EcoVineyards are growing resilience and future proofing production whilst adapting to disruptive change

We stand at a crossroads in history. The impacts of geopolitical tensions, climate change, wildfire, extreme weather events and loss of biodiversity are some of the immediate challenges impacting our capacity to grow agricultural crops sustainably. But we must do so whilst avoiding the depletion of natural resources and maintaining agroecological balance.

Consumer perceptions are rapidly changing, with growing demand for transparency and verifiable environmental credentials. The decisions that are required now to create step change have the capacity to influence the course of history, and the success (or not) of these endeavours, will be felt for many decades to come.

The benefits of ecological restoration through the incorporation of locally adapted, native vegetation are unequivocal but often overlooked or underestimated in a farming context. Increasingly though, this is changing. This article explores ways we can align ourselves with nature's intelligence to create and maintain functional agroecosystems.

EcoVineyards are embracing regenerative techniques and the benefits that arise from increased functionality and resilience, including weed suppression, erosion control, nutrient cycling, soil moisture retention, organic carbon, and biological activity to future proof production and contribute to natural climate solutions. These insights are applicable to a broad range of production systems.

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Key messages

- Monoculture plantings have a negative impact on biodiversity. Whereas functional biodiversity is associated with greater resilience and stability in production systems.
- When native vegetation is reduced, natural processes can break down and valuable fauna species otherwise found including predatory arthropods, birds and microbats are lost.
- Diverse native insectary plantings provide tangible benefits. Growers can enhance biodiversity through ecological restoration with native insectary plants to enhance the performance of agroecosystems and help safeguard against biosecurity incursions.
- Native insectary plants are resilient, versatile, naturally adapted to Australian conditions and can be showcased as marketing collateral to differentiate our uniquely Australian products in the crowded international marketplace.
- Growers in the EcoVineyards project report lower pest problems and less intervention with chemicals when native insectary plants are incorporated in and around production systems. Growers intervene less, saving time, money and resources.

Introduction

Our key to survival is continual adaptation. Disruption creates an environment for innovation. The wine community is known for its innovation and is leading the way in creating step-change in vineyards. At the property and landscape scale, we will discuss the importance of functional biodiversity and ways we can grow resilience and stability in production landscapes. We also demonstrate how EcoVineyards are embracing ecological restoration techniques to future proof their production.

Ecological infrastructures are defined as any infrastructure within a radius of 150 metres of a farm or vineyard that has an ecological value to the production system and increases the functional biodiversity of the property (Boller et al., 2004). Within a vineyard, existing vegetation structures such as windbreaks, vegetation corridors, mid-row or under-vine ground cover and headland plantings can be created and/or enhanced to provide resources for predators that contribute to pest control throughout the year. Similarly, creek lines that may be infested with exotic woody plants can be rehabilitated with native plants which offer multiple benefits.

In addition, our native flora and fauna is globally unique, and this provides a novel way to stand out in a crowded international marketplace. By making our vineyards look uniquely Australian, we can create unique marketing collateral while showcasing our environmental stewardship credentials.

Resilience is an important underlying feature of functional systems and can be defined as the capacity of a system to reorder itself after local disturbance (Tscharntke et al., 2005) including extreme weather events (Yachi & Loreau, 1999). Functional diversity and interconnectivity are required to create resilience in a system (Goerner et al., 2009). A balanced approach between research, technology and nature is required to fully elucidate multifaceted and long-term solutions to some of the current challenges being faced by producers throughout Australia.

Some of the impacts negatively affecting agricultural businesses include extreme weather events driven by climate change, market volatility caused by geopolitical events and the COVID-19 pandemic, changing consumer expectations including reduced chemical use and the increasing need to demonstrate environmental credentials for market access.

Concurrently there is greater emphasis on circular economy principles to reduce waste and recycle existing resources and an acceleration of technological advances including machine learning, artificial intelligence, robotics and automation. While technology can be an effective tool to support productivity gains, it does not solely contain the solutions that are needed to strike the balance between agricultural production and environmental needs.

