Agricultural Innovation Hubs Program Technical Report

Activity 3

Enhancing Orchard Soils

PROJECT LEAD: University of Adelaide

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Australian Government
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SA DROUGHT HUB
THE UNIVERSITY of ADELAIDE

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Contents

PROJECT SUMMARY

Many current practices in agriculture degrade soils and rely heavily on inputs from the farmer to ensure nutrient and water availability meets crop requirements. The apple and pear industries are no different; inter-rows are mown to keep grass low, while the under-trellis is maintained “weed free” via the use of herbicides. With tightening regulations (including many export markets) and increasing concerns from consumers (i.e. affecting market access), and economic opportunities in carbon sequestration, orchard floor management methods that reduce costs, improve biodiversity and build resilience and sustainability are increasingly sought after. This project directly exhibits new alternatives to standard orchard floor management methods. By comparing these new ‘Ecologically Intensive’ methods to ‘business as usual’ approaches, growers will be able to make informed decisions on how to change practice. Five different orchard floor practices were established. We were able to observe certain trends, specifically, an increase in soil nitrogen and organic carbon concentrations under treatments planted with living cover. By connecting with growers and agricultural consultants through workshops held at the trial, we were able to provide education on topics of soil health and soil carbon accounting, and demonstrate exactly how cover-cropping methods can be implemented in The Riverland.

EXECUTIVE SUMMARY

This project was conceived with several core aims in mind. At its heart, the project sought to extrapolate from significant research conducted in other systems, where Dr Thomas Lines conducted trials to understand the influence of soil management on vineyard floor and grapevine health. Work of this nature is vitally important in the extreme environments of The Riverland, where growers are highly dependent on herbicides for maintaining bare earth. In these climates, with high volume production and minimal economic margin, growers need support to transition to more resilient and sustainable systems. Moreover, the adoption of "alternative practices" is, above all, a social issue – a human activity – and thus requires both evidential bases, as well as consistent outreach and communication. Therefore this project was undertaken with regional outreach and communication in mind. Over the course of a year, the trial experimented with five orchard floor management practices, those were: Herbicide tree-row; Volunteer Sward– whole floor; Pollinator Mix – whole floor; Medicago and Rye – whole floor; and; *Festuca arundinacea* (tall fescue) tree-row. The herbicide treatment functioned as the "business as usual" *control*.

Soil sampling and apple harvesting were conducted, with samples of each processed in a laboratory and analysed for certain physical, chemical and biological properties. This approach allowed those researchers to better understand the influence of various orchard floor management practices on the ecological intensification of the orchard – that is, how various physical, chemical and biological properties can function synergistically to reduced human input (akin to a natural system). After one year of trial, we did not expect to find statistically-significant results, although we were able to discern certain trends emerging. Notably, we observed a trend of increased soil nitrogen and organic carbon under treatments of living cover, especially those planted with medic & ryegrass and fescue UT. Given longer, these would be expected to increase and separate from the herbicide treatment, owing to the living cover providing a photosynthetic pathway to allow atmospheric carbon to become assimilated and translocated to the roots and soil. Moreover, results from previous studies have shown improved soil structure, water infiltration and water holding capacity under living cover. Although we did not observe statistically-significant differences in this trial, we would expect to see these present with more time.

Over the course of the project, two workshops were conducted. Attendance was small but engaged, with notable regional interest. Grower attendance was warmly welcomed, with grower views and concerns heard and discussed. As part of both open days, Dr Lines explained the rationale behind the use of alternative practices, presenting data from both this current trial and previous work of a similar nature. In each, the advice and research were framed in the context of the industry and the region – one affected by extreme climates. A survey was used to better understand growers' knowledge surrounding soil health and the use of alternative practices. In addition, a flyer was distributed to attendees highlighting the background and methodology of the trials, with some key points on how growers might implement certain practices, including seeding regimes and management to achieve the best emergence and maintain cover.

The results and outreach from this trial offers growers the ability to understand how several different orchard floor management practices influence both soil properties and apple yield and quality. Providing information on several strategies allows different growers to find and implement

the correct practice for their orchard and achieve the desired outcome. Outcomes may alter depending on apple cultivar or soil type. The importance of conducting these trials in the Riverland itself offers regional specificity and provides relevant information on treatment influence and treatment implementation for those wishing to reduce inputs and enhance the ecological intensification of their orchard system. The development of flyers ensures that relevant information is distilled into a short, readable format that can be expanded through further reading and communication with Dr Lines and his team.

For further information on this and other weed management trials in The Riverland and across South Australia, Dr Thomas Lines can be reached at Thomas.lines@adelaide.edu.au and he will be more than happy to provide flyers, other resources, or specific advice on how best to manage soil health in your agricultural system.

PROJECT BACKGROUND AND OBJECTIVES

The original scope and objectives of the project were to quantify and report on the influence of alternative orchard floor management practices versus the “business as usual” herbicide control, while also performing workshops that aim to educate local growers on the topics of soil health. Originally, it was proposed that six treatments would be implemented; however, it was decided to omit a high-risk native plant mix (owing to poor germination and emergence) and instead implement five treatments in total (see above). To best understand the influence of these practices, we proposed to measure the following metrics: ground cover; tree leaf area index (LAI); soil moisture; soil physicochemical properties; yield (total yield, apple size, quality); sugar content and; soil bacterial biodiversity. Sampling and analyses were conducted as per the original objectives, with all data analysed for statistical significance. Despite no statistical significance observed, descriptive plots were created to highlight the data and show potential trends. That no statistical differences were observed is not surprising, given that the trial has only been effective for one year. Over time, with close maintenance of the trial, we would expect to see certain differences separate between treatments and become statistically different.

Further to sampling and data reporting, conducting outreach in the form of workshops, information flyers and surveys was part of the original scope and objectives of the project. As mentioned above, two trial-based workshops were conducted in Loxton, thus allowing Dr Lines to communicate directly with growers and stakeholders within the region. Dr Lines worked with national grower groups, including Apple and Pear Australia (APAL), CitrusSA, Fruit growers SA, Almond Board Australia and Riverland Wine to promote open days and disseminate research findings. Moreover, Dr Lines adopted a foundational education approach, explaining basic information around ecology and soil health to provide a framework of knowledge from which interested parties could build. Through these outreach sessions, Dr Lines also disseminated flyers providing basic information on treatments, soil health, implementation guides and relevant results. To better understand participant knowledge both before and after the workshop, Dr Lines conducted an online survey after the second workshop to understand growers’ understanding of soil health and their appetite for implementing new management practices in orchards. The results of this survey demonstrated a high uptake of the information and a very high level of satisfaction and intention to use cover crops into the future.

