International Journal of Agricultural Sustainability

ISSN: 1473-5903 (Print) 1747-762X (Online) Journal homepage: www.tandfonline.com/journals/tags20

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To cite this article: Ebba Engström, Myriam Prasow-Emond , Caroline Howe , Catherine Matilda Collins & Robert Fish (2025) The sustainability benefits and limitations of green infrastructure in vineyards – exploring the experiences of winegrowers, International Journal of Agricultural Sustainability, 23:1, 2533640, DOI: 10.1080/14735903.2025.2533640

To link to this article: https://doi.org/10.1080/14735903.2025.2533640

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Published online: 17 Jul 2025.

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INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY
2025, VOL. 23, NO. 1, 2533640
https://doi.org/10.1080/14735903.2025.2533640

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The sustainability benefits and limitations of green infrastructure in vineyards – exploring the experiences of winegrowers

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ABSTRACT

Winegrowing is traditionally associated with intensive management practices and there is a need for sustainability in the sector. *Green infrastructure*, encompassing non-vine vegetation, water bodies, and other human-made structures, can contribute to this sustainability from a multi-dimensional viewpoint. In the United Kingdom (UK), viticulture is one of the fastest growing agricultural sectors and simultaneously, agri-environmental schemes are encouraging the integration of green infrastructure in agriculture. In this study, we explored the sustainability impacts from green infrastructure in vineyards as experienced by English and Welsh winegrowers. We find that multiple sustainability benefits and limitations are experienced – pertaining to the environmental, economic, social, and cultural realms. Impacts are influenced by contextual factors, including vineyard management approaches, the placement of green infrastructures, and the person who is having the experience. Participants in this study also conveyed various assumptions, expectations, and values in relation to green infrastructure, as well as perspectives on sustainability, which may have come to shape their experiences. Our findings identify opportunities to increase the understanding of the effects of green infrastructures in UK winegrowing, and to effectively communicate this knowledge to winegrowers. Additionally, it could be valuable to provide additional support to winegrowers to manage challenges associated with green infrastructures.

ARTICLE HISTORY
Received 24 January 2025
Accepted 5 July 2025

KEYWORDS
Viticulture; experiences; sustainability; multi-dimensional; wine

Introduction

Winegrowing – the growing of grapes (viticulture) for wine production – was estimated to make up approximately 55% of the total global production of grapes as of 2022 (Costa et al., 2022). Viticulture is traditionally associated with intensive management practices, including extensive use of pesticides or tillage and a simplification of landscapes (Giffard et al., 2022; Winter et al., 2018). These practices contribute to negative environmental impacts such as biodiversity loss, increased soil erosion, and air and water pollution (Christ & Burritt, 2013; Giffard et al., 2022). There is therefore a need to promote sustainability in winegrowing. One set of interventions which can support sustainability in the sector is *green infrastructure* (Goodall et al., 2023; McWilliam & Wesener, 2021) or *ecological infrastructure* (OIV, 2018). In the viticultural context, green infrastructure has been defined by McWilliam and Wesener (2021, p. 3) as, 'multi-spatial scaled networks of natural, semi-natural or human-constructed/planted areas of non-vine vegetation, water elements, and other structures (e.g. nesting boxes), that provide key ecosystem services to winegrowers, communities, and markets'. The concept encompasses many infrastructural components – including cover crops, hedgerows, flower

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strips, ponds, nestboxes, and meadows (McWilliam & Wesener, 2021; OIV, 2018; Rosas-Ramos et al., 2019), which are intentionally kept in viticultural systems. These can provide benefits such as pollination and natural pest control from increased biodiversity (Winkler et al., 2017; Winter et al., 2018), weed control (Giffard et al., 2022), and improved soil structure and reduced soil erosion (McWilliam & Wesener, 2021). However, they may also incur negative impacts to viticultural systems, through harbouring pests, unwanted competition with the grapevines, aesthetic disservices, and potential health and safety concerns (Bigot et al., 2022; Goodall, 2020; McWilliam & Wesener, 2021).

The potential benefits of green infrastructures have led to their promotion as part of several initiatives, including management certification programmes, multi-stakeholder collaborations involving vineyards, and agri-environmental schemes. For example, the Biodynamic Federation Demeter International (2024) certification requires farms to set aside 10% of their land for habitat which promotes biodiversity. Additionally, the multi-stakeholder collaboration – the Greening Waipara project in New Zealand (Cullen et al., 2013; Forbes et al., 2013) – promoted the restoration of natural habitats and native floor cover vegetation in vineyards (Cullen et al., 2013; Forbes et al., 2013). The European Union's (EU) Common Agricultural Policy (CAP) also provides opportunities for viticulturists and other agriculturists to receive payments for setting aside land which promotes biodiversity through their agri-environmental schemes (Homet et al., 2024).

The viticultural sector is one of the fastest growing agricultural industries in the United Kingdom (UK) (WineGB, 2023). This growth is partially attributed to the increase in average growing season temperatures, which has made the climatic conditions for the production of popular, commercial wine grape varieties more reliable (Nesbitt et al., 2022). As this sector grows, there has been a need – as in the general industry – to minimize its potential negative sustainability impacts. This is exemplified through the development of the Sustainable Wines of Great Britain (SWGB) scheme under the trade organization Wines of Great Britain (WineGB, 2024). Furthermore, in the UK, there are several initiatives encouraging the integration of green infrastructure in viticulture and furthering the understanding of their impacts. For example, there have been investments into exploring the impacts of various cover crops (NIAB, 2022). At the governmental level, the Environmental Land Management schemes (ELMs) (UK Government, 2021) and the Sustainable Farming scheme (Welsh Government, 2022) are promoting the establishment and management of semi-natural and natural areas or structures on agricultural lands. Furthermore, even though broadly stated, the SWGB (2023, p. 11) has the set objective to, 'Conserve the vineyard (and surrounding) environment and promote biodiversity'.

With the promotion of both sustainability in UK winegrowing and green infrastructure in UK agriculture, there is a need to better understand how green infrastructures contribute to the sustainability of UK winegrowing systems. Thus, we ask: *What sustainability impacts do green infrastructures have, as experienced by UK winegrowers?* The aim of our study is to explore how UK winegrowers view the impacts of green infrastructures on the sustainability of their winegrowing systems and ventures. To address our aim, we undertook *walking interviews* (Evans & Jones, 2011; Kinney, 2017) with winegrowers across vineyards in England and Wales. Our study provides insight into the types of sustainability advantages and disadvantages provided by green infrastructure in winegrowing systems from a multi-dimensional viewpoint, as experienced by different winegrowers under varying contextual influences. Understanding these experiences is valuable as they could shape further adoption of green infrastructures in the context of vineyards striving to become more sustainable (Goodall, 2020; Goodall et al., 2023). Additionally, it can help decision-makers and practitioners understand which impacts may need to be considered when assessing the sustainability of green infrastructures in winegrowing systems, as well as the sustainability challenges for which winegrowers may need further support to address.

Background

In the context of viticulture and wine-making, sustainability has been described as multi-dimensional by the International Organisation of Vine and Wine (OIV, 2008, p. 2), encompassing environmental, economic, social, and cultural elements:

> … incorporating at the same time the economic sustainability of structures and territories, producing quality products, considering requirements of precision in sustainable viticulture, risks to the environment, products safety and consumer health and valuing of heritage, historical, cultural, ecological and landscape aspects.

Here, the environmental dimension of sustainability encompasses factors such as biodiversity, agrochemical use and efficiency, and water use and efficiency (Baiano, 2021; Flores, 2018; Luzzani et al., 2021; Marta-Costa et al., 2022). The economic dimension includes, in turn, factors such as costs, income (revenue), and economic efficiency (Marta-Costa et al., 2022). The social dimension relates to several social groups, including workers, value chain actors, local communities, and broader society, and concerns factors such as the health and safety of workers and the provision of employment to local communities (Arcese et al., 2017; Luzzani et al., 2021; Marta-Costa et al., 2022; Martucci et al., 2019). Finally, the cultural sustainability dimension, includes for example, heritage and aesthetic values (Luzzani et al., 2021). Figure 1 summarizes these sustainability dimensions and aspects.

These sustainability dimensions need to be understood in the context of the wider ecosystem services they depend on. The provision of ecosystem services forms a vital part of achieving sustainability in agricultural systems in general (Harrington, 2016; Pretty, 2007). In the context of viticulture and winegrowing, ecosystem services include: regulating services, such as pest control and climate regulation; supporting services, such as nutrient cycling and management, and soil formation and erosion control; provisioning services, such as wine and grape yield and genetic resources (e.g. grapevine varieties); and cultural services, such as aesthetic values, science and educational values, and existence values (the value of knowing something exists) (see variously Sandhu et al., 2018; Tompkins et al., 2012; Winkler et al., 2017; Winkler & Nicholas, 2016).

In relation to winegrowing, there are many studies which have examined the impacts pertaining to green infrastructure (Engström et al., 2025). These relate to factors such as biodiversity, costs and revenue, and cultural value (Engström et al., 2025) – which are encompassed by the dimensions of sustainability (see Figure 1). In this context, even though authors like McWilliam and Wesener (2021), Goodall (2020), and Schütte and Bergmann (2019), have explored the attitudes and experiences of winegrowers regarding varying green infrastructures, there have been generally few studies which have taken this type of approach (Engström et al., 2025). Furthermore, there is opportunity to study the impacts of green infrastructures in the context of winegrowing through a multi-dimensional lens – covering environmental, economic, and sociocultural aspects together, to provide a more holistic understanding of their effects (Engström et al., 2025; Rusch, 2025).