Notwithstanding that we are limited in our capacity to quell geopolitical tensions or international pandemics, we can employ proactive techniques to combat a range of disruptive forces, improve the stability of production systems, adapt to extreme weather events, reduce the impact of biosecurity incursions, and intervene less with fewer chemicals. There has also been much written about the role of natural climate solutions and ecological restoration in the mainstream media (Dennis, 2019; Monbiot, 2019; Schwab & Rechberger, 2019). Planting locally adapted trees is reported to be by far the biggest and cheapest way to tackle the climate crisis (Carrington, 2019), whilst simultaneously contributing to functional biodiversity enhancement.

In addition, other informative resources are becoming available. For example, the Climate Atlas was recently released by Wine Australia (2021) in partnership with the University of Tasmania. It considers the impact of seasonal climate variability and longer-term climate trends on the wine sector in Australia out to 2100. This helps to answer the question, what will my region's climate potentially look like in the future, thereby helping inform future management decisions. Many Australian wine companies have already started to purchase vineyards in cooler wine growing areas and plant heat and drought tolerant wine grape varieties in anticipation of a warming climate.

EcoVineyards

EcoVineyards is a National Landcare Smart Farms Small Grant Round 2 and 4 funded participatory action research project in partnership with the Wine Grape Council of South Australia, Retallack Viticulture Pty Ltd and more than 70 partnering agencies and grape growers.

Forty-five regenerative demonstration sites are being established across all of the major winegrowing regions of South Australia. They are showcasing a range of native insectary plants that provide habitat to support populations of predatory arthropods (insects and spiders), insectivorous microbats and predatory bird species, which contribute to the biocontrol of insect pests and a range of ecosystem services in vineyards.

While the concept of ecosystem services is a human centric theme, we focus on a more balanced biocentric view (Humphrey, 2016) that elevates the intrinsic value of a broad suite of native flora and fauna. Each EcoGrower develops a Biodiversity Action Plan (BAP) to create a tailored solution for their property and contribute to regional benefits.

Native insectary plants (seed and tube stock) are incorporated in and around a production area to bolster existing vegetation structures such as windbreaks and vegetation corridors, or as mid-row, under-vine and/or headland plantings to provide resources for predators that contribute to insect pest control throughout the year. Many growers are also replacing rose bushes which lack intrinsic value with native evergreen shrubs at the end of strainer posts to improve functional benefits (Retallack, 2018b).

Figure 1: Riverland EcoVineyards participant Starrs Reach Vineyard is showcasing the use of native saltbush and creeping boobialla in the undervine area [Photo: Mary Retallack] (a), McLaren Vale EcoVineyards participant Bondar Wines have established native insectary shrubs and signage in their vineyard [Photo: Andre Bondar] (b) and field day participants learn about soil microbial health (c) [Photo: Mary Retallack].

It is possible to boost the functional biodiversity close to 100% coverage when a combination of native perennial grasses/forbs and evergreen groundcovers and shrubs are incorporated in and around a vineyard. These plants provide habitat for a range of predatory species, help capture carbon dioxide from the atmosphere and improve soil health. In addition to the establishment of native insectary plants EcoVineyards provide additional habitat via the use of microbat boxes and raptor perches to supplement existing structures. Photo points are used to capture the progress of each project over time.

Case study

A Barossa EcoGrower with a history of planting a suite of wallaby grasses, *Rytidosperma* ssp. in the vineyard mid-row has been able to demonstrate sustained benefits.

The focus of the project is:

- To use the drought-tolerant and deep-rooted native perennial grasses to improve water retention in soil profiles, thereby reducing dependency on irrigation.
- Improve habitat value of degraded pasture areas and surrounding native vegetation for native birds, particularly seed-eating and insectivorous species.
- Achieve a significant reduction in the abundance and distribution of weeds.
- Reduce the reliance on chemical intervention for pest weed and insect control.

