practices designed to provide more diversity and more complexity to their farming ecosystems*" (Mulville, 2019). Mulville has a real belief in using plants as liquid carbon pumps for the soil encouraging a diverse range of microflora that will, in turn, produce a healthy plant with high sap Brix levels resistant to pest and disease. Fundamental to this is the establishment and management of a diverse pasture species in the new vineyard. The problem with sheep managing grass in vineyards explained Mulville is that "*they need to be removed when pasture growth is at its peak during early spring*" (Mulville, 2019). This is a loss for the system in a number of ways:

1. It limits the opportunity to finish off the sheep and use them as an income stream for the vineyard or requires additional land to do this.
2. It restricts the ability to remove considerable costs from the vineyard system by the elimination of all, but the most essential tractor passes through the vineyard.
3. It limits the time and therefore the effectiveness of the high-intensity rotational grazing method to increase soil carbon storage through the plant-soil microbe liquid carbon pump (Mulville, 2019).

These challenges led Mulville to design a vineyard trellis system that allowed the sheep to be in the vineyard for the entire year without damaging the vines during the growing season. This system has led to a fruiting wire at 1.8m in height with a V-shaped foliage system to keep most of the foliage out of the sheep's reach. This has allowed the sheep to be cell grazed in the vineyard right through the growing season or until the pasture requires resting over summer where they are moved to another part of the property. It is early days for this system as the vineyard was only planted in 2017 but it focuses on one of the often talked about aspects of RA; the reduction of inputs, diversification of income streams leading to increased productivity of the farming system. Mulville also touches on the plant health benefits of RA systems that the author heard at multiple visits around the globe that; a plant grown in a high functioning, microbially and plant diverse ecosystem will be nutritionally dense with high Brix sap levels making it potentially resistant to pest and disease attack. Mulville is keen to pursue and test this theory as this project proceeds.

Left - Figure 23. Unique trellis designs at Paicines Ranch California, allowing sheep grazing all year round. (Author, 2019)

Right - Figure 24. Unique trellis designs at Paicines Ranch California, allowing sheep grazing all year round. (Author, 2019)

5.5 Linnburn Station – Maniototo Plain, Central Otago New Zealand

RA practices implemented:

- Total soil cover
- No cultivation
- Diverse cover crop
- Living roots all year
- Livestock integration
- Feeding the soil

If seeking a place to see Gabe Brown's book "*Dirt to Soil*" in action, Linnburn Station is the place. Linnburn is a family-owned beef and sheep property situated between Dunedin and Wanaka in the South Island of New Zealand, with an annual rainfall of 400mm. It is 9300 Ha of developed dryland country with 500 Ha of that in the form of irrigated flats.

The property has been managed by family member Peter Barrett from 2007 who outlined the property's transformation through RA. Barrett explains that upon returning in 2007 he embraced a traditional high input farming model of soluble fertilizers, cultivation, simple pasture mixes and chemical pest control. After a number of seasons of poor results and continually getting the same agronomic advice he sought out an alternative and came across Brown's book (Barrett,2019). Starting in 2014, Barrett has implemented the six RA practices listed in this report on 900 Ha of Linnburn Station with some visually remarkable results.

This was a truly inspiring visit as a large-scale representation of the RA practices at work and some of the highlights were:

- The detail Barrett has gone into to make cover crop selections based on his resource concerns and what he is trying to correct and, matching that to his climate and soil type are incredibly impressive. With numerous spreadsheets detailing everything, he needs to know about his paddocks and the plants he might use to correct the issues in them.
- The difference in the treated paddocks as opposed to the yet to be treated was remarkable with impressive increases in plant diversity, soil structure, soil macro, and microbial life and soil moisture retention.
- Plants can do all the work for us; Barrett has taken the same budget he had for the traditional high input model that covered 250ha and is now doing 900ha under RA practices.
- Be flexible, stay patient, be observant and curious and look to mimic nature's rhythms as much as you can Barrett believes are to keys to developing your system.
- Incorporate as many different plants in your cover crop mix, Barrett is currently using 60+ in his summer mix. Barrett expects not all will come up, but he believes the soil and the biology will choose the ones they need to correct the issues that paddock has.
- Where possible let things go to seed to build up your own seed bank in the soil.