Perhaps the primary limitation of the project pertains to the length of the trial. One year post trial establishment is typically not long enough to see strong differences between treatments. Subtle trends were evident in nitrogen and carbon; however, these would be expected to separate further over time. There were also limitations with respect to the seeding of the living cover, with seeding occurring later than ideal. This seasonal interference likely led to poorer than expected seed germination and seed set, especially with certain treatments, and also likely contributed to a lack of statistical significance between treatments. In all, the project was conducted with a high degree of professionalism and adhered well to the original scope and objectives.

METHODOLOGY

In its essence, this project was designed as a randomised complete block design (RCBD) to test the effect of a number of different ground cover species selections, and aimed to provide this information and leverage the real-world experience of growers, to inform other interested parties on how best to enact practice change.

To do this, a number of steps were taken:

1. Planning – The literature and experienced growers in South Australia were consulted. A number of treatments were settled on (see figure 1 below)
2. Site design and establishment – The biometry assist package in R was used to design a randomised complete block trial layout. This allows for four replicates in randomised order. The treatment plots were 8 trees long (or 9 if they contained a pollinator tree). These plots were replicated along rows, with buffer rows either side to minimise effects of mid-row seed sowing. Buffers were also allowed for at the start and end of each row.

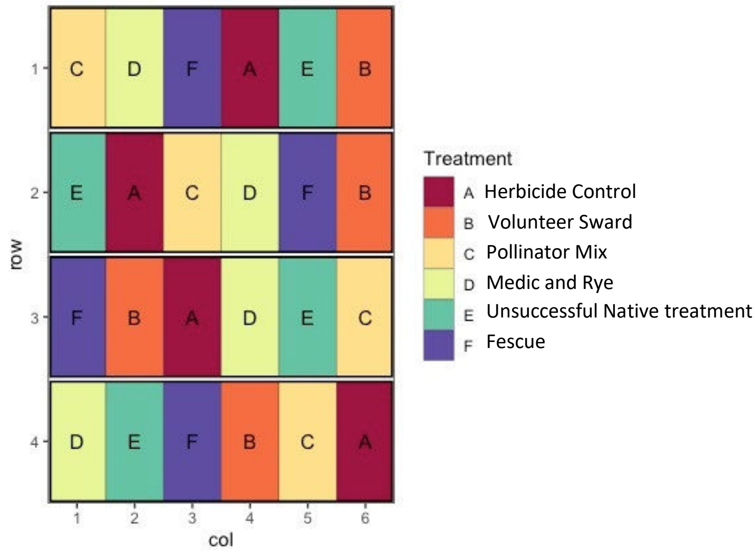

Figure 1: Randomised complete block design and treatment names.

The trees were drip irrigated, with two dripper lines running down either side of the trees along the soil surface. Overhead sprinklers were also present, and were used to ensure seed germination through a dry winter. These sprinklers were not used for tree irrigation.

3. Data Collection – Data was collected on a wide variety of variables, focussed at harvest (March 2023). These variables included soil physicochemical properties, such as total nitrogen, nitrate and ammonium, total soil carbon, organic and inorganic carbon, cation exchange capacity and mineral nutrient concentration. Data was also collected on soil health parameters, such as water holding capacity, infiltration, ground cover (%) and microbial diversity (soil microbiomes). Harvest data was collected on tree physiological properties, such as yield, apple count and leaf area index (LAI). Finally apples were juiced, and samples were sent for chemical analysis to determine sugar content, pH, and titratable acidity (TA).

4. Analysis – Once data had been collected or returned from the respective commercial laboratories, data analysis could commence. This involved both direct statistical analysis, or highly detailed sequence analysis in the case of microbiome data. To determine microbial diversity and compare results among treatments, Qiime2 was used to process the biom data provided by the Australian Genome Research Facility (AGRF). Diversity metrics of both alpha and beta diversity were collected, and taxa bar plots were generated.
   Statistical analysis was performed in R using R-studio and a number of packages including biometryassist, asreml-R and Ggplot. Asreml-R was used to generate linear mixed models to allow for comparisons among treatments. This data was then input into Ggplot for use in the flyers and other work.

5. Outreach – In December 2022, Dr Lines held a workshop at the trial site to present the trial in its established state. Growers could walk through the trial, ask questions and discuss amongst themselves. Professor Timothy Cavagnaro also attended and presented at the workshop. A flyer and accompanied presentation by Dr Lines led attendees through the benefits of reduced herbicide usage and cover crop selection.
   In August 2023, Dr Lines held a second workshop, with the aim of reinforcing the lessons taught in the first workshop, while also disseminating the results of the trial after the first year, and getting the lived experience of the local site manager on his opinion of cover cropping. An online survey was distributed at the conclusion of this workshop, to collect the effectiveness of the workshop and trial itself. Variables that were surveyed include:
   - Attendees' approach to herbicide before the workshop.
   - Whether the grower/attendee had used cover crops in the past.
   - Whether the grower/attendee would sow cover crops in the future.
   - Whether the grower/attendee feels they learnt valuable information at the workshop.
   - What impediments the grower/attendee felt there were preventing them from planting a cover crop.
   - What the grower/attendee believes can be improved via the use of cover crops.
   - Whether the grower/attendee would like to see future research into this area, and what specifically should be investigated.
   - Whether the grower/attendee was satisfied with the workshop.

Photos/images

All photos below were taken by Dr Thomas Lines. These can be found at the end of the document.

LOCATION

Where demonstration sites, field trials, events or other activities have been conducted, provide the following location details in the table below: latitude and longitude for field trials, or LGA for events and other activities. (Add additional rows as required.)

Site # and name	Latitude (decimal degrees)	Longitude (decimal degrees)	LGA
Duxton Apples	-34.39859	140.62509	Riverland

RESULTS

The results from the trial are presented in boxplots below. There were no statistically significant results; however, there are certain trends emerging that, with more time, may separate further and become statistically significant. All analyses were conducted using R Studio statistical software package.

