VINEYARD FLOOR MANAGEMENT INTENSITY IMPACTS SOIL HEALTH INDICATORS AND BIODIVERSITY ACROSS SOUTH AUSTRALIAN VITICULTURAL LANDSCAPES

Authors: Merek M. KESSER[1], Timothy R. CAVAGNARO [1], Roberta DE BEI[1], Cassandra COLLINS[1,2]*

[1]The University of Adelaide, School of Agriculture, Food and Wine, Waite Research Institute, PMB 1 Glen Osmond, 5064 South Australia, Australia.

[2]ARC Industrial Transformation Training Centre for Innovative Wine Production, Waite Research Institute, PMB 1 Glen Osmond, 5064 South Australia, Australia.

*Corresponding author: cassandra.collins@adelaide.edu.au

Keywords: vineyard floor management, soil health, biodiversity, management intensity, viticultural landscape

Introduction

Vineyard floors in warm, dry landscapes including those in South Australia, have traditionally been managed using intensive practices such as tillage and herbicides to control weeds and vegetation, thereby limiting competition with grapevines for water and nutrients in order to not compromise yields (Celette et al., 2009). However, due to increasing awareness about the detrimental environmental impacts associated with chemical herbicides, tillage, and resulting bare earth on soil health and biodiversity (Winter et al., 2018; Guzmán et al., 2019), many recent investigations have been made as to the potential of increasing vineyard floor ground cover through the use of sown or spontaneous vegetation in addition to reducing the frequency and intensity of tillage and herbicides (Garcia et al., 2018).

Although there has been a noticeable shift in vineyard floor management towards more extensive and ecological practices in the last two decades, there are differences in the rates of adoption between winegrowing regions and between the mid-row and under-vine row areas in vineyards (Payen et al., 2022). While it has been demonstrated that in some vineyard sites, competition with grapevines for water and nutrients limiting grapevine yield is one of the main factors restraining the use of complete vineyard floor vegetation cover (Karl et al., 2016), this yield discrepancy is not always significant (Giese et al., 2014). Recent investigations of complete vineyard floor coverage systems have been predominantly focused in cool, wet winegrowing regions such as those in the Eastern United States, where many studies have indicated improved provisioning of ecosystem services in addition to more ideal vine balance as a result of these strategies (Vanden Heuvel and Centinari, 2021).

Thus, we propose to investigate how complete vineyard floor coverage is used by commercial vineyards in drier viticultural regions, such as those of Australia, and specifically, we aim to assess how these systems comparatively affect biodiversity and soil health indicators. Findings from another viticultural landscape study in a drier climate in Spain indicated that vineyards with cover crops compared to bare soil had higher soil organic carbon and greater plant biomass; however, this study focused solely on vineyard mid-row areas (Guzmán et al., 2019). Furthermore, a landscape study demonstrated that high mid-row management intensity at vineyards across Austria, France, Spain and Romania reduced plant species richness (Hall et al., 2020). Therefore, it is yet to be determined how plant biodiversity and soil health indicators compare at South Australian vineyard sites across a landscape with different floor management intensities, and in both the mid-row and under-vine row areas. In order to address these questions, a comprehensive investigation at the landscape level of varying intensity levels of vineyard floor management practices used in the Barossa and McLaren Vale regions was conducted to explore the effects on various environmental indicators of biodiversity and soil health.

Research objectives

The objectives of this landscape study were to characterize the intensity of different vineyard floor management strategies used in the mid-rows and under-vine rows of South Australian vineyards compared to adjacent unmanaged native areas; and to investigate the emergent relationships between floor management intensity, soil health indicators, and plant diversity at four seasonal measurement times during the 2020-2021 growing season. Ultimately, this research provides insights to how the varying intensity of floor management practices across a viticultural landscape can be intrinsic drivers of environmental resilience and functionality.