Before starting all this work Barrett undertook an extensive number of baseline soil tests and measurements across the property. Barrett does not want to get bogged down in the data but is keen to revisit it in the future to gain an understanding of what changes have occurred and why? (Barrett, 2019).

Most importantly Barrett believes "*it's your system unique to your farm you need to own it" "Do not bow to other people's beliefs and opinions*" (Barrett, 2019).

Left - Figure 25. Multi-species cover-crop before rolling, Linnburn Station, NZ (Author, 2019)

Right - Figure 26. Peter Barrett and Author looking at crop after rolling with a crimp roller, before seeding summer pasture, Linnburn Station, NZ (Kate Scott, 2019)

Conclusion

Globally, researchers and farmers are beginning to understand the value that the complex plant and soil microbial network interaction can provide to agriculture. This has led to not only short-term thinking and benefits, but generational thinking and understanding that sustaining soils and farming systems where they are now is not good enough.

Real change in soil management and soil health is needed. An admission that some conventional farming practices have damaged and degraded the soil is the important first step to changing the mindset towards more regenerative management techniques.

Science and technology are increasingly looking at how they can measure and quantify the soil-plant microbicrobial interaction. Next-generation DNA sequencing is now giving insights into soil biological diversity, mineral and nutrient cycling and availability, pathogen threats, beneficial microbe populations and species identification.

As more data is collected globally, it furthers understanding of what benefits the soil microbial network can have on agricultural systems. Equally important is determining over time which management techniques enhance these complex microbiome networks and how they do it (Matthesen, 2019). As more data is collected, researchers and scientists will be able to track changes to soil microbial populations based on management techniques. This will be key to developing farm management systems that reduce the reliance on synthetic fertilizer/chemical inputs and build long-term soil health and fertility through the use of plant diversity and reduced cultivation. In the near future, farmers will be able to leverage these microbial interactions between soils and plants. In the short term, generating high-quality meaningful data is the key to building creditability and trust (Wilson, 2018).

For this to happen, a shift in management thinking needs to occur. Vineyard management needs to firstly become about farming sunlight and promoting carbon capture through plant diversity in the mid-row zone and even the under-vine area. Secondly, soil management needs to focus on developing and strengthening the soil microbial ecosystem and reducing practices that are harmful to it. This change to a more holistic vineyard management approach through the use of RA practices has the ability to:

- Increase soil capacity for water and nutrient retention.
- Increase soil microbiome populations and diversity and potentially reduce inputs.
- Reduce chemical use through developing habitats for predator and beneficial insects.
- Maximise the benefits of livestock through effectively planned grazing strategies.

Years of poor soil management and degradation will not be repaired in one or two years. RA and the six practices in Chapter 4 give vineyard managers a template to follow as they develop a system best suited to their individual operation and a roadmap to improving soil health. There is no “one size fits all” system. Managers need to understand the resource limitations they are seeking to fix and the most effective way to do that within the current limitations of their operation.

In vineyard systems, there is more than one "right way" to do something. What managers must do is limit the multitude of "wrong" ways to do something. During the transition and development of an RA system, many farmers that the author spoke to believed letting go of, or breaking, long-held beliefs of "the right way to do things" was the hardest part. Once they moved to a more open-minded thought pattern, not only did they find the transition easier, but the speed in which they administered change accelerated as well. With this came more trust and confidence in the systems they were developing and a feeling that they were in control of their own decisions and outcomes.

During the compiling of this report, the author has read equal numbers of reports both downplaying the claims for RA and ones that show its success. Much of what the author has seen during the many farm visits are highly evolved RA farming systems with anecdotal successes being reported by farmers without the usual scientific reporting or replication. Just because there is no scientific data around some of these systems does not mean we should reject what we see and feel to be working. This sentiment was echoed by Rich Collins an asparagus farmer who stated: "*We have set up a number of trials to collect data, but I am an observations farmer if I see it working I don't need to know the numbers*" (Collins, 2019).