Results include:

- The cost and benefit of establishing native perennial wallaby grasses in the mid-row when compared to triticale an annual cereal crop is compelling with the wallaby grasses breaking even by year three, with ongoing savings of $615 per ha p.a. (Arbuckle, 2012).
- In addition, there's been a significant reduction in the abundance and distribution of undesirable pest plants and on the reliance of chemicals for weed and pest insect control. Before the trial commenced, the owner was slashing the volunteer sward of exotic weeds three to four times a year and was applying more irrigation through the summer months. The native perennial grasses are cut once after they have set seed in November with a side throw slasher, which applies the cuttings under-vine as a layer of mulch.
- Wallaby grasses provide valuable habitat for a range of predatory arthropods (brown lacewings and spiders) which manage light brown apple moth (LBAM) populations below economically damaging thresholds without the need for chemical intervention.
- The pest weeds (salvation jane, wireweed and evening primrose) are no longer an issue. Wallaby grasses are able to outcompete them once they are established.
- There is much less intervention required in the vineyard (soil cultivation, sowing, slashing, herbicide inputs).

Figure 2: The Seeding Natives Incorporated 'Blue Devil' specialised native grass seeder [Photo: Dan Falkenberg] (a), Dan Falkenberg and wallaby grasses in establishment (b) and fully established (c). [Photos: Mary Retallack]

- The owner is saving time and resources by not having to intervene as often to manage the mid-row area. The grasses were maintained over a 10-year period without the need for intervention and have recently been over sown with a 20 multispecies mix of perennial grasses and forbs to provide additional benefits.

Disruptive challenges to viticulture

We are entirely dependent on our natural resources and need to proactively demonstrate their considered use. We are facing some of the most disruptive changes of our lifetime, including our constrained capacity to access natural resources, the declining functionality of ecosystems and lack of resilience within 'monoculture' production systems.

A simplistic ecological network with fewer connections will invariably lead to instability within a production system and require constant human intervention to maintain function (Meehan et al., 2011). When diverse natural systems are replaced with monocultures, this often has a negative impact on biodiversity (Hooper et al., 2005; Meehan et al., 2011). There is indisputable evidence that the efficiency of multiple ecosystem functions is reduced as biodiversity is lost (Cardinale et al., 2012).

Loss of habitat is regarded as the greatest threat to biodiversity (Brooks et al., 2002). It is generally regarded that as the proportion of suitable habitat in the landscape is reduced to less than 30% of original vegetation cover, a loss of biodiversity is caused – that is, a reduction in species numbers and population densities for all fauna (Andren, 1994; Hanski, 2011). Conversely, in structurally complex landscapes predation and parasitism tends to be higher and crop damage lower than in simple landscapes (Marino & Landis, 1996; Thies & Tscharntke, 1999; Tscharntke et al., 2002).

A reduction in semi-natural habitat has also been linked with a reduction of biological pest control in cultivated land by up to 46%, when compared with more complex landscapes (Rusch et al., 2016). In agricultural landscapes, insecticide use often increases with an increase in the size of a production area and decreases with the proportion of semi-natural habitat present (Meehan et al., 2011).

Precision agriculture techniques can be used to improve efficacy of pest control as pesticide application is often imprecise. It is estimated that 98% of sprayed insecticides and 95% of herbicides miss their intended target species (Miller, 2004). Moreover, the destruction of predator populations leads to explosions in prey numbers, not only freeing target pests from natural controls but often 'promoting' other non-pest species to pest status (Daily et al., 1997).

It is reported that LBAM causes economic damage of about $18 million per year across Australian vineyards and predisposes bunches to botrytis and other bunch rots that cause an additional $52 million per year. So, if we can head off the damage caused by LBAM we can potentially save more than $70 million per year (Scholefield & Morison, 2010). It is also reported that up to 90% of newly hatched caterpillar larvae may be killed by predators in the absence of toxic chemicals (Helson, 1939; Waterhouse & Sands, 2001).

There are also many innovative solutions including the important contribution of 'natural climate solutions' through the considered planting of native trees, ecological restoration, and the principles of agroecology, all of which encourage the need to:

- preserve soil quality
- develop functional biodiversity
- reduce the use of phytosanitary products
- implement biocontrol measures
- promote better water management
- use plant material adapted to agroecological issues
- preserve air quality
- pursue better energy management
- mitigate and adapt to the impacts of climate change.

