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Master thesis

presented for the degree of **Agricultural Engineer**
Domain: **Viticulture and Oenology**

Assessment of Green Infrastructure and its Design in Vineyards



Presented by **Nadège GRISARD**

2019

Host University: **Lincoln University, New Zealand**
School Of Landscape Architecture (SOLA)



Master thesis

**presented for the degree of Agricultural Engineer
Domain: Viticulture and Oenology**

Assessment of Green Infrastructure and its Design in Vineyards



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RESUME

Titre: Evaluation des Eléments de Biodiversité et de leur Design dans les Vignobles.

La monoculture viticole menace la biodiversité en occupant des habitats clés et en simplifiant les communautés écologiques. La simplification des paysages est reconnue comme étant une raison des invasions d'insectes ou de maladies depuis plusieurs dizaines d'années maintenant. Des changements qui ne modifient pas radicalement la nature monoculturale des agrosystèmes peuvent temporairement réduire les impacts négatifs, mais pour une réelle résilience et des bénéfices durables, des mesures agro-écologiques radicales sont nécessaires. La diversification réfléchie des écosystèmes incluant un design de la biodiversité comme l'agroforesterie est un exemple. Dans les systèmes viticoles, l'utilisation de plantes de couverture est souvent le seul outil de management basé sur la biodiversité. Un plus large panel d'Eléments de Biodiversité (végétation autre que la vigne ainsi que le réseau d'eau, appelées Green Infrastructure (GI) en anglais), comme des réserves d'insectes ou haies, doit être utilisé comme outil de travail pour une approche systémique allant vers des agrosystèmes plus équilibrés, utilisant des insectes prédateurs pour combattre les parasites et des buissons pour réguler les flux d'air.

Alors que les connaissances sont nombreuses sur les bénéfices de l'incorporation de plus de biodiversité pour diminuer les impacts négatifs de la monoculture, ainsi que pour fournir des services écosystémiques, seulement peu d'études existent sur sa mise en place dans les vignobles. De même, très peu d'études cherchent à comprendre si le design de la biodiversité dans les vignes résulte d'une action volontaire ou alors, si et comment, il est planifié. La biodiversité en tant qu'outil ne semble pas faire partie du processus de plantation même dans les régions viticoles récentes.

Des interviews longues semi-structurées ainsi que la cartographie des GI sont les méthodes utilisées dans la région viticole de Waipara pour comprendre comment les vignerons choisissent la localisation de la biodiversité et pour identifier les GI présentes dans les vignes. Aussi, pour augmenter la prise de conscience sur le sujet, les résultats seront diffusés de façon compréhensive et informative avec les interviewés.

Cette étude montre que le processus de design des vignobles n'inclut pas l'incorporation de GI et l'utilisation de cartes des vignobles est très limitée. La présence de GI est faible et principalement limitée à des zones non exploitables pour une production viticole. Trois types de design ont été identifiés : des vignobles conventionnels homogènes, des fermes conventionnelles utilisant des haies, et des fermes plus diversifiées. La présence d'un caveau de dégustation ou d'un Airbnb sur la propriété augmente la présence de biodiversité alors que la certification ou la taille du vignoble n'est pas un facteur explicatif majeur. Fournir des cartes et une évaluation personnalisée de la biodiversité sur les domaines vise à augmenter la conscience des vignerons vis-à-vis de leur biodiversité et à leur donner des outils de planification. Puisque la biodiversité présente sur chaque propriété est insuffisante pour former un réel réseau, il serait judicieux de travailler à l'échelle des paysages avec l'implication d'acteurs régionaux ainsi que d'institutions viticoles, pour lier les propriétés voisines entre elles et construire un réseau de végétation basé sur les cours d'eau.

Mots clés

Eléments de biodiversité, Biodiversité, Design, Vignobles, Vignes, Service Écosystémique, Haies.

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ABSTRACT

Title: Assessment of Green Infrastructure and its Design in Vineyards.

Vineyard monoculture poses a threat to biodiversity by occupying key habitats and simplifying ecological communities. Landscape simplification is known as a cause of insect and disease outbreaks for a few decades now. Changes that will not radically modify the monoculture nature of agrosystems may moderate negative impacts temporarily. Though, for real resiliency and durable benefits, radical agroecological measures are needed to strengthen farming resiliency. Diversification of agrosystems in the form of biodiversity-wise designed systems such as agroforestry are such measures. In vineyard systems, cover crop is often the only biodiversity feature part of the farming strategy. A broader range of Green Infrastructure (GI, non-vine vegetation and water-systems) such as insectaries and hedgerows would be necessary for a systemic approach to better-balanced agrosystems, using predatorial insects to fight pest and shrubs for regulating airflow.

While a great deal is known about the benefits of incorporating more biodiversity to mitigate negative impacts of monocultural farming, and to provide an increase of ecosystem services (ES), little study of its implementation within vineyards exists. Nor much study about whether vineyard owners purposely design for greening and how. Biodiversity as a tool does not seem to be part of the planting process even in new wine regions.

Semi-structured long interviews and GI mapping are used in Waipara Valley wine region to understand how winegrowers make decisions about the incorporation of GI in vineyards and to locate them. Also, to increase farmer awareness, results will be shared in a comprehensive and informative way with the interviewees.

The study shows vineyard design process doesn't include GI, and the use of farm maps is very limited. GI presence is low and mainly limited to areas that aren't suitable for production. Properties show three types of design: conventionally designed homogeneous vineyards, conventionally designed farms with the use of hedgerow and more diverse vineyard farms. The cellar door or Airbnb presence on properties increases the GI whereas certification or vineyard size are not major factors. Providing managers with a personal map and a biodiversity assessment as feedback is aiming at increasing their awareness on their biodiversity and give them a designing tool. As patches on each property are too limited to support a real biodiversity network, it would be good to work on a landscape scale with the involvement of regional and wine organisations to bind neighbouring properties together and build a biodiversity network based on waterways.

Key words

Green Infrastructure, Non-Vine Plantings, Biodiversity, Design, Vineyard, Shelterbelt, Hedgerow, Cover crop.

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It was nice to be hosted in Lincoln University facilities and it is a really good thing Montpellier Supagro enables its students to get experience abroad and granting me a scholarship. Thanks to Occitanie region too for the financial support.

This experience has not only helped build up my theoretical knowledge about biodiversity design but as well to comfort it by practical feedbacks about existing implementation and design around vineyards.



'What good are all those species that man cannot eat or sell?' (Odum, 1971)

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FOREWORD

This study is completed at Lincoln University following Wendy McWilliam previous work in Oregon evaluating a biodiversity-based wine grape production system. The interview process is done along with Anna-Kate Goodall's master thesis study about Enablers and Barriers of GI in vineyards.

GLOSSARY

Biodiversity: Consists of plants that provide ecosystem services such as nitrogen fixation, decomposition, facilitation of nutrient uptake by plants, pollination, pest control and ecosystem engineering (Moller *et al.*, 2008).

AirBnB: Airbnb is an online marketplace for arranging or offering lodging, primarily homestays, or tourism experiences.

Basemap: Refers to a collection of GIS data and/or orthorectified imagery that forms the background setting for a map. The function of the basemap is to provide background detail necessary to orient the location of the map. Basemaps also add to the aesthetic appeal of a map [Webography, 5].

Biodiversity trail: Bush planting with a path and informative signs for customers to discover NZ natives, set up by Greening Waipara programme.

Block: Vineyard block consists of rows of grapevines and their directly associated management areas, which consist of inter-rows, tractors turn-around areas at the end of grapevine rows, and inter vineyard block roads (McWilliam, draft).

Cellar door (CD): consists of the building in which the wine is sold to the visiting public, in addition to its associated landscaped areas, driveways and parking (McWilliam, draft).

Corridor: A corridor is an area of habitat connecting wildlife populations separated by human activities or structures (such as roads or fields).

Cover: Is the area of ground covered or the relative proportion of coverage a particular plant species, vegetation layer or plant form represents (Lee *et al.*, 1998).

Cover crop: Plant such as rye, alfalfa, or clover that are planted in between the main crop in order to maintain a plant cover on the land and thus reduce erosion and leaching (Park, 2007).

Crop: Plant grown for food (2006).

Drainage channel: a ditch or open channel that is used to carry excess water or sewage downstream (Park, 2007).

Farm map: Map showing much of the farm inventory. Can graphically show the natural and cultural features present on the farm and their spatial relationships (Padgett-Johnson, 2003).

Gully: A gully is a long narrow valley with steep sides [Webography 4, Collins].

Green Infrastructure (GI): For winegrape production systems we define it as networks of natural, semi-natural or human-constructed/planted non-vine vegetation and water-systems that may or may not contribute directly or indirectly to production, and provide ecosystem services and functions to vineyard farmers and their communities (McWilliam, draft).

Hedgerow: A hedgerow is a row of bushes, trees, and plants, usually growing along a bank bordering a country lane or between fields [Webography 4, Collins].

Irrigation reserve/dam: open-top water pool storing water for irrigation and frost protection.

Land sharing or wildlife-friendly farming: integrates conservation and production within more heterogeneous landscapes (opposed to land sparing, homogeneous areas of farmland are managed to maximize yields, while separate reserves target biodiversity conservation) (Fischer *et al.*, 2008).

Meadow: An area of closed herbaceous (pertaining to or resembling an herb or a non-woody plant stem) vegetation dominated by grasses (Lewis, 2002).

Nor'wester: wind from the North-West, typically strong in Waipara Valley.

Patch/polygon: An area of vegetation that has a uniform structure and composition, and differs from the surrounding vegetation (Park, 2007).

Pests: Pests are insects or small animals that damage crops or food supplies [Webography 4,

Collins].

Pond: pool of still water, often artificially created (Park, 2007).

Shapefile: The shapefile format is a common format for storing vector GIS data. Shapefiles store non-topological vector data along with related attribute data [Webography, 5].

Shelterbelt: a row of trees providing shelter from the wind [Webography 4, Collins].

Shrub: A low woody perennial plant that has no trunk but several major branches at or near the base giving a bushy appearance, usually less than 6m tall (Park, 2007).

Stream: A natural body of running water that flows along a channel (Park, 2007).

Tree: A large perennial woody plant that usually has one main trunk, a number of branches, and a crown of foliage (Park, 2007).

Wastewater: Wastewater is water which has been used in people's houses or in industrial operations [Webography 4, Collins].

Weeds: A weed is a wild plant that grows in gardens or fields of crops and prevents the plants that you want from growing properly [Webography 4, Collins].

Wetland: Land that is partially or totally covered by shallow water, with soil saturated by moisture part or all of the time (Smith, 2011).

Winery: consists of the structures associated with wine production in addition to its associated landscaped area (McWilliam, draft).

ABBREVIATIONS

ArcGIS: Architecture GIS, a suite of desktop softwares developed by ESRI (Environmental Systems Research Institute).

ArcMap: Architecture Map, software part of ArcGIS suite.

CD: Cellar Door

DDs: Degree Days

ES: Ecosystem Services

GI: Green Infrastructure

GIS: Geographic Information System

GW: Greening Waipara

GWP: Greening Waipara Programme

HC: Hierarchical Clustering

ID: Identification number

NZ: New Zealand

NZW: New Zealand Winegrowers; New Zealand Winegrowers is the national organisation for the country's grape and wine sector.

OIV: International Organisation of Vine and Wine

PCA: Principal Component Analysis

SWNZ: Sustainable Winegrowing New Zealand; an industry-wide certification programme led by New Zealand Winegrowers.

INTRODUCTION

Agriculture is the single largest cause of biodiversity loss, greenhouse gas emission, consumptive use of freshwater, loading nutrients into the biosphere (nitrogen and phosphorus) and a major cause of pollution due to pesticide. Conventional viticulture is among the most pesticide consuming agricultural systems (Provost and Pedneault, 2016) and grape production internationally has intensified with more grapes produced on a decreasing land area (OIV, 2012), and is thus well part of that picture.

Current management systems can temporarily mitigate the negative implications of monocultural systems, but radical agroecological strategies and techniques breaking severe monocultures are needed to re-establish a systemic resilience (Cox and Underwood, 2011; Altieri *et al.*, 2015). Landscape simplification is known as a major driver in the increased pest and disease outbreaks observed over the last few decades. (Andow, 1983; Barbosa and Schultz, 1987). However, even in new wine regions such as Waipara Valley, Green Infrastructure (GI) is rarely part of the planting process. Green Infrastructure is defined for winegrape production systems as networks of natural, semi-natural or human-constructed/planted non-vine vegetation and water-systems that may or may not contribute directly or indirectly to production, and provide ecosystem services and functions to vineyard farmers and their communities (McWilliam, draft). In vineyard systems, for example, cover crop is often the only biodiversity feature that is part of the vineyard management. Amending cover crop with other non-vine plantings such as insectaries to support predatorial insects or hedgerow and shrubs management to optimise airflow may hereby create better-balanced agrosystems. Such strategies and techniques include the diversification of agroecosystems by implementing biodiversity enhancing systems such as agroforestry. *‘Everyone in the world depends on nature and ecosystem services to provide the conditions for a decent, healthy, and secure life. Humans have made unprecedented changes to ecosystems in recent decades to meet growing demands for food, fresh water, fiber, and energy. Human activities have taken the planet to the edge of a massive wave of species extinctions, further threatening our own well-being.’* These three statements are part of the outcomes from the Millenium Ecosystem Assessment (Millenium Ecosystem Assessment Board, 2005). This report called for by the United Nations has been built up by a group of 1360 experts worldwide and the robustness of its findings had been scrutinized by governments and independent scientists. Going toward a resilient farming system based on ecosystem services appears as the key.

In New Zealand, despite the very recent human arrival, landscapes have been badly degraded, and keep on degrading with indigenous species extinction still occurring. Thus the population and the government are trying to protect the remaining natives and implement more. Though, biodiversity does not appear to be part of the recently developed vineyard landscapes. Recent vineyards means that people who planted and designed them are often still owning them. Thus it is possible to get in touch and try to understand why so little vegetation has been planted even when the importance of biodiversity was already documented. As Waipara Valley Wine region has been through a greening programme (Greening Waipara Programme, GWP), that should have increased biodiversity presence and stakeholder’s awareness about ecosystem services and make the discussion a bit more documented.

It is why I seized the opportunity to work in a research environment on the design aspects of Green Infrastructure in vineyards. At Lincoln University, New Zealand (NZ), my work was supervised by Wendy McWilliam, an expert in biodiversity landscaping, together with Olaf Schelezki, an expert in grape and wine production. Previous work by Wendy McWilliam in Oregon (not published yet), ‘An evaluation of biodiversity-based wine grape production systems’ is assessing the role of biodiversity in vineyards in Oregon. She found that little

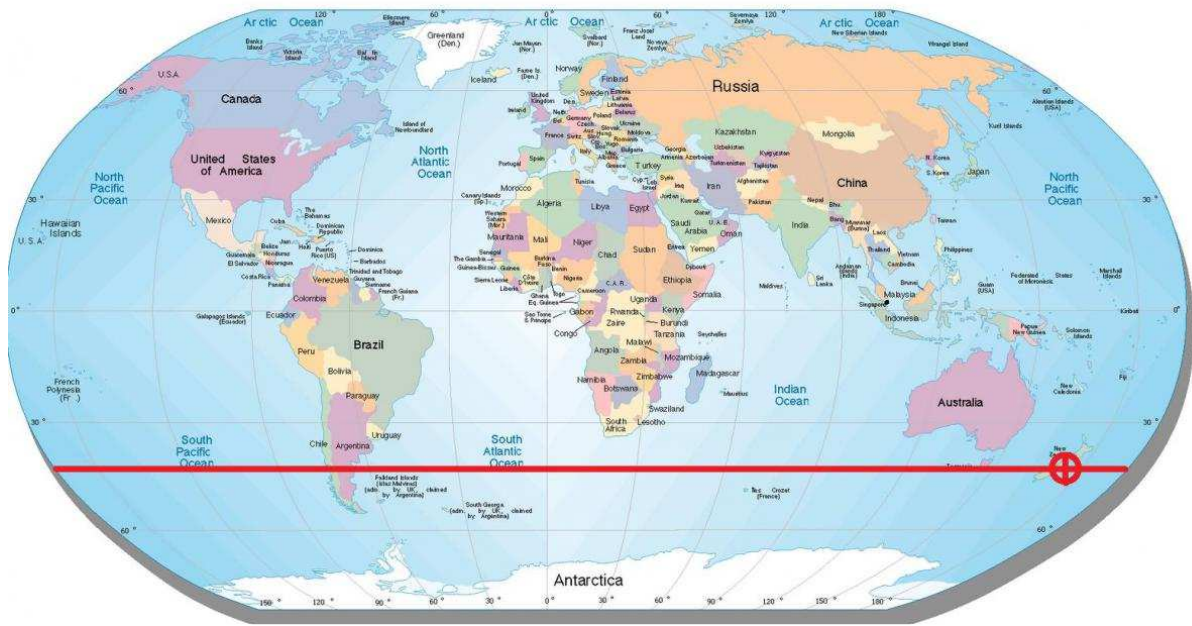


Figure 1: World map locating New Zealand

attention was given to increasing the resilience of vineyard systems through either GI or additional production systems. “Designing and managing production and GI as integrated systems, versus isolated components, across expanded spatial and time scales, would assist in minimizing externalities, maximizing ecosystem services, and enhancing resilience. In addition, further research is also required to test alternative designs in support of stakeholder ecosystem services to demonstrate effectiveness and enable implementation” (McWilliam, draft).

This study is aiming at understanding the design strategies in vineyards and studying the resulting biodiversity layout. Properties involved in Greening Waipara Programme were interviewed about the design process of their vineyard and their use of a farm plan. A mapping process of biodiversity presence has been undertaken as well while visiting the vineyards. Data are collected during an interview process completed along with Anna-Kate Goodall’s Master project about Enablers and Barriers of GI.

After a background presentation of the study area as a wine-producing region in New Zealand, we will identify the research objectives and then have an overview of the different concepts it embraces. Then the method will be detailed before results are presented and discussed.

1 WAIPARA VALLEY, A WINE REGION IN NEW ZEALAND

1.1 New Zealand

1.1.1 General presentation

New Zealand, or Aotearoa (Māori name), is a very rural country, half the size of France, and an average density of 18 people per square kilometre (2017) [webography, 1]. Of the 4.7 million New Zealanders, approximately 69% are of European descent and 14.9% are indigenous Māori, the first settlers. Thus, names of places, fauna, and flora can be either from English or Māori descent. Sitting in the south-western Pacific Ocean between latitudes 34°S and 47°S (Figure 1), it consists of two main islands that are narrow (maximum width is 400 km) and called the North Island and the South Island. NZ has a temperate marine climate with cooler summers and milder winters than comparable latitudes in the northern hemisphere (Howland, 2014). Thus, even if Waipara Valley is 43°S, i.e. opposite to Narbonne (Franch city), it is a cool climate viticulture. Waipara Valley (means Muddy Water Valley in Māori) is located in the North Canterbury wine region, the main city of the region is Christchurch (see Figure 4).

1.1.2 New Zealand vegetation history

NZ is geographically isolated land for millions of years, it got split from Australia about 80 million years ago. Thus flora and fauna adapted and evolved independently from its progenitors (Newsome, 1987). Its long insulation from other lands and latitudes extending from subtropical to Subantarctic leads to a unique flora and highly diverse vegetation (Wardle, 1991). Indigenous biodiversity is called native.