Observation skills are one of the key attributes of skilful RA farmers the author encountered during his travel. This "citizen science" as New Zealand Nuffield Scholar Kate Scott calls it, is common in the RA sphere. To drive majority practice change by vineyard managers, solid credible evidence of the impacts of RA systems on the physical, chemical and biological health of soils may be required. However, for now, the author remains convinced that the implementation of the six RA practices outlined have the ability to provide long-term environmental, economic and social benefits to the Australian wine industry.

"The greatest obstacle to discovery is not ignorance, it is the illusion of knowledge" ~ Danial J Boorstin.

"*Read books and study nature, when the two don't agree, throw out the books*" ~ William Albrecht.

"*Remember that wishful thinking isn't a plan*"- Toby Bekkers. 2017 Nuffield Scholar

Recommendations

The Australian wine industry should aspire to be more than just sustainable when it comes to the management of vineyard soils and ecosystems. In order to move to a more regenerative path the following recommendations are made.

- Rethink the use of cover crops in the vineyard midrow zone. Increase plant species diversity and consider both winter and summer sowing to have living roots year-round.
- Research suitable plant varieties and weather conditions for the region, suitable for the task they are intended for.
- Utilise living plants in the under-vine zone as a cost-saving and soil health building alternative to cultivation and herbicide application.
- Explore the potential beneficial role of the soil microbial network in established horticultural crops as a way of delivering reduced inputs and cost savings to industry.
- Start at a manageable level, identify an area where there is comfort in making mistakes and where financial consequences are bearable. Trial the system, which should be unique to both grower and environment.
- Budget for any machinery or capital infrastructure required to change systems.
- Maximize the benefits of livestock with infrastructure to allow planned rotational cell grazing techniques.
- Undertake regular soil testing for nutrition and soil biology. Set baselines and track changes over time with management changes.
- Link innovative RA vineyard managers and researchers together to set up longer-term trials and data collection assessing the impacts of RA techniques over time.
- Develop insectary plantings and beneficial habitats for predator insects in non-productive areas for ecosystem pest and disease control.
- Find and collaborate with RA farmers across all farming industries. Mentors are extremely important in the initial stages of system changes to give guidance and confidence.
- Look to partner with local natural resource management organisations to improve overall property plant species diversity.
- Have an open mind about how vineyards need to look and how common jobs are done. Through RA systems there may be ways to add value to the vineyard system and reduce detrimental impacts on soil structure and soil ecosystems

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Plain English Compendium Summary

Project Title:	**Is Being Sustainable Enough for Australian Wine? Regenerative agriculture can redefine what is best practice viticulture**
Nuffield Australia Project No.:	1716
Scholar:	Richard Leask
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Objectives	Examine and understand the key principles and practices of Regenerative Agriculture systems and how they may be incorporated into wine grape production to improve soil health, soil capacity and reduce inputs.
Background	Winegrape production systems are facing increasing pressure on their environmental sustainability credentials. The industry is also facing increasing climate variability, limited water resources, rising input costs and resistance problems with commonly used herbicides. This has led toward a shift to organic farming systems at the risk of increased soil degradation.
Research	Extensive travel through ten countries meeting with Regenerative Agriculture farmers and leading soil researchers. They were interviewed to determine the validity of Regenerative Agriculture to improve soil health, reduce inputs and increase ecosystem diversity to support healthy wine grape production.
Outcomes	The study revealed that soil health, microbial diversity, soil capacity and a reduction of synthetic inputs can be achieved using the six Regenerative Agriculture practices outlined in this report. These practices can be modified to fit existing wine grape production systems and enable producers to have a more environmentally sensitive management program.
Implications	Producers willing to change management practices that place greater emphasis on improving soil health and microbial diversity will over time be able to reduce synthetic chemical inputs. Their production system will be more resilient to the continued climatic challenges facing producers and be able to take the full value of improved ecosystems and the services they provide.