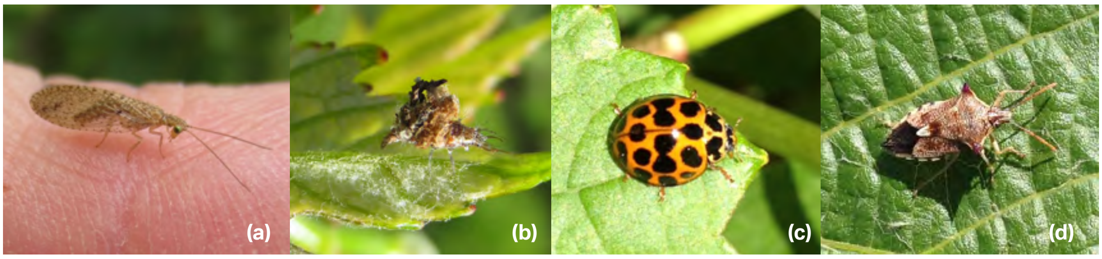

Figure 3: **Examples of predatory arthropods including brown lacewing,** *Micromus tasmaniae* **(a), green lacewing larva ('junk bug'),** *Mallada signata* **(b), common spotted ladybird beetle,** *Harmonia conformis* **(c), predatory shield bug,** *Oechalia schellenbergii* **(d) [Photos: Mary Retallack].**

Underpinning themes: modified from Retallack (2019a)

1. A suite of locally adapted insectary plants has the capacity to support populations of insect predators and parasitoids throughout the year. They also provide continuity of resources during a resource 'bottleneck', which may otherwise occur in production systems where deciduous vines and crop trees go through a period of dormancy.

2. Insectary plants have the capacity to provide food, shelter, alternative prey and hosts which nourish and support the presence of predatory arthropods and parasitoids in association with a broad range of crops. Predatory arthropods and parasitoids contribute to biological control of insect pests and provide a food source for higher order predators including lizards, microbats, insectivorous and raptor bird species.

3. A broad range of predatory arthropods are found in association with native plants including neuropteran larvae (brown and green lacewings), earwigs, ladybirds, carabid and rove beetles, predatory Hemiptera (shield and damsel bugs), predatory Diptera (hover flies and robber flies) and parasitic wasps.

4. Native insectary plants have the potential to enhance pest control for the following reasons.

   a. Many Australian native plants are not likely to be host plants for exotic pests; hence pest populations are unlikely to develop on them.

   b. 90% of the insect pests of all major Australian horticultural crops are exotic (Taverner et al., 2006), and pest insect species are more likely to be found on exotic (crops), rather than native plants.

5. Our native flora and fauna are globally unique. More than 90% of flowering plants and insects are endemic to Australia (SoE Committee, 2011), which include many predatory arthropods. Endemic predatory arthropods and parasitoids have naturally evolved and are commonly found in association with native insectary plants. This provides a unique opportunity to mobilise the existing benefits of conservation biological control (CBC) by utilising predatory arthropods that are already present.

6. Locally adapted native perennial plants are preferred as supplementary flora, as they are naturally adapted to Australia's various climatic conditions and can also help preserve soil quality.

What can growers do to enhance biodiversity?

The agricultural sector plays a primary role in managing large sections of privately held land. Proactive decisions on land use and management have the capacity to positively impact on biodiversity and ecosystem services. Thomson et al. (2007) suggest that a surrogate indicator such as the diversity of predatory invertebrates, which have a direct impact on pest abundance, can be used as one way to assess the benefits of enhancing biodiversity.

For example, stands of native vegetation adjacent to vineyards have been associated with increased biodiversity (Thomson & Hoffmann, 2010b; Thomson & Penfold, 2012; Smith et al., 2015; Gagic et al., 2018) and provide season long benefits to boost the activity of predators and parasitoids (Thomson & Hoffmann, 2013). Existing vegetation structures can be enhanced to provide insectary resources (Nicholls et al., 2001; Thomson & Hoffmann, 2009, 2010a) and/or stands of remnant vegetation can be preserved and maintained.