Materials and methods

Description of vineyard and unmanaged native sites

This study was conducted during the 2020-2021 growing season at twenty-four commercial vineyard sites and four unmanaged native sites in the Barossa and McLaren Vale regions of South Australia. At each vineyard site, three equidistant replicates of three panels (containing three or four vines) were established along the longest diagonal transect of the site. Samples were collected from the mid-row and under-vine areas at each replicate separately. At each unmanaged native site, three equidistant replicates were also established along the longest diagonal transect of the site, each totaling approximately 14 meters in length to coincide with the average length of the replicates in the vineyard sites.

Categorization of sites into floor management intensity groups

A questionnaire was completed by the growers managing each of the twenty-four commercial vineyard sites and four unmanaged native sites in relation to their floor management practices, namely those used to control weeds, conserve soil health, and conserve water. The information provided by the growers reflected the nature and frequency of practices such as herbicide applications, tillage, usage of cover crop, slashing, and animal grazing. Based on the reported floor management practices carried out in the mid-rows and under-vine rows, a categorization of the sites into three distinct floor management intensity groups of Low, Medium, and High intensities was then undertaken. Sites in the Low intensity group reported no passes of tillage nor herbicides in the under-vine row and managed the mid-rows only by slashing and animal grazing. Sites in the Medium intensity group included one pass of herbicides or tillage in the under-vine row, while the mid-row was managed only by slashing and animal grazing. The High intensity group was characterized by between two and four passes of herbicides or tillage in the under-vine row and a mid-row managed with cover crops or permanent vegetation with tillage and slashing. The native unmanaged sites were located adjacent to vineyard blocks and did not undergo any reported floor management interventions. All sites included in this study had been managed consistently for at least the previous three growing seasons prior to collecting measurements.

Plant biodiversity surveys

Plant surveys to assess plant species biodiversity and coverage were carried out at all sites during four seasonal sampling times spanning the 2020-2021 growing season in winter (June-July) 2020, spring (September-October) 2020, summer (December) 2020, and autumn (February-March) 2021. At each of the sites, a total of nine mid-row and nine under-vine row assessments were made. The surveys were undertaken by placing a $1m^2$ wooden frame with a 10 x 10 cm string grid in the centre of the panel in each mid-row and under-vine area, after which the plant species and percent ground coverage within the frame were identified (Guzmán et al., 2019). After the species surveys were carried out, a $0.25\ m^2$ wooden frame was randomly placed in the middle of each mid- and under-vine row replicate and all above-ground plant biomass was harvested and dried for seven days at 65˚C, after which it was weighed.

Measurement of soil health indicators

At the same four seasonal sampling campaigns where plants were surveyed, 500-gram composite soil samples were collected from the top 2-12 cm in the mid- and under-vine rows at each replicate to assess plant-available nitrogen as nitrate (NO_3^-) and ammonium (NH_4^+), in addition to soil gravimetric water content. Soil bulk density and *in situ* water infiltration measurements were captured during spring 2020 at every site and were measured in triplicate at every replicate, separately in the mid- and under-vine rows. During the autumn of 2021, soil samples were collected and comprehensive soil physiochemical analyses were measured by the Australian Precision Agriculture Laboratory (APAL, Adelaide, Australia) including soil texture, pH, electrical conductivity, cation exchange capacity, total nitrogen and carbon, total organic carbon, and Colwell phosphorus according to the protocols in Rayment and Lyons (2011).

Statistical analysis

Data analysis was performed using R (version 4.1.2, R Core Team, 2021) and non-parametric Kruskal-Wallis tests were used to measure differences in the measured plant biodiversity including species richness and biomass, in addition to various soil health indicators between the management intensity groups. All figures were made in ggplot2 in R.