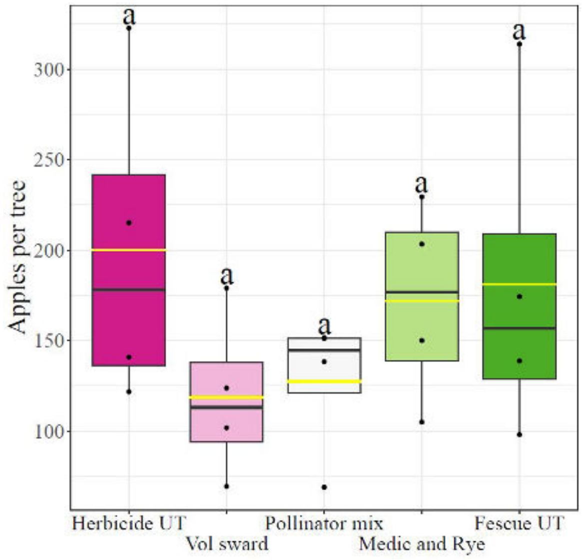

Figure 2. Boxplot displaying median and mean (yellow line) values for number of apples per tree.

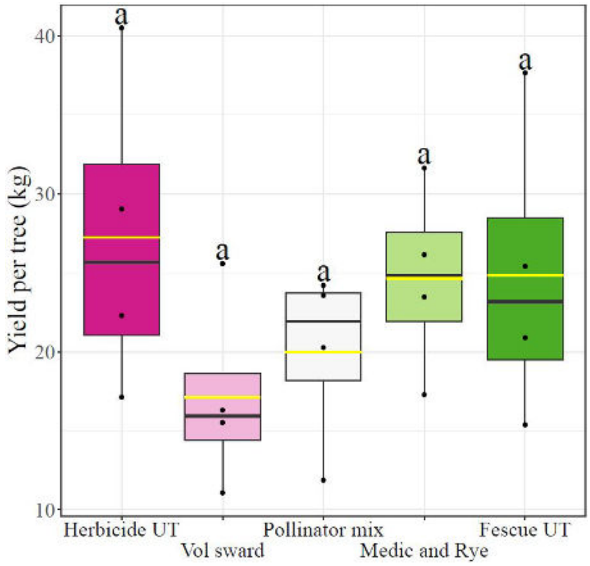

Figure 3. Boxplot displaying median and mean (yellow line) values for apple yield per tree.

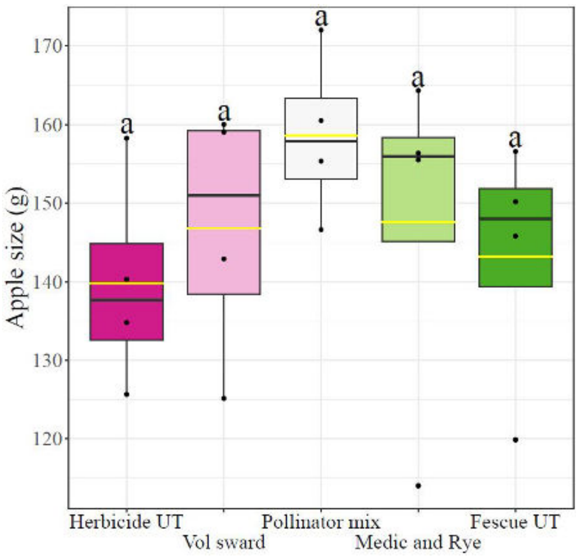

Figure 4. Boxplot displaying median and mean (yellow line) values for individual apple size.

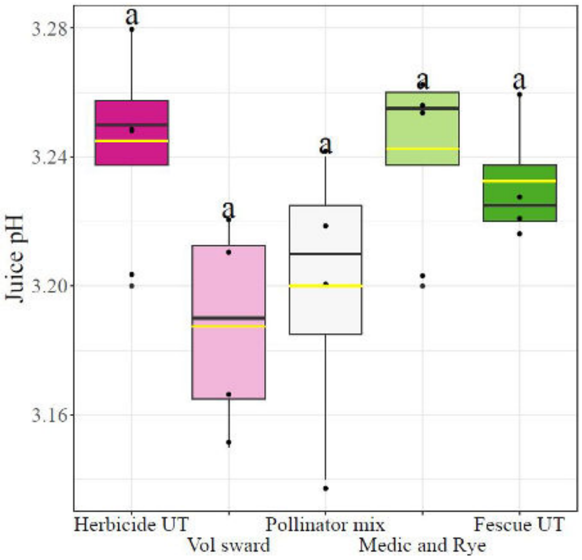

Figure 5. Boxplot displaying median and mean (yellow line) values for apple juice pH levels.

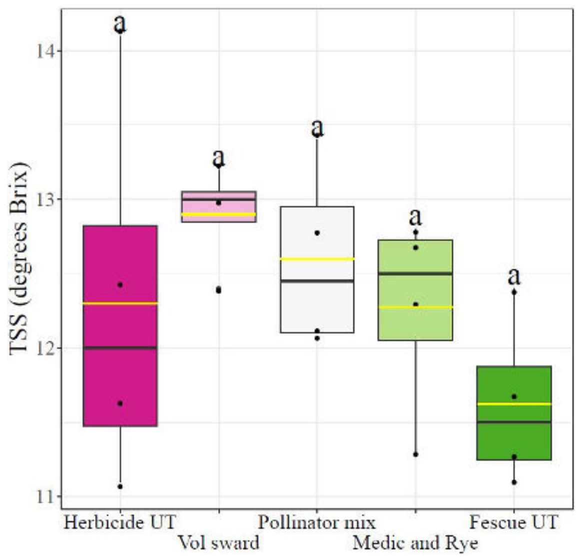

Figure 6. Boxplot displaying median and mean (yellow line) values for apple juice sugar concentration.

