

Review

# Sustainable Development Directions for Wine Tourism in Douro Wine Region, Portugal

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**Abstract:** Despite sustainable wine tourism being one of the hottest topics of the moment, there is still a considerable knowledge gap. If managed with due care and consideration of the region's carrying capacity, wine tourism can be an essential regional development tool for improving business performance, environmental awareness, and community values. On the other hand, it can be responsible for negative environmental impacts, creating local resentment. This paper explored and contextualized wine tourism and sustainable winegrowing practices in the Portuguese Douro wine region. The aim was to offer practical recommendations and directives for such a unique landscape. From the adoption of regenerative agriculture and natural-based solutions at the field level to engaging in sustainability wine programs or certification schemes integrating both sectors, it is indispensable to develop frameworks to assess sustainability performance, tourism development, and the impact on the local population. Nevertheless, to accomplish business success and territorial development, a win-win relationship between all stakeholders is foremost needed. The Douro region must therefore start by investing in stronger collaboration networks between local actors through careful and integrated planning so that the needs of all interested parties, including its residents, are considered and incorporated in future sustainable tourism initiatives.

**Keywords:** terroir; viticulture; wine tourism; sustainable agricultural practice; clean productions



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## 1. Introduction

Wine tourism, as an experiential tourism activity that brings together wine, food, culture, and the experience of wine and how it is produced, has huge potential for wine-producing areas. It is important to promote sustainable tourism as a tool to attain sustainable development that can be used as a means of rural livelihood activity and an avenue to safeguard the natural environment. Wine tourism has multiple aims of promoting the economic wellbeing of local wine producers without compromising the integrity and quality of the natural environment. Thus, while providing a learning and a fulfilling wine experience to the tourists, it should support the conservation and sustainable use of natural resources and positively benefit local people and communities [1].

Wine tourism has long benefitted many Douro Demarcated Region (DDR) winegrowers. It offers various sources of income that wineries pursue such as accommodation, cellar door sales, events, and wine and food festivals [2]. It is seen as a brand differentiator that allows wineries to meet consumers and promote a long-term relationship with the wine consumed at its place of origin. Nevertheless, wine tourism must also encompass an expanding commitment to environmental issues such as biosecurity and sustainability. Since being sustainable can create benefits for the companies (in terms of marketing, corporate image positive feedback, or cost savings), sustainability has been used by winegrowers

as part of their business strategy [3]. However, some winegrowers misunderstand being sustainable with being organic or biodynamic. Therefore, it is urgent to understand if wine tourism in DDR is truly engaged in sustainability.

This paper aimed to clarify this question by providing a comprehensive examination of sustainable wine tourism (SWT) practices in DDR. This work explored and contextualized the wine tourism and sustainable winegrowing practices in DDR and outlined the main challenges that sustainable winegrowing and wine tourism currently face in the region. To the best of our knowledge, this is the first paper aimed to define sustainable development directions of wine tourism in DDR.

## 2. Wine and Territories: Wine Tourism as a Sustainable Development Tool

According to the recently published Intergovernmental Panel on Climate Change (IPCC) report, global surface temperatures have risen faster in the last 50 years than in any other equivalent period of the past two millennia, already affecting every region across the globe in some way [4]. The strong interdependence of viticulture to environmental conditions impels its susceptibility to the adverse impacts of climate change. Extreme weather events and rising global temperatures are already impacting and affecting the viability of renowned wine regions and their wine quality [5–7].

To cope with the climate change risks and impacts, market pressures, new environmental policies, and even reduced available inputs, the global wine industry is starting to recognize the benefits of embracing a more sustainable approach and perceive it as a competitive factor [8,9]. Winegrowers of today are therefore looking for and demanding means to improve their sustainability performance.

Institutional pressure is also considered one of the main stimuli for the development of several sustainability initiatives in the wine industry, including a demand for policy compliance [10]. In contrast, the lack of institutional support is also pointed out as one of the reasons for a slower rate of adoption of sustainable practices by small winery operations and the wine industry in general [11]. Support from organizations including the government, local agencies, and industry associations is required to assist the industry's quest for long-term sustainability while maintaining the business viability or product quality. Therefore, it is necessary to achieve a balance between national initiatives and firm goals. However, there are significant economic, environmental, social, and marketing issues at both the corporate level and within the governing bodies that are responsible for implementing sustainable winegrowing initiatives [11]. A strong environmental and social stewardship is the firms' competitive advantage that can only be perceived in the marketplace if consumers recognize wine companies' sustainability focus and orientation. In such regard, some defend the significance of wine tourism in businesses with the adoption of sustainability practices. Such a solution may be possible and a driver for naturalness, social and cultural sustainability, and even wine and national branding [11,12].