There are three simple steps growers can adopt to encourage populations of natural enemies, modified from Retallack (2019a):

1. Firstly, reduce broad-spectrum pesticide use that can also kill predators. Only use targeted application of selective insecticides to reduce pest populations to below damaging levels, and only if they are required. Consider organic inputs as alternatives.

2. Secondly, consider adopting a truly integrated approach to pest management, which incorporates cultural and biological control, as a longer-term approach to integrated pest management (IPM). Monitor populations of predatory arthropods and augment with the release of biological control agents if required.

3. Thirdly, incorporate suitable, locally adapted, native insectary plants boost the presence of predators and parasitoids in and around production systems throughout the entire year and further reduce the need for chemical intervention.

Key recommendations: modified from Retallack (2020)

Ecosystem services and functional biodiversity

1. ***Growers are encouraged to adopt ecological restoration measures that preserve and maintain the full functionality of ecosystem services including biocontrol, weed suppression, erosion control, improved aesthetics, nutrient cycling, soil moisture retention, soil organic carbon and soil biological activity.***

Rationale: We are entirely dependent on our natural resources and the ecosystem services they provide. The protection of functional biodiversity is needed to ensure immediate and long-term benefits. Healthy ecosystems provide services that are the foundation for human wellbeing, and it is in our best interest to value and preserve them. Environmental stewardship has the capacity to provide multiple benefits to both land managers and the environment.

For example, the value of shelterbelt vegetation to pest control adjacent to a vineyard is estimated by calculating the value of the natural enemies present if they were purchased from commercial suppliers. Over a shelterbelt lifetime of 20 years, this represents a net gain of $8,203 for an unfenced 4m wide and 100m long shelterbelt installed by a grower (Thomson & Hoffmann, 2010a).

2. ***Adopt a fully integrated approach to pest management which includes the use of biocontrol, cultural, and targeted chemical intervention as a last resort (only if required) to reduce pest insect populations below damaging levels.***

Rationale: Insect pests cause economic damage in production systems each year. There are a range of biocontrol agents that contribute to their control (predatory insects, spiders, parasitic wasps, microbats, and insectivorous birds).

The use of chemicals will invariably result in collateral damage to non-target species (Thomson & Hoffmann, 2006, 2007; Thomson & Nash, 2009; Bernard et al., 2010; Pennington et al., 2018). The overuse of pesticides may result in a range of unintended consequences including the development of resistance in some insect pests (Whalon et al., 2008).

Biocontrol is estimated to provide five to 10 times more control of pests than pesticides (Pimentel et al., 1992). A reduction in chemical use will reduce off target damage to predators and plants, reduce the likelihood of pest resistance, pollution of waterways and air, contribution of greenhouse gasses through the use of fossil fuels and reduce damage to soils through compaction, erosion and accumulation of chemicals toxic to soil dwelling arthropods and microorganisms.

At least 100 visually distinct morphospecies of natural enemies were recently found in association with native insectary plants and grapevines in a recent study, including 55 morphospecies in vineyards (Retallack, 2018) and more than 40 morphospecies of predatory arthropods were identified in a recent, smaller-scale study of native insectary plants and pistachios (Retallack & Pettigrew, 2021).

Biodiversity and provision of ecosystem services can be improved by at least 20% in vineyards by retaining inter-row vegetation cover in preference to intensive soil tillage and herbicide use (Winter et al., 2018) and farming without disturbing soil could cut agriculture's climate impact by 30% (Cooper et al., 2021).

Conservation biological control and native insectary plants

3. ***Establish locally adapted, native insectary plants in and around production systems in strategic locations to provide habitat for predatory species that contribute to the biocontrol of economically damaging insect pests.***

Rationale: Conservation biological control involves the conservation and augmentation of predator species that are already present or have the capacity to be readily available in association with production systems. This can be achieved through the incorporation of native insectary plants which provide food, shelter and alternative prey/parasitoid hosts and habitat for higher order predators including microbats, and insectivorous/raptor birds.