NZ colonisation by humans is very recent and brought along a massive biodiversity loss. The earliest conceivable arrival was about 750 AD (Newsome, 1987), with Polynesian repeated accidental colonisation. The Maoris used fire as a tool in hunting Moa (extinct indigenous giant bird), clear land for food crops and open routes. The forest, covering a major part of NZ land, reduced from approximately 75% between 750AD and 1800AD (Newsome, 1987). With the year 1840 and the start of the European era comes along with more fire land

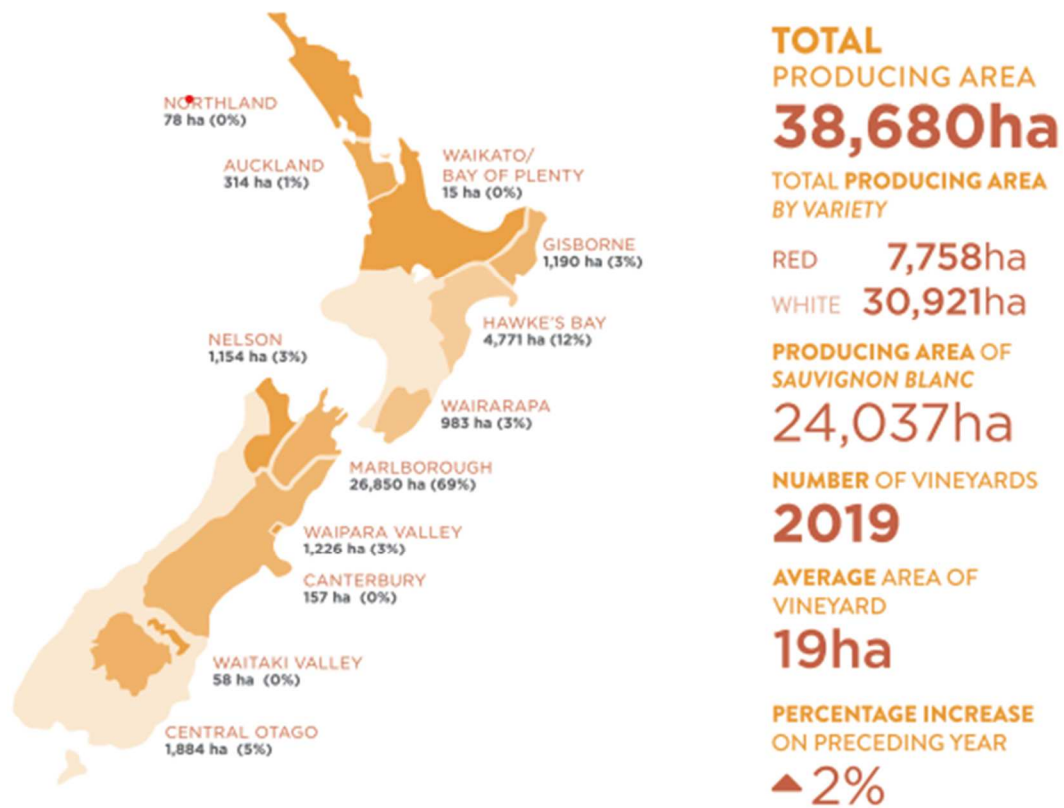


Figure 2: A snapshot of NZ wine (NZWine, 2019)

clearing and the start of extensive sheep grazing. By the middle of the 20th century, all the plains and downlands had been cleared of forest and scrub and converted to agricultural use. On top of that destructive behaviour, the early settlers had brought with them an array of exogenous plants, mammals and birds. Many of those introduced species had little impact, but others soon became nationwide pests and still are today. One consequence has been the impact on forest health and regeneration capability, including loss of vigour and death of palatable trees, increased susceptibility to diseases, reduction or loss of understory shrubs and seedlings. Some naturalised exotic flora species thrive (such as gorse (*Ulex europaeus*), sweet briar (*Rosa rubiginosa*), broom (*Cytisus scoparius*), thistles, etc.) and spread around as weeds, jeopardising significantly agricultural practices, or harming indigenous species as the *Pinus contorta*.

Recently, these issues around environmental conservation has received wider public attention and focus has been given to land planning, district, and regional schemes, reserves creation, etc. Land and people co-existing in harmony is still far in the future but it is a general aim for NZ (Newsome, 1987).

1.1.3 Water management and pollution (Cullen *et al.*, 2006)

The ongoing availability of freshwater used to be taken for granted in New Zealand. However, this time is long gone, with demand for water increasing steadily in several regions of New Zealand and availability is limited, particularly during low-rainfall periods. Diffuse sources of nitrates have caused nitrification of several NZ lakes, many streams, and some major aquifers. Agriculture is recognized as a major cause of this declining water quality, particularly because of its intensification and the growth of dairy farming. Agricultural irrigation has increased at a rate of about 55 percent per decade between 1965 and 2006. Water resource allocation and water quality are issues of national importance.

In Brief

NZ native biodiversity is fragile and endangered. Only rare patches remain in agricultural landscapes when exotic species spread. Water is available but recently became scarce in some regions.

1.2 New Zealand wine industry

1.2.1 Production characteristics

Wine industry in NZ is very young. Even though the first vines were planted in the early nineteenth century, there was only 388ha across NZ in 1960 (Moran, 2016). In 2019, about 39 000ha are planted in NZ (Figure 2, (NZWinegrowers, 2019)) and growth is ongoing with a 3% increase from 2017 to 2018. Responsible for just 0.7% of global production in 2010, NZ built up its fame with its Marlborough Sauvignon blanc. (Howland, 2014). 7% of New Zealand's vineyard producing area operating under recognised certified organic programmes (SWNZ, 2016). Marlborough wine region is quite intensive, with high yields and 69% of the national area. With 3% of it, Waipara Valley wine region sits far behind, and other types of agriculture remain important. Yield in Canterbury reaches an average of 7.7 t/ha in 2018 (2018 being a quite high yielding year for the region), the average NZ yield is 11.1t/ha (NZWinegrowers, 2018). The total production of 300 million litres is mainly exported (85% exported in 2018).

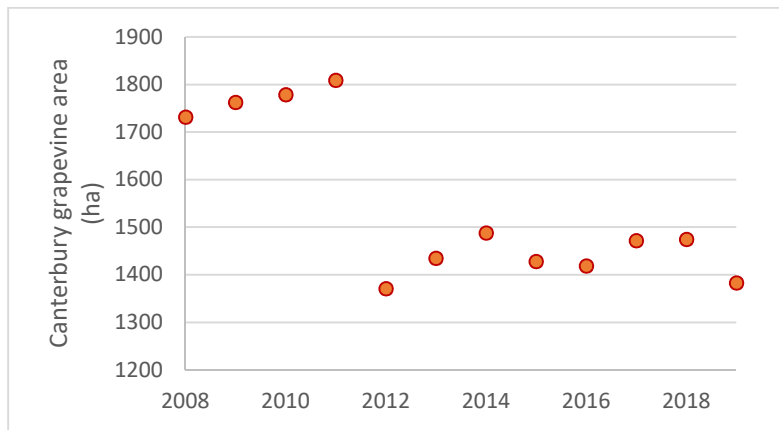


Figure 3: Evolution of the grapevine area in Canterbury over the past 11 years

1.2.2 Landscapes simplification

This wine industry tremendous growth results in landscapes simplification and vineyard monoculture in Marlborough, and in parts of Gisborne and Hawke's Bay landscapes. Not only they are less aesthetically desirable than the smallholding, but the use of pesticides and fertilisers is higher, and disease risk more prominent. (Pawson, 2018)

1.2.3 Sustainable Winegrowing NZ (SWNZ)

Singular thing in New Zealand is the presence of a national sustainable certification, Sustainable Winegrowing New Zealand (SWNZ), introduced commercially in 1997 and adopted by grape growers across the country's winegrowing regions: 98% of NZ's vineyard area is SWNZ certified (NZWinegrowers, 2018). The Sustainable Winegrowing New Zealand programme is based on continuous improvement and adherence to recommendations and guidelines issued by the International Organisation of Vine and Wine (OIV). SWNZ was developed to provide 'best practice' model of environmental practices. SWNZ ensures members meet international standards for sustainability practices while helping the environment, businesses and local communities to thrive. Sustainable winery certification standards were established in 2002 and adopted by New Zealand wineries, closing the circle on the industry's sustainability commitment.

In Brief

NZ wine industry is less than **60 years old**. Vineyard area now reaches **39 000 ha**. **Sustainable Winegrowing NZ** certification gathers **98%** of the vineyards.

1.3 Waipara wine region

1.3.1 Wine history and economic system (Schuster *et al.*, 2002)

The planting of grapes in Waipara in the 1960s arose from the need to find alternative crops in an area of economically marginal, relatively small sheep farms with a difficult climate prone to prolonged summer drought. Thus Glenmark irrigation scheme was developed in the 1970s to give economic viability to traditional farms (fat lambs, wool, wheat, barley, and ryegrass). It turned out to allow as well possibilities of new ways of farming, now the area is well suited to the production of many horticultural crops including vineyard grapes. Availability of irrigation water remains a limiting factor to a rapid expansion of vineyards in Waipara, although all of the present vineyards do so with apparent ease and have found sufficient water on their sites. Waipara wineries range from large producers to smaller, boutique properties. Most are open to the public for tastings, winery tours or restaurant meals. In 2008-2009, following the financial crisis of 2008, Sauvignon blanc sales dropped which caused a 'Savi mountain'. Grape prices dropped and contracts were cancelled, provoking a lot of economic issues to wine companies. Thus, many companies were bankrupted and changed hands around that time (personal communication during interview phase). It probably explains as well as is confirmed by the major grapevine area decrease from 2011 to 2012 (reduction of 400ha), see Figure 3.

Waipara is a small producers region of 1316 ha (3% of NZ) (NZWinegrowers, 2018). There are a couple of bigger properties but their production environment makes it hard to compete with Marlborough yield-based strategy. Fruit and wine quality is usually said to be high, and they are starting to get known for Pinot noir. Though, Waipara wine region doesn't have a common marketing strategy nor an image even nationally-speaking. Thus they have a

harder time to make their business profitable, especially as supermarkets have pushed the price of wine down. There used to be a Waipara Valley wine association but they recently merged with other wine areas in Canterbury to become the North Canterbury Wine Region. Most vineyards are grazed by sheep at least over winter time and sometimes as well for leaf-plucking.

1.3.2 Waipara climate and soils (Schuster *et al.*, 2002)

In Waipara, a range of coastal hills protects the area from the cold and persistent north-easterly winds (up to 100 more degree days (DDs) than exposed Canterbury plains). Temperatures are often similar to the Marlborough district, and Waipara is regularly one of the warmest spots in NZ. With annual DDs between 950 and 1050, it is suitable for grape growing as a cool climate region.

Canterbury plains have an annual average of 650mm rain. Irrigation is required in most vineyards for establishment, and in those with low water retention, for continued production. Dry autumn weather reduces the incidence of fungal diseases close to harvest. The soils are moderately heavy clay loams, rich in ironstone and chalk, and have similarities to soils in Burgundy. But important variations across the valley soils is mentioned in interviews. Riesling does particularly well, and some vineyards have produced good wines from Cabernet Sauvignon, especially when blended with Merlot. Best performers so far are Riesling, Pinot noir and Chardonnay. All interviewees mentioned very dry climate (most properties use irrigation) and strong Nor'wester (wind from North-West). Wind is a major issue in some vineyards as it can damage vine shoots and trellis and is especially unpleasant for staff working in the vineyard. Others see it as a major help to reduce disease pressure.

Waipara is described as a frost-prone area, so most of the vineyards can get frosted during spring time and fans, sprinklers, and helicopters are used for frost fighting.

1.3.3 Main specificities production challenges in the region

The information in this section is from the interviews. Only facts mentioned several times are used.

Major pests and climate issues

Powdery (*Erysiphe necator*) is often mentioned as the major concern, especially since the sexual strain of *Erysiphe necator* appeared (2013) (Cooper *et al.*, 2015) and became especially present over the past 3 years.

Botrytis cinerea is often mentioned as an issue, more or less major depending on vineyards, but mostly a problem in years when they get very heavy fruit set and post veraison rain and cloudy cool conditions.

Birds are a major pest as everywhere in New Zealand. Especially exotic flocking birds such as starlings (*Sturnidae*), silvereyes (or wax-eye, *Zosterops lateralis*), common blackbirds (*Turdus merula*) and thrushes (*Turdidae*). In order to protect their crop, most vineyards are netted from the start of the veraison.

Other pests

Leafroller caterpillars are sometimes mentioned as being already an issue in some vineyards whereas it has not been recorded yet in others. Light Brown Apple Moth (*Epiphyas postvittana*) is often the mentioned specie. 'We've only really in the last couple of years started to see its impact. I don't know why it's all of a sudden, it might be the climatic sort of conditions, but now it's become quite a pest. Like climatic conditions have changed and it seems to be overwintering a lot more because it's not getting frosted out so much.'

The endemic **grass grub** *Costelytra zealandica* (Coleoptera: Melolonthinae) has been a pasture pest for more than 100 years in New Zealand. Recently, adults of this species (bronze or brown beetles) have been found feeding on horticultural crops such as vines amongst others. Adults damage vines by feeding on leaves, shoots and inflorescences and can produce a substantial defoliation, reaching in some cases 100% (González-Chang, 2016). In Waipara, they are reported as flying out from neighbours sheep pastures and impacting mostly rows on the fringes (two to ten rows). They are usually not too worried as they see it to a varying extent each year, they tend to be less of a problem when droughts occur.

Minor concern

The **mealybug** is the vector for the Grapevine Leafroll associated Virus 3, and is a problem in the Marlborough wine region [webography, 2] but not in Waipara yet. Most interviewees did not record any yet but think it will eventually reach the area. Only two interviewees mentioned having mealy bugs.

A lot of the first plantings were own-rooted because they did not have **phylloxera** back then. But within a couple of years, it started to appear so everybody moved to a grafted situation. Ungrafted plants are sometimes still present in part of the vineyards.

Trunk diseases, mostly *Eutypa dieback* (*Eutypa lata*), threaten the sustainability of New Zealand vineyards and are becoming an increasing problem as vineyards age. Though, no preventative or remedial treatments are employed in typical New Zealand vineyard (Sosnowski and McCarthy, 2017).

Rabbits can be a big thing in NZ vineyards (dig holes, chew nets, cause trouble with new plantings) and they try to shoot them while bird scaring. Though the population does not seem to be too high at the moment (virus released) and most interviewees were not complaining about that.

Climate change is rarely mentioned and does not seem to lead to a change in practices. Warmer climate could lead to a higher prevalence of some insect pests. Some mentioned changes in rainfall patterns leading to more stress periods (increased late summer rainfall and reduced early summer rainfall).

1.3.4 Greening Waipara Programme

Greening Waipara Programme (GWP) is a research-driven project initiated by Lincoln University, local wine growers, the Hurunui District Council and Landcare Research. The objective was to help the area regenerate through the planting of natives. Vineyards were mostly targeted as a major industry in the area.

Stephen Wratten from Lincoln University was part of a six years government-funded programme called 'Biodiversity, Ecosystem Services and Sustainable Agriculture is a key'. Indeed, as already mentioned, government concern for biodiversity (see 1.1.2.) has become prominent. Over 6 years, they got a 2.3 million dollars fund from Foundation for Research, Science and Technology (FRST, public service department of NZ by then). It benefited not only research but as well vineyard properties of the area. It is the start of the so-called Greening Waipara Programme (personal communication from Stephen Wratten and (GWP, 2006)).

The approach was to engage individually with the property owners involved through soil analyses, mesoclimate examination, but as well taking into account they want to achieve: what areas, how big, how they want it to look, what constraints they face, and what timeframe is realistic. They were more specifically looking at services such as biological control of pests, pollination and keeping soils fertile, among many others. It aims to boost nature's

overall contribution to agriculture. The Greening Waipara Project developed and introduced seven environmental innovations for Waipara vineyards and wineries to adopt (Appendix 1, GWP innovations and (Forbes *et al.*, 2013). Though, adoption of the Greening Waipara Project was, with one exception, relatively low. The costs associated with the innovations tend to outweigh the benefits. Only one innovation has been widely adopted. The adoption of that innovation, conservation of native flora and fauna, has been heavily subsidised by the Greening Waipara Project, and its adoption has been almost costless and risk-free for winegrowers. (Cullen *et al.*, 2013)

In Brief

- Study area ‘**Waipara Valley wine region**’ stands for **3%** of NZ vineyards and is included in the North Canterbury wine region. **Pinot noir** and **Riesling** are main grape varieties.
- Dry and windy climate, irrigation and frost fighting are common practices so is sheep grazing. **Powdery mildew, birds and botrytis** are the major pests. Other mentioned pests are **leafroller caterpillars**, grass grubs, mealybugs and rabbits.
- Greening Waipara Programme took place from 2005 to 2010 to increase biodiversity in vineyards (**native plantings** and cover crops).

2 BIODIVERSITY DESIGN IN VINEYARDS

After presenting New Zealand context and mentioning the overall issues of agriculture and more especially grape growing, it is important to gather a baseline knowledge about what exists in terms of vineyard and biodiversity design.

2.1 Resilient farming systems

2.1.1 Biodiversity inclusion in sustainable farming certifications

Sustainable Winegrowing New Zealand

SWNZ has a dedicated ‘Biodiversity Enhancement’ section that vineyard members complete in their annual scorecard. They ask for the types of biodiversity enhancement programmes vineyards have in place (compulsory question, SWNZ comment mentions ‘Diversity of composition in non-productive areas (such as structure of headlands, windbreaks, etc.) should enhance the habitat for natural biodiversity including predators/competitors for pests. Host plants for pests should be avoided.’), the type of inter-row sward (compulsory question) and the total area contributed to protection, restoration or enhancement (non-compulsory, SWNZ comment details ‘Please include the total area of biodiversity contribution, excluding vineyard sward and off-site activities’), see Appendix 2. That last question (total area contributed to biodiversity) enable SWNZ to assess that 2500 ha was set aside for biodiversity protection, restoration and enhancement by vineyards and wineries in their 2016 biodiversity report (SWNZ, 2016).

In regards to mapping, SWNZ members are required to have a current site management plan with map(s) identifying key areas (i.e., blocks and varieties) including hazards, protected natural areas, location of chemical stores, fuels, emergency equipment and boundaries. They don’t ask members to submit their site management plan and maps annually (they simply answer ‘yes’ or ‘no’ to having them), but they are required to hold them on file and show

them to their auditor during on-site audits (personal communication from Meagan Littlejohn, systems administrator, SWNZ).

Organic

In New Zealand, BioGro and AsureQuality provide internationally recognised organic certification. BioGro organic standards states as part of the main organic principles and methods (2.1.) (BioGroNZ, 2009): a. Foster beneficial processes and interactions such as occur in natural ecosystems, thus encouraging internal stability. e. Minimise any deleterious environmental effects of particular management practices, including any that may reduce the natural diversity to the detriment of plant and wildlife habitats. Biodiversity is part of the principles but no clear standard is stated regarding its protection.

Biodynamics

Demeter NZ describes biodynamics (“biological-dynamics”) as a systems approach, where the farm, vineyard, orchard or garden is viewed as a living whole and each activity affects everything else. It is a method of organic agriculture that applies to any farm or horticultural enterprise by following a series of practical steps. The steps include: Widening the range of pasture species. Planting trees for multiple purposes. Biodiversity seems to be more important

In Brief

Environmental certification such as Sustainable Winegrowing NZ, Organic and Biodynamic often mention and/or highlight the importance of biodiversity but don't have specific requirements.

than in organics but still no clear standard is included.

2.1.2 Hedgerow/shelterbelt use as a vineyard management tool

‘Compared with vines growing without protection from the wind, those sheltered by windbreaks exhibit (i) better budburst; (ii) larger leaves with more stomata; (iii) more clusters per shoot; (iv) longer internodes and longer shoots; (v) higher pruning weights; (vi) increased capacity to carry and ripen a crop; (vii) increasing phenolic content in the fruit.

Sheltered vines are also less susceptible to damage caused by whipping of the shoots and breakage (usually snapped off at the base early in the season). Sometimes loss of shoots can result in a potential 10-15% loss of productivity. Studies that have compared the productivity of sheltered versus non-sheltered vines tend to show around a 15% increase in yields. One South Australian study suggested that yield gains are from increases in flower cluster number rather than from percentage fruit set or berry size.

Ideally, a windbreak is permeable to the wind so that the air moves both through and over the top of the obstacle. This slows the speed of the air in the vineyard and also protects from the fastest air, which is shunted over the shelter. The latter is provided for a distance up to 20 times the height of the windbreak, so windbreaks need to be high enough to justify the area of land that they take up. However, with their use comes competition with grapevines for water, nutrients and even sunlight due to shading, especially at latitudes closer to the poles.

Judicious use of windbreaks can help in areas that are frost prone by preventing cold air from moving into a vineyard area from above (deflecting it away), though this precludes the use of deciduous plants in their make-up. However, deciduous tree shelters better allow cold air movement through them in the dormant season, which can be helpful in frost-prone areas as well. Windbreaks do require extra effort and cost to establish and maintain, take up land

area that could be used to grow grapes and also can be a nesting site for pest bird species; however, in certain areas, these drawbacks are countered by increased production and greater vine productivity.’ (Creasy, 2018)

In Brief

Hedgerows are commonly used as a **windbreak** but they have to be **judiciously designed** to get shelter while keeping appropriate airflow.