Methods and materials

The walking interview method

In this study, we employ the walking interview method (Kinney, 2017), an immersive qualitative method for eliciting perspectives from people navigating localities and surroundings, which has been applied to rural and agricultural areas (Bardsley et al., 2019; Chambers, 1994). Evans and Jones (2011) describe how, when moving through an environment related to a given research topic, interviewees are provided with visual prompts that can provoke certain memories or experiences that may not be fully captured by sedentary interviews. This method was deemed particularly applicable to our study, as it could encourage both the interviewer and interviewee to identify green infrastructures, which may not have otherwise been mentioned during a sedentary interview. Additionally, it would allow the interviewee to consider certain impacts by seeing and interacting with green infrastructures in their contexts. In developing our method we drew on Emmel and Clark's (2009) approach, in which interviewees were asked to plan a route for the walk. Additionally, we drew inspiration from Chang (2017) and incorporated a 'pre' and 'post'-walking interview stage, during which we explored questions related to the background and characteristics of the vineyard visited, and participants' experiences of the industry. The post-interview stage also gave the participant the opportunity to provide any concluding inputs or feedback.

Sampling and recruitment

16 participants were interviewed across 15 commercial vineyards or vineyard estates. These people and vineyards were sampled through a purposive approach (Newing, 2010). As our study aimed to better understand the sustainability impacts of green infrastructures experienced by UK winegrowers, we wanted interviewees to represent vineyards which had incorporated various green infrastructures. Representatives of vineyards were therefore recruited based on the respective vineyards having various green infrastructures incorporated beyond grass groundcovers – which are commonly adopted in UK vineyards (Griffiths-Lee et al., 2022;

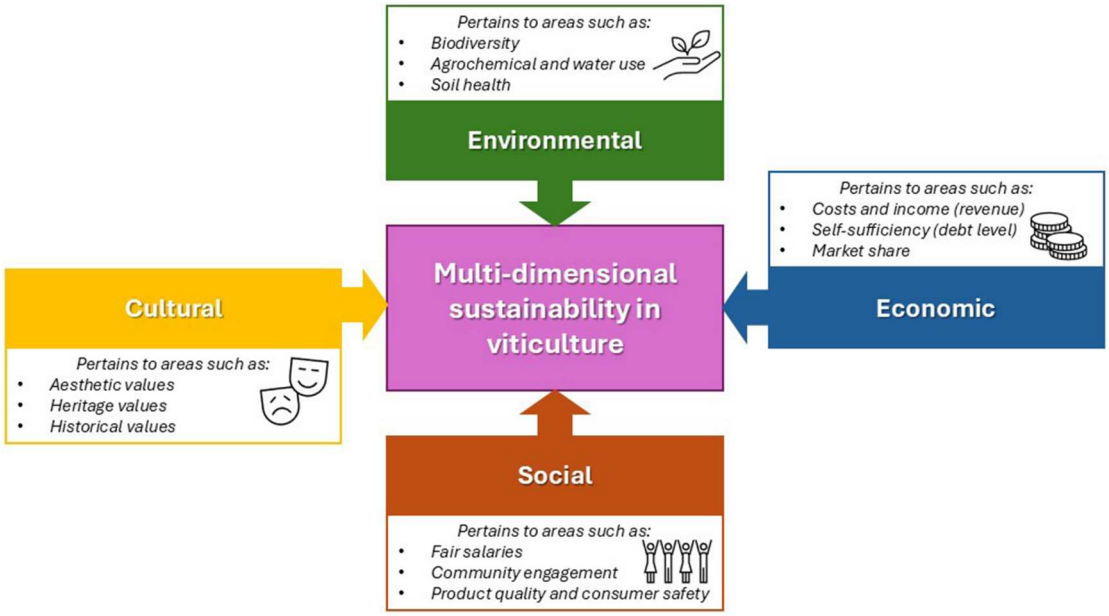

Figure 1. A multi-dimensional sustainability framework for viticulture.

Vinescapes, 2021). These characteristics were identified through grey sources (e.g. company websites) (Haddaway et al., 2015) and informal conversations and vineyard visits.

To gain a breadth of perspectives and insights into the experiences of green infrastructures, we recruited interviewees from vineyard properties or estates located in different geographical regions with different growing conditions (see Figure 2). However, it should be noted that the greater proportion of vineyards in the UK are located in southern areas of England, including Kent, West Sussex, East Sussex (Skelton, 2025). Additionally, we wanted the interviewees to represent vineyards run under different management systems and which had different sized areas of planted vines. As a result, the interviewees recruited (see Table 1 for a summary of some of the interviewee details) represented vineyards across different counties in England and Wales and were of different sizes. The vineyard properties were also sometimes composed of several sites. Specifically for the vineyard sites visited, for example, one of the smaller sites was planted with 0.4 hectares of vines and one of the larger sites was planted with over 90 hectares of vines. The vineyards were run under different management systems and had different backgrounds and structures to their businesses. Here, conventional systems refer to management systems which are not certified organic or biodynamic. Organic systems fulfil the criteria for, and have attained organic certification by an approved UK organic control body (UK Government, 2023). Biodynamic vineyards are biodynamically certified with the Demeter certification, regulated by the Biodynamic Association of the UK (BDA, 2021).

From these vineyard properties or estates, we aimed to speak to individuals who were directly involved in vineyard operations. Our interviewees therefore held roles as Vineyard Manager, Estate Manager, Vineyard Technician, Chief Executive Officer (CEO), and Owner (see Table 1). The sample of vineyards, although not necessarily representative of the sector, serve as key informants who can provide insights into experienced sustainability impacts from green infrastructures.

Interviews

The interviews were carried out between August and December, 2023, and lasted between 1.5–3.5 hours. With the given interviewee sample, we found similar green infrastructures reoccurring in the vineyards and experiences described in relation to these, and therefore determined a point of saturation to have been reached with the sample size (Newing, 2010).

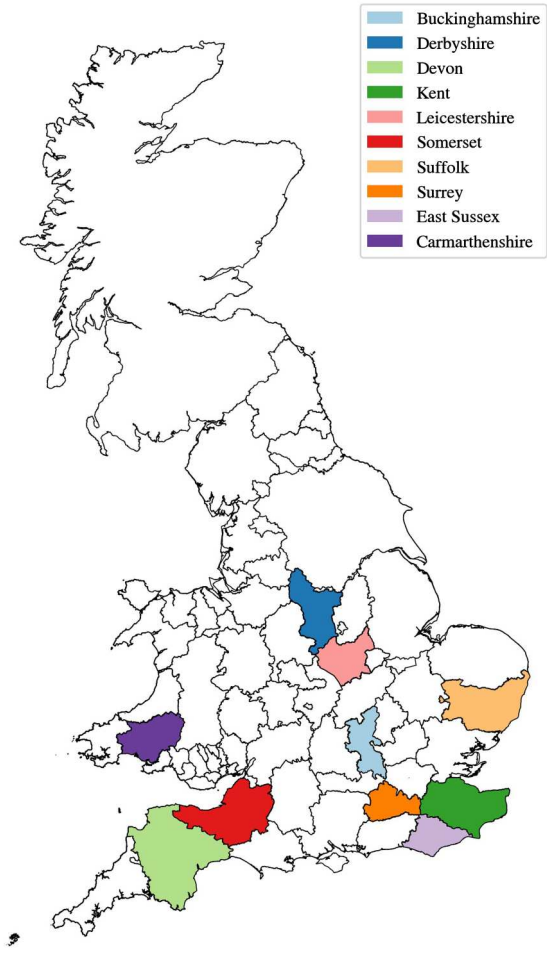

Figure 2. Counties of vineyards visited for interviews.

This follows a similar approach to Bardsley et al. (2019) who noted in their walking interview study that more interviews can generate greater rigour, but how for their sample of interviews there were noticeable repetitions of themes related to their research questions. The interviewees in our study were informed upon recruitment via email that the study was about sustainability impacts related to green infrastructures. An overarching description of green infrastructure, together with some examples of these structures, were provided via this email. The interviewees were encouraged to think about the structures present on their properties and to plan a walking route in relation to these.

For an infrastructure to be counted as a green infrastructure it had to be located within the property lines of the vineyard or estate, or adjacent to this, and had to be under managerial control by the vineyard in question. Due to the broad nature of the concept of green infrastructure, in order to help identify these structures on different properties the authors drew on several works including that of McWilliam and Wesener (2021), Goodall (2020), and the OIV (2018). We were interested in learning about all forms of non-vine vegetation and water bodies – however, we did not focus on other crops within a property which were solely grown for produce and which held the same importance as the grape production to the winegrowers. In terms of human-made infrastructures, this can encompass a myriad of structures including farm buildings, nestboxes, and perches (McWilliam & Wesener, 2021). We, therefore, focused on structures which had been implemented for purposes beyond the fundamental running of the vineyard (e.g. trellis systems) or associated winery. These structures were only further discussed if impacts not necessarily associated with the everyday running of a vineyard were brought up by the participant. Additionally, even though structures such as ponds can be constructed by humans, we counted these as *water body infrastructures*.

