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Evaluation of an Incentive Programme for Increasing Green Infrastructure on Vineyards

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Abstract: Wine grape ecosystems with low species richness and reliance on agrichemicals have weak resilience to environmental impacts. Increasing biodiversity through green infrastructure (GI) not only helps mitigate some of these impacts but can provide additional benefits to growers and the public. Despite this, many vineyards have limited GI. While scholars suggest incentive programmes may help to encourage GI implementation, few studies have evaluated their effectiveness. We surveyed winegrowers and their vineyards in the Waipara Valley sub-region, New Zealand, to evaluate an incentive programme aimed at increasing GI on vineyards, particularly indigenous vegetation. The results indicated the programme was effective in encouraging growers to plant indigenous plants in areas incapable or unsuitable for growing grapes, largely in support of nature conservation, aesthetics, branding, and sales. It was less successful in encouraging growers to plant them in productive areas. While substantial GI, primarily in the form of inter-row cover crops, was managed in these areas, most were exotic plants seen by growers to provide superior services (especially erosion control, weed suppression and pest regulation) at lower management complexity and cost. Growers identified six GI enablers: (1) promoting GI types that provide greater grower services than disservices and costs of implementation and management; (2) implementing GI where biophysical conditions support success; (3) providing assistance with plant selection and design; (4) providing GI implementation and/or management funding; (5) developing GI certification policies and regional association programmes; and (6) providing government GI regulations, strategies, and incentives. They also identified five barriers: (1) insufficient grower appreciation for indigenous GI services; (2) grower concerns that some GI disservices were greater than their services; (3) grower belief that costs of GI implementation and/or management were greater than those of alternative practices; (4) harsh and remote GI growing conditions; (5) lack of grower knowledge regarding how to design plantings, especially those that could provide multiple services; and (6) lack of sufficient financial resources for GI implementation and/or management. Twenty recommendations for improving GI implementation are provided.

Keywords: green infrastructure implementation; indigenous plant communities; winegrower attitudes and behaviours; vineyard greening; service plants

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1. Introduction

Conventionally designed vineyards characterised by high reliance on agrichemicals, such as fungicides, insecticides, and herbicides, and low species richness are often associated with environmental degradation. These include low local and regional biodiversity [1], reduced soil quality [2], and pollution of groundwater [3], surface water [4], and the air [5]. In addition, high use of herbicides and pesticides has led to herbicide-resistant weeds [6], increased incidence of vineyard pests [7], and human health impacts leading to respiratory diseases [8] and lung cancer [9]. Furthermore, wine quality is negatively affected by pesticide residues interfering with the fermentation process [10].

Winegrowers worldwide are shifting to more sustainable production practices [11] in response to increasing demands from governments, retailers, and consumers [12]. Certification programmes are increasingly advancing sustainable winegrowing practices [13] that include reduced agrichemical use, and to a lesser extent, the implementation of Green Infrastructure (GI). We define vineyard GI as a multi-scaled network of non-vine vegetation and waterways within the vineyard and across its landscape that provides key ecosystem services to the grower, community, and market (adapted from [14]). For example, GI components may include inter-row cover crops under and between vine rows, shelterbelts and hedgerows, riparian vegetation, and landscaped areas around cellar doors.

While few studies have evaluated indigenous GI on vineyards some studies have demonstrated disservices associated with GI in general. For example, inter-row cover crops can compete with vines for water and nutrients [15], negatively affecting vine growth, yield, and fruit composition [16]. In addition, the compensatory pumping of water to irrigate GI increases carbon emissions [17]. However, many more studies support its benefits. It can significantly increase all kinds of biodiversity [18], whether exotic or indigenous, benefiting ecosystem health. For example, it can increase the diversity of arthropods [19], indigenous vegetation, bees, birds, and bats [20–22]. It can increase the abundance of vine pest enemies, which can reduce pesticide use [23], leading to health impacts [8]. It can substantially increase carbon sequestration [24], reduce carbon emissions [25] and soil erosion [26], and improve soil quality [27]. Furthermore, it can conserve water [28], improve water quality [29], and support cultural heritage [30]. These benefits are mediated through enhanced environmental authenticity at the cellar door, translating into wine and restaurant sales [31], agritourism [32], and 'point of difference' green wine branding [33].

Despite their many benefits, few studies have demonstrated widespread wine grower GI implementation, whether indigenous or exotic, especially GI types other than inter-row cover crops. Some studies suggest particularly poor adoption in Italy, Spain, and New Zealand [34–36], and argue external incentive programmes are needed to encourage GI implementation [37]. However, few studies have evaluated the effectiveness of such programmes or identified enablers and barriers to GI implementation.

Using the New Zealand Waipara sub-region as a case study, we employed long interviews with winegrowers and site surveys after an incentive programme to determine its effectiveness in encouraging GI implementation, particularly indigenous GI. We also identified enablers and barriers to its implementation and recommended 20 ways to improve it.

2. Materials and Methods

2.1. Case Study

We have followed a case study approach in this research, which we define not as a method but interest in a single case of specific and particular interest [38]. As such, the results are not anticipated to be generalisable but rather reflect the unique characteristics of the region under study [39].

The case study is Waipara, a sub-region of the North Canterbury wine region located a 45 min drive north of Christchurch, South Island, New Zealand (Figure 1).