2.1.3 Ecosystem services (ES)

Ecosystem services can be defined as the contribution that ecosystems make to human well-being. Highlight is put on the ecological outcomes that particular ecosystem characteristics or processes generate, which can ultimately benefit people. This definition is from the Common International Classification of Ecosystem Services CICES (Haines-Young and Potschin, 2018). This study will only consider economically valuable ES (this aspect is important as it has been identified as a main enabler for the adoption of environmental innovations (Forbes *et al.*, 2013)). They are as follow: pest control, disease control, micro, and regional climate regulation and aesthetics. They were selected out of the 27 ES identified as relevant for vineyards by Winkler *et al.* (Winkler *et al.*, 2017). They are always mentioned in the interview process and closely linked to design. When biodiversity is mentioned, it only includes plantings and vegetation. Soil biodiversity and quality is not part of the study.

Pest control

Pest control is usually a major concern in vineyards as insect species can directly damage the crop as well as being a vector of viruses. Insecticide is the most common pest management tool. It did not use to be a major issue in Waipara, but some concerns have been brought up during the interview process so it is part of the study. Pest control through the design of biodiversity need to be planned ahead. The development of crop monoculture and landscape simplification are known to be the cause of pest outbreak for a few decades now (Altieri *et al.*, 1984). Though even the newly developed agricultural systems such as NZ vineyards stick to monoculture. In Portugal, for example, vineyard European Union (EU) policies led to landscape simplification from traditional hanged vineyards to monoculture. It led to less predatorial species, more grapeherbivores and a higher botrytis prevalence even with more fungicide applications (Altieri and Nicholls, 2002).

Disease control and mesoclimate mitigation

No much in the literature documents the impact of biodiversity on disease. Especially once the disease is already present all around the vineyards, it is too late to use vegetation as a barrier to their dispersal. Though, disease control is closely linked to mesoclimate regulation, as aeration, temperature and humidity are three major factors in disease contamination and spread.

Climate regulation

The presence of vegetation, especially hedgerow (see 2.1.2.), have a major impact on wind and thus, aeration, temperature and humidity around the vines. That impacts vineyard growth and integrity, grape ripeness, disease as already mentioned, as well as understory grass growth.

Aesthetics

Beautification is often mentioned as a major motive for planting. It is indeed the easiest service to gain and assess as being gained. It can be part of a marketing strategy along with cellar-door and AirB&B experience as well as it can be a personal preference or dedicated to staff well-being.

In Brief

The study of biodiversity in vineyards is closely related to the understanding of ecosystem services that can be of **interest** for vineyard managers: **pest and disease control, climate mitigation and aesthetics**.

2.2 Design of biodiversity around vineyard farms

2.2.1 Vineyard establishment recommendation

Biodiversity is rarely mentioned in grape growing reference books, and if so, it is only hedgerows or cover crops. Usual recommendation for vineyard establishment and designing are as follow: ‘Land that is less suited to grapes is better used for other supporting structures such as buildings or access ways. All of these take up valuable space, and so their placement should be planned to take greatest advantage of the land. It is important to use the soil information to help with the placement of blocks, as erosion and potential vigour of the area are two important factors that impact on future management. The block shape and size may be determined by a number of factors that may or may not be controllable. It can be defined by soil changes, access roads, source of irrigation water, row length, slope, etc. For many, minimizing the amount of variation within a management block is a desirable goal. Row orientation for most vineyards will run somewhere near north to south to allow for even ripening and fruit exposure on both sides of the canopy. If the area where the vineyard is to be established has high winds, it is worth considering establishment of windbreaks.’ (Creasy, 2018)

2.2.2 Farm plan use by vineyard managers

In vineyard management, spatial aspects often boil down to precision agriculture considerations (Smith and Whigham, 1999), with identified key opportunities being as follow. ‘Identification/delineation of spatial blocks with similar characteristics (ie site selection), specific measuring and monitoring of zones. Targeting management procedures to controllable factors. Analyses of results, in grapes and wine, compared to variables of location. Selection of grapes at harvest, based on spatial similarities.’ Nothing is mentioned about a broader landscape-based design approach.

Larger scale mapping is a recommended tool to provide information on agriculture and its impact on the environment (Adina, 2000). Mentioned advantages of mapping is the providing with ‘more information [...] to understand the consequences of vineyard expansion on a landscape scale as well as what site-specific vineyard development and management techniques can be used to minimize negative impacts to agriculture in general, neighbouring landowners and the environment.’. Their method is designed for county- or regional-scale analysis to assist land-use planners, natural resource protection agencies and land conservation programs in protecting valuable environmental resources while sustaining a vital agricultural economy. Although, on a farm scale, mapping is important. ‘Maps play a useful role in the development and presentation of a farm plan. Much of the farm inventory can be shown on maps. Maps can graphically show the natural and cultural features present on the

farm and their spatial relationships.’ (Padgett-Johnson, 2003). Recommendations about farm plan development process are detailed. GIS being mentioned as one method. Though farm map use is not common practice.

In Brief

- Vineyard establishment literature typically doesn’t mention biodiversity. Occasionally value the use of windbreaks and/or of cover crops.
- Mapping can be useful on a property scale but is not very common.

2.3 Study objectives

In the context of a pretty poor status of viticulture sustainability and a general will to make progress towards biodiversity enhancement, this study aims at increasing knowledge about the existing design of biodiversity in Waipara Valley vineyards. Christ & Burritt (2011) attest in their review that collecting quantitative data on the environmental implications associated with wineries activities would support wine organisations stakeholders to make progress : “knowledge in this field remains underdeveloped and the literature would benefit from additional research designed to bring about a greater understanding of how different combinations of activities undertaken to preserve ecosystem integrity can be used to bring about tangible forms of economic and environmental improvement.” (Christ and Burritt, 2013).

In most vineyards, Green Infrastructure is not part of the design process (see 2.2.1). The use of farm map is low (see 2.2.2). In a context of vineyard simplification (see Introduction), it is consistent to assume that vineyard owner strategy is to plant as much land as possible in grapevine and plant vegetation only on land unsuitable for vine or around buildings for aesthetics (see (McWilliam, draft)). For testing that hypothesis, the central question in this dissertation asks how does the vineyard design process includes GI in Waipara wine region and what is the resulting GI layout?

Smaller properties with certification (see 2.1.1) and more involvement of the owners are likely to have more biodiversity and a better strategy design than others. It is why another question is: what types of property have a higher presence of GI and show a more developed design strategy?

Increasing knowledge of managers about biodiversity in their properties is likely to increase their will to do more (Christ and Burritt, 2013). Thus, this research seeks to address the following question: what feedback would help to improve the use of biodiversity design within vineyards towards more complex agrosystems?

In Brief

Characterise and understand the design of biodiversity around the vineyards in order to help the wine industry make progress toward sustainability.

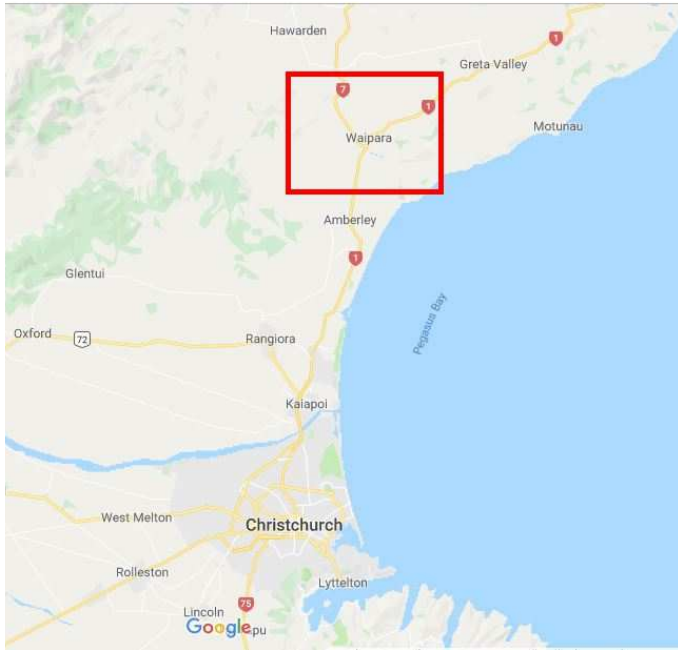


Figure 4: Sample location – red rectangle is the study area

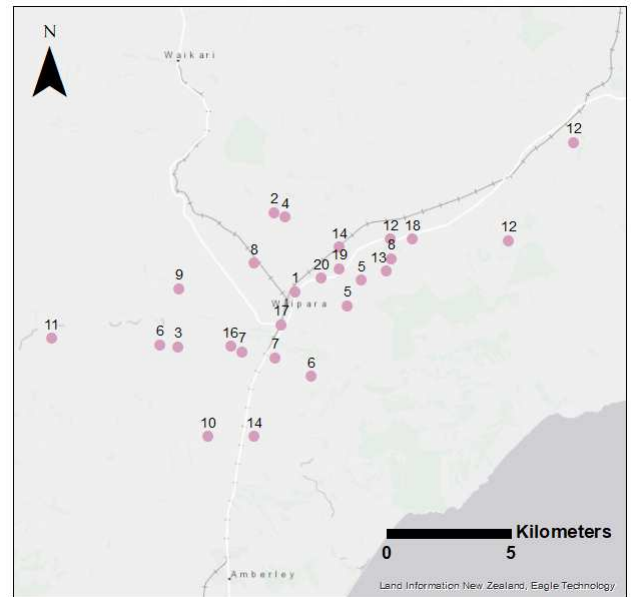


Figure 5: Vineyards location map

Table 1: Interviewed properties description

Estate ID	Vine (ha)	Size	Certification	Management	Tour	Cellar door	Main business	Number of blocks
1	20	Medium	SWNZ	Family owned and managed	Walk	Yes	Yes	4
2	1	Very small	None	Family owned and managed	Walk	Yes	No	1
3	13	Medium	Organic	Family owned and managed	Walk	Yes	Yes	1
4	4	Very small	Organic	Family owned and managed	Drive	No	?	1
5	50	Large	Organic	Family owned only	Drive	Yes	Yes	2
6	70	Large	SWNZ	Family owned only	Walk	Yes	Yes	2
7	210	Very large	SWNZ	Corporate	Drive	Yes	Yes	3
8	3	Very small	SWNZ	Family owned only	Walk	Yes	No	1
8bis	3	Very small	SWNZ	Family owned and managed	Walk	No	No	1
9	20	Medium	SWNZ	Family owned and managed	Walk	No	Yes	1
10	330	Very large	SWNZ	Family owned only	Drive	No	Yes	1
11	23	Medium	Organic	Family owned and managed	Drive	Yes	Yes	1
12	23.1	Medium	Biodynamics	Family owned and managed	Walk	Yes	Yes	3
13	9	Small	SWNZ	Family owned and managed	Walk	Yes	Yes	1
14	200	Very large	SWNZ	Corporate	Drive	No	Yes	2
15	Not part of GWP							
16	7	Small	SWNZ	Family owned and managed	Walk	No	No	1
17	1.5	Very small	SWNZ	Family owned and managed	Walk	Yes	No	1
18	6	Small	Organic	Family owned and managed	Drive	No	Yes	1
19	0.5	Very small	None	Family owned and managed	Walk	Yes	No	1
20	4	Very small	None	Family owned and managed	Walk	No	No	1

3 METHODS

3.1 Sample

This study aims at studying the design of GI in vineyards. It is interesting to study the design aspects in NZ as it is a very recent wine-producing country so most owners and managers planted their vineyard and remember the design process of it. Regarding biodiversity, it is more interesting/relevant to interview people that are aware of biodiversity role in order to have some informative and diverse conversations. The Greening Waipara Programme is the only example of a greening programme in NZ and aimed at increasing biodiversity presence as well as stakeholder's awareness about ecosystem services. Thus, properties that were part of Greening Waipara Programme were selected for the case study.

Properties are spread out in an area around Waipara township, 14kms North/South and 22kms East/West (Figure 4 and Figure 5). A total of 998ha of vineyard are owned/managed by the interviewees, i.e. 75% of the vineyards in Waipara Valley, and a total digitized area of 2000ha. 10% of the sample surface area is certified organic which is slightly higher than the 7% in NZ. All properties part of GWP that still exist have been contacted and accepted to be interviewed (Table 1). The most recent contact list of involved wineries was used – about 50, last updated in 2009. As many properties had changed hands since, a lot of them haven't been reached (phone line lost, outdated email). The 20 properties had either experienced the programme process or bought vineyards that had plantings from it. Main attributes of each property are gathered in Table 1. Estate ID (identification number) will enable to identify each property without naming in order to preserve anonymity. Amongst the interviewees, 11 of them had actually been part of the planting/designing process of their vineyards, whereas 7 were only part of the company afterward or bought the vineyard already planted. Half of them are living on the farm property. Property size distribution is shown in Figure 6.

In terms of vineyard size, the sample is representative of vineyards in Waipara (Figure 6 and Figure 7), except that the sample has one more vineyard over 100ha (probably explained by the fact one property lease most of its land), and less vineyard in the category 5-10ha than Waipara. It covers about 75% of the regional vineyards. Still, in terms of vineyard size, Waipara is very representative of vineyards in NZ (Figure 7 and Figure 8). Though it only stands for 3% of NZ vineyards, which is really low. 10% of the sample surface area is certified organic which is slightly higher than the 7% in NZ.

Summary

Interview process of vineyard managers or owner of 19 properties that were part of the Greening Waipara Programme. The sample is quite representative of NZ vineyards in terms of property size.

3.2 Research design

Interview questions (see 3.2.1. and 3.4.1.) will help understanding vineyard owners behaviour toward design, while mapping (see 3.2.2.) will enable to assess the biodiversity presence. Putting both in relation will enable to understand the vineyard design process impact on the Green Infrastructure layout. To understand what types of property have a higher presence of GI and show a more developed design strategy, analysis based on the mapped data will be processed (see 3.4.2.). In order to share results and answer the question about feedback helping to improve the use of biodiversity, a personal feedback will be put together (see 3.5).

Data are collected during an interview process completed along with Anna-Kate Goodall

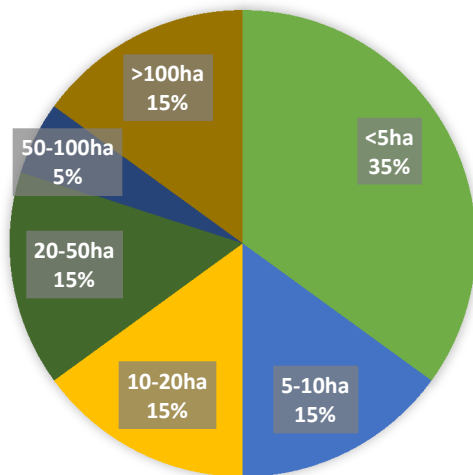


Figure 6: Distribution of the size of vineyards in the sample, percentage of properties

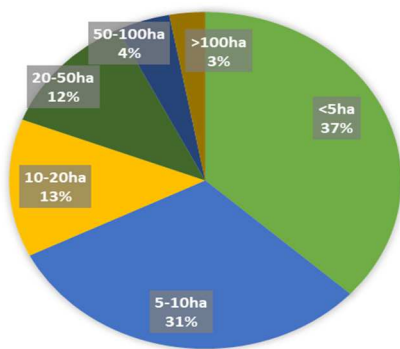


Figure 7: Distribution of the size of vineyards in Waipara, percentage of properties (NZWine, 2019)

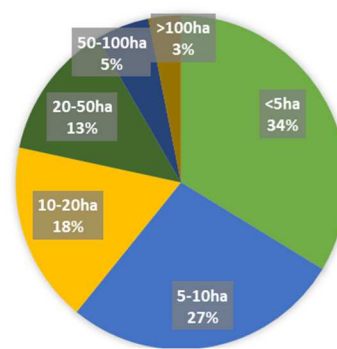


Figure 8: Distribution of the size of vineyards in NZ, percentage of properties (NZWine, 2019)

- 1 - Background information.
- 2 - Design planning.
- 3 - What non vine plantings existed, were planted and are currently in participant vineyards?
- 4 - To what extent does the GI planted mitigate key environmental impacts and increase ecological services?
- 5 - How might GI effectiveness be improved?
- 6 - How might GI be increased in the vineyard? What are the enablers or barriers for its implementation?

Figure 9: Interview script sub-sections

Master's thesis about Enablers and Barriers of GI. First part of the interview process lasted from May, 8th until June 5th. Second part of the interview process was on July 1st and 2nd. One interview was split into two parts: interview and vineyard tour. It could last up to 2.5 hours both included.

3.2.1 Interview

After introducing the study and our study background, the interviewee had to sign and approve the conditions of interviewing (Appendix 4), then the recording and the actual interview could start. A total of 19 vineyard managers or owners were interviewed in a long semi-structured interview. One of the interviewees was managing a property and owning another one, so it stands for 20 properties in total. It was agreed to stick to the script layout to a small extent. Questions order was changed if judged appropriate in order to be closer to a real conversation fluidity. Making interviewees more confident and talkative allows to capture more richness and information. Not leading questions were asked, giving them time to answer. Vocabulary was adapted. For example, 'GI' were called 'Non-vine plantings', and defined as everything that is not a vine, including cover crops, hedgerows, natives, water features. The interview script was divided into 6 parts (Figure 9 and Appendix 5 for full script). Only the first and second part will be analysed for this study.

Background information

The objective is to get information about the interviewee (role, experience), property size and certification for the latter analysis. That will allow to classify the different types of properties in Waipara.

Design planning

Focus section for this study is the second of the interview. The objective of it is to understand how vineyard managers designed their vineyard and whether they use a farm plan. In case they have one, a copy of it was collected. Thus, the aim is to obtain information about the choice-making criteria resulting in the actual design of vineyards.

The script is limited to the 4 following main questions:

- Did you design your vineyard? Do you have a farm plan? Yes/No question
- If no: why not?
- If yes: Why? What do you use it for?
- What do you think of shelterbelts? Why? Why not?

Few additional questions were often added for a better fluidity/better introduction to the topic.

- When has the vineyard been planted?
- What was the land use before? Did you inherit anything from that?
- What were you looking at when you designed your vineyards? What were the main criteria?
- Do you use your farm plan to make decisions/manage your property?
- What is recorded on the plan? Are the GI recorded? Why?
- Did you inherit shelterbelts? What would be the ideal design of a shelterbelt?

Others questions

Two other questions part of Anna-Kate's script were often useful.

- What percentage of land would you say is suitable for grapes on your property?
- How do your plantings create a system or network within your vineyard?

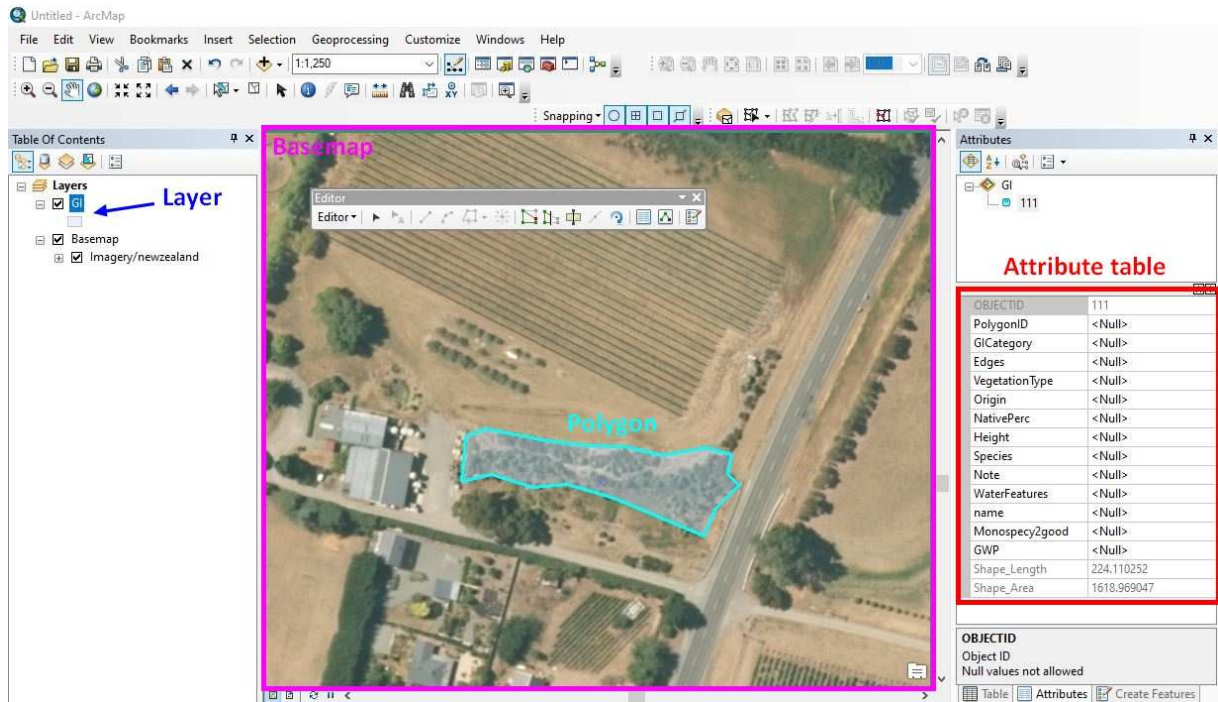


Figure 10: ArcMap interface and drawing of a polygon identifying a Green Infrastructure in sky blue.