The interviews were guided by open-ended questions in relation to: (1) details about the vineyard or estate and the role of the interviewee; (2) perspectives on sustainability and business/management practices; and (3) green infrastructures and sustainability impacts expressed as benefits or limitations. We were interested in impacts from green infrastructures based on personal observations and experiences of winegrowers, as well as those garnered from more formal studies, e.g. according to planned scientific protocols with research expertise input (Šūmane et al., 2018). We used the four dimensions of sustainability (economic, environmental, social, and cultural) presented in Figure 1 to create prompt questions and to better understand and classify described impacts. Even though McWilliam and Wesener (2021) have defined green infrastructures in relation to ecosystem service provision, we were interested in impacts on sustainability more generally. For example, green infrastructures can influence vineyard management requirements (McWilliam & Wesener, 2021; Schütte & Bergmann, 2019), which is an impact that cannot be classified as the provision of an ecosystem service or disservice. Beyond the planned discussion points, other general topics arose during the interviews – for example, related to general knowledge management around viticulture, and sustainability and green infrastructure developments in the industry and the UK.

Table 1. Summary of interviewee details.

Interviewee code	Role	County	Management system	Category of area size of planted vines (hectares [ha])
V1	Owner	Derbyshire	Conventional*	$0 \leq 5$
V2	Owner	Somerset	Biodynamic	$0 \leq 5$
V3	Vineyard Manager	Buckinghamshire	Organic	$5 \leq 10$
V4	Vineyard Technician	East Sussex	Conventional	$10 \leq$
V5	Owner	Suffolk	Conventional	$0 \leq 5$
V6	Owner	Carmarthenshire	Conventional*	$0 \leq 5$
V7	Vineyard Manager	Kent	Conventional	$10 \leq$
V8	Chief Executive Officer	Devon	Conventional*	$10 \leq$
V9	Vineyard Manager	Surrey	Conventional	$10 \leq$
V10	Owner	Somerset	Conventional*	$0 \leq 5$
V11	Owner	Kent	Organic; Biodynamic	$0 \leq 5$
V12	Owner	East Sussex	Organic	$0 \leq 5$
V13A and V13B	Estate Manager; Vineyard Manager	Surrey	Organic; Biodynamic	$5 \leq 10$
V14	Owner	Somerset	Conventional*	$0 \leq 5$
V15	Owner	Leicestershire	Conventional	$0 \leq 5$

The details provided only regard the sites visited, and not additional sites owned by the vineyard businesses. *The vineyard either uses minimal intervention methods or uses organic or biodynamic methods, without being organic or biodynamic certified. The areas of planted vines were attained from Skelton (2025) and asked about during the interviews.

Ethical approval for this study was provided via the Science Engineering Technology Research Ethics Committee at Imperial College London (ID: 6674659). Prior to conducting the interviews, interviewees were asked for their consent to be audio recorded and for potential pictures to be taken for research purposes. The interviews were recorded and then transcribed verbatim. The transcripts were uploaded into NVivo version 14 and qualitatively coded according to guidance provided by Saldana (2016). Within NVivo the interviews were initially coded against the key interview themes providing pre-defined codes, using the 'coding' function of the software. The interviews were then recoded based on emergent codes[1] (developed based on the data analysed), also using the coding function. The transcribed material was then organized according to both the pre-defined and emergent codes in NVivo, which allowed the authors to aggregate the results presented for the different themes – but also to identify any potential patterns in responses provided by the different interviewees and groups of interviewees (determined by some of the defined interviewee characteristics, including their vineyard roles, the size of the vineyard, and the vineyard management systems in which they worked).

Results

Perspectives on sustainability

The interviewees provided general insight into their varied views on sustainability (or related concepts deemed to provide additional value beyond sustainability, e.g. regeneration (Villat, 2021)). Many associated the concept with long-term thinking and ensuring the survival of both the vineyard and the associated environment. Several interviewees referred to sustainability as multi-dimensional, integrating dimensions of the environment, economics, and sociocultural aspects in differing ways. Indeed, for some, the environmental and economic dimensions were of emphasis, whereas for others it was the environmental and social dimensions. It was also emphasized how sustainability is contextual, depending on spatial, temporal, and vineyard and business conditions: 'And maybe it's that everyone's situation is different, and everyone's sensibilities are different, so there isn't one right answer'. (V14). Furthermore, sustainability was not necessarily seen as equivalent to a certain viticultural management system (e.g. biodynamic, organic, or conventional), and several interviewees referred directly to certain practices or outcomes to exemplify sustainability – for example, low intervention, ensuring profitability and sustaining fair livelihoods, and enhancing local resource use. In organizing and analysing our interview data using NVivo, we did not identify a particular pattern whereby different characteristics of the interviewees seemed to correspond with different perceptions of sustainability.

Approaches to green infrastructure integration and management

There were varying approaches to how green infrastructures had been implemented and maintained.

Certain interviewees emphasized the value of setting aside bigger areas for natural land, and for some the implementation of green infrastructure was driven by land availability: 'If we are not using it for growing grapes or anything. We got to do something with it, so it's not waste of ground.' (V3); ' … yeah, so we don't have enough land to be planting forests and all that kind of stuff … ' (V14). The vineyards categorized as having the largest area of planted vines (10 ≤ ha) were all situated on large properties and had woodlands, shrublands, or more extensive rewilded areas integrated – but also smaller vineyards such as V1 and V10 had land on their properties set aside for natural areas. Sometimes the integration of certain green infrastructures was also restricted to areas dedicated to trials or experimentation.

Some vineyards actively encouraged green infrastructures to grow with limited intervention or management throughout their properties: 'Apart from the vines, the rest of the farm is pretty unmanaged really. It's not rewilding as such, but it's sort of very much leaving it to get on with itself'. (V12). This applied to vineyards run under the various management systems (conventional, organic, and biodynamic). For certain interviewees this management approach was associated with increased operational efficiency (due to reduced management resources dedicated to these structures or areas) and benefits for biodiversity. In some cases, keeping green infrastructures less managed was influenced by who was accessing and needed to have unimpeded access to the property area: ' … this is a big a public vineyard. So we have to maintain it a little bit more to facilitate people to walk through the vines'. (V13B).

Different viewpoints were held on how green infrastructures were part of the vineyard businesses – including their management and sustainability strategies. The integration of green infrastructures was sometimes important to the overarching management system followed, e.g. biodynamic production. The ability of green infrastructures to promote biodiversity, nature, and environmental benefits was also expressed as important to interviewees, and for some these were aspects they wanted to contribute to with their ventures: ' … it's all about how we can use this area to bring in more bird species and more floral diversity … ' (V2).

Other interviewees (e.g. V2, V10, and V13A – representing different management systems) described how they kept green infrastructures to support the well-being of workers or visitors, and one participant (V13A) mentioned how green infrastructures could attract larger visitor groups to their vineyard. Green infrastructures were also implemented and kept to provide educational and community engagement value by serving as talking or information points as part of vineyard tours or visits. Interviewees had also integrated green infrastructures for their potential aesthetic, agronomic, and cost-saving benefits, as well as due to personal affinities held towards them. These expectations were sometimes discussed in the context of climate change and how the green infrastructures would counteract challenges related to a drier and warmer climate.

Types of green infrastructures

The green infrastructures identified and discussed are grouped into 12 categories, summarized in Figure 3. All vineyards kept floor cover vegetation throughout their vineyard properties, often consisting of grasses. Here, we use the term *groundcover* to refer to vegetation not specifically found interrow (between grapevines), under-vine (in-row), or in areas specifically set aside for grasslands. We therefore count vegetation in field margins and headlands as groundcover. Headland vegetation sometimes served as ecological corridors, to allow organisms to pass between natural areas. The groundcovers were managed differently between vineyards. Some vineyards kept their groundcover tall throughout the year. Others mowed or cut their groundcover to a great degree especially during certain times of the year, for example, to reduce frost risk on-site or improve site accessibility for vineyard workers. Certain vineyards planted shorter growing vegetative species to avoid these types of management issues.

All vineyards additionally kept vegetation in all or alternate interrows. This interrow vegetation, like groundcover, often consisted of grasses, and was managed for various reasons: to ensure site accessibility by vineyard workers; to minimize wet working conditions; to allow sprays to reach the grapevines; to provide weed competition; and to improve airflow to manage humidity and disease risk. Sometimes interrow vegetation was more managed in areas where vines were young to reduce competition for nutrients and water with the grapevines, as well as where fruiting wires in trellis systems were placed closer to the ground. Vineyards kept interrow vegetation to improve the health and structure of soil, for weed competition, and to enhance biodiversity.