Results

Floor management intensity impacted under-vine plant species richness and biomass

The average plant species richness sampled at all four seasons during the 2020-2021 growing season was higher in the Medium intensity mid-rows compared to the High intensity mid-rows, while the above-ground plant biomass was similar for all mid-row areas of the twenty-four commercial vineyard sites included in this study (Figure 1). Alternatively, the plant species richness was higher in the Low intensity compared to High intensity sites for the vineyard under-vine areas (Figure 1A); and additionally, different management intensities resulted in lower average plant biomass in the under-vine rows of the High management intensity sites compared to the Low management intensity sites (Figure 1B). The widest range of plant species richness was observed in the Native sites, which was between seven and twenty-one species (Figure 1A). For the under-vine areas, the average plant biomass ranged from 0.05-1.91 t ha^{-1} for the High intensity group, 1.61-3.69 t ha^{-1} for the Low intensity group, and 0.79-3.83 t ha^{-1} for the Medium intensity group (Figure 1B). These findings indicate that the more frequent usage of tillage and/or herbicides, in particular by the High intensity group where between two and four passes were used per year to control under-vine vegetation, are in fact effective at reducing plant biomass and species richness. In addition, the average plant biomass was least variable across the sites managing with Low intensity where no passes of tillage and/or herbicides were used to manage vegetation, resulting in the highest average biomass.

Soil organic carbon was not impacted, while soil water infiltration was increased by lower management intensity in the under-vine area

Measurements of soil organic carbon were not different between the management intensity groups for both mid-row and under-vine areas, where they ranged from 0.94-4.08% in the mid-rows and 0.98-6.21% in the under-vine rows across all sites. Soil organic carbon was variable at the Native sites as well, where it ranged from 1.82-6.19% (Figure 2A). Similar to plant biomass, the average soil water infiltration rates measured in the mid-rows of the vineyards was not different depending on the different management intensity groups, yet there were differences between groups for the under-vine areas with the Low intensity sites displaying faster infiltration rates compared to the High intensity sites (Figure 2B). It is possible that the higher plant biomass found in the under-vine areas of the Low intensity sites contributed positively to faster water infiltration by the provision of bio-pores created by plant roots, in combination with less frequent passes by machinery to apply tillage or herbicide treatments, of which there were none applied to the Low intensity group of sites. Thus, higher under-vine management intensity across vineyard sites with different characteristics consistently resulted in lower plant species richness, biomass, and slower water infiltration.

Conclusion

This study assessed the impact of vineyard floor management intensity on plant biodiversity and soil health across South Australian viticultural landscapes. Findings demonstrated that plant species richness and biomass, in addition to soil water infiltration in the under-vine areas were negatively associated with increasing management intensity. Soil organic carbon was not significantly different between sites due to its relatively high variability. These are particularly relevant findings for vineyard managers, indicating that floor management strategies should be selected with upmost consideration to balance production goals with environmental health, as the long-term resilience of vineyards may be compromised by higher intensity practices.

Acknowledgements

The authors thank the growers who provided access to their sites for sampling and measurements, in addition to information regarding their vineyard floor management practices. Thank you to Jacques Vos and Willem Joubert for their assistance with data collection and to Chris Penfold for his help with plant species identification. This research was funded by a post-graduate operating scholarship for M.M. Kesser from The University of Adelaide and Wine Australia.