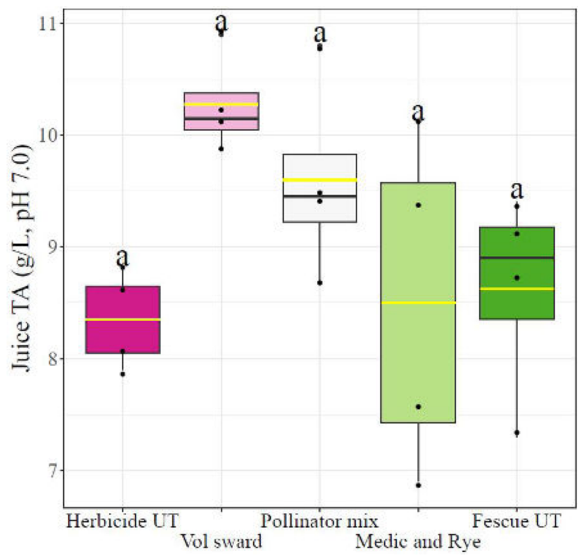

Figure 7. Boxplot displaying median and mean (yellow line) values for apple juice tartaric acid concentration.

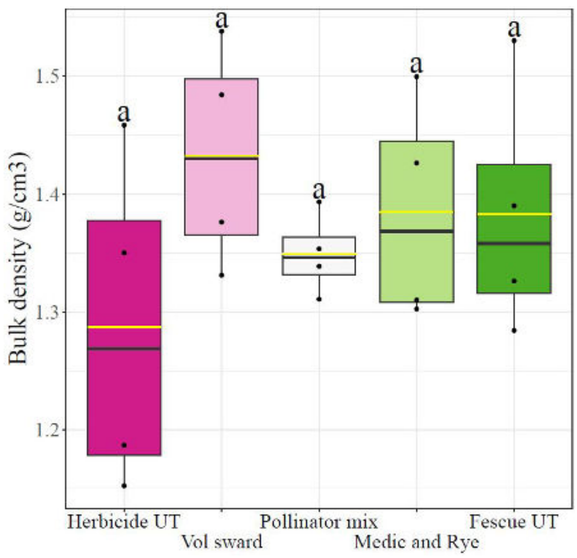

Figure 8. Boxplot displaying median and mean (yellow line) values for soil bulk density.

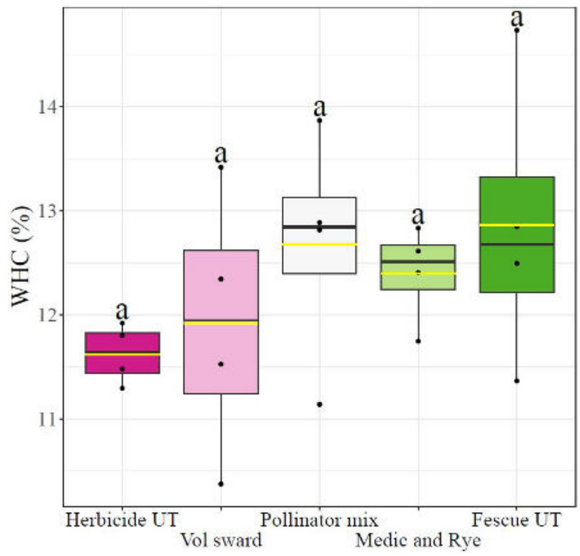

Figure 9. Boxplot displaying median and mean (yellow line) values for soil water holding capacity.

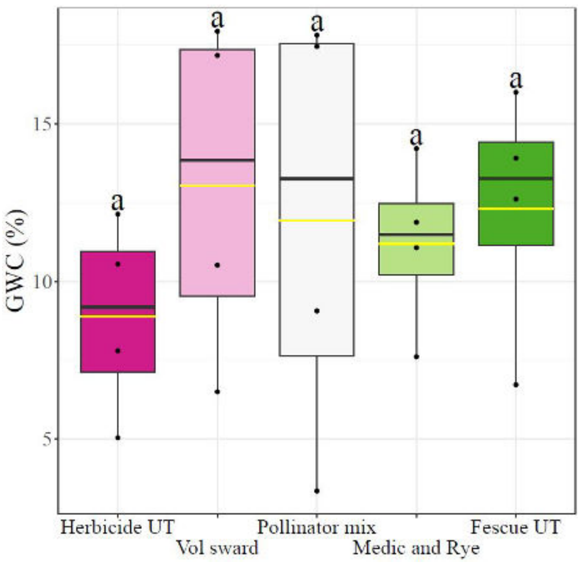

Figure 10. Boxplot displaying median and mean (yellow line) values for soil gravimetric water content.

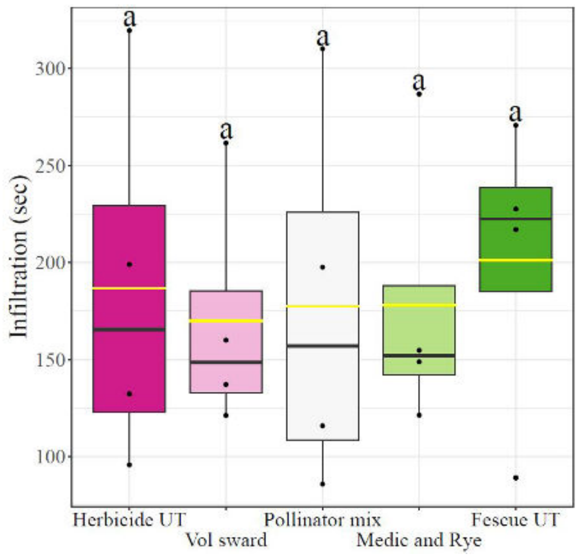

Figure 11. Boxplot displaying median and mean (yellow line) values for soil water infiltration.

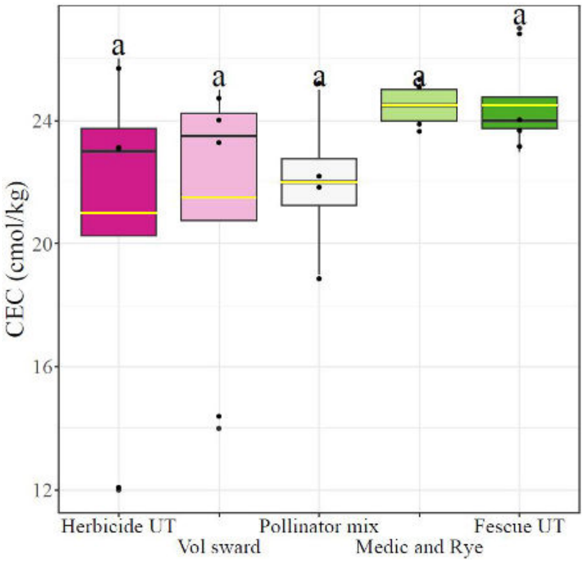

Figure 12. Boxplot displaying median and mean (yellow line) values for soil cation exchange capacity.