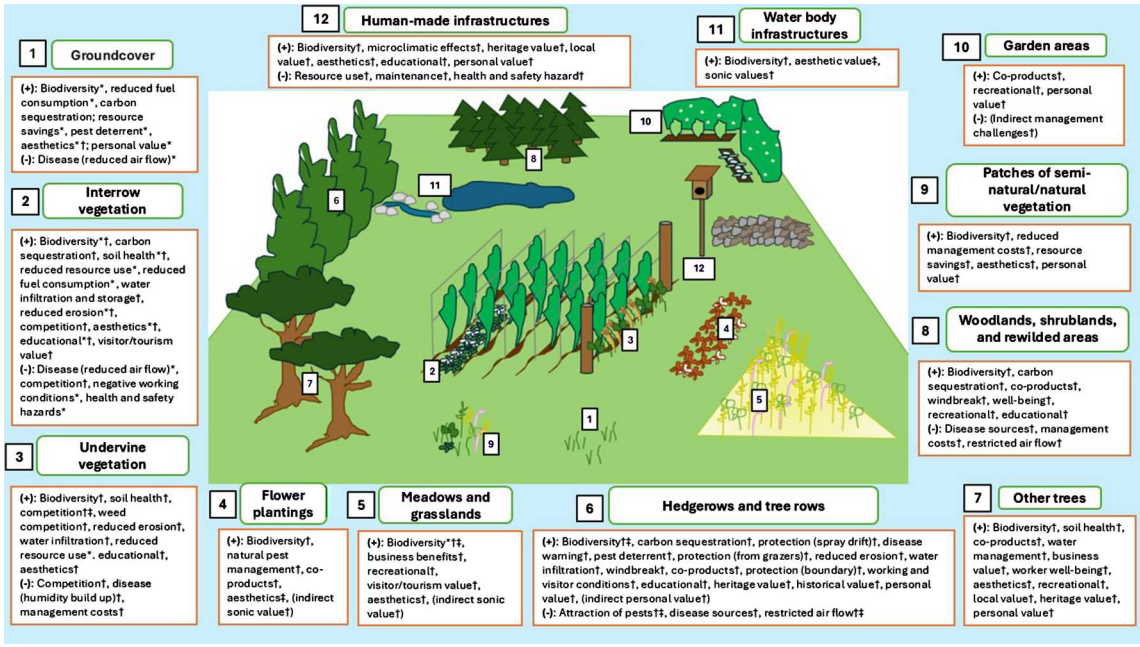

Figure 3. Summary of experienced sustainability impacts from green infrastructures in vineyards.

For the vineyards which kept undervine or in-row vegetation as part of their standard operations, this vegetation was managed through mowing or cutting to varying extents, for example to reduce humidity and fungal disease risk. Vineyards which did not keep constant undervine vegetation, used herbicides or cultivation methods to remove it, or mulches or covers to suppress it. Here, only some vineyards which were under conventional management used synthetic herbicides as part of their management regime at the time of interviews. As in the case of interrow vegetation, several interviewees indicated they had a different management regime for their younger vines, involving the removal of undervine vegetation to eliminate unwanted competition with the vines. Among the interviewees, reasons were provided for both keeping and removing undervine vegetation in relation to competition with the vines: 'This system, with growing a lot underneath, will increase competition, reduce yield. But improve the health of the vines'. (V2).

Several vineyards had specific areas set aside for flower plantings, which were not part of the groundcover, interrow vegetation, or undervine vegetation. These had been implemented to create habitats for organisms, to promote natural pest management, and for aesthetic purposes. For flowers planted at the end of rows, this was sometimes done out of tradition, with these having historically functioned as early warning systems for fungal disease spread. Furthermore, some vineyard properties of varying sizes and employing different management systems (e.g. V1, V13, and V9) had specific areas dedicated to grasslands and meadows. These areas were mowed to improve site access by workers and visitors, and the meadows were managed to allow certain species to grow without being outcompeted. Many grassland areas had been set up to support business functions, such as hosting events or car parking.

Most of the vineyards had either, or both, tree rows and hedgerows integrated, including as property boundary markers and windbreaks. Some interviewees felt more positive towards leaving these structures less managed (e.g. V1 and V5 – both conventionally run vineyards), while others emphasized the importance of managing them to avoid negative impacts (e.g. V11, V3, and V12), for instance, excessive shading and increased frost risk. In addition to tree rows and hedgerows, several vineyards had other trees implemented – including groups of trees, such as fruit orchards (e.g. apples) and tree plantations. One vineyard also had trees planted alongside their grapevines which functioned as a trellis system. These tree structures had in many cases been

integrated, or kept, to produce co-products, out of personal interest, and to manage water levels on-site. Furthermore, some properties had larger areas dedicated to woodlands, shrublands or rewilded areas. In most cases the management of these was minimal and was especially performed for safety reasons, for example, to avoid hazards from falling trees. Some vineyards had introduced fencing in these areas to prevent vertebrate pest species from entering their vineyard fields. Beyond larger rewilded areas and meadows, some vineyards had patches of semi-natural or natural vegetation. These were not always purposefully created but sometimes left over from mowing regimes or where management was not easily conducted.

Several vineyard properties also had garden areas, which had been integrated for reasons such as recreational use and business activities, e.g. wine tastings. Vineyards managed their gardens to different extents, whereby this management was sometimes influenced by the vegetation species planted. A few vineyard properties had water bodies in the form of ponds or surface-level freshwater streams. In terms of human-made infrastructures, several of the vineyards of varying sizes and with different management systems integrated, had bat and bird boxes (referred to here collectively as *nestboxes*) integrated, with the purpose to promote biodiversity and to increase biological control of pests. Furthermore, certain vineyards kept structures to promote insects or mammals on-site, e.g. mammal boxes, beehives, and 'bug hotels', and some vineyards had wooden trellis posts and stone walls on site.

Although several interviewees demonstrated systems thinking in relation to their vineyards, most indicated that their green infrastructures had not been integrated as networks and were not managed as such:

> I think we do still manage them in their component parts, and we'll acknowledge and kind of take into consideration the bits that are linked, but that's probably something that we will strive to get towards, because I think you do need to manage them as one. (V11).

In fact, only two interviewees demonstrated making management decisions which take into consideration the connection between structures, for example by mowing their groundcover in a certain way to enhance the habitats of organisms in other green infrastructures. Interviewees did, however, speak about the sustainability impacts from their green infrastructures as collective units.

Environmental and eco-economic sustainability

Interviewees mentioned the creation of habitats for organisms and the promotion of biodiversity as environmental sustainability benefits, which were provided by most green infrastructures (see Figure 3): 'Insects and there'll be lots of little mice and hedgehogs' (V11) (referring to groundcover kept long in headlands and field margins); 'I see a lot of gold finches during the spring in the trees. Lots of other birds as well … I guess from a wildlife perspective, I think that is a positive' (V4). The green infrastructure was sometimes counted to this biodiversity as well. Grasslands were mentioned to especially provide biodiversity benefits when the vegetation was kept tall and had certain vegetative species integrated: 'Well, the clovers we will do just for the nectar, for all things that love nectar really. The bees love it. Some of the butterflies' (V3). Similarly, for hedgerows and tree rows, it was pointed out how biodiversity benefits were dependent on the species of trees integrated. In the case of the flower plantings, meadows, and grasslands, it was sometimes mentioned how in attracting other organisms, for example insects, this had subsequently provided sonic (auditory) benefits. Certain interviewees also obtained personal value from seeing these additional organisms on-site. For several green infrastructures (interrow vegetation; meadows and grasslands; hedgerows and tree rows; and woodlands, shrublands, and rewilded areas), certain interviewees did not want to overstate the green infrastructures' impacts on other organisms due to not having formally assessed these.

Carbon sequestration was also mentioned as an environmental sustainability benefit associated with green infrastructures (see Figure 3) by vineyards who determined this through formal assessments. Additionally, one interviewee noted how their trees had contributed to the build-up of topsoil with organic material and thus, soil health. By keeping interrow vegetation and groundcover tall, this had resulted in environmental benefits from reduced fuel consumption related to less management needs – and in the case of interrow vegetation this had also led to reduced economic costs. Hedgerows and tree rows had provided both economic (agronomic) and environmental benefits by acting as protective barriers against spray drift and grazing animals, reducing soil erosion, improving soil water infiltration, and functioning as windbreaks. Interrow

and undervine vegetation had also simultaneously improved soil health and grapevine growing conditions: 'Soil biodiversity. Soil health overall. Yeah, oxygen. Water penetration, water holding. Carbon capture. And then the biodiversity aspect of it as well. And reduction in soil erosion'. (V2). As in the case of biodiversity promotion, some interviewees did not want to overstate these types of impacts though due to not having formally assessed them. Furthermore, with green infrastructures collectively increasing biodiversity on-site, a couple of interviewees expressed how this had in turn promoted economic sustainability benefits, such as the resilience of their vines against disease, natural pest management, and improved soil health.

In regard to wooden trellis posts (which had provided habitats for insects and landing sites for birds), a few interviewees discussed the environmental impact of the material they were made of – and wood was sometimes considered a more environmentally sustainable material than metal. However, concerns were raised over the costs and resource use associated with the annual maintenance of wooden trellis posts, which generated both negative economic and environmental impacts. This issue of potential costs from maintaining and also replacing wooden trellis posts were not discussed by the vineyards with the largest areas of planted vines (10 ≤ ha) – who might not have been as impacted by these costs, but some of them also had to a large extent metal trellis posts integrated. Additionally, in terms of nestboxes, interviewees mentioned how they had either not perceived any noticeable impacts from them, or they did not want to overestimate their impacts. To further the understanding of their impacts, however, one vineyard had installed cameras to observe occupation patterns in them.