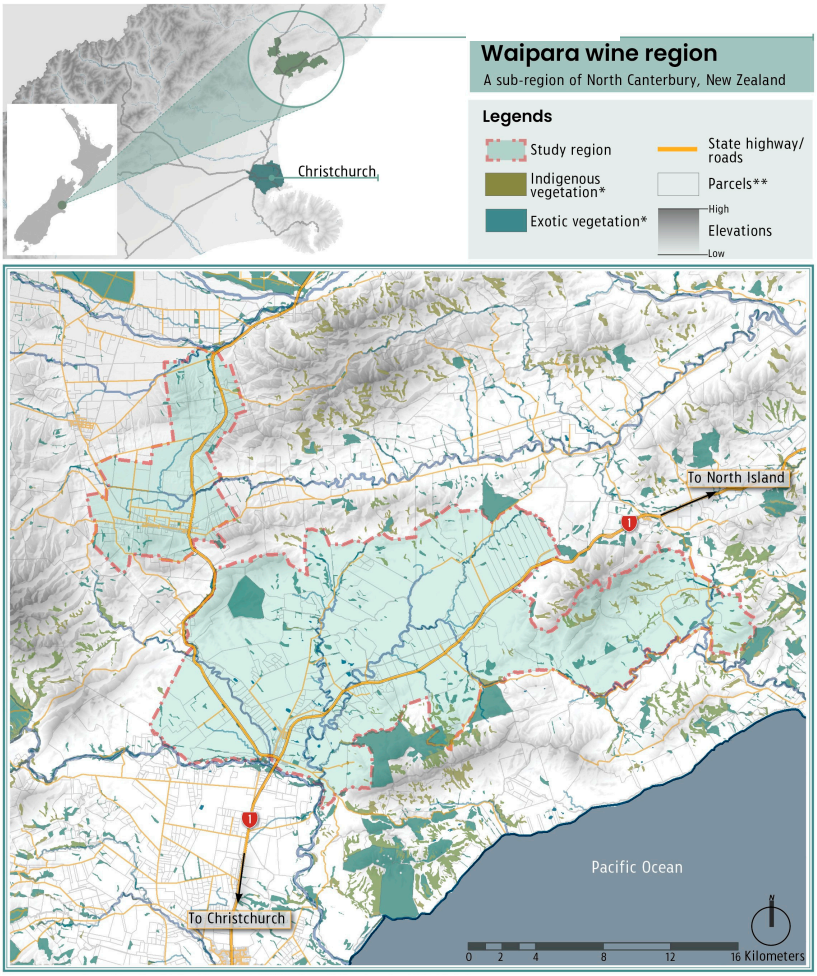

Figure 1. Waipara wine region, New Zealand (map produced by S. Muangsri, 2023 from: * 2021 Landcare Research and ** 2023 Land Information New Zealand data. The basemap data was provided by Land Information New Zealand, and Environment Canterbury).

Historically, the sub-region was characterised by forests of indigenous totara (*Podocarpus totara* G. Benn.), matai (*Prumnopitys taxifolia* Banks & Sol.), lacebark (*Hoheria angustifolia*), kōwhai (*Sophora microphylla*), lancewood (*Pseudopanax crassifolius*), broadleaf (*Griselinia littoralis*), and kanuka (*Kunzea ericoides*), with shrubs of matagouri/tumatakuru (*Discaria toumatou*), miki (*Coprosma* spp.), korokio (*Corokia cotoneaster*), and grasses [40,41]. Most of the forest was cleared in the mid to late 1800s for dryland sheep and mixed crop farming [42], with exotic coniferous shelterbelts introduced in the late 1800s [43]. Vineyards began to be introduced when pastoral farming became less profitable in the 1970s [44].

Today, while larger areas of indigenous plant communities remain on the surrounding hills, non-vine vegetation within most of the vineyard landscape is characterised by small, fragmented pockets of indigenous and exotic shrubs, such as tumatakuru, scrambling pohuehue (*Muehlenbeckia complexa*), European gorse (*Ulex europaeus*), and broom (*Cytisus scoparius*), in addition to a predominance of exotic herbs and grasses [45]. In 2020, the region had 1497 ha planted in vines [46]. Growing conditions are highly variable in terms of soil type, topography, and microclimate, and sometimes challenging [47]. Relative to other New Zealand wine regions, it has a long growing season, one of the coolest climates (with varying frost incidence), some of the highest summer temperatures, and lowest rainfall levels [48]. Although the Teviot hills protect many of its vineyards from easterly winds, many are significantly affected by hot, dry north westerlies, which can damage vines during flowering and prevent fruit set [44].

According to Overton [44], the variations in growing conditions have led to the use of multiple grape varieties, and some high quality and distinctive wines have contributed to the region's wine tourism experience. However, he notes some growers think these attributes have not been sufficient to support the development of a strong brand, as the region lacks a distinctive landscape character or other local tourist attractions. And, while almost all vineyards were historically small (e.g., <10 ha), large corporate vineyards began moving into the region in 2000, which has further undermined the region's branding efforts.

2.2. Greening Waipara (GW) Programme

The GW incentive programme ran from 2006 to 2012. Its goals were to: increase regional indigenous biodiversity and environmentally friendly farming practices (e.g., reduce agrichemical use), improve wine region branding and wine marketing, and reduce vineyard labor costs [36]. It was led by Lincoln University, Landcare Research, the Waipara Valley Winegrowers Association, and the Hurunui District Council.

The programme funded the plants and planting of four types of indigenous GI. The first was a vine, New Zealand jasmine (*Parsonsia heterophylla*), for location at the ends of vine rows, to provide habitat for parasitoid wasps meant to kill leafrollers (*Planotortirix* and *Ctenopseustis* genera, associated with *Botrytis cinerea*) [49] and reduce reliance on pesticides. An indigenous groundcover was promoted within vine rows to suppress weeds, provide habitat for unspecified beneficial insects, reduce soil erosion, and either improve soil structure (where rows were previously cultivated), or reduce broad-spectrum herbicide use (where weeds had been controlled via herbicides). Indigenous trees along boundaries (to form windbreaks) were promoted to mitigate damaging or unpleasant winds and provide habitat for beneficial insects. And, lastly, small patches and corridors of indigenous plants (in locations determined by growers) were promoted to provide habitat for indigenous flora and fauna, but also to reduce soil erosion, suppress weeds, support ecotourism, support wine region branding, and educate visitors regarding traditional Māori plant use.

Evaluation by some programme leaders in 2013 argued the programme was successful, pointing to 55 winegrowers who had signed up and 40,000 plants planted (most in vineyards) [50]. In addition, a 2011 survey of 220 visitors to two participating wineries found GI had enhanced their winery/restaurant experience, in support of vineyard ecotourism [51]. A survey of 14/32 GW growers showed most had established small patches or corridors of indigenous vegetation, while only two growers had planted indigenous vines and vine row cover crops, and two had planted indigenous windbreaks [36]. Furthermore, the only GI service perceived by the growers was support for indigenous fauna and flora. However, the study results only reflected the experience of 40% of GW growers, and most surveyed had only planted in 2009 or 2010, allowing them only two to three years to grow and evaluate GI performance. Furthermore, little is known about why GI adoption and benefits were low among growers who participated in the GW programme [37].