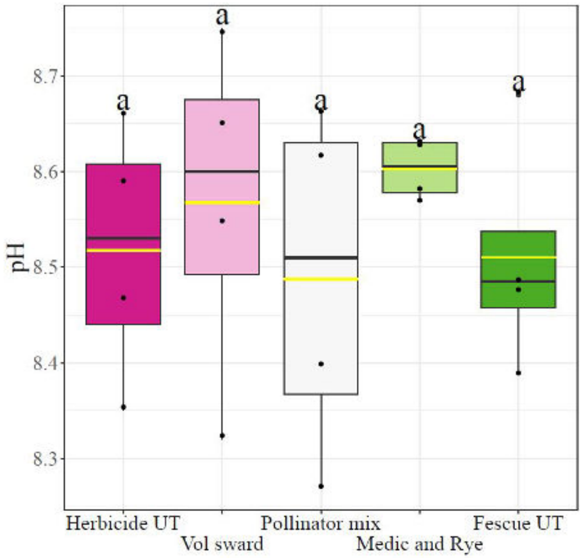

Figure 13. Boxplot displaying median and mean (yellow line) values for soil pH levels.

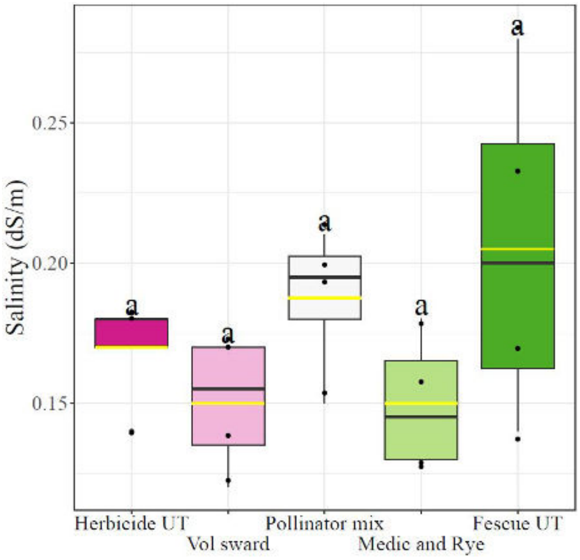

Figure 14. Boxplot displaying median and mean (yellow line) values for soil salinity.

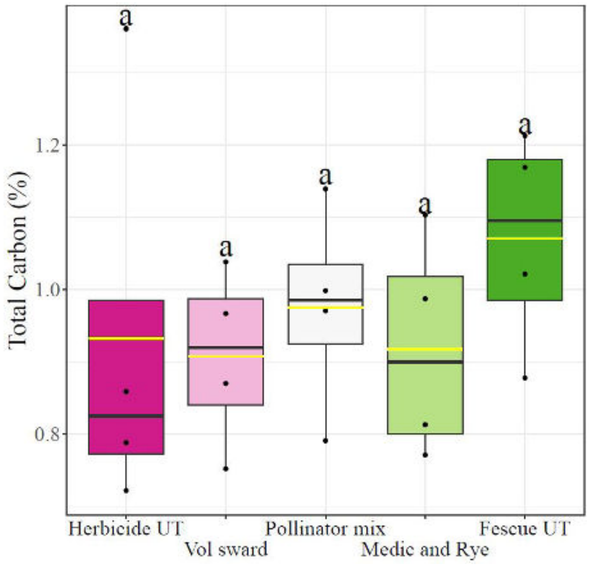

Figure 15. Boxplot displaying median and mean (yellow line) values for total soil carbon concentrations.

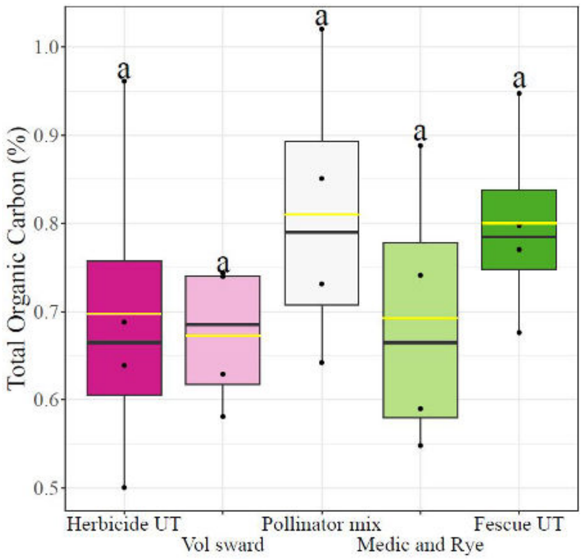

Figure 16. Boxplot displaying median and mean (yellow line) values for soil organic carbon concentrations.

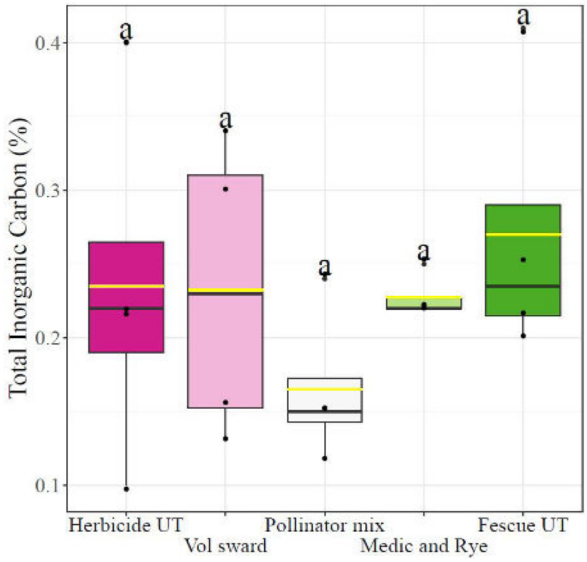

Figure 17. Boxplot displaying median and mean (yellow line) values for soil inorganic carbon concentrations.