Economic sustainability

Economic sustainability benefits (see Figure 3) included resource savings (e.g. working hours, fuel) associated with less mowing and keeping groundcover, interrow vegetation, undervine vegetation, and semi-natural and natural patches tall or as low intervention systems. However, in some cases, keeping undervine vegetation and maintaining it through strimming and mowing incurred higher costs than using herbicides, which posed a barrier to its integration. Costs were also associated with managing the expansion of invasive species in rewilded areas. Furthermore, on one vineyard property, their garden area was open to the public community for recreational use. This recreational use had complicated some operations on-site, e.g. spraying grapevines with nutrients or pesticides, causing economic sustainability challenges.

Keeping groundcover and interrow vegetation tall, as well as having undervine vegetation integrated, could reduce airflow and increase humidity levels on-site – thereby elevating the risk of fungal diseases in grapevines. These risks were sometimes minimized by growing certain grapevine varieties, for example fungus-resistant varieties (Finger et al., 2022); by setting wires in trellis systems at higher heights; and by increasing the distance between planted vines. These types of methods had been used by vineyards with different management systems (conventional, organic, and biodynamic). In some vineyards, woodlands and rewilded areas, together with hedgerows and tree rows, had restricted air flow on-site, and due to their placement, sometimes caused additional frost risk. However, these structures had also influenced microclimatic conditions positively, including through sheltering or windbreak effects. One interviewee additionally referred to the agronomic (economic) benefits of radiation reflecting off stone walls and creating a warmer microclimate for grapevines.

In certain vineyards interrow vegetation and undervine vegetation had contributed to welcomed competition with the grapevines for nutrients and water – making the vines less vigorous and more manageable: 'Actually, the undervine cropping has helped us hugely with controlling the canopy and the vigour, it used to be a really vigorous site here' (V3). One interviewee even noted how they perceived this competition to have enhanced the quality of their wine. However, whether this competition was considered positive sometimes depended on the climate and weather conditions (i.e. whether they were hot and dry). In the case of undervine vegetation, some interviewees had experienced too much competition between these structures and the grapevines.

Undervine vegetation had provided economic benefits through competing out weeds which otherwise would have needed to be managed. Several green infrastructures had also played a role in redirecting pests from grapevines, contributing to biological control on site. For example, tall-growing groundcover had provided food sources for certain pests that would otherwise damage grapevines,

notably rabbits, and for flower plantings it was mentioned how: 'The roses get the Aphids before anything else. And then you see an army of ladybirds coming along and munching them like Pacman, which is always nice to see' (V7). However, interviewees mentioned that they would want further scientific or formal studies to be undertaken to assess these impacts, and they did not necessarily always know how to conduct these studies themselves. Hedgerows and tree rows could also function as early alarm systems for disease spread, showcasing symptoms prior to the grapevines. By becoming infected with diseases and attracting pests, green infrastructures could pose a risk to grapevines by contributing to crop damage and yield losses. These risks were, however, managed in vineyards by, for example, using protective netting to cover the grapevines and guard against pests. By attracting and providing habitats for insects, wooden trellis posts could also be negatively impacted from their reduced durability and longevity.

Interrow vegetation, undervine vegetation, and other trees were also described to have improved agronomic conditions by supporting soil water infiltration and storage, and interrow vegetation and undervine vegetation had improved agronomic conditions by preventing soil erosion. In addition, many green infrastructures had provided economic sustainability benefits through the generation of co-products e.g. seed, berries, fruits (including for cider and liquor production), biomass for fuel, compost components, and materials for grapevine sprays, for vineyards of different sizes and with varying management systems (conventional, organic, and biodynamic).

Social sustainability

In regard to social sustainability impacts, it was mentioned how interrow vegetation could negatively impact working conditions due to humidity build-up causing wet working environments. Green infrastructures such as interrow vegetation and semi-natural and natural vegetation patches could also expose workers to ticks and prickly or stinging vegetative species, e.g. nettles, and one interviewee described how their fruit orchards (apple) had attracted insects such as wasps, which were sometimes not appreciated. However, even if some interviewees were aware of these conditions and health and safety concerns, they did not always see them as negative sustainability impacts. These interviewees represented vineyards of the varying management systems (conventional, organic, and biodynamic). Additionally, the health and safety hazards associated with the coating used on wooden trellis posts were also discussed by a couple of the interviewees.

Hedgerows and tree rows had contributed to safety on-site by serving as boundary structures, and those which provided shelter from wind and sunlight, were described to improve conditions for vineyard workers and visitors. One interviewee more so mentioned how their fruit orchard (apple) had contributed to the well-being of their workers: ' … working out in the orchard and in the vineyard was really good for him … ' (V1). Interviewees also described how woodlands, shrublands, and rewilded areas promoted community and worker well-being by these actors being able to access and enjoy these areas. Such opportunities were however, sometimes missed out on: ' … the issue is that nobody can see it, so nobody's kind of benefiting in that sense' (V1).

Cultural sustainability

Cultural sustainability impacts included aesthetic benefits provided by almost all forms of green infrastructure identified (Figure 3). For meadows, grasslands, and flower plantings, these aesthetic benefits were spoken of in relation to the interviewees themselves, visitors, and surrounding communities: ' … especially when we first put them [flower plantings] in, everyone's saying how lovely they were. I've had a few emails and phone calls from people which was nice' (V3). One interviewee, however, noted that the way in which their flower plantings were experienced depended on the context and surrounding landscape factors, e.g. the proximity to roads. Additionally, whether fresh-water streams provided aesthetic and sonic benefits depended on if they were flowing (and not dried out). The aesthetic benefits provided sometimes led to subsequent visitor value, and business (economic) benefits (e.g. in the case of meadows and grasslands): 'If you look through our Instagram profile, you can see that we have got images from the summer gone … with the sunlight over it, and it looks quite stunning. So yes, in an economic sense, it has appeal' (V1).

Several green infrastructures provided recreational value, including for both workers and visitors. Indeed, one interviewee recounted how children played in their meadows, and in another vineyard, their garden area was open to, and could be enjoyed by, the public. Sometimes these recreational benefits

had subsequently led to economic benefits. Furthermore, the provision of visitor value was attributed to keeping larger natural areas as part of vineyard properties or estates. Many green infrastructures also served as talking or information points as part of vineyard tours or information boards. This amplified the educational value of vineyard sites. To get the full extent of educational and visitor value from green infrastructures however, interviewees noted that visitors and other stakeholders may need an underlying interest or appreciation of green infrastructures: 'Specifically, unless you're from an agricultural background or you know, ecological background – it goes over people's heads' (V3).

Furthermore, certain interviewees highlighted the historical, heritage, or local values provided by their hedgerows: 'So on a pure species basis, you're probably looking about 7–8 different species, therefore can extrapolate 7–8 centuries – it's always good. (V1), other tree structures: '… people are quite excited about it locally, because they are all varieties of Derbyshire apples that will be eaten that will come from their local orchards' (V1), and stone walls: 'So culturally, locally important dry-stone walls have been around for millennia in this neck of the woods' (V1). Additionally, green infrastructures had provided personal value to the interviewees: 'I love it. I mean as a being, it's very special. This is an interesting patch.' (V2); 'Sometimes you can just provide a bird box and feel happy about it' (V1). For one interviewee their garden area more so had a spiritual dimension: '… It has wonderful memories, but it also connects me. They act as places to allow for those connections, to encourage those connections. It's almost deeper than working in the vineyard' (V2).

Assumptions, expectations, and values related to green infrastructures

In discussing their experiences, assumptions were sometimes expressed by the interviewees related to the effects from their green infrastructures, e.g. the promotion of interactions between organisms: 'I'm not an entomologist, but I'm sure the insects have a relationship between the grass and the trees and the bracken area … there must be a reaction or an interaction there' (V6). Interviewees additionally described how their green infrastructures had not always fulfilled their expectations regarding making their properties and ventures more sustainable. One interviewee had for example, expected their collective unit of green infrastructures to have a greater and faster impact on biodiversity promotion: 'And if anything, 30 years I've been here, I've seen a slight decline in biodiversity in terms of the number of butterflies or wildflowers or something … ' (V12).

Interviewees also described the ways in which they valued green infrastructures and the potential impacts they can provide. These values had sometimes influenced the implementation of green infrastructures and the way the structures were maintained. For example, interviewees valued people's well-being and biodiversity: 'It's definitely more on a personal level, I'd love there to just be flourishing wildlife everywhere' (V11), and nature:

> I think nature has a wonderful way of achieving a balance. If you don't interfere. And the trouble is most farmers is they interfere too much. And then nature gets out of balance and then you end up with problems (V12).

Some interviewees also discussed the value of green infrastructures in the contexts of their businesses: 'The value in this site is not just the wine. The value in this site, is the site itself. And the whole ecosystem. The woodland and the wildflowers which look amazing' (V10) or weighed them against other business values, e.g. producing high enough grape yields of sufficient quality and minimizing workloads: '… because the bigger the area, the more they'll look after the wildlife … From a business view I should clean it out, make it all clear and lovely, but I actually like it, like it is' (V5).