Considering that the relations between firms and the regions where they act are reciprocal, such interconnection is not only a key issue for the understanding of the development of both businesses and territories, but it is considered relevant in creating a sense of place as it affects the potential and attractiveness of the region itself. In this regard, wine tourism cannot be perceived as just tourism, mainly as the business models and innovation profiles of many of the wineries that are engaged in such activities today tend to be far more focused on the regional development and their social and institutional relationships than other businesses in the tourism sector [11,13].

As wine tourism is starting to be strongly developed in many regions around the world, its sustainability awareness must be questioned at the community level as well as at environmental and business level. It is important that the wine and tourism industries are concerned about long-term economic sustainability in the face of increasing competition, but they must find out how to highlight the landscape and cultural heritage while seeking benefits for residents [14–16]. This strong linkage between wine tourism to the culture and distinctive traits of the local community and place is well established in the literature.

According to some authors, for the wine tourism industry to be viable, it must combine ethical and resource conservation concerns with the local community's needs and culture to pursue diversification of the rural economy. When this perspective is taken, then we can assume sustainability becomes a comprehensive concept of such business models [14,17].

The International Organisation of Vine and Wine (OIV) has also established sustainable vitiviculture as being sensitive to social and cultural aspects by remarking that any sustainable development initiative should consider the objectives of stakeholders as well as the entire community [18]. Beyond referring to concerns related to working conditions and workers' health and safety, the importance of developing relations with the population and assuring proper integration with the local socio-economic and cultural environment is often pointed out. The role of rural areas with cultural specificities such as the classification of wine regions as United Nations Educational, Scientific, and Cultural Organization (UNESCO) world heritage sites, has also been recognized in protecting and respecting the culture and history of the region [18].

It is in this context that the qualification of the European wine regions and wines with geographical indications establishing intellectual property rights for specific products (Protected designation of origin, PDO and Protected Geographical Indication, PGI) is seen as crucial to the success of wine regions, namely through tourism. In Portugal, the recognition of vineyard heritages by UNESCO such as the Douro Valley (continental Portugal) and the vines of the Pico Island (Azores, Portugal) implies the protection of its unique elements or landmarks [19]. Thus, any development initiative in these territories, or "touristic terroirs" as coined by Johnson et al. [20], must always respect the landscape including its natural, social, and cultural resources. These wine regions, as the result of the natural environment and civilizational background, partake in the art of producing and trading wines with a terroir signature [21].

The suggestion here is that if wine tourism complies with preserving the authenticity, health, and quality of landscapes and terroirs, together with its facility in merging the primary (agriculture), secondary (wine industry), and tertiary (tourism) sectors, it can be an integrated tool for regional development and even national sustainable development goals. Through the lens of economic, social, cultural, environmental, and political affairs, wine tourism can therefore emerge as a form of sustainability driver for the wine industry for its capacity to improve business performance, environmental awareness, and enhance community values and relations network.

#### *Sustainable Wine Tourism*

Successful implementation of wine tourism in rural areas can be extremely challenging in some regions for being largely adverse to mass tourism features. If not managed with care, wine tourism can be responsible for negative environmental impacts, thus creating disputes with the rural communities. Friction with residents can be created from increased traffic because of growing tourist numbers, increased prices for rural properties, the feeling of a "shift in sense of place", among others. In other words, tensions emerge when the exchange relationship between wineries and tourists becomes more economic than social [22].

Napa Valley in California is perhaps the world's most developed wine tourism destination. They have reached a point where several de-marketing strategies were employed to limit development [14]. Already back in 1968, Napa Valley was voting to form an agricultural preserve and thus slowing business and residential incursion around that area. Twenty years later, large festive events started also to be banned to discourage mass tourism in the area. Such awareness and measures were made Napa Valley, and later South Africa, the early leaders of SWT [14].

Academia is also showing interest in the impacts and sustainability of wine tourism. It is currently one of the current hottest topics throughout the wine industry, especially after studies have identified basic aspects such as visiting wineries and experiencing the

attributes of a wine region as the most carbon-intensive element among all the phases of wine consumption and production [23].