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Tables and Figure

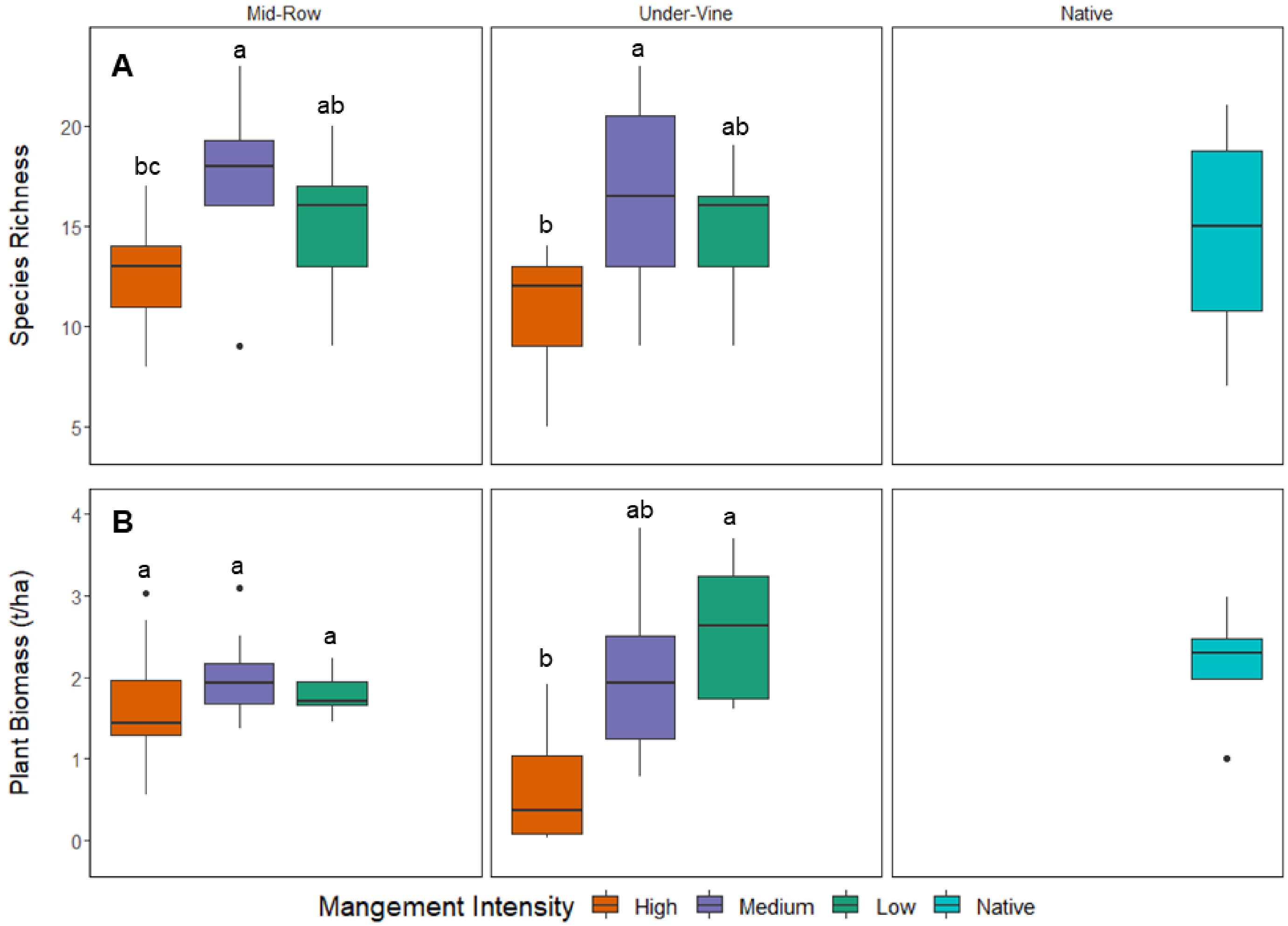

Figure 1. Boxplots showing mean measured values of (A) plant species richness and (B) plant biomass in the mid-row and under-vine rows of commercial vineyards where floors are managed with High (n = 9), Medium (n = 8), and Low (n = 7) intensities throughout the 2020-2021 growing season. Means of measurements at the native unmanaged sites (n = 4) are also shown. Means were compared between management intensity groups at the mid-row and under-vine areas using a Kruskal-Wallis non-parametric test where different lowercase letters indicate differences at $p < 0.05$.