Understanding impacts

As noted in our prior results sections, some interviewees described how they did not want to overstate the impacts of their green infrastructures – either because they did not have this knowledge, or they had not officially studied the impacts. Interviewees also admitted to not always having considered certain impacts, e.g. related to working conditions or visitor experiences, and not knowing how to measure or study certain impacts: 'But these are all things that I want to do … I've never really thought about how I would measure this' (V7). There was, consequently, a call for further studies to be undertaken to understand impacts from green infrastructures and their management. Several interviewees did, however, describe how they undertook formal measurements to e.g. measure carbon sequestration and were engaged in green infrastructure trials or

experiments. Interviewees were interested in studies being carried out by persons with domain or research expertise but also indicated that they would like to conduct experiments themselves. Furthermore, when new findings about green infrastructures are generated, interviewees expressed the importance of them receiving this knowledge in an effective way. In this regard, interviewees recognized that certain voices may have more influence than others when it comes to knowledge exchange: '**…** but that's the way they do it, because that's what the consultant tells them to do. And some wildlife advisor telling them that he's concerned about the wildflowers. Not their problem' (V12), and how some findings may not be applicable to all contexts.

Discussion

Green infrastructure impacts are multi-dimensional and contextual

Overall, we found that interviewees described various sustainability benefits and challenges from their green infrastructures. Some of these impacts were interrelated and indirect (e.g. the attraction of additional organisms providing sonic benefits) – which sustainability impacts have been described to be within winegrowing in prior (Santiago-Brown, Jerram, et al., 2015; Santiago-Brown, Metcalfe, et al., 2015). Although not necessarily discussed within the context of viticultural sustainability, the impacts identified from green infrastructures have been found by other studies. In studies which have sought the viewpoints of viticulturists, positive experiences have included habitat provision for pollinators, windbreak (sheltering), on-site water management, promotion of pest management, soil erosion control, and aesthetic values (Goodall, 2020; Goodall et al., 2023; McWilliam & Wesener, 2021; Riekötter & Hassler, 2022). Regarding negative experiences, this has included reduced air flow, unwanted competition with the grapevines, and the attraction of pests (Goodall et al., 2023; McWilliam & Wesener, 2021; Schütte & Bergmann, 2019). One aspect which was not mentioned by our interviewees, but for example, in the interviews with viticulturists conducted by McWilliam and Wesener (2021), is how green infrastructure can contribute to the branding of wine, which could be of interest to explore further in the UK context. Furthermore, concerning e.g. tree structures, Riekötter and Hassler's (2022) described how these had provided sustainability benefits by generating cooling effects in vineyards and protecting grapes from sun damage. These impacts were not described in our study, which could be attributed to differences in study contexts.

The impacts described pertained to the various dimensions of sustainability. This multi-dimensional nature should be considered when promoting green infrastructures as part of sustainability efforts, e.g. sustainability certification schemes such as the SWGB (2023). For practitioners, if the multi-dimensional nature of these impacts is not considered, this could potentially result in unintended negative sustainability impacts when integrating green infrastructures in winegrowing systems, but also missed opportunities or opportunity costs from not obtaining certain benefits. In making this argument, it is important to recognize that impacts from green infrastructures must be understood in their respective contexts, not least in relation to management practices – which played a key role in reducing potential negative impacts (as in studies by Goodall et al., 2023; McWilliam & Wesener, 2021). Sustainability impacts were additionally influenced by green infrastructures' placements, the grape variety planted, the green infrastructure species, and climatic conditions. Other viticultural studies regarding green infrastructural impacts remark on the influence of external factors, e.g. features at the landscape level (Brambilla & Gatti, 2022). Contextuality also concerns who has access to and engages with the green infrastructures. In our study, interviewees described how certain benefits from green infrastructures may not be gained due to visitors and surrounding communities not having direct access to these. For certain cultural sustainability benefits (e.g. educational value) to be obtained in their full extent from green infrastructures, there may be a need to ensure that visitors and other stakeholders have an interest in green infrastructures or potentially, a sufficient level of understanding of their functions (Falk, 2006).

In terms of how experiences of green infrastructures are shaped by those engaging with these structures, it is important to recognize that the assumptions and expectations held by individuals regarding the green infrastructures, can influence the experiences articulated (Snyder, 1984; Villiger, 2024). We also acknowledge that the values held by the interviewees in relation to green infrastructures and their potential impacts may have factored into their experiences, as values shape our attitudes (Nazirova & Borbala, 2024). Furthermore, we found that

winegrowers had slightly differing perspectives on sustainability, as described by other studies (e.g. Riekötter & Hassler, 2022). Indeed, in the viticultural context, there are a multitude of perspectives of what sustainability is and the aspects it encompasses (Flores, 2018). What is deemed sustainable is contextual (Flores, 2018; Purvis et al., 2019), and can also be shaped by values and beliefs (Ives & Kidwell, 2019; Leiserowitz et al., 2005; Leonidou et al., 2022; Purvis et al., 2019). In our study, some interviewees discussed certain impacts which could potentially be interpreted as negative, but which were not perceived so by themselves. From our findings, we identify the opportunity for further research to be undertaken which explores the correlations between the values and perspectives held by UK winegrowers and the impacts they have experienced from green infrastructures.

Additionally, it should be noted that the experiences of green infrastructures and viewpoints on sustainability could differ between different types of vineyard stakeholders (e.g. vineyard managers, other workers, local communities, visitors). Some interviewees did not always consider these perspectives of other stakeholders, for example related to working conditions. To obtain an encompassing understanding of the sustainability impacts from green infrastructures in winegrowing contexts, it is however, key that the experiences of different stakeholders are considered.

Implications for research, policy, and practice

In undertaking our study, we identify opportunities for future research. Firstly, there is a need for further research regarding impacts from green infrastructures (as also found in Goodall et al.'s (2023) study) – including studies which account for the perspectives of different stakeholders. This is important as prior studies have described how knowledge related to green infrastructures and their management, together with recognition of their benefits, enable their integration (Goodall et al., 2023; McWilliam & Wesener, 2021; Schütte & Bergmann, 2019). Our findings indicate that both formal knowledge (e.g. research conducted by research institutions and practitioners) and informal knowledge (e.g. local research conducted by practitioners themselves not always with standardized approaches) generation routes (Šūmane et al., 2018), could be valuable towards studying impacts from green infrastructures. For findings from research to be locally applicable, studies may have to be repeated in different local contexts (Šūmane et al., 2018).

Secondly, it would be valuable to explore the ways in which values and perspectives held by winegrowers in the UK may shape how they experience sustainability impacts related to green infrastructures. More so, it could be of interest to simply further examine the values UK winegrowers associate with green infrastructures. This understanding of associated values could support the design of initiatives which promote green infrastructures, including by institutions and policy (as described by Leduc et al. (2023) for organic farming practices) – by allowing for communication strategies to target and be aligned with these values. Furthermore, it would be of interest to conduct a study with a larger sample of UK winegrowers representing different vineyards, to better understand the precise correlations between factors such as the type of vineyard management system and the size of the vineyard, and the reported sustainability impacts from green infrastructures. This could help to determine how (and if) these vineyard characteristics shape potential green infrastructural experiences.

Thirdly, there is opportunity to investigate how UK winegrowers attain knowledge related to green infrastructures and how this type of knowledge can best be delivered to them. The need for effective communication of knowledge surrounding green infrastructures in viticulture was also recognized by Goodall et al. (2023). At the policy and practice level, various institutions, organizations, and actors can play a role in furthering and disseminating knowledge surrounding green infrastructures in UK viticulture. This includes, non-departmental funding bodies such as UK Research and Innovation (UKRI, 2022) and research institutions, e.g. NIAB (2022). Additionally, vineyard employees and owners, educational institutions, and sector or trade associations can contribute to knowledge transfer and creation (Turner, 2010).

With winegrowers aiming to increase the sustainability of their vineyards, their experiences of the sustainability impacts from green infrastructures could come to shape the further adoption and maintenance of green infrastructures (Goodall, 2020; Goodall et al., 2023). Therefore, it could be valuable for institutions and policy to increase support for winegrowers to further manage challenges and enhance benefits related to green infrastructures. There are currently

governmental schemes at the UK level which could provide further monetary support for agriculturists to maintain and implement green infrastructures (UK Government, 2021, 2024; Welsh Government, 2022). These types of schemes should make sure to account for the costs related to the management of green infrastructures, as a limitation of similar programmes has been the lack of support for additional management requirements (Goodall et al., 2023). Additionally, it would be of value to increase education surrounding green infrastructures and their potential impacts. This would allow visitors and surrounding communities to vineyards to fully engage with green infrastructures and associated information, potentially leading to greater educational value being obtained from them (Falk, 2006).

Conclusions

In our study we undertook walking interviews across vineyards in England and Wales to better understand the sustainability impacts from green infrastructures in winegrowing systems as experienced by UK winegrowers. The study identifies a broad set of benefits and challenges across multiple sustainability dimensions, which are context-dependent – including related to environmental conditions, management approaches, and who is experiencing an impact. Regarding who is experiencing an impact and engaging with the green infrastructure, it is important to consider that the assumptions, expectations, values, and perspectives made and held concerning green infrastructures, green infrastructural impacts, and sustainability, could potentially play into the experiences of green infrastructures. Our study also identifies the need and opportunities for further research to be undertaken focused on the impacts of green infrastructures, the values held by UK winegrowers in regard to green infrastructures and sustainability, and knowledge management and exchange surrounding green infrastructures. Policy and practice could support this research and potentially provide further valuable support for UK winegrowers towards the management of sustainability challenges from green infrastructure.