2.3. Research Methods

From a list of 32 of the original GW vineyard participants, 24 were still in business, with 19 agreeing to be interviewed. Farms ranged in size from 0.5 to 330 ha, with the majority being less than 10 ha. Eleven of these vineyards were Sustainable Winegrowing New Zealand (SWNZ) certified, five were BioGrow (organic) certified, and three held no certification. Vineyard interviewees were chosen non-randomly through purposive and snowball sampling methods, consisting of those judged knowledgeable and sufficiently experienced in their implementation and use of GI on their farms. They held one or more of five roles: (1) vineyard manager; (2) vineyard manager and owner; (3) vineyard manager, owner, and winemaker; (4) vineyard manager, owner, and consultant; and (5) vineyard manager and winemaker.

Long interviews were conducted lasting an average of 80 min. The interview design was semi-structured, with pre-determined questions asked in a systematic order according to Frankfort-Nachmias et al. [52]. The script was pilot tested through an interview with

a non-participating vineyard manager. Questions were mostly open ended, allowing respondents to answer in their own words and express whatever they felt was most important. Some closed-ended questions were asked after open-ended questions to avoid bias. Following the interview, the GI on the vineyard farm was surveyed and mapped. Transcribed interview data were iteratively analyzed for themes and sub-themes of related information. We used an inductive approach, identifying themes directly from interviews. We also analyzed the data according to a deductive approach, using themes from the literature.

3. Results

In the following sections, key informants who provided quotes are referenced according to a number rather than their name to preserve their anonymity.

3.1. GI Promoted by the Incentive Programme

Many interviewees said funding provided by the GW programme was a key enabler for planting: '*They did some funding which was excellent* (4)'. In addition, they appreciated the advice of programme leaders regarding plant selection: '*Greening Waipara expertise was really great. They had knowledge of the right plants—what to plant, where to plant, and the timing* (4)'.

3.1.1. Indigenous Vines at Ends of Vine Rows

A couple of growers had planted New Zealand jasmine at the end of some grapevine rows for aesthetic purposes: '*They are for people to see. My idea was to use native plants. There's not much point using roses like they do in Bordeaux* (7)'. One grower also said indigenous vines increased his vineyard's plant diversity in support of ecosystem health. Both growers said they were doubtful whether widespread vine growth at the end of vine rows could provide substantial pest control services and were unsure whether there was any science behind the vines providing this service: '*I know some Lincoln University research was done, but I don't know what came of it* (3)'. Given this uncertainty, plantings were limited to vine rows visible to visitors and both growers continued to rely on chemical pesticides for pest regulation. Few of these vines were planted following the programme's end.

3.1.2. Indigenous Vine Row Groundcover

One grower implemented indigenous groundcover, such as hells bells (*Anaphalioides bellidioides*) and piri piri (*Acaena inermis*), under his grape vines by his cellar door for aesthetic purposes and in support of green vineyard branding, but also to suppress weeds. Relative to herbicides, he said planting and managing this groundcover was more expensive as it had to be hand-weeded and closely planted given its slow growth: '*We have native groundcover in this block here, but it's not representative of what we do in all our blocks. It's a very small amount. It requires quite a bit of maintenance because often there are weeds coming through and you have to deal with them* (7)'. While programme organisers argued the groundcover could provide pest regulation services (by attracting parasitic wasps), the grower said he was uncertain whether he could rely on wasps to provide these services. The risk of failure was too high to shift from pesticides and herbicides, and he could not make a strong argument to his commercial vineyard employer to invest in them further.

Almost all other growers were reluctant to plant any plants under their vines due to concerns regarding their disservices, including competition for vine resources, interference with vine management, blocking airflow, and risk of providing pest habitat. As a result, they either sprayed herbicides or cultivated to remove weeds. Despite this, many growers using broad-spectrum herbicides said they would be interested in growing groundcover in their vine rows if they could identify one with no, or acceptable, disservices. They were concerned about herbicides leading to herbicide-resistant weeds, future government bans on broad-spectrum herbicides, and the negative impacts and costs of cultivation.

3.1.3. Indigenous Shelterbelts/Hedgerows along External Boundaries

Two growers said they had planted indigenous shelterbelts/hedgerow corridors along one or more property boundaries. One had replaced an exotic shelterbelt with indigenous trees, and another had planted indigenous trees alongside exotics. The latter said his indigenous plants did not grow well, as they were outcompeted by exotics for resources: '*We planted natives on the boundary of them* (the exotic shelterbelt). *But as you can see, these first two or three rows struggle because of the shade and because of competition with the existing trees. But we are loath to cut them down* (18)'.

Both said they planted indigenous plants for aesthetic purposes and to support indigenous flora and fauna. One said he had a bed and breakfast operation, and their aesthetics attracted visitors. He also grew indigenous shelterbelts to mark his property as he did not have fences. Neither grower planted them for microclimate mitigation as their properties had adequate exotic shelterbelts or excessive winds were not a concern: '*Our property is relatively sheltered from the norwesters. North Canterbury used to have these very very strong norwesters through the summer, but that's changed. You might get two or three days in a row now, but no more than that* (18)'.

Most growers had exotic shelterbelts previously planted by sheep and beef farmers on some boundaries. Most had Radiata pine (*Pinus radiata*), Monterey cypress (*Cupressus macrocarpa*), gum, or poplar spp. A minority of growers said they had planted new or replaced shelterbelts with one or more of these species since establishing their vineyards. While all growers thought indigenous species were superior for supporting indigenous flora and fauna, many thought indigenous trees would not survive or grow fast enough to provide timely microclimate mitigation given the poor growing conditions: '*I prefer natives, but we've got to think about what's going to be able to establish and grow quickly* (1)'. Others said they did not think indigenous species could survive with little to no management, which was important in areas without access to infrastructure like irrigation.

Most growers indicated their exotic shelterbelts mitigated hot and dry northwest winds: '*In North Canterbury you plant your rows, so the wind is going directly across your shelterbelt* (6). These winds cause significant damage, especially to young vines: '*We've got a shelter on the other side, but our Chardonnay vines are still really struggling to get going. The wind just comes up, and then the little shoots get bashed around and stop growing* (5)'. They also said their shelterbelts reduced the drying and erosion of soils: '*The Norwester is bad in that it pulls a lot of moisture out of the ground and the vines* (6)'. A few mentioned their importance for providing thermal comfort to residents, visitors, and workers; however, one grower said she achieved the same service from her topography: '*The house was built at the bottom of the hill for a reason. The wind comes screaming down the valley and sort of hits the hill and then shoots over the top* (15)'.