Attribute table (red) gathers details about GI, basemap (purple) shows the satellite image, and layer (dark blue) enable the addition of different types of information.

3.2.2 Mapping field data gathering

After the interview questions, the property visit was completed, driving through the vineyards with the interviewee most of the time. More questions could be asked. Only a few visits were done by ourselves. This part usually lasted 30 minutes. The objective is to understand the actual design of Green Infrastructure by obtaining a map with location and description of GI.

The first method was based on the use of the app ArcCollector for tablet –enabling to draw polygons straight away in the field, thus more accuracy. Though as the vineyard tour was done with the interviewees most of the time, the method was readjusted. Indeed, the use of ArcCollector and the drawing of polygons in the field is very slow. The second method was taking pictures during the walk or the drive and digitalizing afterward on the computer with ArcMap. Not only the method was quick but as well it enables to look at things several times. A ‘Microsoft Surface go’ tablet was used for taking pictures. The objective was to get as many information as if it was done on site. Multiple pictures were taken from different angles to be able to identify each feature on the satellite image (Figure 10) and make sure that basemap matched the reality (by comparing the relative position of the different GI on the pictures). Most of the time GI appeared accurately on satellite imagery, but few times GI did not appear on the satellite image because recently planted. It was important to have pictures taken from close enough to identify and describe the vegetation type.

In Brief

- Interview process is based on a face-to-face interview (10 minutes for design) followed by a tour of the vineyard.
- Design interview questions look at the vineyard establishment **design** motives, use of a **farm map** and **hedgerows**.
- Vineyard tour aim at **picturing** biodiversity for a later **identification** and **digitizing**.

3.3 Data transcription

3.3.1 Interview transcribing – 19 scripts

Transcription from audio to text is processed by Descript software. Second step is to listen through the script again using a foot pedal and Express Scribe Transcription Software to correct mistakes (often due to strong New Zealand accent or background noise). The last step is to read through all script highlighting/identifying parts of interest, then classifying them in themes and gathering quotes in an excel file.

3.3.2 Digitizing process – 20 properties

Software presentation

ArcGIS is a Geographic Information System (GIS) for working with maps and geographic information. ArcMap 10.6 desktop was used for this study (Figure 10). ArcMap is the main component of ESRI ArcGIS suite of geospatial processing programs. It is used to view, edit, create, and analyse geospatial data. It allows the layering of information. For this study basemaps and shapefiles have been used. A basemap refers to a collection of GIS data and/or orthorectified imagery that form the background setting for a map. A shapefile is a common format for storing vector GIS data. Satellite image basemap (NZ imagery: [Canterbury 0.3m Rural Aerial Photos \(2014-2015\)](#)) was the main one used for orientation (locating the vineyards).

The coordinate system is NZGD_2000_New_Zealand_Transverse_Mercator.

Table 2: Digitizing process associated to the part of the property considered (✓: is digitized, ✗: isn't digitized)

Part of the property			Case	Property	Zone	Crop	Exclusion zone	GI	Water feature
Whole property	Visited block	Inclusion area	1	✓	✓	✓	✗	✓	✓
		Exclusion area	2				✓	✗	✗
	Not visited blocks	Farm plan possession	3				✓	✗	✗
		No farm plan	4				✗		

Table 3: Classification of zones

Category	Sub-category		Definition
Food production area	Vine block		Rows of grape vines and their directly associated management areas (inter-rows, turn-around).
	Other	Orchard	Mostly olive grooves or other fruit trees such as feijoas, or other crops and their directly associated management areas.
		Pasture/animal production	Land covered with grass and grazed by or suitable for grazing by livestock or any area of fenced land for animal (pigs).
		Fallow	Nitrogen fixing crops cultivated back to the soil.
		Unproductive vines	Vine blocks not harvested or pulled out with remaining trellis system.
Boundary	External		A strip between above or below zone and adjacent neighbour properties. Must be embodied by a hedgerow.
	Internal		A strip between zones and within zones (possibly different grape blocks). Must be embodied by a hedgerow.
Building associated area			Cellar-door and winery, residence, work-yard building areas and major machinery sheds.
Waterway			Pond, irrigation dam, major stream or drainage channel and their direct surrounding area.
Area with no use attributed to it			Often slopy area such as gullies and banks, often composed of naturally regenerating scrub or grassland. Can contain minor or temporary waterways. Can be pine tree plantation.

Digitizing task

The digitizing task itself consist of delineating the feature/polygon with the help of the satellite imagery basemap (Figure 10). For each feature, the attribute table has to be filled up with the related information. Different types of polygons are created. They are presented in the following sections. All the polygons of one type are gathered in one layer (shapefile/.shp).

3.3.3 Layers and data subdivision presentation

Property layer: First step is to identify the exact property boundaries. The farm map provided during the interview was used along with the NZ cadastral basemap [webography, 3] to draw one polygon for one vineyard block. Thus, only the GI within the properties boundaries will be considered.

Zones layer: The property polygon is split between different zones such as building or vineyard (see classification below). Every area in the property belongs to a zone.

Green infrastructure layer: A GI polygon is an entity of vegetation that has a uniform structure and composition and differs from the surrounding vegetation (definition of patch (Park, 2007)). Any major interruption (road, building, gap, etc.) of the vegetation cover ends the polygon. The goal is to distil the natural diversity and variability of plant communities to a small number of relatively uniform vegetation units. This definition is inspired by the finest level of resolution of the Ecological Land Classification for Southern Ontario - vegetation type (Lee *et al.*, 1998). The drawing of the polygon is based on vegetation cover displayed (Figure 10) on the NZ satellite imagery basemap. It is the more practical way to locate and measure the vegetation identified during the field observations. Comparison with GoogleMap satellite imagery displaying more recent data is often helpful. That enables to locate more recent plantings and changes that are not displayed on the NZ basemap. GI polygons are strictly within the property boundaries. The accuracy of the satellite displayed vegetation cover method is not very high, but in terms of design, the exact area does not really matter, it is more about the respective location.

Exclusion zones layer: Some areas of the property are far from the vineyard zone thus not visited. These are not really relevant to consider and describe precisely. Exclusion area polygons are a portion of the property polygons. No GI polygon is drawn in them, only zones (Table 2). Few blocks have not been visited but the farm plan provided enables to locate them. They are treated/identified as exclusion zones, and only zones are digitized on them.

Crop layer: Polygons are drawn on vineyards and other crops (olives), based on vegetation cover displayed on the NZ satellite imagery basemap.

Water feature layer: Polygons are drawn based on water displayed on the NZ satellite imagery basemap.

In Brief

7 types of polygons are created and gathered in shapefile layers: property, zone, crop, exclusion zone, GI and water feature. All layers but 'exclusion zone' and 'water feature' have at least one polygon per property.

3.3.4 Property description – 20 properties

Digitizing specificities

Most properties were visited in full and have no exclusion area (case 1). Four properties (1, 6, 7 and 12) are split into several blocks but only one of the blocks was visited. For these, GI and water feature layers could not be filled in. The different cases are presented in Table 2.

Table 4: Classification of Green Infrastructure

Element		Definition	
Woodland areas	Plantation	Clustered trees used for lumber/firewood production/fruit, including orchards and pine tree plantations.	
	Forest area	Large area where trees grow close together, mostly composed of exotic deciduous trees such as willows.	
	Bush area	Area of dense vegetation, mostly native shrub and few trees and large grasses.	
Naturally regenerative scrubland area		Meadow and shrub or sparse shrub, often located on banks or gullies. Shrubs are mostly exotic.	
Meadow area		An area of closed herbaceous vegetation dominated by grasses (not regularly mowed or grazed).	
Unproductive vines		Vine remaining but not harvested or vines pulled out but with remaining trellis system.	
Fallow		Nitrogen fixing crops cultivated back to the soil before vineyard plantation.	
Hedge-rows	Exotic hedge-row	Shrub hedge	Row of dense trimmed shrubs, often exotic and short and always less than 3 meters high.
		Deciduous tree hedgerow	Row of trees that lose their leaves every year (poplars, willows, etc).
		Fruit tree hedgerow	Row of trees producing edible fruits (olives, cherries, figs, etc.).
		Coniferous tree hedgerow	Row of trees with very thin leaves called needles which they do not normally lose in winter (pine, macrocarpa).
	Native hedgerow		Row of native vegetation, often cabbage trees and shrubs with sometimes few flaxes.
	Mix hedgerow		Row of vegetation belonging to different of the above categories.
Landscaped components	Mown lawn		Largely homogenous sward of frequently mown grass.
	Mixed flowers, shrubs and/or trees		Highly maintained areas with human-planted vegetation such as flowers, shrubs and trees.
	Large grasses area		Area planted with large grasses: can be either flaxes or tussocks.
	Individual tree or shrub		One to four trees and/or shrubs far from any other vegetation.
	Vegetable garden		Area in which vegetable are grown.
Waterway patch		Pond or irrigation dam.	
Waterway corridor		Major stream or drainage channel.	

Property characterisation

Purpose is to identify distinctive features of properties that would typically impact companies' behaviour towards biodiversity.

Certification: biodynamics, organic or SWNZ only.

Size: five categories from very small to very large regarding the size of the total planted vineyard they have.

Management: owner involvement in the business. It is high in family-owned and managed properties, medium in family-owned business, low in corporate-owned businesses.

Cellar door presence: presence of customers on the property coming for wine tasting. Includes as well properties with an AirB&B.

In Brief

Certification, size, management type and cellar door presence are the four characteristics of the property considered for the later analysis.

3.3.5 Classification

Zones: Zones have to be classified so that we can understand where the GI tends to be planted in relation to land use and function (aesthetics, production and boundary), see Table 3. For constructing the classification, Wendy McWilliam's categories are used as a common base and adjusted to Waipara study case. Categories were constructed after the completion of few interviews in order to have a better understanding of the general organisation of properties. Some areas of the property could belong to two zones. For example, a hedge by the entryway could be in a boundary zone but as it was planted primarily for aesthetics, it belongs to the category cellar door. It is a comprehensive classification. The zone 'boundary' exists only if there is a GI 'hedgerow'. Though the GI 'hedgerow' does not always cover all the 'boundary' zone.

Green Infrastructure: To describe and understand the design of GI, information about location, shape and vegetation type is important. It must be as detailed as possible but still simple enough to be able to get information from pictures, without deviation along the digitizing process and without mistake. The first key was built ahead of the interview process and had to be readjusted after a few interviews. The final key is presented in Table 4. To avoid bias because of misidentification during the process, the classification key is based on precise definitions. For building the vegetation type key, Ecological Land Classification for Southern Ontario (Lee *et al.*, 1998) was used as an example. Opposite to them, it isn't based on a percentage of vegetation type because method based on pictures cannot provide with such precise information. Moreover, most of the vegetation in Waipara's properties is not natural but planted. Definitions are based on a dictionary, as well as on Wendy McWilliam's definitions but most of them had to be adjusted to the study context. GW plantings are always classified as 'Native bush patches'. Native presence key (Table 5) has to be simple as their identification is tricky. Few widespread native species such as cabbage trees, flaxes, tussocks, and lancewood are easily recognisable and they enable to spot patches planted to be natives. Exotic species such as deciduous and pine trees are easy to spot most of the time as well. Key for the number of species is bimodal (Table 6). Monospecific or bispecific entities are easy to spot because they are planted to be so.

Water features: Water features not covered by vegetation are classified (ponds and dams) in the water feature shapefile/layer, whereas water features covered by vegetation (not visible on satellite imagery) are classified as part of the GI patch (stream, wastewater discharge area, drainage, wetland; see Table 7).

Table 5: Key assessing the presence of native species in Green Infrastructure

Not known
No natives 0%
<50% Natives
>50% Natives

Table 6 : Key identifying the number of species in Green Infrastructure

One or two dominating specie on at least 75% of the polygon.
More

Table 7: Key identifying the water feature

A natural body of running water that flows along a channel.	Stream
Area where waste water out of the winery is discharged.	Wastewater
A ditch or open channel that is used to carry excess water or sewage downstream.	Drainage
Land that is partially or totally covered by shallow water, with soil saturated by moisture part or all of the time	Wetland

Table 8: Summary of data collected and their related variables

Data type	Unit	Total area	Variables	Method
Interview (quotes)	19	-	Vineyard size, Management type, Certification, Cellar door or Airbnb, Living on the property, Main business, Farm plan possession, Farm plan use	Qualitative
Farm plans (maps)	15	-	Estate, Property boundaries, Name of the block, Variety, Clone, Surface of Inner-blocks, Rows, Buildings, Fans, Irrigation features, Natural Water features, GI, Neighbours, Other land use, Geology, Roads, Date, Others	Key
Blocks (area)	26	2000ha	Estate, visited or not	Evaluation of property area
GI (area)	758	102ha	Vegetation type, Zone, Native %, Number of species, Water feature presence, Estate <u>Calculated:</u> Area	ACM, proportions
Zones (area)	471	2000ha	Type, Exclusion zone or not, Estate <u>Calculated:</u> Area	Proportions
Crops (area)	26+4	998ha	Type (vine or olives), Estate <u>Calculated:</u> Area	Evaluation of production area
Waterways (area)	16	5ha	Type (natural water patch or irrigation water patch), Estate <u>Calculated:</u> Area	
Properties	20	-	Vineyard size, Management type, Certification, Cellar door or Airbnb presence, Living on the property, Main business. <u>Calculated:</u> Area, %GI in the property, GI area, %hedgerow in the property, part of the GI being hedgerow, % of each zone type, % of each GI type, % of crops, area of waterways.	ACM, proportion

In Brief

- Two main types of data are collected: **qualitative** with interview quotes and **quantitative** with surface areas of polygons.
- Interview data enable the **understanding of the behaviour** toward design and Green Infrastructure, whereas quantitative surface area along with classification keys enable the **characterisation of Green Infrastructure**.
- Data collected are **diverse**, they are summarized in Table 8.

3.3.6 Extraction / correlation

Identity tool is used to correlate Green Infrastructure and zones, thus identify the GI as belonging to the overlapping zone. Data are extracted with 'Table to Excel' ArcMap conversion tool. It results in an excel table with surface areas of all polygons and related information (estate identification, etc.). One polygon is one excel line.

3.4 Data analysis

3.4.1 Qualitative analysis of data from the interview

Themes and quotes of the interviews are gathered in an excel file. Key in Table 9 enables to know how important a theme was for the interviewee. A theme is stated as major for an interviewee if emphasis was explicitly put on it by the use of words such as 'the most', 'first', 'very important', etc. As the questions are open/not orientated, the themes mentioned are spontaneously brought up by the interviewee in most cases which shows their importance. Out of the 19 interviews, only 18 of them were used for qualitative analysis because the recording of interview 9 was lost.

3.4.2 Analysis of the mapping data

Proportions calculated with the ArcGIS polygons

Different excel files were built up in order to analyse information. For the GI and the zones, one table was gathering all features without specific property identification to have an overlook on Waipara's sample. General results for Waipara are not the average of properties but based on unidentified features. Another table had a sheet per property in order to obtain the results and percentages for each property. Pivot tables were used to calculate proportions.

Multivariate analysis

Principal Component Analysis (PCA) and Ascending Hierarchical Clustering (AHC) were completed with properties as individuals in order to analyse the similarities between estates as well as to identify profiles and assess the relationship between different variables and the properties. Both PCA and AHC (Ekstrøm, 2016) are processed with R studio. 'HCPC – Hierarchical Clustering on Principal Components' function was used on the PCA results, most functions that were used are part of the FactoMinR library. The aggregation method used when running an AHC on principal components is Ward's agglomerative criterion (analysis of variance). Active variables are quantitative (see below and Appendix 7), and explanatory ones are qualitative (see details below) (Cornillon, 2012). A limited number of variables are chosen so that they are not redundant. They represent the design of the property: biodiversity presence and zones repartition (some similar zone types have been gathered).

- Vine %: vineyard plot surface area divided by visited block surface area.
- GI %: vegetation surface area divided by 'included' surface area (the surface in the

Table 9: Key of analysis stating in what way a theme was mentioned

0	Theme not mentioned
1	Theme mentioned
2	Theme mentioned as major
3	Theme mentioned as not important

property that is not part of the excluded polygon).

- Hedge% in GI: hedgerows (all types) surface area divided by vegetation surface area.
- Food production: surface area of the zones 'Vineyard', 'Orchard', 'Pasture', 'Fallow' and 'Unproductive vines' divided by the total property surface area.
- Building: surface area of the zones 'Building associated area' divided by the total property surface area.
- Waterway no use: surface area of the zones 'Waterway' and 'Area with no use attributed to it' divided by the total property surface area.
- Boundary: surface area of the zones 'Boundary' divided by the total property surface area.

Individuals ID (identification number) is the same as in the rest of the study, except for property 8bis here named 15. A limited number of explanatory qualitative variables were selected to test the relation between design and property characteristics:

- Vine size cat, 3 clusters: size of the vineyard comprised between 0 and 5ha (**small**), or 10 and 25ha (**medium**), or over 25ha (**large**).
- Certi, 2 clusters: organic certification or SWNZ certification (biodynamics property is with organic certification and non-certified ones are considered as SWNZ to avoid rare categories).
- Family managed, 2 clusters: if family-owned and managed (opposed to only family owned or corporates).
- CD, 2 clusters: presence of a cellar door (CD) or AirB&B on the property

Cluster analysis

The property more precisely analysed is the closest to the barycentre of the cluster.

3.5 Feedback

Objective

To thank the interviewees for the time they spent to answer questions and show their vineyards despite their busy schedule, it is fair to send them the results of the study as an acknowledgment. As well, the gathered data and ideas can be useful to them and help them to design a better-balanced agrosystem. Improve awareness about biodiversity role in vineyards by identifying in data what is useful knowledge for them, what can make them react and improve. Identify gaps and opportunities for improvement of GI in order to get more ecosystem services. Important figures that can easily help them make progress in terms of biodiversity implementation have to be identified.

Method

The method is established after the interview phase to have sufficient hindsight on challenges and needs. One property that was not part of GWP was interviewed (Interview 15), its data are included in the feedback but not in the rest of the study analysis. It must be easy to read, with not too much information, be positive and careful not to discourage them if they have little biodiversity. It is a presentation of the results of the study, production orientated, including links where they can find more information if they want. Vocabulary has to be adjusted in order to be understandable by vineyard stakeholders, whereas the vocabulary used in this document is research orientated. A personal factsheet about the presence of GI in their property and a personal farm map with biodiversity presence and areas that they could plant are constructed.

Table 10: Method summary: data and process

Objectives		Task	Data	Transcription	Analysis		Result
1	Vineyard design process and resulting biodiversity layout	Behaviour toward design	Interviews	Audio -> text + reading check	Text -> excel file / themes identification + quotes gathering	Excel file -> qualitative comment	Comment on what people look at when designing vineyards and where they would/wouldn't implement biodiversity
		Farm map	Farm maps collection	Listing displayed features on the gathered farm maps			Proportions
		GI layout	Biodiversity picturing	Digitizing (ArcGIS), data extraction	Identifying key variables, Principal Component Analysis, Hierarchical Clustering, proportions.	Description of GI in Waipara's vineyards, identification of farm type groups in terms of design	
2	Relation between GI design and type of property / Factors of influence on GI layout	Biodiversity description	Biodiversity observation	Classification, key construction			
		Property description	Gathering information through website and interviews	Identifying characteristics of interest, gathering and categorisation (size, certification, management type, CD, lifestyle block)			
3	Feedback to improve design of biodiversity	Personal factsheet	Biodiversity picturing	Digitizing (ArcGIS), data extraction	Identification of numbers of interest, individual farm proportion calculation, factsheet layout	1 Factsheet/ property highlighting main biodiversity characteristics of the property and comparing it to sample	
		Farm map		Digitizing (ArcGIS)	Legend construction, layout adjustments	1 Farm map/ property including biodiversity location aiming at a better management in regards to the design	

Personal factsheet

The winery water report and the winery electricity report from SWNZ was used as an example. It gathers figures about the property GI percentages and compare them to the sample. It contains a map of their vineyard with zones so they can understand the charts.