Note

1. The emergent codes regarded the types of green infrastructures present; the types of impacts experienced; the management related to the green infrastructures; assumptions and expectations of green infrastructural impacts; values held of green infrastructures and their potential impacts; and learning and knowledge held surrounding green infrastructures.

Acknowledgements

The authors would like to thank Dona Frost for their input on the thematic guide and prompt questions for the interviews. Conceptualization – Engstrom, E. Formal analysis – Engstrom, E. Funding acquisition – Collins, C.M., Engstrom, E., Howe, C. Investigation – Engstrom, E. Methodology – Engstrom, E., Howe, C. Project administration – Engstrom, E. Supervision – Collins, C.M., Fish, R, Howe, C. Visualization – Engstrom, E., Prasow-Emond, M. Writing – original draft – Engstrom, E., Fish, R. Writing – review and editing – Collins, C.M., Engstrom, E.; Fish, R., Howe, C., Prasow-Emond, M.

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CRediT: **Ebba Engström:** Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing; **Myriam Prasow-Emond:** Visualization, Writing – review & editing; **Caroline Howe:** Funding acquisition, Methodology, Supervision, Writing – review & editing; **Catherine Matilda Collins:** Funding acquisition, Supervision, Writing – review & editing; **Robert Fish:** Supervision, Writing – original draft, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The study was conducted as part of the PhD research of Ebba Engstrom at the Centre for Environmental Policy, Imperial College London. This work was supported by the Natural Environment Research Council [NE/S007415/1] and the Centre for Environmental Policy, Imperial College London.

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References

Arcese, G., Lucchetti, M. C., & Massa, I. (2017). Modeling social life cycle assessment framework for the Italian wine sector. *Journal of Cleaner Production*, *140*, 1027–1036. https://doi.org/10.1016/j.jclepro.2016.06.137

Baiano, A. (2021). An overview on sustainability in the wine production chain. *Beverages*, *7*(1), Article 1. https://doi.org/10.3390/beverages7010015

Bardsley, D. K., Palazzo, E., & Stringer, R. (2019). What should we conserve? Farmer narratives on biodiversity values in the

McLaren vale, South Australia. *Land Use Policy*, *83*, 594–605. https://doi.org/10.1016/j.landusepol.2019.02.036

BDA. (2021). *Home*. Biodynamic Association. https://www.biodynamic.org.uk/

Bigot, G., Mosetti, D., Cargnus, E., Freccero, A., Moosavi, F. K., Lujan, C., Stecchina, M., Tacoli, F., Zandigiacomo, P., Sivilotti, P., & Pavan, F. (2022). Influence of vineyard inter-row management and clone on 'Sauvignon Blanc' performance in Friuli Venezia Giulia (north-eastern Italy). *Vitis – Journal of Grapevine Research*, *61*(2), Article 2. Scopus https://doi.org/10.5073/vitis.2022.61.53-62

Biodynamic Federation Demeter International. (2024). *Biodiversity – Demeter International*. https://demeter.net/biodynamics/biodiversity/

Brambilla, M., & Gatti, F. (2022). No more silent (and uncoloured) springs in vineyards? Experimental evidence for positive impact of alternate inter-row management on birds and butterflies. *Journal of Applied Ecology*, *59*(8), Article 8. Scopus. https://doi.org/10.1111/1365-2664.14229

Chambers, R. (1994). The origins and practice of participatory rural appraisal. *World Development*, *22*(7), 953–969. https://doi.org/10.1016/0305-750X(94)90141-4

Chang, J. S. (2017). The docent method: A grounded theory approach for researching place and health. *Qualitative Health Research*, *27*(4), 609–619. https://doi.org/10.1177/1049732316667055

Christ, K., & Burritt, R. (2013). *Critical environmental concerns in wine production: An integrative review | Elsevier Enhanced Reader*. https://doi.org/10.1016/j.jclepro.2013.04.007

Costa, J. M., Catarino, S., Escalona, J. M., & Comuzzo, P. (2022). Chapter 1 – achieving a more sustainable wine supply chain – environmental and socioeconomic issues of the industry. In J. M. Costa, S. Catarino, J. M. Escalona, & P. Comuzzo (Eds.), *Improving sustainable viticulture and winemaking practices* (pp. 1–24). Academic Press. https://doi.org/10.1016/B978-0-323-85150-3.00009-8

Cullen, R., Forbes, S., & Grout, R. (2013). Non-adoption of environmental innovations in wine growing. *New Zealand Journal of Crop and Horticultural Science*, *41*(1), 41–48. https://doi.org/10.1080/01140671.2012.744760

Emmel, N., & Clark, A. (2009). *The methods used in connected lives: Investigating networks, neighbourhoods, and communities*. NCRM Working Paper Series.

Engström, E., Fish, R., Howe, C., Collins, C. M., Roberts, B. J., Watkins, S., & Collins, A. (2025). Green infrastructure impacts in winegrowing: A systematic map. *Agriculture, Ecosystems & Environment*, *385*, 109546. https://doi.org/10.1016/j.agee.2025.109546

Evans, J., & Jones, P. (2011). The walking interview: Methodology, mobility and place. *Applied Geography*, *31*(2), 849–858. https://doi.org/10.1016/j.apgeog.2010.09.005

Falk, J. H. (2006). An identity-centered approach to understanding museum learning. *Curator: The Museum Journal*, *49*(2), 151–166. https://doi.org/10.1111/j.2151-6952.2006.tb00209.x

Finger, R., Zachmann, L., & McCallum, C. (2022). Short supply chains and the adoption of fungus-resistant grapevine varieties. *Applied Economic Perspectives and Policy*, *45*(3), 1753–1775. https://doi.org/10.1002/aepp.13337.

Flores, S. S. (2018). What is sustainability in the wine world? A cross-country analysis of wine sustainability frameworks. *Journal of Cleaner Production*, *172*, 2301–2312. https://doi.org/10.1016/j.jclepro.2017.11.181

Forbes, S. L., Cullen, R., & Grout, R. (2013). Adoption of environmental innovations: Analysis from the Waipara wine industry. *Wine Economics and Policy*, *2*(1), 11–18. https://doi.org/10.1016/j.wep.2013.02.001

Giffard, B., Winter, S., Guidoni, S., Nicolai, A., Castaldini, M., Cluzeau, D., Coll, P., Cortet, J., Le Cadre, E., d'Errico, G., Forneck, A., Gagnarli, E., Griesser, M., Guernion, M., Lagomarsino, A., Landi, S., Bissonnais, Y. L., Mania, E., Mocali, S., … Leyer, I. (2022). Vineyard management and Its impacts on soil biodiversity, functions, and ecosystem services. *Frontiers in Ecology and Evolution*, *10*, 1–21. https://www.frontiersin.org/articles/10.3389fevo.2022.850272

Goodall, A.-K. (2020). *Green infrastructure, ecosystem service and the enablers and barriers for implementation within wine-grape vineyards: A thesis submitted in partial fulfilment of the requirements for the Degree of Master of Natural Resource Management and Ecological Engineering at Lincoln University* [Thesis, Lincoln University]. https://hdl.handle.net/10182/12749

Goodall, A.-K., McWilliam, W., Meurk, C., Schelezki, O., & Muangsri, S. (2023). Evaluation of an incentive programme for increasing green infrastructure on vineyards. *Land*, *12*(9). Article 9. https://doi.org/10.3390/land12091765

Griffiths-Lee, J., Goulson, D., & Nicholls, E. (2022). Grape expectations: A survey of British vineyard land management practices from an environmental perspective. *Journal of Agriculture and Sustainability*, *15*, 1–26. http://infinitypress.info/index.php/jas/article/view/2099

Haddaway, N. R., Collins, A. M., Coughlin, D., & Kirk, S. (2015). The role of google scholar in evidence reviews and Its applicability to grey literature searching. *PLoS One*, *10*(9), Article 9. https://doi.org/10.1371/journal.pone.0138237

Harrington, L. M. B. (2016). Sustainability theory and conceptual considerations: A review of Key ideas for sustainability, and the rural context. *Papers in Applied Geography*, *2*(4), 365–382. https://doi.org/10.1080/23754931.2016.1239222

Homet, P., Gallardo-Reina, MÁ, Aguiar, J. F., Liberal, I. M., Casimiro-Soriguer, R., & Ochoa-Hueso, R. (2024). Viticulture and the European Union's Common Agricultural Policy (CAP): historical overview, current situation and future perspective. *Journal of Sustainable Agriculture and Environment*, *3*(2), e12099. https://doi.org/10.1002/sae2.12099

Ives, C. D., & Kidwell, J. (2019). Religion and social values for sustainability. *Sustainability Science*, *14*(5), 1355–1362. https://doi.org/10.1007/s11625-019-00657-0

Kinney, P. (2017). *Walking interviews*. Social Research Update. https://sru.soc.surrey.ac.uk/SRU67.pdf

Leduc, G., Billaudet, L., Engström, E., Hansson, H., & Ryan, M. (2023). Farmers' perceived values in conventional and organic farming: A comparison between French, Irish and Swedish farmers using the means-end chain approach. *Ecological Economics*, *207*, 107767. https://doi.org/10.1016/j.ecolecon.2023.107767

Leiserowitz, A. A., Kates, R. W., & Parris, T. M. (2005). Do global attitudes and behaviors support sustainable development? *Environment*, *47*(9), 22–38.