Native, perennial wallaby grasses, *Rytidosperma* ssp. provide a valuable complementarity habitat for arthropod species other than those commonly found in association with native woody perennial shrubs and may increase the net number of predator morphospecies by around 27% when planted in association with vineyards (Retallack, 2019b).

It may also be possible to increase the functional diversity of predatory arthropods by more than 3x when native evergreen shrubs Christmas bush/sweet bursaria/ native blackthorn, *Bursaria spinosa* or prickly tea-tree, *Leptospermum continentale* are present versus grapevines only (Retallack, 2018a; Retallack et al., 2019). This gives wine growers the confidence to incorporate a diversity of native insectary plants in and around vineyards.

4. ***Prioritise the use of native insectary plants in preference to introduced species.***

Rationale: Locally adapted, native insectary plants are preferred as supplementary flora, as they are naturally adapted to local

Figure 4: Christmas bush, Bursaria spinosa (a), Prickly tea-tree, Leptospermum continentale (b), and Wallaby grasses, Rytidosperma ssp (c) [Photos: Mary Retallack].

climatic conditions (Danne, et al. 2010, Pandey, et al. 2018) and are consistently reported as having a low occurrence of pests and a high occurrence of natural enemies. Enhanced functional biodiversity can lead to greater natural biological control, resilience within the system and improved ecosystem services.

5. ***Incorporate a diversity of native insectary plants to provide functional biodiversity benefits throughout the entire year including ground cover (grasses, forbs, woody prostrate growing plants), shrub, tree and evergreen species to avoid 'resource bottlenecks' from occurring when resources are otherwise limited.***

   Rationale: It is generally regarded that if a greater diversity and species richness are present, then it is less likely that individual weeds or arthropod pest species will dominate (Bianchi et al., 2006). This also has implications for biosecurity preparedness. The strategic use of native insectary plantings, both spatially and temporally is important to deliver insectary services when they are needed.

6. ***Incorporate the use of species-specific predator perches and/or nesting boxes to support populations of predatory birds (including endangered species).***

   Rationale: Predatory birds will feed on a range of lower order mammals, birds, lizards and/or insects. If they are territorial, they may patrol the perimeter of the vineyard and help keep fructivorous birds at bay, as well as helping to control rodent pest species. If naturally occurring tree hollows and vantage points are not present, then nest boxes and predator perches may be needed to augment the existing habitat.

7. ***Incorporate the use of native insectary shrubs, trees and/or species-specific nesting boxes that support populations of insectivorous birds.***

   Rationale: Insectivorous birds contribute to the biocontrol of economically damaging insect pests.

8. ***Incorporate microbat boxes to supplement natural habitat and to boost the presence of microbats in and around vineyards.***

   Rationale: Microbats are reported to eat up to half their body weight in insects at night (Dillon, 2019) and are able to contribute to the biocontrol of economically damaging insect pests. Predation on agricultural pests by insectivorous bats may enhance the economic value of agricultural systems by reducing the frequency of required spraying and delaying the ultimate need for new pesticides (Federico et al., 2008).

Conclusions

We are entirely dependent on our natural resources and the functionality of production systems to reliably produce food and fibre. There is urgency to address the degraded landscapes on which we farm. Our collective task is to rebuild the health of these agroecological systems for current and future generations.

Wine growers are encouraged to enhance the functional biodiversity and resilience of their vineyards by preserving stands of remnant vegetation, reclaiming creek lines that may be infested with exotic woody plants and revegetating adjacent land with native plants derived from pre-European plant community lists. Native plants must be selected that are appropriate for use in and around vineyards.

This information could help wine grape growers to manage damaging insect pests, save time and money by producing grapes with lower pest incidence. Enhancing biodiversity using native plants, and this also adds to our capacity to tell our unique Australian story and demonstrate our clean and green credentials to the broader community. These insights are widely applicable to a broad range of production systems.

About the author

Dr Mary Retallack is a third-generation viticulturist, and agricultural scientist who brings a wide range of skills and experience from

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