Despite these valued services, most said they were concerned about disservices and were removing indigenous shelterbelts where microclimatic mitigation was not needed. They negatively impeded air circulation, increasing the incidence of frost damming and mildew, leading to botrytis (*Botrytis cinerea*) and/or powdery mildew (*Uncinula necator*): '*We have been removing shelter to get rid of botrytis and the new powdery epidemic—everyone's going for air circulation* (7)'. However, some growers said these disservices could be controlled through pruning and thinning: '*We move the bottom branches of our shelterbelts so the air can get through* (6)'.

Many growers were concerned indigenous shelterbelts competed with their vines for resources, including rooting space, water, nutrients, and sunlight: '*They impact probably the first two or three rows of vines, because those trees suck the nutrients and water out of the ground. Those vines tend not to crop anywhere near what the rest of the block does* (1)'. In addition, many thought they increased bird predation of grapes, particularly by exotic birds: '*Starlings are just crazy around here. The native birds aren't as much of an issue for us, except for the little Wax eyes. The thrushes and blackbirds come in bigger numbers and cause damage. It's a pity* (1)'. However, some growers said the birds would arrive no matter how little woody vegetation was present, especially when grapes were ripe, as the birds came from

neighboring properties. They managed the birds through scaring, netting, or other methods. Lastly, some growers said their shelterbelts detracted from their vineyard's aesthetics by being in poor condition due to harsh growing conditions and lack of management.

3.1.4. Indigenous Plantings on Land Unsuitable for Wine Grape Production

Most interviewees still had small GW patches or corridors of indigenous trees and/or shrubs located in places incapable or unsuitable for growing grapes; however, a few of these plantings had died and not been replaced. GW plantings were largely small and fragmented, placed adjacent to structures such as cellar doors and sheds, or were narrow corridors along boundaries or driveways.

This GI type was the only one of the four original types that continued to be planted by about half of growers following the programme's end. Growers indicated their plantings were enabled by the expertise of local nursery staff who helped them identify the right plants for their growing conditions: '*This has been planted with plants recommended by a nursery. Their choices make sense for this place. This here is a plant from the Hurunui gorge. I believe it is quite hardy. We want stuff that is bulletproof* (4)'. One grower also said she benefitted from internet information on regional indigenous species: '*There was a good thing on the internet on butterflies in North Canterbury* (4)'.

3.2. GI Not Supported by the Incentive Programme

3.2.1. Indigenous, Exotic, or Mixed Plantings on Land Unsuitable for Wine Grape Production

Following the programme's end, indigenous plantings were also planted in vineyard areas incapable of growing grapes, which were small and fragmented. Both large and small vineyard managers indicated a key barrier to planting, particularly in larger areas, was a lack of financial resources. Smaller vineyards only had enough money to implement and manage small plantings at one time and were unsure whether they were large enough to substantially increase local or regional biodiversity: '*For a small family-owned vineyard, I think we spent a substantial amount of money on this, although I don't know if it is big enough ecologically* (4)'. Large vineyard managers said it was difficult to obtain the owner's support for plantings unless they could claim the plantings substantially contributed to wine production.

Plantings continued to be planted adjacent to structures; however, new areas were included alongside regional cycleways connecting some vineyards together: '*There's a bank we planted up with natives. That's because when people come up on the cycle trail, it's just a nice sort of entry to the vineyard* (8)'. These growers said a key enabler was funding provided by the Hurunui Trails Trust, a not-for-profit organization seeking to develop cycling and walking trails in the region: '*We did it with the Trails Trust. They bought the plants. We put up the land and had to do weed control* (8)'. A few growers had implemented indigenous plantings around their agritourism accommodations: '*We've got a Purepod accommodation. We're trying to regenerate the native bush around it and along the entryway* (5)'. Others planted on unproductive steep slopes to reduce soil erosion: '*We've done a few plantings upon the hillside to control erosion, but they're not natives, they're exotics—poplars* (5)'. A few growers implemented indigenous plantings in gullies: '*There's lots of birds and things live in there. A little stream runs through when there is enough water* (5)'. In addition, a few planted indigenous species along stream corridors to replace exotic willows they viewed as pests: '*I have a few willows on my property and they just smash apart and cost me a lot of time* (18)'. None of these latter growers said they did so to improve surface water quality, even though some said they were concerned about it: '*This is the stream. It is looking very murky at the moment, and it stinks too* (5)'. Many growers with ditches, dams, or man-made ponds had not implemented plantings, saying they needed to retain their water-holding capacity for frost control and/or irrigation. They were concerned plantings would lead to costly management to prevent this from occurring.

Following the GW programme, most growers planted exotics or a mix of exotic and indigenous species instead of, or in addition to, indigenous species, depending on their desired services. They thought indigenous plants provided higher quality habitat for wildlife: '*My goal was to attract bell birds. Kowhai provide food and are just full of bell birds going mental* (11)'. They also thought indigenous plantings increased plant diversity, which supported vineyard health: '*I've been trying to introduce some diversity in the vineyard* (7)'. Plantings also supported grower and employee environmental values: '*I think it just makes growers feel good about doing the right thing* (11)'. However, they also thought exotics grew faster, were easier to care for, and were superior for some services, such as microclimate mitigation. They planted a mix in support of multiple benefits: '*We have a mixture, but mostly exotics with some grasses. They're pretty easy care* (15)'.

Growers were divided regarding whether indigenous or exotic plants were superior in terms of vineyard aesthetic experience. Some thought they were more aesthetically pleasing, especially when placed adjacent to highly visible areas accessed by workers and visitors: '*We did some indigenous plantings around our buildings just for beautification, basically to define areas a bit more* (1)'. However, others thought indigenous plantings were ugly, especially those that were planted in unproductive remote areas: '*It's kind of ugly, but probably serves a really good purpose if you're a purist. But, at least in this area, it kinda fills a gap* (3)'. This grower argued plantings needed to be attractive in order for visitors to benefit from the cellar door experience and improve wine sales: '*It's a matter of justifying the expense. We need to create a good cellar door experience* (3)'. All cellar doors were dominated by large areas of lawn, high canopied deciduous shade trees, and exotic flowerbeds. Some of these growers argued this type of landscape design was more attractive to visitors than indigenous bush, which they described as visually impenetrable and lacking in colour: '*I'm not sure it* (the indigenous plants) *actually draws anyone in. Of greater value to us are these more European looking exotic gardens with the flowers that we put in* (11)'.