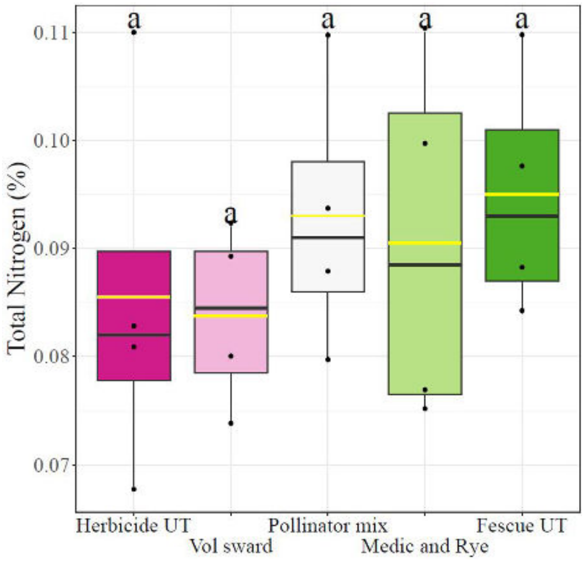

Figure 18. Boxplot displaying median and mean (yellow line) values for total soil nitrogen concentrations.

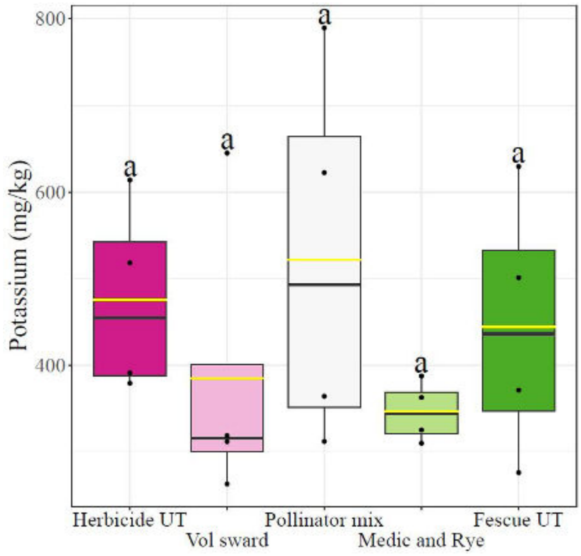

Figure 19. Boxplot displaying median and mean (yellow line) values for total soil potassium concentrations.

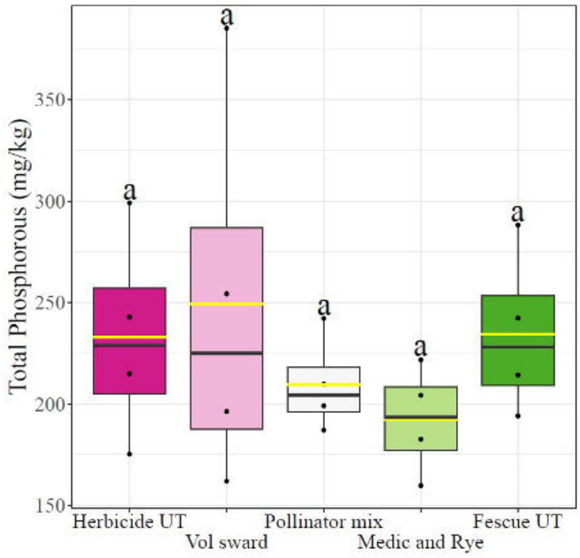

Figure 20. Boxplot displaying median and mean (yellow line) values for total soil phosphorus concentrations.

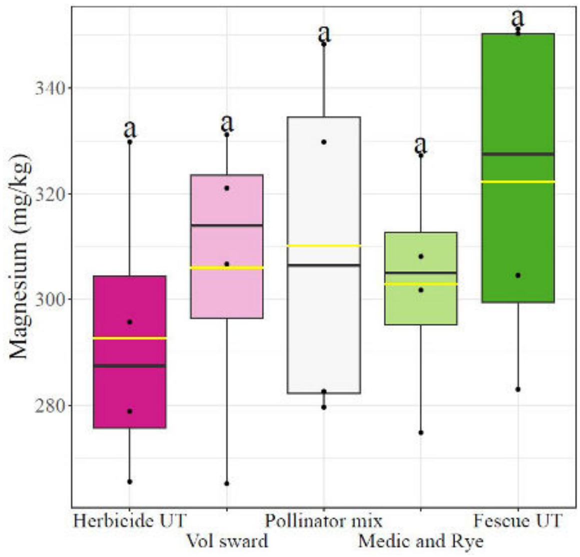

Figure 21. Boxplot displaying median and mean (yellow line) values for total soil magnesium concentrations.

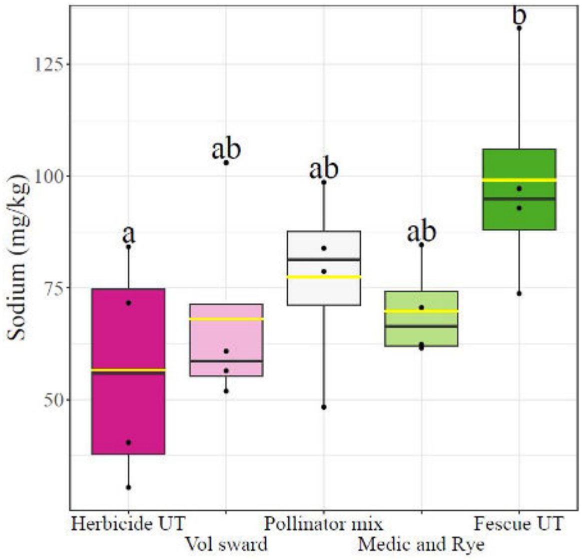

Figure 22. Boxplot displaying median and mean (yellow line) values for total soil sodium concentrations.