Personal farm map

Use ArcGIS software to obtain a map showing vegetation and that can be used for designing. What needs to be on the map is as follow:

- Vineyard blocks. Boundaries.
- Green Infrastructure and natives areas.
- Padgett-Johnson recommends to include topography, hydrology and natural features (water features) (Padgett-Johnson, 2003). Data are provided online on Land Information New Zealand (LINZ) website (NZTopo50 Hydrography Data, NZ Topo50 Relief Data, NZ Native Polygons [webography, 3]). The previously mentioned features are displayed when on the farm or adjacent to your farm.

The key is built in order to highlight GI importance and to be easily understandable/readable. Information on the map should not be too dense.

Table 10 is a Method summary.

4 RESULTS

4.1 Vineyard design process

4.1.1 Behaviour toward vineyard design

Qualitative analysis of the interview enables to identify points of focus when planting, interviewees mentioned criteria related to vine physiology, as well as economic and social ones. In most interviews, at least one criterion related to vine physiology or economy was mentioned. Social criteria were mentioned exclusively when the interviewee was living on the property, apart from one who mentioned the importance of aesthetics for customers coming to the cellar door.

Vine production

Criteria related to vine production mentioned as being part of the vineyard design process are soil, row orientation, slope, wind, irrigation and temperature (only mentioned twice). Often vine density and post alignment is mentioned as part of design consideration as well but it is not part of this study concern.

Soil: Soil is overall the most mentioned criteria, embodied as a major part of the design considerations in five interviews.

“I mean we definitely looked at the soil types and within the property which are only small variations, but still makes a difference” (3)

“Yea, we’ve got about three or four distinct soil type. So we read books and match the variety to the soil type that we actually thought” (11)

“And depending on what variety we wanted and soil types that dictate as well.”(14)

It was one time mentioned as not important.

“Not really. No, they’re just planted it out. The soil is similar across the block” (10)

Row orientation: Mentioned in more than half the interviews.

“So in an ideal world you would like your rows to run pretty much north-south, maybe slightly west of North because it gets warmer in the afternoon so you could maybe get a bit more sun on that side because when it comes across.” (1)

“Orientation of the rows was set to the north” (4)

Slope: Slope was mentioned in half the interviews, but rarely as being a big part of their consideration as most vineyards are flat. Though it is the main driver of the row orientation choice on slopy ones.

“So we never went round hills or did the orientation that you would say in France where instead of you know, going up and down a hill, you go around it. We didn't do any of that here.” (16)

“Everything is planted down the fall line.” (18)

Wind: Wind in relation to row orientation and disease pressure or risk of wind damage is mentioned a few times.

“Aw the wind flow, they in North Canterbury you just kind of planting your rows so that the wind is going to be directly across it. Yeah, so your exact angle is say if the row is that way it'll be pretty much of the Northwester going exactly across it.” (6)

Irrigation: Irrigation is mentioned a few times as dictating block size and shape, one time being one of the main criteria for the block design.

“Of it's probably designed and the size for irrigation mostly because to make it more efficient” (10)

Economics

Criteria related to the economy are as follows: maximizing vine area, avoiding short rows, wasteland, and block shape.

Maximizing vine area: Mentioned in almost half the interviews, most of the time viewed as major when mentioned, mentioned in all of the large vineyards.

“Your main aim was to maximize, you know, get as many vines as you could onto the property.”(1)

“We planted any areas that it's probably most convenient to be planted in for the vines.” (10)

“You're obviously going to utilise much of your area as possible to plant your vines in because it's the way you make your money obviously.” (14)

It appears especially major in larger vineyards whereas in smaller they tend to produce as much as they feel like and are able to manage.

“He just wanted a small vineyard” (19). “I suppose the size of each block was calculated on the yield that we would feel happy with and our smallest unit in the winery.” (2)

Block shape: Mentioned a good couple of times in the interviews. Property boundaries and hedgerow/shelterbelts seem then to dictate part of the design.

“This did worked out very nicely because we just run parallel” (20)

“And so the shelterbelt plantings were already there [00:10:00] and they just kinda planted within those shelterbelts just using that same kind of like the orientation of the rows was just running.” (6)

Avoiding short rows: Mentioned three times, two times appeared as quite major consideration due to mechanization.

“Not much point to have a row which is 30 meters long, it's a bit, for us, we do mechanize a lot. You need to have a certain, you know, to make it worthwhile, so a certain length.” (7)

One vineyard owner of a smaller vineyard was going the opposite way though, arguing short rows are nicer to work in.

“It worked that well because I don't expect long rows, a bit hard on you know mental health but. Some of those rows would kill me they're long.” (17)

Wasteland: More often brought up out of the design question, when people are asked about % of land suitable for grapes. Mentioned in more than half the interviews. Wasteland is the part of the land that is not suitable at all for grapes: flood-prone zones, gullies, banks and

steep slopes, (very frost-prone zone).

“It was areas that we wouldn't ever plant vines. Yeah, so it's quite a significant swale so you wouldn't plant vines here.” (1)

“It's probably like a meter and a half of impermeable clay. Yeah through most of that and grapes do not like that.” (6)

“So there is some very steep slopes there that are paddocks” (12)

“I've got some flat areas that a flood-prone and frost-prone, yeah right on our neighbour boundary. So there's no way we could plant them out. We actually used to lease it.” (14)

Wasteland is different to less suitable land. They would plant lower quality land and manage it differently.

“So at the time though people ignored that fact and then just produce wine of a combination of those things. We don't think that. It's probably more management.” (1)

Social

Criteria related to social considerations are customers, living place and aesthetics. Most of the time appears as major when mentioned.

Living place: The location of the house is said as put first before the vineyard in a third of the interviews, in all of them the owner was living on the property. As well as pre-existing building dictating a no go area for more vines.

“And then I decided well, let's put the house where it's the best place for the view. You know we gotta live there.” (8)

“Because the sheds were already there” (16)

Aesthetics: Aesthetics is mentioned as major in five interviews and only mentioned in one more. All but one are vineyards where owners are living on the farm.

“Find out whether I'm more about the Aesthetics. Yeah, and the overall picture what I can feel from it. [...] It's more of a romance thing.” (2)

“But a lot of it's just personal how we want it to look.” (11)

Plantings location: Most interviewees haven't thought of building a biodiversity network yet.

“Well not so much. Well, we wanted to have plenty of plants we need but we have a vineyard. Yeah, but the GWP tried to create a bit of corridors” (17)

“We're just starting to talk about either putting in as a farm forestry blocks or Nursery blocks, and it would be part of that, I guess here. You know is it corridors.” (5)

“We but we try and like you said trying to have a quite pockets all around the vineyard eventually. So, you know you hope that you can have an effect on the whole vineyard eventually but you know it takes time. Yeah could fill in some gaps in there be quiet a good idea I've got some space down there an irrigation tank and bore I know there's plenty of places to plant.” (10)

But two see their biodiversity as an ecosystem.

“And it's all entire property and ecosystem if you like. I want to start linking the Blobs of natives that we have around the place and I want to enhance the banks.” (11)

“So the outside of the vineyard we plant areas where they can habit and be active in the vineyard. So we've learned over time we need those species in the actual vineyard row to make sure the predators go there.” (12)

The main thing they are looking at when designing their plantings is aesthetics, mentioned in a third of the interviews.

“More for aesthetics than for beneficial to the environment sort of sort of thing I suppose.” (13)

“We just did some plantings just but beautification basically just define areas a bit more and those kind of things. On here, so we obviously planted out of the vines that are around the staff area are done.”(14)

A driver to biodiversity layout, as well mentioned in a third of the interviews is gaps and wasteland.

“And some of it, it’s impractical to look after. Because any other way of managing it would either be too wet when it rained just grows grass. So you still gotta look after it yet. So why not convert it into something that that, a bit more attractive.” (8) “Because I should have planted out that big depression. [...] No that was the only area.” (20)

In Brief

The design of the vineyard is based on **production, economic and social** criteria. Green Infrastructure is not part of the design but only when it comes to aesthetics. Running a **business**, managers mostly look at **production** quality and quantity. They never mention biodiversity as part of the planting strategy.

4.1.2 Farm map

Behaviour toward farm map use

Farm map possession: Thirteen said they have a sort of farm map.

“We’ve got maps of our vineyards that shows the blocks. [...] They are pretty basic.” (12)

Five of them said they had none (two were only using Google Map or nothing).

“I just have Google Maps really” (1)

GI presence on farm maps: Only two said they have some plantings marked on it.

“Not really no we do have a farm plan that we need to do for our Organic certification. So kind of mark Biodiversity areas yeah. We just need to show that we are improving the environment.” (5)

“You’d be able to see them on that all the all the lines are shelter.” (11)

Most of them replied they don’t have GI on it.

“No, it’s not. It’s just general map with every block.” (7) “Hum no, we don’t unfortunately” (14)

Farm map use

Most of them said they are not using it. Almost a third mentioned using it. Though even those saying they are not using it sometimes mentioned a legal or former use of it such as certification or irrigation implementation. The main mentioned uses are irrigation and certification purposes, both mentioned by a third of the interviewees.

“Not so much. No, only that we have to for sustainable winegrowing, but otherwise not so much.” (6)

“So we’re looking at getting certified Demeter and they do insist on having a farm management plan” (12)

“To keep my certification with SWNZ.” (17)

“Irrigation is also important. Waters a serious consideration. So layout of how you’re going to get your water.” (1) “they would have been would have been irrigation plans originally” (4)

A couple mentioned using it for management.

“Or if we using any contract labour then with a map of the block you can say we want this area done so we have those Maps.” (12)

Farm map irrelevance

They often argued they have no need of it. Mostly because it is not appropriate to their property.

“Well not for us because we know where they are and we planted of them.” (1)

“Probably didn’t even know what a farm plan” (3)

“We don’t really use them anymore we are small so don’t need it now” (16)

“Yeah, it’ll be because it’s all Pinot. Oh, yeah, well, I know where the rows are. So we with a small vineyard I don’t think it’s quite and I can see what you saying with a big great vineyard yeah a map. Yea I know exactly where every set of clone planted so I just.” (17)

“The guys just know.” (14)

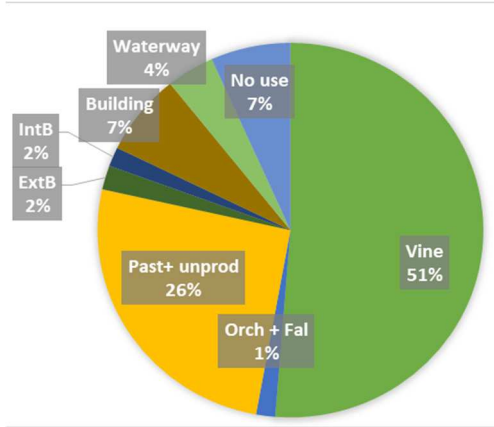


Figure 11: Zone types distribution in Waipara

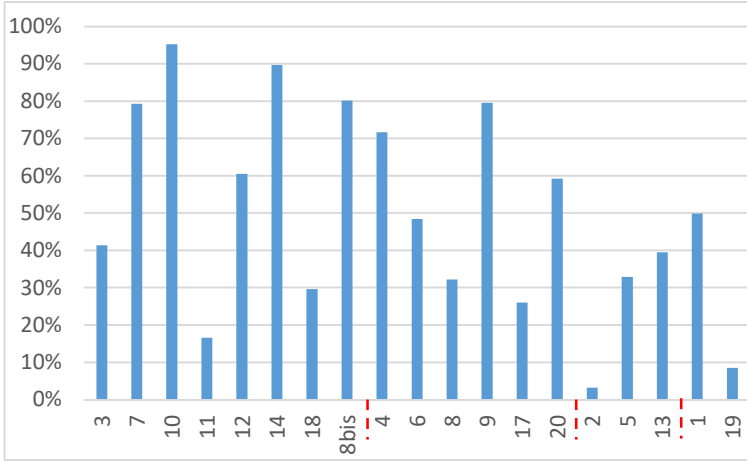


Figure 12: Percentage of vineyard zone in each property Ordered by cluster (cluster 1 to 4 from left to right)

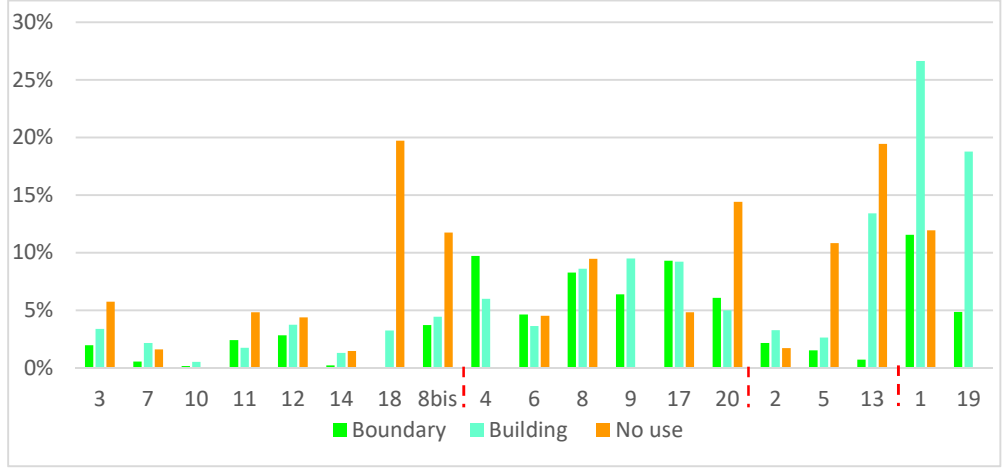


Figure 13: Percentage of 'Boundary', 'Building' and 'No use' zones in each property. Ordered by cluster (cluster 1 to 4 from left to right)

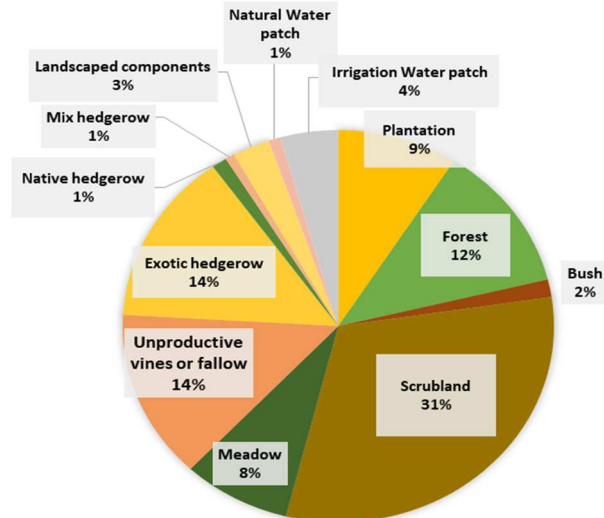


Figure 14: Vegetation type distribution in Waipara's GI

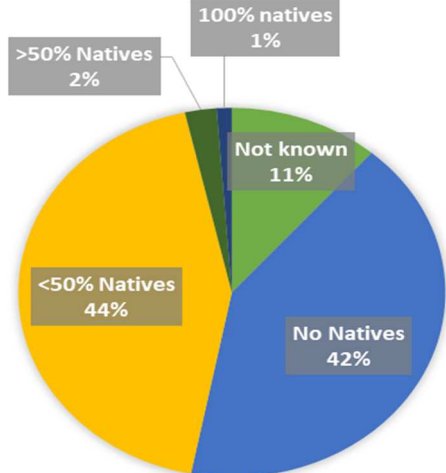


Figure 15: Native percentage distribution in Waipara's GI

Design planning

A couple told us about the design process when asking if they would use a farm map for that. A few said there was no need for a map for design planning.

“So it was wasn't rocket science. It didn't need too much planning.”(1)

“I just did it roughly get by pacing I think and as you go as you as you change from going up the hill to a lot. You know your distance with a tape measure changes.” (2)

“No, I don't think it's probably planned. [...] because you didn't land it all at one time. I think you've been doing it over a few years. So when you started it, you didn't know what was going to like you you knew that the first part will be there and afterwards you didn't know.” (3)

“Don't have to worry about them He said, one of the ways you can do it is you can just drive around and go, oh I like that plant. We go to a nursery, oh I like the look of that and I like the look of that and you can talk to them about the suitability.” (8)

Few mentioned the use of a map for design planning.

“This is all done through Blenheim through yea we've got development managers in that. So they dug a heap of holes and went around tested and then it basically they took a paper drawn it all out and then this variety better than this variety.” (14)

“So it's really important to be straight so quite a lot of detail in mapping and surveying that block and then planting it.” (12)

“Because I designed the vineyard and then where the house would go and [...] then went to a landscape guy and said this is where I want to plant the vineyard, that he sort of, he changed my mind. [...] And so he started throwing a few ideas around and then I decided well, let's put the house where it's the best place for the view.” (8)

Farm maps characterisation

Seventeen maps were gathered, but only twelve properties are represented. Most common displayed features on the gathered farm maps are: property boundaries, property surface area, name of the block, variety, clone, surface of inner-blocks, rows, buildings, fans, irrigation features, natural water features, GI, neighbours, other land use, geology, roads. These are all on at least two farm maps. More than half the maps display property boundaries, name of the block, variety, rows. Only a couple show natural water features, GI, neighbours, other land use.

In Brief

- Most companies have a farm map as part of **SWNZ requirements**. Most of them don't use it and if they do it is only for **management** reasons. They don't see the need for one as they know their vineyard. Most are confused about the use they could possibly have of a farm map.
- Farm maps are usually **basic** and rarely display GI and if they do it is only the most important ones.

4.1.3 Zones analysis

On average, 78% of the properties is dedicated to food production, most of what is not vineyard is pasture (21%), see Figure 11. 51% is vineyard. The repartition is very heterogeneous, vine zone % going from 3% to 95% of the property (Figure 12). The other uses stand for 22% of the properties on average. Building zones are 7% of the properties. Boundary zones stand for 4%, equally shared between internal and external boundaries. Waterway is 4% and no use zones is 7%. Here again the share is very heterogeneous between different properties (Figure 13).