Only one grower said he thought his plantings contributed to vineyard or regional branding or wine sales. Many growers said the plantings had infrequent visitors or were inaccessible: '*the number of visitors using our walkway where the native plants are located is small. Visitors don't usually walk in the vineyard—only now and then, but to see the planting you have to walk, you know, a couple hundred meters* (11)'. Those with cellar doors said visitors were focused on tasting their wines and dining rather than on how the grapes were grown, and most said their regional branding remained indistinctive because the region did not have any outstanding geographical features or significant tourist attractions. One grower, however, argued he did not think there were enough GI plantings to make a strong visual impact in the region. Most growers indicated, due to their harsh growing conditions, their plantings would not grow well without substantial management, for which they did not have time or money. In addition, some growers who had planted in remote locations said they did not always notice when management was needed and/or they lacked infrastructure such as irrigation: '*The planting needed a little more management than it got. It didn't get the water it needed when it was very dry and windy. It's a large area that requires a lot of time, and it was during a critical time when we just didn't have any free staff to look after it* (15)'. One grower said he reduced the need for irrigation and weeding by using mulch: '*We've done a huge amount of mulch—truck loads!* (16)'. A few growers also said their sheep helped weed their plantings through grazing, but this sometimes resulted in plants being eaten or damaged: '*It's not the tidiest thing. It's kind of gone back to its native state. The sheep get in a bit. They help reduce the rank grasses that can choke out the plants, but they also eat the plants* (18)'. While some growers avoided this through fencing, they said this significantly increased the cost of implementation, impeded management, and degraded their vineyard's aesthetic appearance.

3.2.2. Inter-Row Cover Crops

All interviewees grew inter-row cover crops between their mature vine rows, and many maintained bare earth (through the use of broad-spectrum herbicides) between young

vine rows. In terms of young vines, they were concerned cover crops would compete for resources, negatively affecting their growth: '*We get rid of the weeds. We used to use plastic, but that was too messy, so now we spray a strip. If you have competition, they won't grow because it's a tough climate—hot and dry, cold, and wet. You got to give your plants a chance to establish* (1)'.

Spontaneous Cover Crops

Most growers maintained naturally occurring exotic cover crops. They appreciated their low cost and ease of management relative to sown plants: '*To get buckwheat in there, you've got to first put a cultivator through. Then you got to seed it. Then you've got to mow it. So, there's about three jobs there versus just one* (1)'.

All growers appreciated the erosion control services of their exotic grasses, saying they did not compete too much with vines compared with forbs: '*The grass is good for holding the ground together and not competing too much with the vines* (7)'. However, about half of growers indicated they appreciated the diversity of their forbs: '*There's at least 10 different species in there—the greater the number, the better* (6)'. Those forbs that fixed nitrogen helped improve vine and grape growth by increasing soil fertility: '*The nitrogen fixers are crucial to us as we don't use any nitrogen fertilisers* (6)'. Some provided habitat for parasitic wasps that helped control leafroller caterpillar species (*Planotortrix* and *Ctenopseustis*). These growers mowed their swards high to extend their flowering season and ensure seed set, in support of beneficial insects and honeybees for nature conservation: '*High mowing is critical. We mow every second row during the season. This leaves a row unmown so there's always flowers, and then next time we mow, we swap-over—so the bees have always got food* (17)'. They were concerned close mowing led to declining service plant diversity over time. However, some also mowed close every other row to prevent frost damming, increased mildew, and allow for vine management.

The other half of growers considered forbs weeds: *'Nitrogen fixing plants are weeds. The biggest problem we have is controlling the bloody things* (19)'. They did not believe they supported wasps or provided substantial pest regulation: '*They're promoting bluebells and daisies and all sorts of stuff to get the wasp in, but it doesn't work. It's fine in theory, but in reality, we have to spray* (19)'. The growers pointed to their substantial disservices, arguing forbs competed with vines for resources, interfered with vine management, encouraged frost damming, and trapped humidity in support of grape mildew, especially when allowed to grow tall. They argued close mowing or grazing, and if needed, broad-spectrum herbicides, were essential to avoid these disservices, '*Sometimes it gets too high, and you worry about it affecting the management of your grape vines. In summer we'll keep it down because it's competition for the vines* (1)'. They also said low mowing made their vineyards look tidy and well cared for.

Sown Cover Crops

A minority of interviewees sowed forbs with some grasses every 2nd or 10th row of their spontaneous cover crop corridors, saying they were vital for pest regulation, '*I think there's clear evidence that planting certain flowering annuals in the inter-row space has a benefit to vines if you can provide wasps with homes and a food source. They play a role in controlling Light brown apple, and other caterpillars that can damage grape bunches which can provide food to harmful fungi* (4)'. Some said cultivation prior to sowing reduced competition for vine resources: '*All the roots of the weeds that compete die, leaving more space for the vines. You do get the cover crop growing, but it only grows for a short period then dies off* (3)'. They also indicated cultivation increased soil organic matter, nutrients, moisture retention, and reduced artificial inputs like water and fertilisers.

While some conceded sown exotic forbs and grasses were more complicated and costly to implement and maintain, others downplayed these drawbacks: '*It's not actually very hard* (17)'. A few were concerned about the negative effects of cultivating their rows. They said it degraded the soil, so they alternated their sown and spontaneous rows every 2–3 years. One grower also said cultivation made the soil surface uneven, which damaged his tractors

and made mowing uncomfortable: '*It's hard on the gears and it's really uncomfortable* (10)'. He said they were thinking of alternatives, such as purchasing a high-pressure water weeder. Despite these drawbacks, all argued sown cover crop services were greater than their disservices.