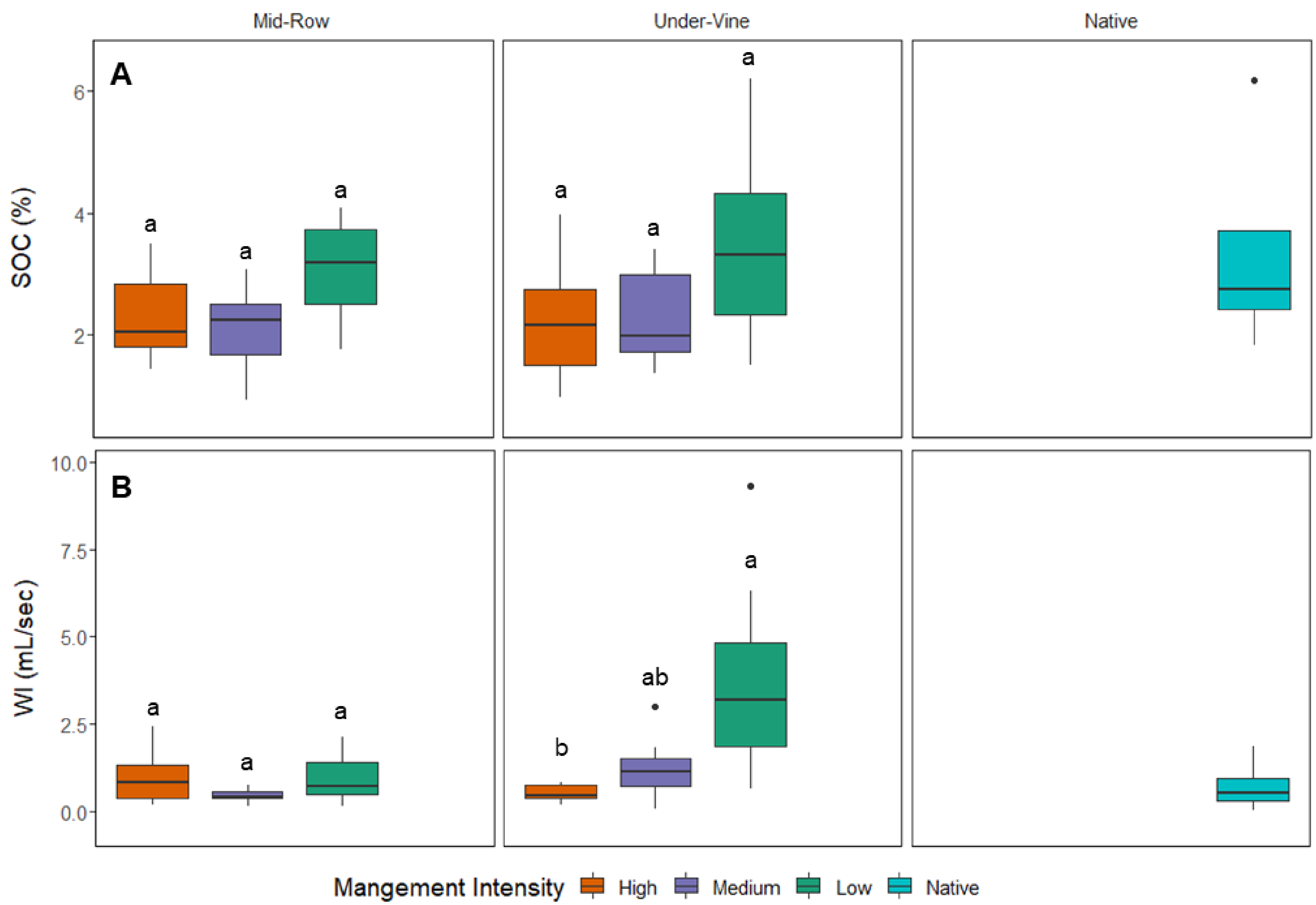

Figure 2. Boxplots showing mean measured values of (A) soil organic carbon (SOC) and (B) soil water infiltration (WI) in the mid-row and under-vine rows of commercial vineyards where floors are managed with High (n = 9), Medium (n = 8), and Low (n = 7) intensities throughout the 2020-2021 growing season. Means of measurements at the native unmanaged sites (n = 4) are also shown. Means were compared between management intensity groups at the mid-row and under-vine areas using a Kruskal-Wallis non-parametric test where different lowercase letters indicate differences at $p < 0.05$.