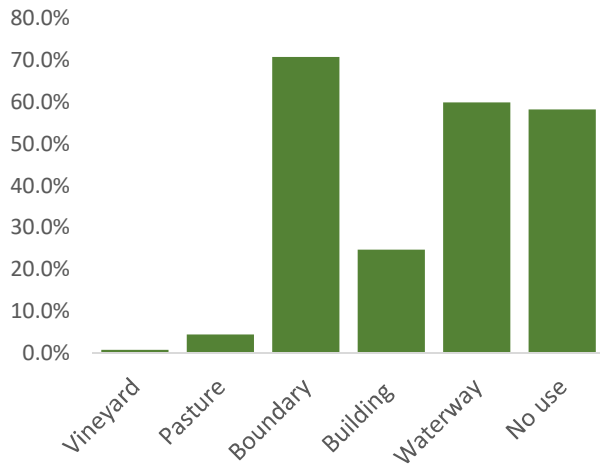


Figure 16: Percentage of GI in each zone type

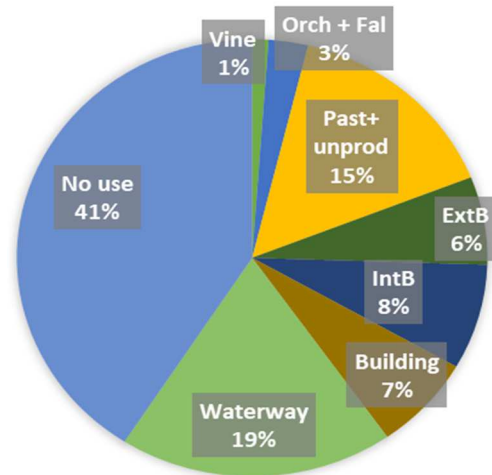


Figure 17: GI repartition in between the different zone types

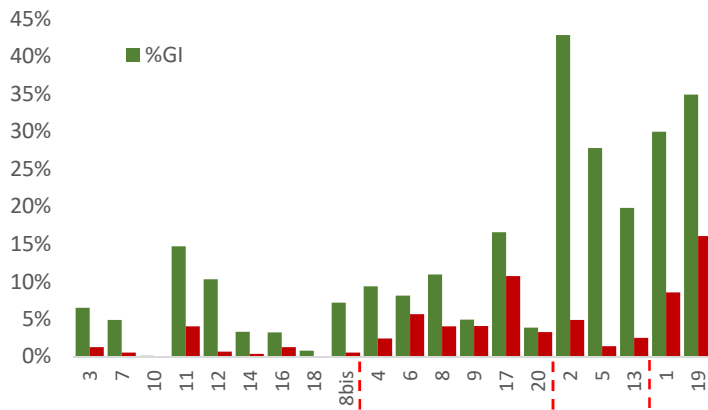


Figure 18: Percentage of GI and hedgerow in each property. Ordered by cluster (cluster 1 to 4 from left to right)

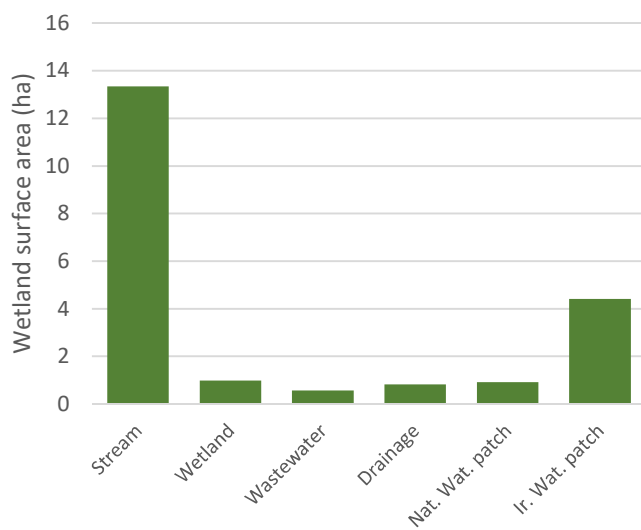


Figure 19: Wetland surface area and types

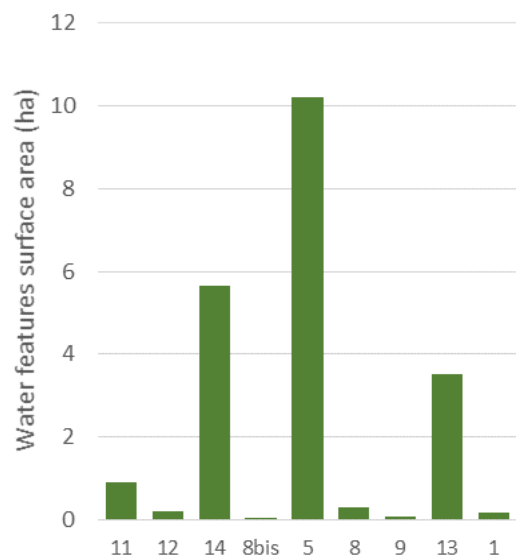


Figure 20: Water features presence by property.

In Brief

The zone share is **heterogeneous** between properties but on average, most of the property is dedicated to **food production** and half to the **vineyard**.

4.2 Biodiversity layout in Waipara Valley

There is 102ha of GI in the digitized areas of the properties (1273ha). The four main vegetation types are scrubland (32ha), exotic hedgerow, unproductive vines or fallow and forest (Figure 14). There is very little natives in the GI, more than 80% of the vegetation is no natives or less than 50% natives (Figure 15). 90% of the hedgerows are monospecific in Waipara.

Vine zones and pastures have less than 10% of biodiversity. Biodiversity in these zone is mostly unproductive vines. Building zones have about 25% of GI and gather 7% of the GI which is equivalent to the zone surface area. Thus building zones don't stand for a lot of biodiversity. Zones Building, Waterway and No use zones are composed of GI for more than half of their area on average (Figure 16). 60% of the GI are located in areas where vine couldn't be planted (No use and Waterway, 7% of the surface area, see Figure 17). Whereas vine zones stand for 51% of the surface area, it gathers only 1% of the biodiversity. Though some of the internal boundaries actually bound two blocks of vineyards.

GI presence in properties is very heterogeneous (Figure 18), from 0.24ha to 40,3ha. In some, GI are mostly hedgerows, in others there is little hedgerows.

There are 21ha of water features. Most of them are streams or irrigation water patch (more than 80%), see Figure 19. Only 8 properties have water features on their land, and the majority of the water features is in 3 properties, see Figure 20.

In Brief

- 102 ha of GI, a lot of scrubland, no much natives, hedgerows mostly monospecific.
- Heterogeneity in GI patterns.
- Low biodiversity in production zones. Major part of biodiversity in areas with no use attributed to them. Building zones don't particularly gather a lot of biodiversity.
- Less than half of the properties have water features.

4.3 Factors of influence on property design

4.3.1 Principal Component Analysis

The two main axis of the graph of variables (Figure 21) reach a cumulative percentage of variance of 72%, so 72% of the information in the data is contained within the first two dimensions. Several relations between variables can be pulled out from Figure 21. Vine% is negatively correlated to GI%. GI% is correlated to Waterway_no_use. Properties with higher building area also have higher GI%. Food production is correlated to Vine%. Hedge% in GI explains 43% of axis 2 (Table 11). Properties 1 and 19 are 'remarkable'.

Figure 22 would tend to show an influence of certification on the property design, but confidence ellipses slightly overlap so it is no significant. Same with the size categories (Figure 23), even if small properties tend to be on the right versus larger on the left, all ellipses overlap, so it is not significant trend. No pattern is shown in Figure 24 in relation to the management type. In Figure 25, confidence ellipses don't overlap, that shows the presence of a cellar door or B&B has a significant influence on the property design.

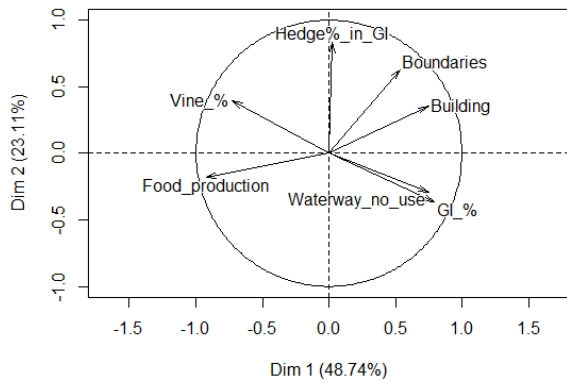


Table 11: Contribution of variable to Principal Component Analysis axis

	Dim.1	Dim.2
Vine_%	15	10
GI_%	18	8
Food_production	25	2
Building	16	8
Waterway_no_use	16	5
Boundaries	8	24
Hedge%_in_GI	0	43

Figure 21: Graph of variables – Principal Component Analysis

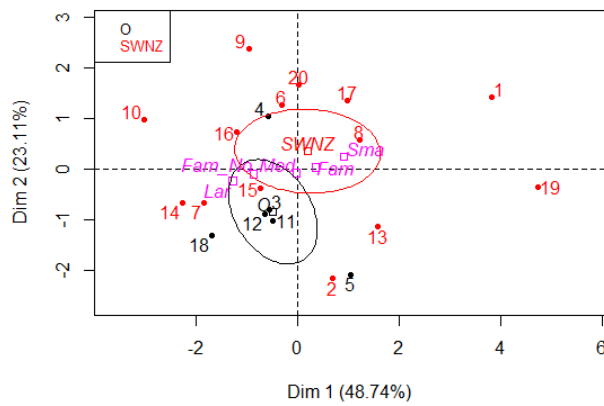


Figure 22: Graph of individuals - Principal Component Analysis - Confidence ellipses related to the certification

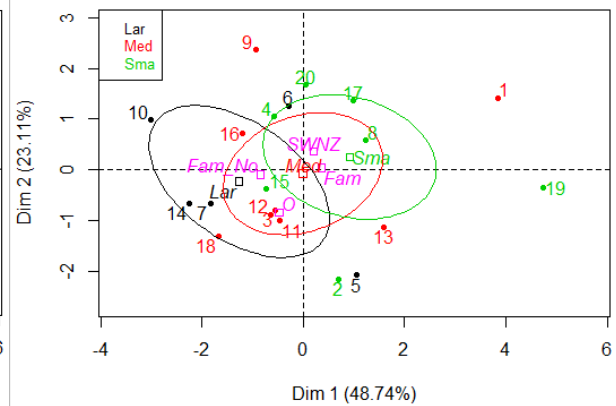


Figure 23: Graph of individuals - Principal Component Analysis - Confidence ellipses related to the vineyard size

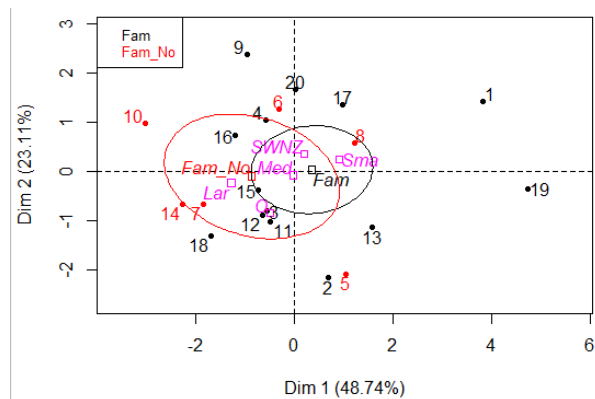


Figure 24: Graph of individuals - Principal Component Analysis – Confidence ellipses related to the management type

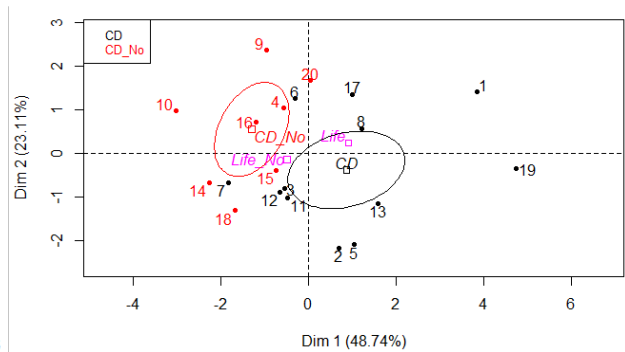


Figure 25: Graph of individuals - Principal Component Analysis - confidence ellipses related to the presence of a cellar door or a Airbnb

In Brief

- The higher percentage of vine, the less Green Infrastructure there is. GI presence is correlated to the presence of land with no use attributed to it.
- **Cellar door presence** impacts the design of GI. Certification, vineyard size and property management don't significantly impact it.

4.3.2 Hierarchical Clustering results

Hierarchical clustering yields automatically the relevant number of clusters. Four clusters are produced, see Figure 26 and Figure 27. The degree of similarity of clusters 4, 3 and 2 is below 0.4. Their homogeneity is good. Cluster 1 is not so homogenous with a degree of similarity over 0.4 and its homogeneity is less high, especially properties 10 and 16 are quite different from the rest. See summary Table 12.

4.3.3 Cluster description

Conventionally designed homogenous vineyard – Cluster 1

Cluster 1 gathers the typical yield orientated properties, with very little GI presence of any sort apart from a couple of landscaped areas/gardens or rare hedgerow. They see vegetation as a loss of land. They are typically conventional, monocultural and homogenous vineyards.

Representative quote:

“You're obviously going to utilize much of your area as possible to plant your vines in because it's the way you make your money obviously.” (14)

Farm design description:

As previously mentioned, most of the property 7 (Figure 28 and Figure 30) is either vineyard or pasture. GI surface area is little and GI is located in the gully down on the northern end and around the cellar door and winery buildings (southwest corner of the property). It is typical of a conventionally designed vineyard, willing to maximise vineyard area and using GI only for cellar door experience. For these types of property, the presence of banks and gullies on the purchased land determines the presence of additional GI.

Conventionally designed farms with the use of hedgerows - Cluster 2

Cluster 2 gathers properties with a high ratio of hedgerows in their GI as well as boundary importance in the property design. Production and yield are still important and they are reluctant to lose land for vegetation but value their hedgerows because of their service as a shelter.

Representative quotes:

“[shelterbelts] one of the biggest benefits is it just makes a lot more pleasant for people to work because especially in a howlings southwest and north westers that are pretty normal in this area. It's bad in that it pulls a lot of moisture out of the ground and out of the vines.” (6)

“Yeah, you want to keep the wind away in North Canterbury. Yeah the nor'west wind will drive you insane. [...] Yeah, the Grapes that were closest to the Hedge always had the better crop than the ones that route and they been hit by the wind. [...] I'd never cut these trees down. That's another thing.” (20)

Farm design description:

Property 6 (Figure 29 and Figure 30) has a major part of its land dedicated to food production (vineyard or pasture). Though the difference is that GI is used for microclimate regulation on top, thus the GI presence is not as low. Vine blocks are split by hedgerows.

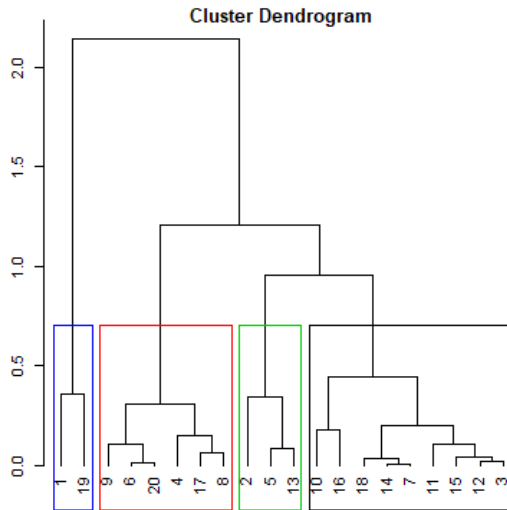


Figure 26: Hierarchical tree and identified clusters

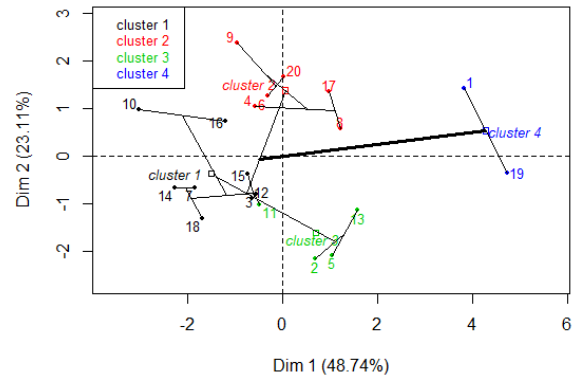


Figure 27: Factor map of clusters

Table 12: Cluster characterisation

Cluster	Properties	High value for the variable	Low value for the variable	Closer individual
1	3, 7, 8bis, 10, 11, 12, 14, 16, 18	Vine% , Food_production	GI%, Boundaries	7 (dist = 0.52)
2	4, 6, 8, 9, 17, 20	Hedge%_in_GI, Boundaries		6 (dist = 0.93)
3	2, 5, 13	GI%	Vine%	5 (dist = 1.22)
4	1, 19	GI%, Building, Waterway_No_use	Food_production	1 or 19 (dist = 1.89)

More diverse vineyard farms – Cluster 3

GI presence is important and vegetation is more diverse with less hedgerows. The vine and food production percentages is lower, partly because of the presence of natural not-usable areas and/or waterways on their land.

Farm design description:

Property 5bis is diverse (Figure 31 and Figure 30). The blocks are more numerous and split by different types of vegetation, not only hedgerow. The presence of olive plantation is an alternate production and fallow is used as a tool for land preparation. Numerous gullies and waterway presence on the land means more greening. Thus GI% is higher and the area dedicated to vineyard is lower.

Outsiders – emphasis on customer experience – Cluster 4

Land is used for customer experience, thus the importance of the building presence rather than other food production (crop nor paddocks). This is related as well to a higher GI%. Property 1 is pulled toward the top of the graph by the importance of its boundaries and hedgerows whereas Property 19 is pulled toward the lower part of it by the importance of waterway. 2 and 17 would be likely to be included as well if only considering the visited part of the property instead of the whole area.

Representative quotes:

“Yeah, but well, sometimes we’ll have people here drinking and Milling around.”(1)

“I think with the sighting was probably Aesthetics. [...] Yeah, I suppose this this particular property is of the whole things just the look of it in you know, it’s important your wine that goes with you with your older house.” (19)

Farm design description:

Property 1 (Figure 32 and Figure 30) is the cellar door and winery block of a bigger property. It is not orientated to the production but dedicated to cellar door experience. It is not representative of the vineyard strategy. Thus the food production surface area is limited to a 0.8ha vine block.

Property 19 (Figure 33 and Figure 30) is a lifestyle block with an AirB&B accommodation. Aesthetics is fundamental and the vineyard is just one part of the look of the property. The owner is very into native plantings and he restores the flood-prone area around his streams with plantings. It all explains that the area dedicated to food production is quite low. It is located by the entrance and only the area closeby has been mapped (see red square in Figure 33).

In Brief

Four types of design can be distinguished: conventionally designed homogenous vineyard (9 properties), conventionally designed farms with the use of hedgerows (6 properties), more diverse vineyard farms (3 properties), outsider (2 properties).

4.4 Feedback

Twenty-one feedbacks are produced: one for each property, including property ‘15’ (interviewed but not part of GWP).

4.4.1 Personal Feedback

The figures highlighted in the personal feedback are as follow: GI types, surface area and percentage of biodiversity, native presence, shelterbelt monospecificity, water feature surface area, zones distribution and GI share in terms of zones (percentage of their total GI in each

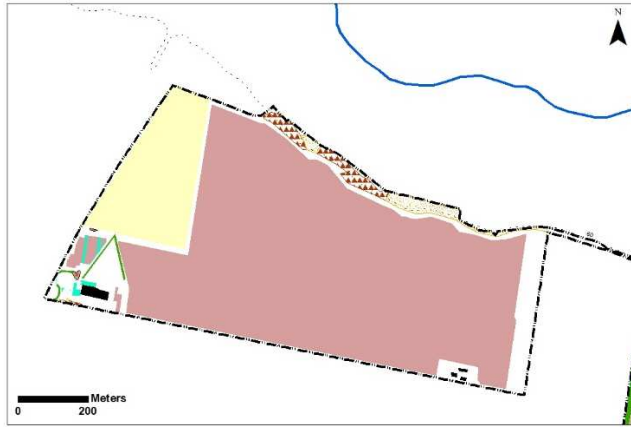


Figure 28: Property 7 - Cluster 1 – Conventionally designed homogeneous vineyard properties

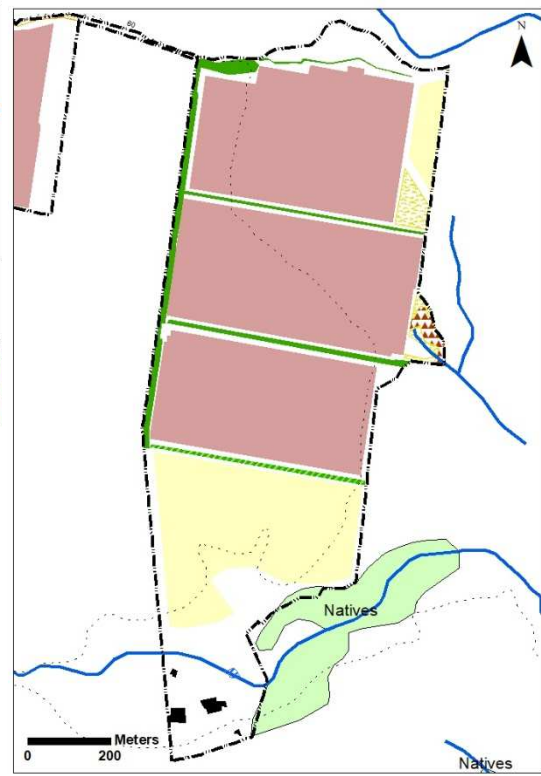


Figure 29: Property 6 - Cluster 2 - Conventionally designed vineyard properties with use of hedgerows

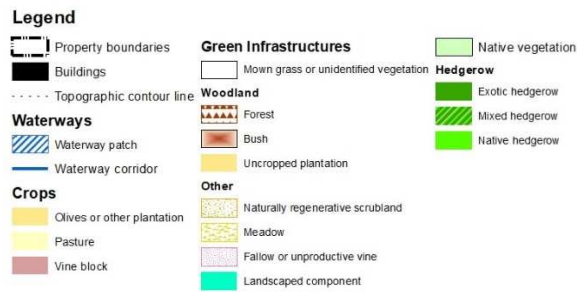


Figure 30: Maps legend



Figure 31: Property 5bis - Cluster 3 - More diverse vineyard farms

zone). These figures are given for their property compared to the sample average. General explanations about the sample and the figures are given on the back as well as the zone map(s), see Figure 34 and Figure 35.