These growers were organically certified and said a key GI enabler was an accreditation policy preventing the use of toxic insecticides: '*We can't spray anything too toxic for the leafroller caterpillar, so it* (pest control services of wasps) *certainly helps us* (2)'. One said a barrier to planting service plants was a lack of strong supporting research, saying there was insufficient evidence for grower benefits: '*They* (researchers) *need to show clearly that they* (sown cover crops) *work and are cost efficient—and focus on pest and disease regulation which is of most interest to growers—not things like biodiversity, or because it looks nice—which is a hard sell. This means little to us. You might do it once for these reasons but won't continue doing it unless it is justified* (3)'. He argued evidence was important as growers could not tell whether services like pest regulation were being provided as they were not monitored: '*It's hard to prove because we don't do ten rows without any* (sown cover crops), *and ten rows with* (1)'.

3.2.3. Spontaneous Vine Row Cover Crops

One grower said she allowed sparse, spontaneous grasses and forbs to grow under her vines to avoid herbicide use and cultivation, reduce soil erosion, and increase beneficial fungi and minerals in the soil. She argued spontaneous plants were more likely to provide these benefits than those sown: '*Nature knows best which plants should grow where. If you don't muck around with them, they do their job, pulling up minerals and such that the soil is missing* (17)'. Under her growing conditions (which she considered poor for spontaneous plants), she did not think they significantly competed with her grape vines, and she was willing to hand weed if she thought competition with vines occurred. She argued most spontaneous plants died off during the grape growing season, and therefore had little impact on vine growth compared with the use of broad-spectrum herbicides and cultivation, which negatively affected soil fungi and health: '*They die back. If they are really competing, pull them out. I'm sure if you did this for a few years, they will go* (17)'.

4. Discussion

4.1. To What Extent Was the GW Programme Successful in Encouraging Grower GI Implemenation?

The GW programme established indigenous plantings in areas marginal to growing vines. These plantings were located outside established rows on field boundaries, in landscaped areas around structures, on roadsides, or along stream edges. Most growers retained their original plantings, and a substantial number continued to plant more following the programme's end. This is the only documented case, to our knowledge, where wine growers have actively restored indigenous vegetation on their land. For example, most growers in the Willamette Valley wine region, Oregon, conserved rather than restored existing indigenous remnants [14], but this is not an option for Waipara growers since there is little remaining indigenous vegetation.

The GW programme was less successful in encouraging growers to plant indigenous GI within areas where grapes were being grown or could potentially be grown. The three other indigenous GI types promoted by the programme for these areas (vines at end of vine rows, groundcover under vines, and shelterbelts) were generally not implemented during or after the programme's end. Most, if not all, GI planted in productive areas were exotics (e.g., in inter-row cover crops, beneficial host plants, and shelterbelts). This was consistent with the study by McWilliam and Wesener [14] who found growers mostly grew exotic GI types in these areas (e.g., in inter-row cover crops, insectary patches, and hedgerows).

Waipara growers also introduced exotic species to their non-vine plantings on unproductive land following the programme's end if they felt exotics brought additional or superior services and benefits compared with indigenous plants (such as improved survivability, faster rate of growth, less management, or improved aesthetics). Waipara

grower attitudes regarding indigenous plants were similar to those of some other farmers in New Zealand. For example, dairy farmers mostly preferred mixtures of indigenous and exotic plantings to maximise services, including amenities and minimum maintenance [53]. Unless research identifies indigenous service plants with acceptable disservices and costs of implementation and management (at least equal to those of exotics) for growers, they are unlikely to implement only, or even predominantly, indigenous plants. This is especially true for productive land where the economic bottom line is paramount.

Although indigenous plants should be promoted as superior to exotics in terms of cultural (existence, place-making) and, particularly, supporting services (host-dependent wildlife), vineyard ecosystem health and resilience should continue to be advocated in support of growers planting GI, regardless of whether indigenous or exotic plantings are implemented. This is especially important in low diversity, homogeneous vineyard landscapes, as species richness (whether exotic or native) provides many benefits, including improved soil quality, carbon sequestration, energy use efficiency, and ability to adapt to climate change [54]. Therefore, there is a case for incentivising exotic GI when indigenous GI cannot perform the required functions or has too many disservices—at least until more research can better quantify the benefits and provide affordable means of integrating indigenous biodiversity into the vineyard. These exotic plants might then be removed over time as higher performing indigenous plants are identified or grow large enough to perform their needed services. We should not lose sight of the critical role of visibility and natural character played by local indigenous species in providing authenticity to the NZ experience—whether for locals, visitors, or tourists [55]—and pushing back against the 6th Great Extinction [56].

4.2. What Are the Enablers and Barriers to Improved GI Implementation?

4.2.1. Ecosystem Services and Costs

A key barrier for growers planting GI was the lack of sufficient services for growers. Two out of four of the GI types (vines at end of rows, shelterbelts) were not sufficiently valued by growers to motivate their implementation. While many growers implemented GI that provided less important services, such as support for indigenous biodiversity (as they believed indigenous plants were superior to exotics in this regard), they clearly indicated they were more motivated to implement GI when it supported production (e.g., erosion control, weed suppression, high wind mitigation, and pest regulation) or sales/marketing. This is true of farmers in general, as they are more likely to adopt innovations they see as being advantageous relative to existing practices [57–60], particularly with respect to increased yields and reduced costs. This is why some winegrowers ceased planting indigenous plants following the GW programme's end but continued investing in exotic GI in productive areas that provided key production-related services.

A second key barrier to implementing GI was grower belief that GI services were less than their disservices. This was the case for indigenous shelterbelts and plants under vines, which they viewed as having too many disservices. A third barrier was a belief among growers that the costs of implementing and/or managing GI were greater than those associated with other practices, like spraying herbicides and insecticides. For example, most growers argued implementing and particularly managing any kind of plant under vines was much more costly than spraying herbicides and pesticides. Growers only identified two types of GI with greater services than disservices and costs: exotic inter-row cover crop rows between vine rows in productive areas, and to a lesser extent, indigenous, exotic, or mixed vegetation patches or corridors in unproductive or marginal areas. For example, almost all growers grew some type of exotic inter-row cover crop where there were mature vines. Most growers highly valued their erosion control, weed suppression, and, to a lesser extent, their pest and fertility regulation services. While growers acknowledged these plants could also lead to substantial disservices, they regarded these as manageable. They argued these plants grew at a sufficient distance from vines to limit competition for resources, interfere with management, or impede positive airflow. This was consistent with

research that demonstrated inter-row cover crops did not significantly affect grape yield, growth, or nutrition relative to the absence of cover crops [61,62].