Leonidou, C. N., Gruber, V., & Schlegelmilch, B. B. (2022). Consumers' environmental sustainability beliefs and activism: A cross-cultural examination. *Journal of International Marketing*, *30*(4), 78–104. https://doi.org/10.1177/1069031X221128786

Luzzani, G., Lamastra, L., Valentino, F., & Capri, E. (2021). Development and implementation of a qualitative framework for the sustainable management of wine companies. *Science of The Total Environment*, *759*, 143462. https://doi.org/10.1016/j.scitotenv.2020.143462

Marta-Costa, A., Trigo, A., Costa, J. M., & Fragoso, R. (2022). Chapter 20 – standards and indicators to assess sustainability: The relevance of metrics and inventories. In J. M. Costa, S. Catarino, J. M. Escalona, & P. Comuzzo (Eds.), *Improving sustainable viticulture and winemaking practices* (pp. 391–414). Academic Press. https://doi.org/10.1016/B978-0-323-85150-3.00022-0

Martucci, O., Arcese, G., Montauti, C., & Acampora, A. (2019). Social aspects in the wine sector: Comparison between Social Life Cycle Assessment and VIVA sustainable wine project indicators. *Resources*, *8*(2). Article 2. https://doi.org/10.3390/resources8020069

McWilliam, W., & Wesener, A. (2021). Attitudes and behaviours of certified winegrowers towards the design and implementation of biodiversity farming strategies. *Sustainability*, *13*(3), Article 3. https://doi.org/10.3390/su13031083

Nazirova, Z., & Borbala, S. (2024). Values, attitudes and the behaviour paradigm: A systematic literature review. *Journal of Human Values*, *30*(2), 214–239. https://doi.org/10.1177/09716858241236902

Nesbitt, A., Dorling, S., Jones, R., Smith, D. K. E., Krumins, M., Gannon, K. E., Dorling, L., Johnson, Z., & Conway, D. (2022). Climate change projections for UK viticulture to 2040: A focus on improving suitability for pinot noir. *OENO One*, *56*(3), Article 3. https://doi.org/10.20870/oeno-one.2022.56.3.5398

Newing, H. (2010). Sampling. In H. Newing (Ed.), *Conducting research in conservation* (pp. 65–82). Routledge.

NIAB. (2022). *News: £350 K grant aids research into viticulture soil health and yields | NIAB*. https://www.niab.com/news-views/news/news-%C2%A3350k-grant-aids-research-viticulture-soil-health-and-yields

OIV. (2008). *OIV guidelines for sustainable Vitiviniculture: Production, processing and packaging of products* (resolution CST 1/2008; Issue Resolution CST 1/2008). https://www.oiv.int/public/medias/2089/cst-1-2008-en.pdf

OIV. (2018). *Functional biodiversity in the vineyard* (OIV Collective Expertise). https://www.oiv.int/public/medias/6367/functional-biodiversity-in-the-vineyard-oiv-expertise-docume.pdf

Pretty, J. (2007). Agricultural sustainability: Concepts, principles and evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1491), 447–465. https://doi.org/10.1098/rstb.2007.2163

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science*, *14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

Riekötter, N., & Hassler, M. (2022). Agroforestry systems in wine production-mitigating climate change in the mosel region. *Forests*, *13*(11), Article 11. https://doi.org/10.3390/f13111755

Rosas-Ramos, N., Baños-Picón, L., Tormos, J., & Asís, J. D. (2019). The complementarity between ecological infrastructure types benefits natural enemies and pollinators in a Mediterranean vineyard agroecosystem. *Annals of Applied Biology*, *175*(2), 193–201. https://doi.org/10.1111/aab.12529

Rusch, A. (2025). Nature-based solutions to increase sustainability and resilience of vineyard-dominated landscapes. *Basic and Applied Ecology*, *82*, 70–78. https://doi.org/10.1016/j.baae.2024.12.005

Saldana, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). SAGE Publications Inc.

Sandhu, S., Soosay, C., Harris, H., Hvolby, H.-H., & Sandhu, H. (2018). Ecosystem services for wine sustainability. In J. Marques (Ed.), *Handbook of engaged sustainability* (pp. 653–682). Springer International Publishing. https://doi.org/10.1007/978-3-319-71312-0_43

Santiago-Brown, I., Jerram, C., Metcalfe, A., & Collins, C. (2015). What does sustainability mean? Knowledge gleaned from applying mixed methods research to wine grape growing. *Journal of Mixed Methods Research*, *9*(3), 232–251. https://doi.org/10.1177/1558689814534919

Santiago-Brown, I., Metcalfe, A., Jerram, C., & Collins, C. (2015). Sustainability assessment in wine-grape growing in the new world: Economic, environmental, and social indicators for agricultural businesses. *Sustainability*, *7*(7), Article 7. https://doi.org/10.3390/su7078178

Schütte, R., & Bergmann, H. (2019). The attitudes of French and Spanish winegrowers towards the use of cover crops in vineyards. *Journal of Wine Research*, *30*(2), 107–121. https://doi.org/10.1080/09571264.2019.1568975

Skelton, S. (2025). *Englishwine.com*. EnglishWine.Com. https://englishwine.com/vineyard-database/

Snyder, M. (1984). When belief creates reality. In L. Berkowitz (Ed.), *Advances in experimental social psychology* (Vol. 18, pp. 247–305). Academic Press. https://doi.org/10.1016/S0065-2601(08)60146-X

Šūmane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., Rios, I. des I., Rivera, M., Chebach, T., & Ashkenazy, A. (2018). Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. *Journal of Rural Studies*, *59*, 232–241. https://doi.org/10.1016/j.jrurstud.2017.01.020

SWGB. (2023). *SWGB-Rule-Book-2023.pdf*. https://winegb.co.uk/wp-content/uploads/2023/04/SWGB-Rule-Book-2023.pdf

Tompkins, J.-M., Wratten, S. D., & Simpson, M. (2012). Enhancing ecosystem services in australasian vineyards for sustainability and profit. In N. J. Bostanian, C. Vincent, & R. Isaacs (Eds.), *Arthropod management in vineyards: Pests, approaches, and future directions* (pp. 139–157). Springer Netherlands. https://doi.org/10.1007/978-94-007-4032-7_7

Turner, S. (2010). Networks of learning within the English wine industry. *Journal of Economic Geography*, *10*(5), 685–715.

UK Government. (2021). *Environmental land management schemes: Overview*. GOV.UK. https://www.gov.uk/government/publications/environmental-land-management-schemes-overview/environmental-land-management-scheme-overview

UK Government. (2023, July 14). *Organic food: Approved UK control bodies*. GOV.UK. https://www.gov.uk/guidance/organic-food-uk-approved-control-bodies

UK Government. (2024). *Countryside Stewardship: Get funding to protect and improve the land you manage*. GOV.UK. https://www.gov.uk/guidance/countryside-stewardship-get-funding-to-protect-and-improve-the-land-you-manage

UKRI. (2022). *UKRI awards more than £8 m to innovative new farming concepts*. https://www.ukri.org/news/ukri-awards-more-than-8m-to-innovative-new-farming-concepts/

Villat, J. (2021). *Down to earth: Identifying and promoting regenerative viticulture practices for soil and human health*. https://dash.harvard.edu/handle/1/37370042

Villiger, D. (2024). The role of expectations in transformative experiences. *Philosophical Psychology*, *37*(5), 1091–1114. https://doi.org/10.1080/09515089.2022.2070063

Vinescapes. (2021). *South Downs National Park Viticulture Growth Impact Assessment*. https://www.southdowns.gov.uk/wp-content/uploads/2021/03/FINAL-VERSION-VGIA-V1.6-compressed.pdf

Welsh Government. (2022). *Sustainable Farming Scheme*.

WineGB. (2023). *WineGB Industry Report 2022*-2023. https://winegb.co.uk/wp-content/uploads/2023/06/WineGB-Industry-Report-2022-23-FINAL-4.pdf

WineGB. (2024). *Making our wines more sustainable*. WineGB. https://winegb.co.uk/our-wines/sustainable-wines-of-great-britain-certification-scheme/

Winkler, K. J., & Nicholas, K. A. (2016). More than wine: Cultural ecosystem services in vineyard landscapes in England and California. *Ecological Economics*, *124*, 86–98. https://doi.org/10.1016/j.ecolecon.2016.01.013

Winkler, K. J., Viers, J. H., & Nicholas, K. A. (2017). Assessing ecosystem services and multifunctionality for vineyard systems. *Frontiers in Environmental Science*, *5*, 1–14. https://www.frontiersin.org/articles/10.3389fenvs.2017.00015

Winter, S., Bauer, T., Strauss, P., Kratschmer, S., Paredes, D., Popescu, D., Landa, B., Guzmán, G., Gómez, J. A., Guernion, M., Zaller, J. G., & Batáry, P. (2018). Effects of vegetation management intensity on biodiversity and ecosystem services in vineyards: A meta-analysis. *Journal of Applied Ecology*, *55*(5), 2484–2495. https://doi.org/10.1111/1365-2664.13124