4.4.2 Personal Farm map

Map has the property as title, is scaled, orientated, dated, states the property size, vineyard size and certification (Figure 36). The background is solid on the property whereas it is satellite basemap around. Displayed features on the property are GI (hedgerows are summarised in exotic and native hedgerows and called shelterbelts), and vineyard and crops. Native patches are highlighted. Hydrology and topography are displayed on both property and around.

In Brief

- **Personal biodiversity factsheet** aims at increasing knowledge and awareness of vineyard managers on their biodiversity.
- **Farm map** is a tool for them to manage and improve the design of their GI

5 DISCUSSION

5.1 Biodiversity design assessment

5.1.1 Vineyard presence and design

Most owners focused on vineyard physiology and economic aspects when planting, they almost never mention biodiversity as part of the planting strategy, and they rarely used a farm map to design the vineyard. It is comforting with the rare mention of biodiversity design in grape growing reference books (Cox, 2015; Creasy, 2018).

GI in each property is overall quite low. Even though no other study document biodiversity presence in vineyard landscapes at a vineyard scale, it is not surprising finding as many studies condemn the simplification of vineyards and the fact vineyard landscapes are 'biologically homogenous with vineyard blocks, and little other vegetation, boundary to boundary' (Stoate *et al.*, 2001; Altieri and Nicholls, 2002; Orre-Gordon *et al.*, 2013; Cox, 2015; McWilliam, draft). We could expect more remaining native patches in such a recent human-impacted landscape (200 years), but NZ farming history and need for pasture explain the destruction of native bush prior to vineyard implementation (see 1.1.2.). It is probably the recent settlement of the country associated with a lower bound to the land that explains the quasi-absence of remaining natives. In contrast to that, care for the landscape is mentioned in Oregon (McWilliam, draft) as well as in Europe where conservation areas are set aside (Cox and Underwood, 2011).

As well, GI almost never forms a network in Waipara's vineyards, because most of them are seen individually and not with a landscaping view. Owners and managers are not looking at building up corridors. Indeed, this is not an important consideration for 'Aesthetics' and 'Microclimate regulation' which tended to be the main ecosystem services quoted in the interviews. Though if you are looking at reducing the use of pesticides, different pest and disease regulation tools are needed. Managing the design of biodiversity on a landscape scale would be more sustainable (Cox and Underwood, 2011).

Despite an overall trend toward simplification and wine regions tending to be mostly

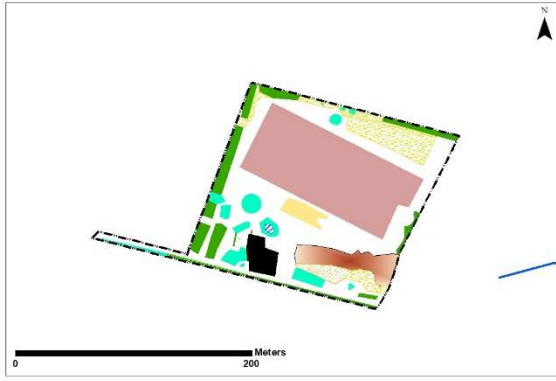


Figure 32: Property 1 - Cluster 4 - Outsiders

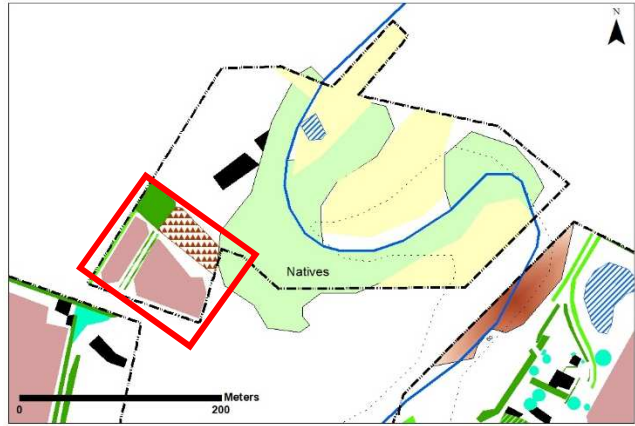


Figure 33: Property 19 - Cluster 4 - Outsiders
Red square shows the mapped area.

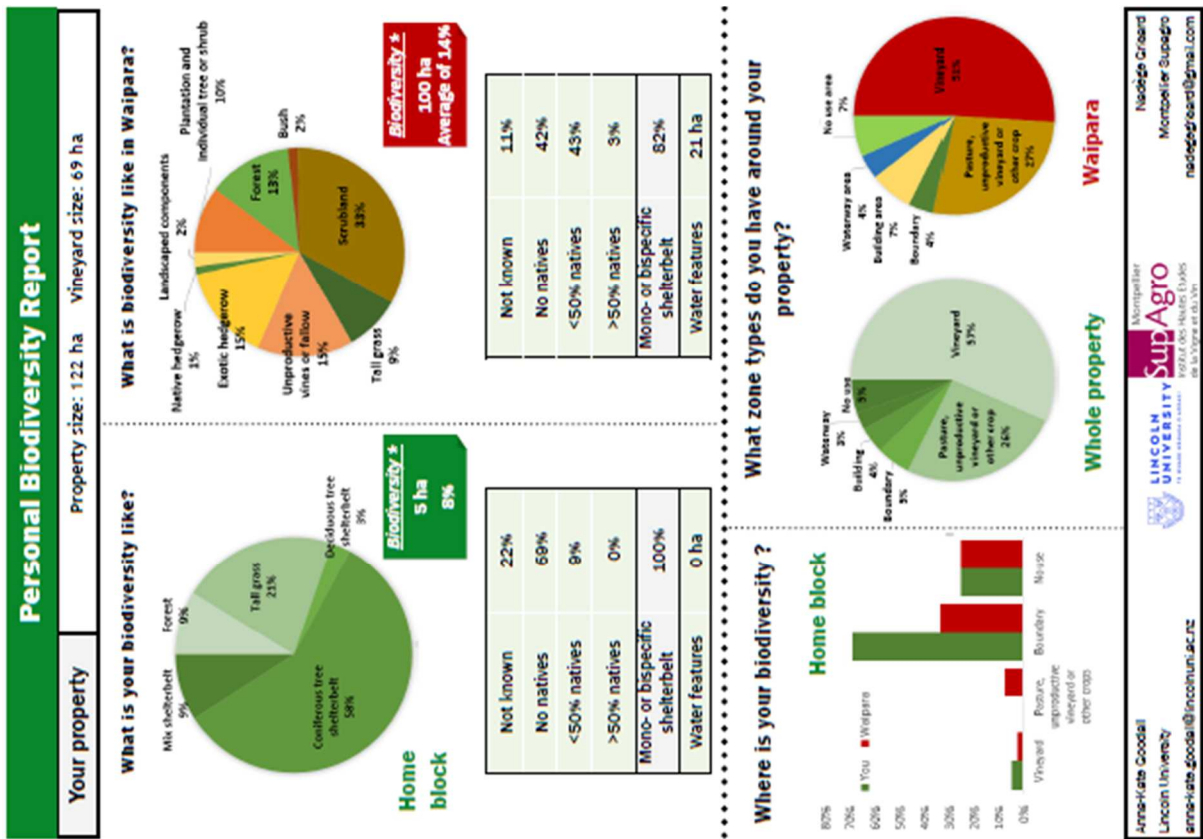


Figure 34: Personal Feedback page 1 - Property 6

monocultural, some more traditional and diverse landscapes remain (Altieri and Nicholls, 2002). Biodiversity was measured in traditional agricultural Italian landscapes and they found a high remaining presence of biodiversity : “Biodiversity richness represents a common trait of the traditional fruit tree and vine cropping systems [...] (with) a high frequency of species, being “out of forest trees”, hedgerows, tree alleys, maquis, and other cultivated species highly represented, contrary to the modernized cropping systems”(Biasi *et al.*, 2012)

5.1.2 Use of mapping

The use of farm maps is not mentioned in most grape growing books reference books (Cox, 2015; Creasy, 2018) so it is not surprising to find that most properties don't use it even if they have one. If used it is only in terms of production and staff management, never related to biodiversity planning. Though several papers in the literature mention the relevance of its use on different scale. Adina (Adina, 2000) mentions both the importance of landscape-scale and farm-scale mapping. The study aimed at mapping vineyard expansion to provide information on agriculture and the environment. The research was designed to document the effects of recent vineyard expansion on Sonoma County's hardwood rangelands. Using GIS, they could assess that a higher percentage of recent vineyard was located on hillsides that supported oak woodlands. Oak woodlands support a majority of the region's biodiversity, provide ecosystem goods and services, and have aesthetic value. This sort of information sounds relevant in terms of council management of the regional development, as more information is needed to understand the consequences of vineyard expansion on a landscape scale. It is useful as well for “site-specific vineyard development and management techniques can be used to minimize negative impacts to agriculture in general, neighbouring landowners and the environment.”

5.1.3 Factors impacting design of biodiversity

The presence of a cellar door or AirB&B accommodation on the property increase GI presence, GI seems to be more diverse with a smaller importance of hedgerows. Customer presence importance in biodiversity planting makes sense as the ecosystem service (ES) there is directly received and marketable, but doesn't necessarily require a specific design. It is supported by findings of the study evaluating GWP success/adoption stating businesses are unlikely to adopt environmental innovations if they don't get commercial benefit (Cullen *et al.*, 2013) from them. It is as well supported by the importance of aesthetics mentioned in vineyards in Oregon (McWilliam, draft).

Certification tends to influence the GI design. Organic certified properties don't have more GI, but their GI tend to be more diverse (lower importance of hedgerows). The lack of influence of organic certification on biodiversity design could be surprising when thinking this certification is meant to aim at sustainability. Though it is not really in regards to the absence of clear regulation about biodiversity (see 2.1.1) in organic certification standards. This is comforting the frequent criticism pointing out that that label is not sufficiently broad as well as studies showing the inefficiency of organic farming to enhance some types of biodiversity (Froidevaux *et al.*, 2017).

5.2 How to improve the use of biodiversity design within vineyards towards more complex agrosystems?

“In contrast to commercial innovations, environmental innovations often bring social benefits but provide limited commercial benefits. Businesses are unlikely to adopt and continue using environmental innovations that provide little commercial benefit unless targeted policies

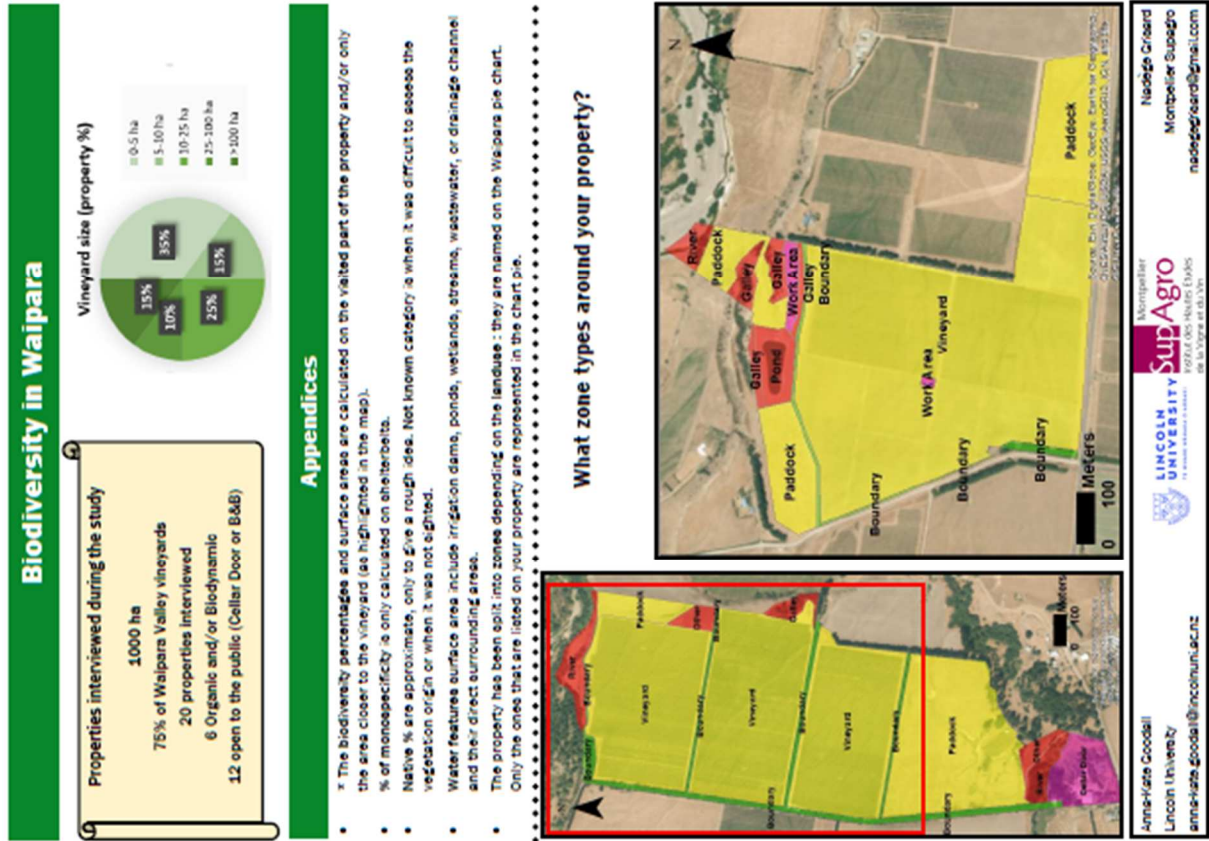


Figure 35: Personal Feedback page 2 - Property 6

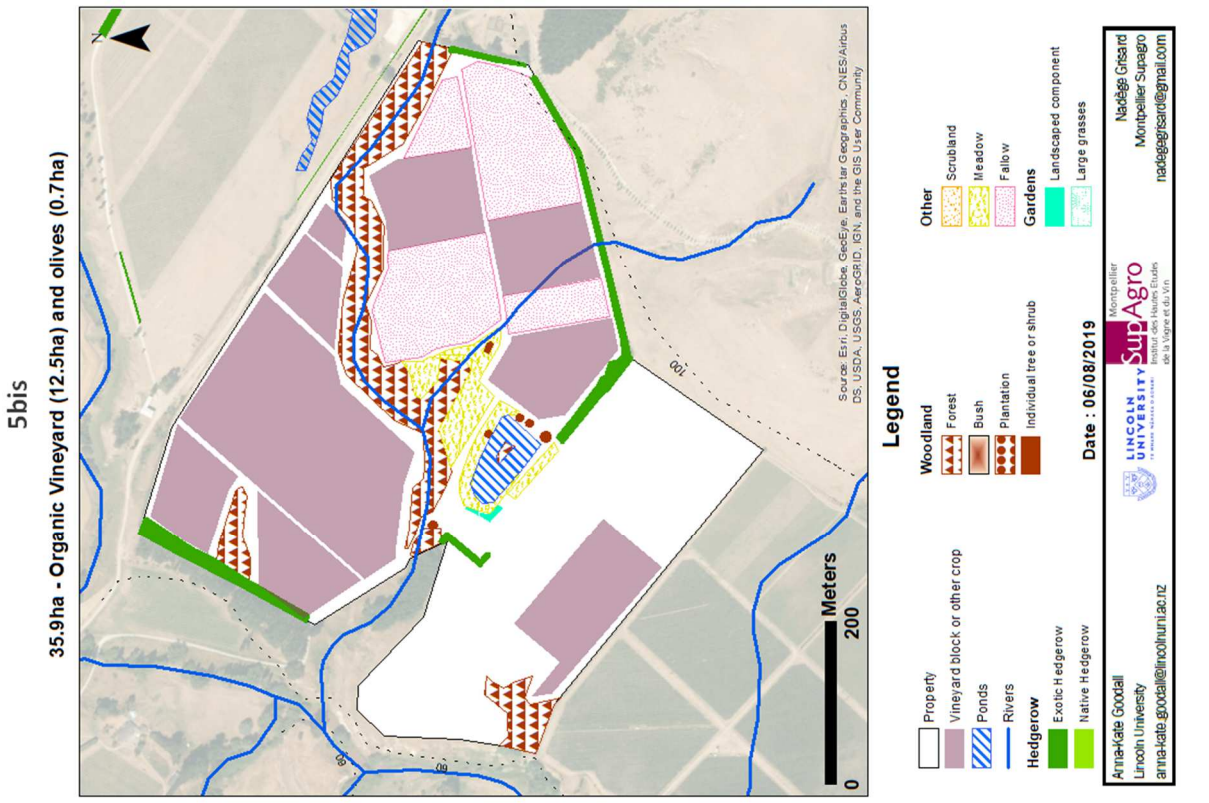


Figure 36: Farm map Feedback - Property 5bis

promote or require their uptake. [...] The costs associated with the innovations tend to outweigh the benefits gained by businesses. There are poor prospects for the adoption of such innovations.” (Cullen *et al.*, 2013) This comment is maybe a bit pessimistic but realistic in showing the importance of including GI plantings in a production strategy by any stakeholder giving a recommendation. It conforms to this study result pointing out the second and third main GI are exotic hedgerow and unproductive vines or fallow, both part of the production system.

The first thing when willing to improve biodiversity design in vineyards would be to start with the vineyard manager’s educational background. After deploring the lack of biodiversity and mapping mention in grape growing reference books, it would be good that authors acknowledge and use literature demonstrating the importance of biodiversity in many aspects (pest-management, climate change resilience, etc.) in order to improve their recommendation with documented guidelines. It needs as well to be included in grape-growing courses.

Documenting biodiversity presence in a region provides tools for informed discussion and decision-making by land-use planners, farmers, residents and environmentalists (Adina, 2000). It would be recommended to start a regional plan to develop a native vegetation network in Waipara.

Biodiversity is a major topic in NZ and the management of it on a landscape level would be very beneficial as previously mentioned. On top, Christ and Burritt state : “Thus it is important wine organisations be able to tangibly demonstrate their commitment to environmental sustainability and preserving the local landscape if they are to maintain good relations with local communities and minimise areas of potential conflict which is in the interests of both individual organisations and society as a whole.” (Christ and Burritt, 2013). SWNZ was contacted and is interested in getting this study results as they are currently entering a biodiversity mapping phase (Appendix 8). This study includes 75% of the vineyards in Waipara. It is a useful tool for them to monitor the region as well as for regional policy-makers to improve local biodiversity, it will especially help with the construction of a biodiversity network.

Properties would have to be monitored differently according to the cluster they belong to. A bigger focus should be dedicated to cluster 1. The internal biodiversity is low and they have no much free space for implementation of GI on site. On top, they are often reluctant to it. It is a challenge to offer them decent alternatives for biodiversity implementation. A big reliance on the neighbouring biodiversity will be necessary. Cluster 2 relies a lot on its hedgerow although these ones are inadequate to airflow regulation in vineyards. A slow replacement of the pine trees by shorter and less dense multi-specific native hedgerow would improve the GI quality. Cluster 3 already shows a variety of GI. A reflexion on their connection through corridors could be the next step. All of them have not enough biodiversity on their property and for a decent biodiversity use, it will be necessary to have a look and use GI outside of their boundaries. On Figure 37, it is noticeable that streams are connecting the properties. It would not be very difficult to try to preserve vegetation all along the waterway corridor so that insect and bird species could circulate. Aiming at a native vegetation corridor would be ideal to prevent exotic bird predation on grapes.