Recommendations:

1. Focus incentive programmes on GI types that provide key production-related services of greatest value to growers.
2. Conduct and effectively communicate research that demonstrates indigenous GI services, acceptable disservices, and costs relative to exotic GI and alternative practices.
3. Conduct research to determine how to effectively communicate evidence in support of GI to growers, e.g., region-specific monitoring and field day demonstrations.

4.2.2. GI Growing Conditions

Many growers indicated harsh GI growing conditions were a barrier to implementing GI, especially with respect to shelterbelts and indigenous plantings. This was responsible, in part, for plants dying, becoming degraded, and/or losing services, such as enhancement of the aesthetic experience. This significantly reduced grower motivation to replace dead plants and to plant more in other such locations. It also led growers to choose exotic plants, as they believed these were more able to survive and required less management than indigenous species. Growing conditions were particularly poor in the more remote and less productive areas of vineyards where growers were most likely to be open to growing GI. These were also locations growers were less likely to frequent and may not notice poor plant conditions and the need for management. Conversely, GI around structures tended to have better growing conditions, access to management infrastructure, and were more visible; therefore, they were more likely to survive.

Regional or local conditions that reduce the incidence of a problem, like plant pests, can enable the implementation of GI with less grower uncertainty. For example, the droughty soil and poor, sparse growth of spontaneous vegetation under a Waipara grower's vine rows reduced her concern about these plants competing with her vines. Cullen et al. [58] reported that an organic Waipara grower believed the level of risk was acceptable for relying on sown inter-row cover crops for pest regulation services versus pesticides because an increase in pests (leafrollers) was unlikely to lead to botrytis in Waipara's dry climate. Similarly, McWilliam and Wesener [14] and Sassenrath et al. [63] both found a low risk of regional pest outbreaks could enable GI implementation even if there was uncertainty about its efficacy. This may be important when GI benefits are difficult to demonstrate [64] or GI is otherwise believed to be risky by growers. The implementation of such GI types may be best supported through region-specific demonstration vineyards that can show how staged adoption reduces risk of costly failure [57].

Recommendations:

4. Conduct research to identify indigenous and exotic plants, planting designs, and management practices that enable plant survival given challenging growing conditions.
5. Provide expert advice and funding to support GI implementation on marginal farmland where conditions are challenging (as this is where indigenous GI is likely to be focused).
6. Establish demonstration vineyards to test GI in limited ways to reduce grower risk.

4.2.3. Plant Selection and Design

Growers indicated it was essential to know which GI plants to plant, where, and when to ensure plants provided targeted services in a timely manner, minimised disservices, and had the greatest probability of survival. They said advice provided by leaders of the GW programme, local nurseries, and, to a lesser extent, websites helped provide this information both during and after the GW programme. Many growers also indicated they had furthered their knowledge regarding how to grow GI successfully under different growing conditions on their properties through trial and error. This further enabled more frequent and successful GI implementation and management on their properties. However,

growers also indicated a main barrier to planting some GI types, like shelterbelts, was their lack of design knowledge regarding how to maximise services while minimising disservices. For example, many growers removed or did not replacing shelterbelts because they did not know how to design and manage their services (e.g., mitigation of strong winds, reducing soil erosion, filtering surface water, enhancing wildlife habitat, and improving vineyard aesthetics), or disservices (e.g., competition for vine resources and blocking positive wind flow).

Recommendations:

7. Provide guidance on which plants to plant, where, and when for maximum services and minimum disservices, implementation, and management costs.
8. Encourage growers, knowledgeable in GI implementation, to share their expertise with others.
9. Provide guidance or conduct research on how to plant GI to maximise their services while minimising their disservices.

4.2.4. Funding

Many growers indicated the funding provided by the GW programme and the Canterbury Trails organisation for purchasing plants and/or the provision of labor for planting was a key enabler for implementing indigenous GI. This was particularly important for GI types viewed as providing services unrelated to production or wine sales, such as support for (indigenous) biodiversity. The value of funding for this type of GI was demonstrated when programme funding ended, and some growers ceased implementing indigenous plantings.

Lack of funding was a barrier to increasing the number or size of indigenous plantings following the programme's end. While growers with smaller vineyards said they could not afford to plant larger or more patches, those with larger vineyards argued they could not justify reducing (often foreign) stockholder profits to invest in plantings that were not seen to significantly contribute to wine production or sales. These findings concurred with those of other studies that found costs of implementation, particularly when compared with alternatives, were significant factors in adoption of farming innovations [59,60], especially for small farms [65–67]. With respect to larger farms, our findings concurred with those of Babin et al. [67] who found growers were less likely to adopt innovations when they thought they did not provide sufficient vineyard benefits.

Costs of management that increased with both GI management intensity and complexity were also major barriers to implementing most GI types, yet neither GW nor the Hurunui Trails incentive programmes provided funding for labor nor management. The fewer services attributed to the GI, the less growers were prepared to invest in management. Therefore, finding ways to reduce these costs, or providing funding for management where this is not possible, may further enable GI implementation among growers.

Recommendations:

10. Conduct research on GI implementation costs and complexities relative to alternatives and determine ways to reduce these costs.
11. Provide funding through incentive programmes to cover the costs of planting and labor.
12. Conduct research to identify GI plants most suited to growing conditions that require simple and minimum management.
13. Consider providing funding for managing GI where management costs cannot be reduced to acceptable levels.

4.2.5. Certification and Regional Association Policies

Organic growers indicated certification policies restricting the use of some pesticides were key to their decision to sow inter-row cover crops between grape vine rows (to provide habitat for biological control of pests) rather than spray prohibited pesticides. These policies were key enablers (or enforcers), as sown cover crops are more complex

and costly to implement and manage than using pesticides. Given that the costs of implementation and management and increased production risks are key factors preventing innovation adoption [59,60], sown cover crops are unlikely to be adopted without these policy incentives.