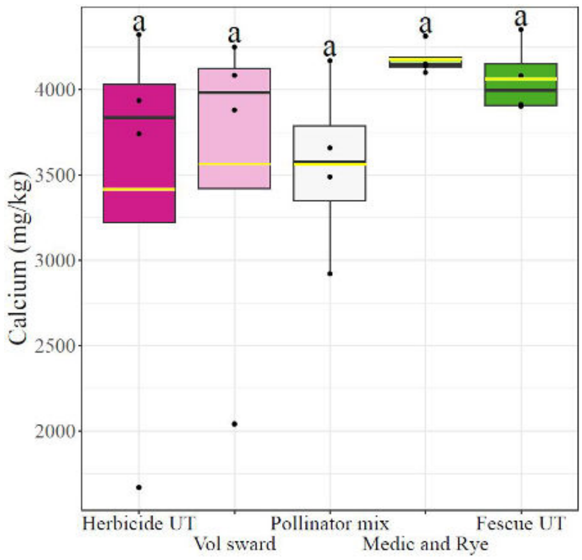

Figure 23. Boxplot displaying median and mean (yellow line) values for total soil calcium concentrations.

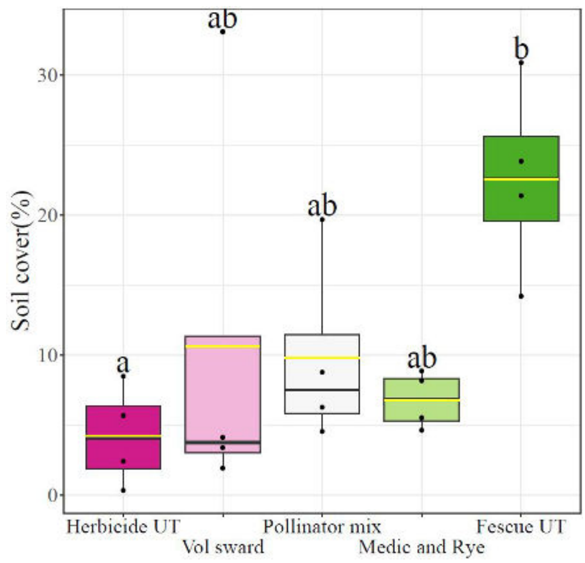

Figure 24. Boxplot displaying median and mean (yellow line) values for soil coverage by cover crops or volunteer sward.

Figure 25. Soil moisture content (top) and soil temperature (bottom) at depths of 10 cm to 80cm at 10 cm intervals as displayed by the green brain platform online.

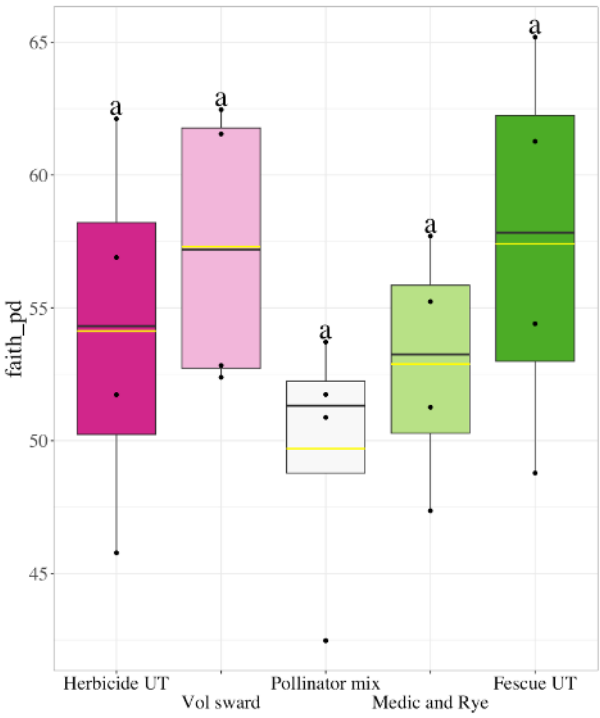

Figure 26. Alpha diversity of soil bacterial (16S) microbiome as defined by faith's phylogenetic diversity (Faith_pd).

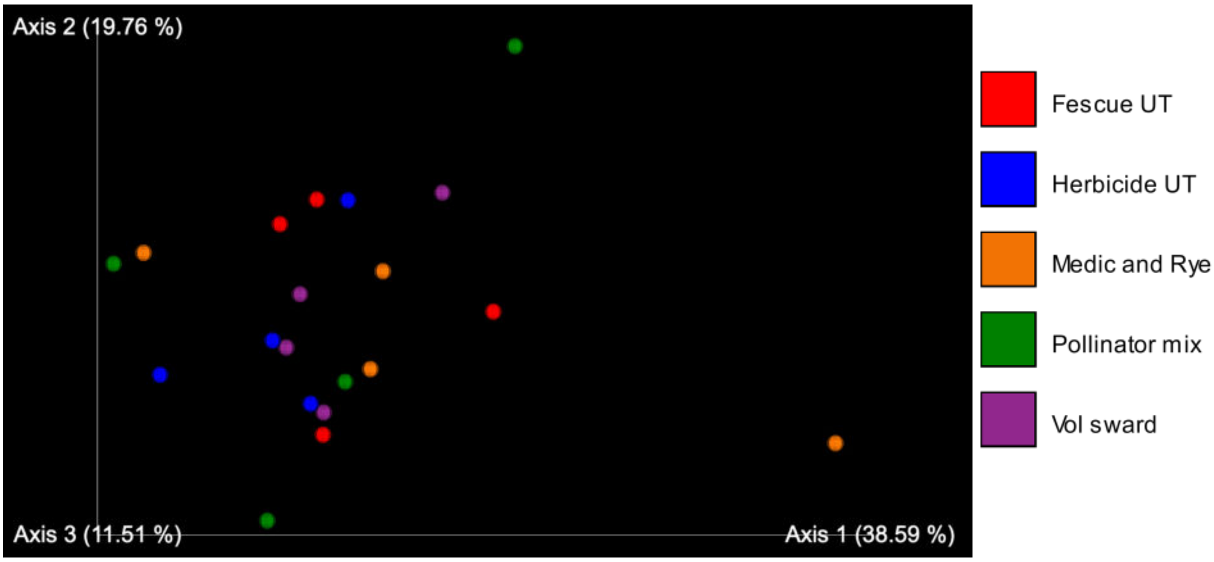

Figure 27. Beta diversity of soil bacterial (16S) microbiome as defined by weighted unifrac diversity. Samples closer together are more similar than samples further apart.