5.3 Further analysis of the data

Gathered data could be farther processed for a better evaluation of biodiversity. For example, Biasi *et al.* (Biasi *et al.*, 2012) completed a landscape metric analysis by detecting Mean Patch Size (MPS), Edge density (ED), Mean Shape Indexes (MSI), which are usually used for landscape pattern interpretation and to evaluate some aspects of habitat connectivity

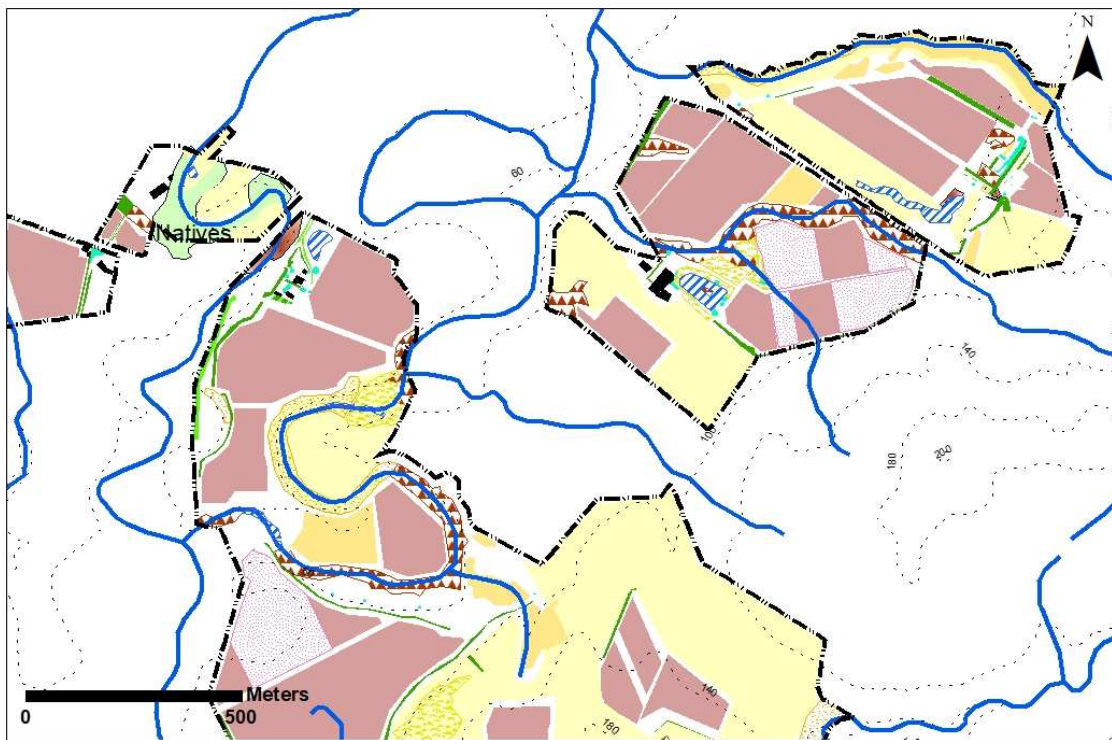


Figure 37: Property 5bis and direct neighbours (13, 5 and 19)

(Tischendorf, 2001). Landscape ecomosaic maps and connectivity maps have been produced by manual photointerpretation of aerial photographs and production of a map of ecosystems. ArcGIS used to analyse distance between GI would enable a more precise characterisation of the biodiversity patterns in terms of land sharing network.

Data collected including pictures are as well a really good base to build a more detailed personal feedback. It could be a personal comment/recommendation as well as a farm map including the identification of the location of potential future plantings considering the gaps and the whole landscape in order to build a network.

Ideally, it would have been good to complete the same sort of study in different wine regions in NZ. This would allow to understand the impact of local context (vineyard economics, farming history, policies, etc.). It would be good to compare as well with other regions of the world such as Europe to analyse the presence of biodiversity in a continent where vineyards were grown for centuries.

CONCLUSION

This study was aiming at studying the design aspects of biodiversity in vineyards based on the case study of Waipara Valley wine region, recently planted in grapes and that has been through a greening programme (Greening Waipara Programme). Data were collected during an interview process split into two parts: long semi-structured interview and tour of the vineyard to identify Green Infrastructure (GI). ArcGIS was used to map and quantify GI. Analysis was completed to try to relate GI to a business strategy and identify design types. A feedback was built to provide tools to improve biodiversity network.

These findings suggest that in general design process doesn't include GI planting, except for one or two companies that mentioned purposely planting hedgerows. Farm map possession is a Sustainable Winegrowing New Zealand (SWNZ) requirement, but their use is marginal and limited to vineyard management. Most of the GI are located in areas not suitable for production including waterways. The only GI part of the vineyard production system are hedgerows. Hedgerow are in most cases inherited features so neither designed nor really suitable to properly provide with ecosystem services without liability. Despite heterogeneity between properties, the GI presence is overall low, especially at direct proximity of the vineyard. The presence of the cellar door is one characteristic of the property impacting design strategy and it increases GI presence. On the other hand, certification, vineyard size and property type of management don't significantly impact the GI design even if trends can be observed. A farm map and GI quantification and description is the feedback to interviewees. It aims to increase knowledge about the existing features as well as awareness of potential improvement and ability to use the farm map as a designing base. Results are shared with the national wine institution (SWNZ). Aim is to enable a landscape-based approach on a larger scale.

The method used present some drawbacks that make the outcome of this study less reliable. 38% of the interviewees were not the one planting the vineyards (but most of them were in the companies for couple of years). Zones and vegetation classification and identification are partly based on personal gut feeling and a good understanding of the properties, their design and the area. Exclusion zones delineation as well. Generalisation of the results to vineyards in the world is probably not possible as NZ is very different to other countries, even from the New World. Even generalisation to NZ country is questionable as the sample has a high ratio of lifestyle blocks (7 out of 20), not growing vines for a living - not very representative of commercial vineyards.

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Appendix 1: Greening Waipara Programme Innovations

- 1 : Inter-row plantings to prevent leaf rollers : flowering plants (e.g. buckwheat) to attract parasitoid wasps, a natural enemy of leafrollers, into the vineyards.
- 2 : Under vine native groundcovers : control under vine weeds and thus reduce the need for herbicide applications.
- 3 : Development of windbreaks through hedging
- 4 : Winery waste water filtering improvement
- 5 : Conservation of native fauna and flora (native plantings) : restoration of natural habitats in and around vineyards and wineries -> assist with the conservation of native fauna and flora, as well as soil retention, weed suppression and eco-tourism.
- 6 : Botrytis management through mulching (i.e. pea straw, linseed straw and grass clippings)
- 7 : introduction of Biodiversity Trails on selected winery properties

Appendix 2 : SWNZ checklist in terms of biodiversity enhancement

11.1. Types of enhancement programmes COMPULSORY ⓘ

Indicate the types of enhancement programmes in place:



- Biodiverse vineyard sward (inter-row sward)
- Practices to enhance soil microbial activity
- Selected vineyard area and surrounds with indigenous plantings
- Selected vineyard areas and surrounds with non-indigenous plantings
- Wetland and waterway protection / Protected natural environment
- Man-made water features
- Habitats for indigenous wildlife
- Participate in off-site company biodiversity initiative(s)
- Participate in off-site regional or national biodiversity initiative(s)
- Other: please include detail in Comments
- None of the above

11.2. Types of inter-row sward COMPULSORY

Indicate the type of inter-row sward present in the vineyard:



- Volunteer sward with more multiple broadleaf species
- Sown sward with multiple broadleaf species
- Specific rows sown for beneficial insects or predators
- Species selected for moisture management
- Species selected for nitrogen fixation
- Species selected for carbon sequestration and / or building organic matter
- Other: please include detail in Comments

Area contributed to biodiversity protection, restoration or enhancement (11.3)

Please record the total area contributed for biodiversity protection, restoration or enhancement.

Please include the total area of biodiversity contribution, excluding vineyard sward and off-site activities.

Note: If you have already answered this question in the winery scorecard for your business please do not count the same areas again.

11.3. Area contributed for biodiversity protection, restoration or enhancement ⓘ

Details	Value	Unit	Quality	Submit...
⋮	3	ha ▾	n.a. ▾	<input type="checkbox"/>

Appendix 3 : Script for phone call

<p>Hello, Its Anna-kate Goodall speaking. I am a Masters student at Lincoln University, researching Green Infrastructure in the vineyard. I would love to have the opportunity to interview the managers or the owners of your vineyard and if possible, have a walk around your property to look at your vineyard system. Is now a good time to talk?</p>
<p>-Yes,</p>
<p>The interview will take approximately 30 min to complete and involves questions about the existing non-vine vegetation on your property and the barriers and enablers for implementing non-vine plantings. Are these topics you would feel comfortable talking about for this project? All interviews would be anonymous.</p>
<p>-Yes</p>
<p style="text-align: center;">When would be an appropriate time for you to conduct this interview?</p>
<p style="text-align: center;"><i>-organise time</i></p>
<p>If you would be able to give me your email address, I will send you an email with a confirmation time and some further information about the project.</p>
<p style="text-align: center;"><i>-gain email</i></p>
<p>Thank-you for your time, I will be in contact and look forward to meeting with you</p>
<p>-No</p>
<p>Is there anyone else who you think would be more able to talk to me about the vineyard?</p>
<p>-yes</p>
<p style="text-align: center;">Would it be possible to grab their contact details?</p>
<p style="text-align: center;"><i>-grab contact details, thank caller, and return to the top.</i></p>
<p style="text-align: center;">-No</p>
<p>Thank-you for your time and consideration. If you change your mind I can be contacted by 0221670300 OR anna-kate.goodall@lincolnuni.ac.nz.</p>
<p>-No</p>
<p>When would be a better time for me to call you? Or if you would prefer, I can send you an email with the details of this project and we can go from there.</p>
<p style="text-align: center;"><i>-call back at appropriate/given time.</i></p> <p style="text-align: center;"><i>-grab email information and email (If no reply from email in a week follow up with a phone call)</i></p>
<p>Thank them for their time, Hang up.</p>

Appendix 4: Consent form for the interviewees to sign

Consent Form

Name of Project: **Green infrastructure, ecosystem services, and the enablers and barriers for their implementation within wine grape vineyards.**

This research project aims to investigate the enablers and barriers for the implementation of green infrastructure in wine-grape vineyards with the aim of identifying ways in which green infrastructure and its private and public ecosystem services can be increased in wine grape vineyards.

I have read and understood the description of the above-named project. On this basis, I agree to participate in the project, and I consent to the publication of the results of the project with the understanding that anonymity will be preserved. I understand also that I may withdraw from the project, including withdrawal of any information I have provided, up to the 15th August 2019.

- I consent to having photos taken of my vineyard, including of non-vine vegetation associated with any vineyard elements, like buildings, that may identify my vineyard
- I consent to having photos taken of my vineyard, but not of non-vine vegetation associated with any vineyard elements, like buildings, that may identify my vineyard

Name:

Signed: _____ Date: _____

Appendix 5: Full Interview Script

<p>Section 1: Background information</p>	<p>What is your role in the vineyard? How long? How large is this vineyard? Do you have others?</p> <p>What is your vineyards unique story or point of difference? Does environmental good practice play a role in this? How is Waipara marketed as a wine region? How does this effect your farm practice?</p> <p>What role do you think non-vine planting has in vineyards?</p>
<p>Section 2 : Design and farm plan questions</p>	<p>Did you design you vineyard? Do you have a farm plan? Yes/No question If no : why not? If yes : Why? Do you use it to make decisions about your property? How do you make decisions / plan the design of your vineyard ? (land sales opportunities, soil, needs)</p> <p>May I have a copy?</p> <p>What is recorded on the plan? Are the GI recorded? Why?</p> <p>Did you inherited shelterbelts? Do you like shelterbelt? Why? Why not? What would be the ideal design of a shelterbelt?</p>
<p>Section 3: What non-vine plantings existed, were planted and are currently in participant vineyards</p>	<p>How has previous land-use effected what non-vine plants you have on your property? I.e have you inherited any NV vegetation?</p> <p>What non-vine plantings do you currently have in your vineyard? Native, exotic,</p> <p>Where are plantings located and why are they located there? When were they planted?</p> <p>How do your neighbours plantings interact with your vineyard system? Does this impact your future plantings?</p> <p>Do you have any water systems? Is it planted? Why/why not?</p>

<p>Section 4: To what extent does the GI planted mitigate key environmental impacts and increase ecological service?</p>	<p>When planting what benefits did you focus on?</p> <p>What benefits do you think you've received? What about dis-service</p> <p>How do you think your plantings have mitigated any environmental effects farming has had on this landscape?</p> <p>What determines the quality of your wine when it comes to vineyard management?</p>
<p>Section 5: How might GI effectiveness be improved?</p>	<p>Do you prefer natives or non-natives? Why</p> <p>How do your plantings create a system or network within your vineyard?</p> <p>Are you currently restoring or planning any plantings?-where, why, how</p> <p>Do you think about what and where this vegetation is when you are planning/restoring yours?</p> <p>Can you think of any things that you, SWNZ, the govt or the uni might to to enable you to grow more non-vine vegetation?</p>
<p>Section 6: How might GI be increased in the vineyard? What are the enablers or barriers for its implementation?</p>	<p>Are you certified? What does this require? Has this helped you to implement plantings? Are you involved in the development of certification practices? Who is?</p> <p>What is the biggest barrier for non-vine plantings on your vineyard?</p> <p>What % of land would you say is suitable for grapes on your property? What do you do with the rest?</p> <p>Are you aware of any funding for plantings? If you've applied, how was the process?</p> <p>How much management do plantings require? Who does this task?</p> <p>Would you be interested in working with your neighbours to connect your non-vine vegetation with theirs? Why/why not? do your neighbours plantings benefit or impact you?how,why,when</p> <p>Is there anything you would like to add that hasn't been asked?</p>

Appendix 6: Connectivity map Traditional Italian Landscape

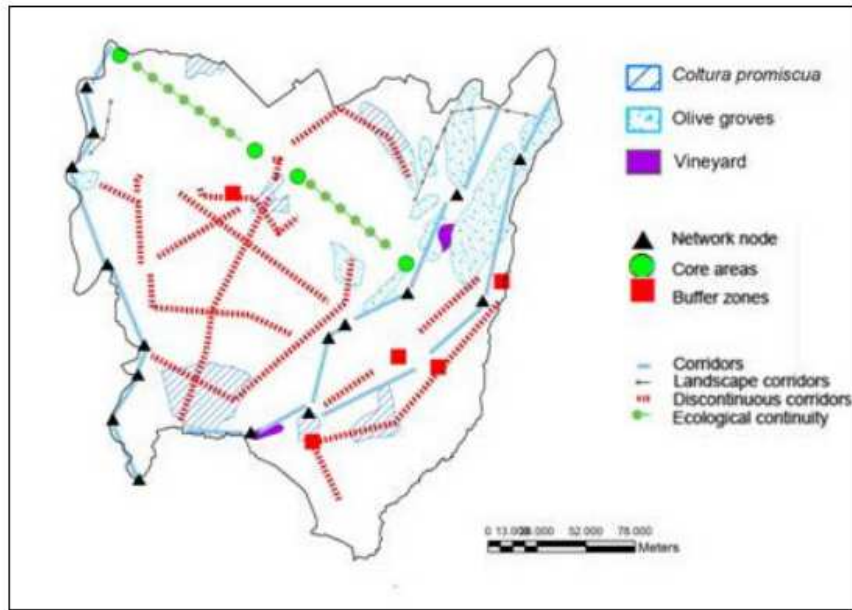


Fig. 6. Connectivity map of in the traditional landscape of olive groves. Study case: Tuscia territorial area, Landscape System Inner Maremma.

Appendix 7: Data used for Principal Component Analysis and Hierarchical Clustering

Vine_%	GI_%	Food_production	Building	Waterway_no_use	Boundaries	Hedge%_in_GI	Vine_size_Cat	Certi	Family_managed	CD	Lifestyle_property
28.57%	29.99%	49.86%	26.64%	11.95%	11.56%	28.58%	Med	SWNZ	Fam	CD	Life_No
1.79%	42.85%	90.35%	3.29%	4.23%	2.18%	11.41%	Sma	SWNZ	Fam	CD	Life
36.26%	6.51%	82.95%	3.40%	11.70%	1.99%	19.41%	Med	O	Fam	CD	Life_No
60.66%	9.37%	84.28%	6.00%	0.00%	9.72%	25.82%	Sma	O	Fam	CD_No	Life
26.47%	26.91%	65.10%	2.09%	23.87%	1.66%	5.13%	Lar	O	Fam_No	CD	Life_No
56.52%	8.16%	70.36%	3.64%	6.83%	4.65%	69.76%	Lar	SWNZ	Fam_No	CD	Life_No
74.43%	4.91%	87.83%	2.17%	5.37%	0.57%	11.16%	Lar	SWNZ	Fam_No	CD	Life_No
24.06%	10.96%	69.29%	8.61%	13.80%	8.29%	37.05%	Sma	SWNZ	Fam_No	CD	Life
73.45%	4.95%	84.11%	9.49%	0.00%	6.39%	82.48%	Med	SWNZ	Fam	CD_No	Life_No
92.29%	0.13%	99.27%	0.54%	0.00%	0.19%	69.23%	Lar	SWNZ	Fam_No	CD_No	Life_No
12.38%	14.72%	90.12%	1.77%	5.68%	2.42%	27.61%	Med	O	Fam	CD	Life_No
37.50%	10.32%	82.92%	3.76%	4.87%	2.85%	6.75%	Med	O	Fam	CD	Life_No
32.17%	19.82%	64.49%	13.42%	21.23%	0.73%	12.63%	Med	SWNZ	Fam	CD	Life_No
83.63%	3.35%	92.59%	1.32%	5.69%	0.24%	11.09%	Lar	SWNZ	Fam_No	CD_No	Life_No
70.83%	7.22%	80.11%	4.46%	11.76%	3.74%	7.57%	Sma	SWNZ	Fam	CD_No	Life
75.68%	3.24%	84.01%	15.48%	0.63%	0.00%	39.55%	Med	SWNZ	Fam	CD_No	Life_No
17.65%	16.58%	76.94%	9.24%	4.84%	9.32%	64.81%	Sma	SWNZ	Fam	CD	Life
38.69%	0.80%	76.86%	3.26%	19.71%	0.00%	0.00%	Med	O	Fam	CD_No	Life_No
6.76%	34.91%	41.56%	18.78%	37.47%	4.87%	46.03%	Sma	SWNZ	Fam	CD	Life
50.60%	3.90%	74.45%	5.01%	14.42%	6.08%	83.86%	Sma	SWNZ	Fam	CD_No	Life

Appendix 8: SWNZ email showing their interest for the study

De: Meagan Littlejohn <meagan.littlejohn@swnz.org.nz> 

Sujet: **RE: SWNZ assessment of biodiversity standards**

Pour: Nadège GRISARD <nadege.grisard@supagro.fr> 

Répondre Transférer Archiver Indésirable Supprimer Autres 9/09/2019, 4:10 PM

Hi Nadège,

Thanks for your email! We would definitely be interesting in getting the results of your master internship – both the ArcGIS info and the general findings would be great to see 😊


Your email is also super timely – I was at a focus group discussion last week about New Zealand's new Biodiversity strategy (still in progress but summary and full discussion document attached, if interested). Part of their initial goals for the new strategy currently include a huge amount of biodiversity mapping. As such, I was thinking your results may be of interest to the Department of Conservation (DOC). Would you like me to put you in contact with the Policy Adviser who led the focus group session?

Many thanks



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Please consider the environment before printing this email

ABSTRACT

Title: Assessment of Green Infrastructure and its Design in Vineyards.

Vineyard monoculture poses a threat to biodiversity by occupying key habitats and simplifying ecological communities. Landscape simplification is known as a cause of insect and disease outbreaks for a few decades now. Changes that will not radically modify the monoculture nature of agrosystems may moderate negative impacts temporarily. Though, for real resiliency and durable benefits, radical agroecological measures are needed to strengthen farming resiliency. Diversification of agrosystems in the form of biodiversity-wise designed systems such as agroforestry are such measures. In vineyard systems, cover crop is often the only biodiversity feature part of the farming strategy. A broader range of Green Infrastructure (GI, non-vine vegetation and water-systems) such as insectaries and hedgerows would be necessary for a systemic approach to better-balanced agrosystems, using predatorial insects to fight pest and shrubs for regulating airflow.

While a great deal is known about the benefits of incorporating more biodiversity to mitigate negative impacts of monocultural farming, and to provide an increase of ecosystem services (ES), little study of its implementation within vineyards exists. Nor much study about whether vineyard owners purposely design for greening and how. Biodiversity as a tool does not seem to be part of the planting process even in new wine regions.

Semi-structured long interviews and GI mapping are used in Waipara Valley wine region to understand how winegrowers make decisions about the incorporation of GI in vineyards and to locate them. Also, to increase farmer awareness, results will be shared in a comprehensive and informative way with the interviewees.

The study shows vineyard design process doesn't include GI, and the use of farm maps is very limited. GI presence is low and mainly limited to areas that aren't suitable for production. Properties show three types of design: conventionally designed homogeneous vineyards, conventionally designed farms with the use of hedgerow and more diverse vineyard farms. The cellar door or Airbnb presence on properties increases the GI whereas certification or vineyard size are not major factors. Providing managers with a personal map and a biodiversity assessment as feedback is aiming at increasing their awareness on their biodiversity and give them a designing tool. As patches on each property are too limited to support a real biodiversity network, it would be good to work on a landscape scale with the involvement of regional and wine organisations to bind neighbouring properties together and build a biodiversity network based on waterways.

Key words

Green Infrastructure, Non-Vine Plantings, Biodiversity, Design, Vineyard, Shelterbelt, Hedgerow, Cover crop.

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