Other certification programmes have successfully introduced policies that have encouraged GI adoption, whether through agrichemical restrictions or requiring a percentage of vineyard area to be devoted to 'nature conservation' [14]. For example, the Low Input Viticulture and Enology (LIVE) certification programme in the United States and the International Demeter Biodynamic certification programme require 5% and 10% of the vineyard area be set aside for this purpose, respectively. However, these policies are much more likely to be adhered to in regions having substantial areas of indigenous or other non-vine vegetation remaining, like in the Willamette Valley wine region [14]. In regions with very little indigenous or non-vine vegetation remaining (like in the Waipara Basin with <1% indigenous vegetation), setting aside of 5–10% may be difficult to achieve unless there is substantial government support, including subsidies and technical advice.

In terms of industry support, the New Zealand Wine Association is currently focusing its sustainability efforts on improving soil health, employee working conditions, vine health (especially with respect to pests), reducing waste and water use, protecting surface water quality, and particularly reducing carbon emissions [68]. However, achieving many of these goals could be accelerated by increasing GI (both indigenous and exotic) on vineyards. For example, soil health could be improved through windbreaks designed to reduce surface water and wind erosion [69] and by incorporating cover crops in vine rows [70] rather than spraying herbicides [71]. Vine health could be improved through pest regulation from adjacent woody vegetation like windbreaks [72], especially those characterised by midstory and understory shrubs and ground covers [73]. Employee working conditions can be improved if shade, thermal comfort, and improved aesthetic and learning experiences are provided through strategically incorporating shrubs and trees adjacent to vineyard blocks where workers manage vines. Surface water quality would be increased if water features (including wetlands, dams, ditches, and streams) had riparian vegetation designed to slow down and filter surface water runoff [74]. Furthermore, growing more vegetation would enhance vineyard carbon stocks and reduce greenhouse gas emissions from soils [75], thereby moving toward carbon neutrality targets [24].

This additional GI will contribute not only to enhancing indigenous biodiversity but also to improving landscape health [76], legibility, and resilience to climate change impacts [77], whether species richness comprises indigenous or exotic plants. The results of this study indicate many growers are already pursuing enhanced vineyard biodiversity as a goal. However national and regional wine grape associations could provide leadership and assistance to further enable GI implementation by these growers.

Recommendations:

14. Introduce restrictions to the use of low-cost pesticides and herbicides that impede the implementation of GI through certification programmes.
15. Develop certification policies that require the retention of remaining fragments of non-production vegetation on vineyards that provide, or could provide, high quality indigenous vegetation or wildlife habitat.
16. Develop certification policies that require growers to set aside/restore a reasonable amount of land in support of indigenous plant and wildlife biodiversity.
17. Develop GI policies that help growers achieve existing certification sustainability goals, such as improved soil quality, vine health, employee wellbeing, reduced water use, improved surface water quality, biodiversity, and increased carbon stocks toward carbon neutrality.

4.2.6. Government Regulations, Strategies, and Incentives

Many growers using broad-spectrum herbicides (glyphosate) to suppress undesirable plants indicated they were looking for an alternative. This was because they expected a

ban by the New Zealand Environmental Protection Authority (EPA). The EPA is currently reviewing these chemicals and a decision in expected in 2023 [78]. They have been banned in at least 10 countries, including Mexico, Germany, and Saudi Arabia [79], and the EU is currently reviewing their use beyond 2023 [78]. A New Zealand government ban could potentially enable implementation of GI cover crops under vines if plants could be identified with acceptable grower disservices and costs of implementation and management.

To encourage growers to plant GI that does not provide substantial production- or sales-related services but provides other services of high value to communities or governments (e.g., support for regional-scale indigenous biodiversity, carbon sequestration, or catchment surface water quality), more direct government involvement will be needed to develop strategies and incentivise their implementation. Governments of many countries have developed such strategies. For example, the European Union's Common Agricultural Policy (CAP) provides EU farmers with direct payments to restore buffer strips adjacent to significant natural features [80]. In New Zealand, a first draft of a new national policy statement for indigenous biodiversity has been issued [81]. One provision proposes councils protect and restore not only areas with high biodiversity value, but also those that buffer or connect these areas. According to this draft statement, New Zealand regional councils will be required to develop regional biodiversity strategies, in the form of networks, to implement this policy statement by 2025. Such networks have been integrated successfully or implemented in vineyard landscapes in Oregon, California, Chile, and South Africa [1,14,18,82,83].

Effective incentive programmes will be needed to encourage farmers to implement such networks on their land; however, many New Zealand farmers find current incentive programmes barriers to implementation [84]. The New Zealand Government does have a programme [85] to incentivise farmers to restore trees that sequester carbon on their land through carbon credit payments. However, the programme would not incentivise winegrowers to grow trees on their land as it requires farmers to restore a minimum of 1 ha of forest, and to a certain size, before they can qualify for credit [86]. Most winegrowers only have small amounts of land incapable of supporting grapes or wine sales for establishing trees. Even where it is possible, restoring this amount of forest is likely to be a costly and lengthy proposition in regions with only small fragments of woody vegetation remaining, particularly where growing conditions are challenging. Growers would not only be left without income from this land, until the trees reach carbon credit size requirements, but they would also have the costs associated with implementation, which may be considerable even if the land were restored through minimal interference management [87].

Recommendations:

18. Develop government regulations that restrict harmful farming practices impeding GI implementation (such as the application of relatively inexpensive broad-spectrum herbicides and pesticides).
19. Conduct research to identify effective GI plants under vines and clarify their services and disservices, such as costs of implementation and management.
20. Develop national and regional GI network strategies and incentive programmes to encourage growers and other landowners to preserve and restore non-productive GI vegetation in support of key public services, such as region-scaled indigenous biodiversity, carbon sequestration, and surface water cleansing across catchments. In New Zealand, the wildlife habitat restoration strategy developed by Meurk and Hall [88] may be effective.

5. Conclusions

GI is a critical part of the production and marketability of wine grapes in New Zealand and worldwide. We need to find ways to incentivise it without net grower costs jeopardising the important domestic and overseas income generated by vineyard farms. This research is based on a case study of a region with unique biophysical and socioeconomic characteristics; therefore, caution should be taken when applying the results to other regions. However,

the case study does provide important insight into how GI implementation is affected by incentive programmes, identifies enablers and barriers, and provides recommendations for improving its implementation based on grower interviews and a literature review. Whereas this study uncovers many challenges associated with greening these otherwise monotonous, regimented landscapes, it also reveals opportunities for restoring their unique and potentially rich natural and cultural heritage, hosting beneficial insects, and thereby increasing vineyard grape production and sales.

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