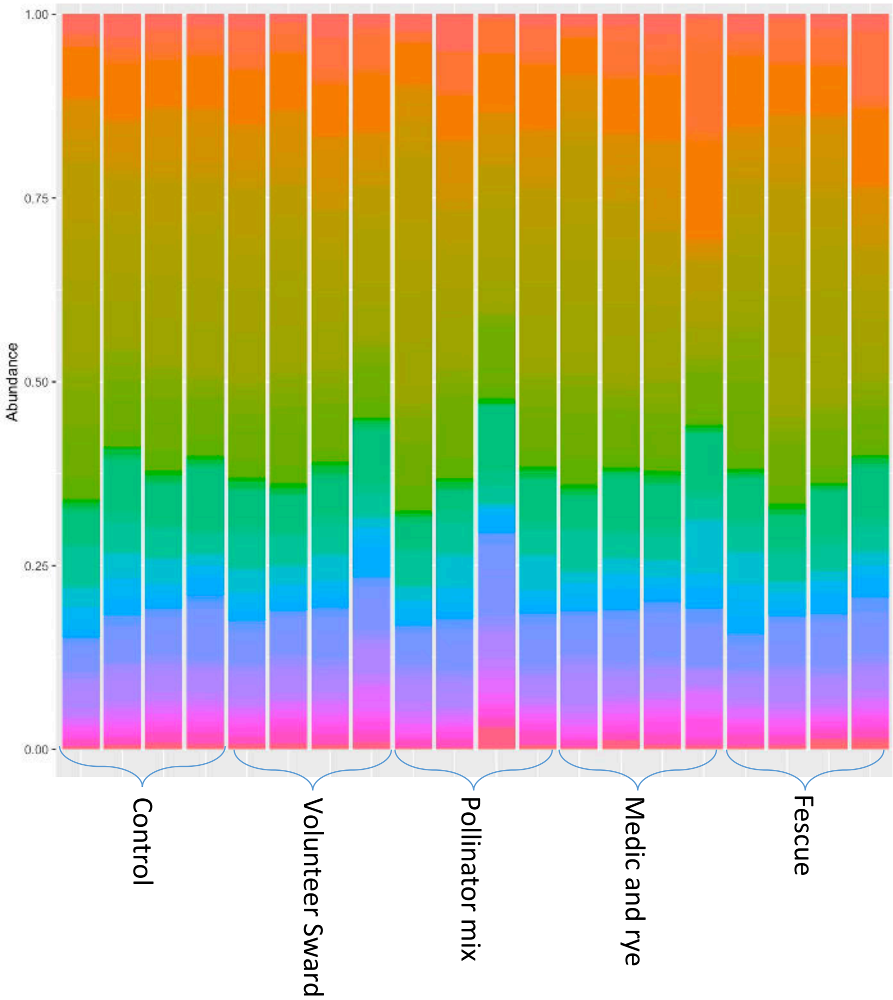

Figure 28. Relative abundance of taxa of bacteria and archaea from 16S microbiome at the family level. Each different colour represents a separate family.

As mentioned previously, it is important to note that one year of trial is unlikely to yield statistically significant results. Despite this, we are able to observe certain trends in data. The first step to interpreting data from a trial of this nature is to ensure that there are no adversely detrimental treatments effects. That is, can we observe data that suggests the "alternative practices" are in some way contributing negatively to either soil health or apple health? In this, we are able to say no, there are no significantly observable results that suggest alternative practices are a hindrance to soil or apple health. That no detrimental effects were observed suggests that the trial may continue to operate, with the same tests conducted over the following seasons to monitor and understand whether orchard floor management practices influence certain soil and apple metrics.

CONCLUSION

This trial was established for several interrelated reasons. This trial was established to provide valuable on-site demonstrations and outreach to growers and interested stakeholders. Over the course of the one-year trial, Dr Lines conducted two open days where growers and stakeholders were invited to attend and observe a presentation highlighting the rationale behind the project, methodology of treatment establishment and results after one year of trial establishment. Secondly, the trial sought to both quantify the effects of different orchard floor management practices on both soil and apple health, as well as provide valuable access to alternative weed management practices through on-farm workshops. The term “health” in relation to soil and apples is broad, and in this context it pertains to certain physical, chemical and biological metrics that, from a holistic perspective, may be grouped to establish a baseline for from which we can monitor, assess and report. From a scientific perspective, the trial builds on previous work in similar perennial systems, where longer-term trials showed the significant and beneficial effects of contrasting management practices on vineyard soil and grapevine metrics.

Although it is difficult to draw conclusions on data after only one year of trial establishment, there are important points to take away. The first conclusion to draw pertains to cover crop establishment. That is, to adhere to best-practice in terms of cover crop establishment, timing is crucial. Sowing cover crop seed requires winter rain to establish, especially in a hot, dry climate such as the South Australian Riverland. Attempting to establish cover crops too late in the season runs the risk of poor germination and emergence, owing to lower soil moisture content and dry, impacted soils hampering root and shoot growth. Furthermore, regarding cover crop selection, previous evidence from vineyard trials showed that in hot, dry climates, overly vigorous cover crops, such as fescue, may prove detrimental to soil water dynamics. In contrast, a combination cover crop, such as medic and ryegrass, may offer certain benefits with regards to nutrient cycling, especially soil nitrogen and soil organic carbon concentrations.

Both the benefits to industry and potential for adoption are evident. Although gleaning too much from the paucity of data collected from this trial is unwise, we are able to extrapolate from data collected in previous trials. Adoption requires evidence, which requires time. We were able to demonstrate the relative ease with which orchard floor cover can be established, as well as discuss methods by which this might be carried out. Therefore, adoption need not require an entire orchard to be covered to understand the benefits and thus growers may opt to “test the waters”, sowing partial cover, while maintaining bare earth elsewhere. The industry benefits of adopting orchard floor cover are noted, with an immediate reduction in herbicide use, soils may undergo “ecological intensification”, with living covers providing certain ecosystem services to the orchard, enhancing nutrient cycling and improving soil structure and porosity, leading to enhanced infiltration and water holding capacity in the medium to long term.