Regardless of the increase in interest among researchers, several knowledge gaps are still pointed out among specialists. There is a lack of longitudinal studies scrutinizing sustainability aspects and outcomes from involvement in this activity, and there is a scarcity of research studies learning and comparing SWT practices and principles from different regions, either between the new and old world or emerging and more renowned wine regions [24]. Additionally, according to Montella [17], the main insights from academic research on SWT come mostly from the new world wine-producing countries. Another crucial knowledge gap is related to the limited availability of conceptual frameworks for understanding the various aspects surrounding SWT including community involvement, destination articulation in wine tourism, and successful SWT business models [21,25].

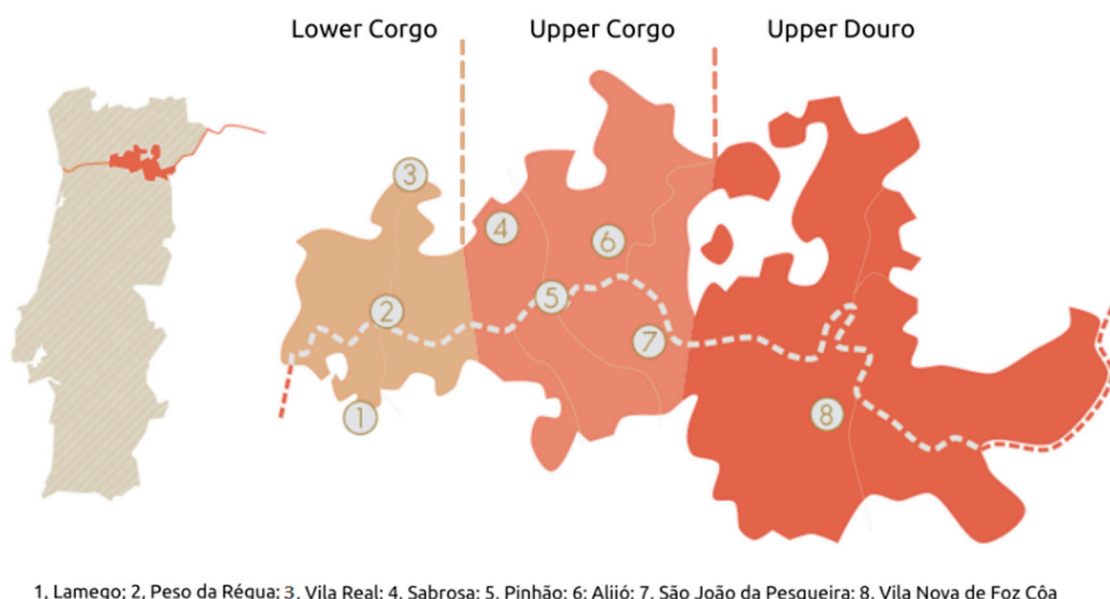
Research on SWT remains limited and is still in its beginning as opposed to sustainable winegrowing stages. Sustainable winegrowing can be summarized as sustainable development and marketing principles being applied to wine tourism in different settings [14]. Therefore, its ultimate implication should be to put sustainability principles at the heart of every decision about tourism at the wine estate. Besides being a leisure activity or an experience provided by the wine business to the tourist that is looking to create emotions, sensations, attachment, and sensory impressions, it also implies communication and education of sustainability awareness, working with local partners and communities, promoting regional development, and assuring natural surroundings are being preserved. It is thus a regional development tool capable of encouraging and being catalysts for change toward sustainability while highlighting the wine territory's attributes and uniqueness of the respective "touristic terroir" [20]. The bottom line is that with the booming of wine tourism, sustainability-oriented wineries must seek balance between economic profits emerging from the tourism business with the carrying capacity of their surrounding area, and the approval and involvement of the community [14,17].

### 3. Douro Demarcated Region: Sustainable Development Drivers

#### 3.1. *The Douro Valley: A Unique and Living Cultural Landscape*

Douro Demarcated Region is a wine-producing region that is approximately one hundred kilometers east of Porto city and the second largest city located in the northern region of Portugal. It is the first demarcated wine region in the world with boundaries administratively established in 1756 despite its landscape being carved by nearly 2000 years of wine production [13]. Within the Douro River basin, this region spreads over a total area of approximately 250,000 hectares with more than 43,000 ha currently occupied by vineyards. It is divided into three sub-regions that differ greatly from each other (Figure 1). The Lower Corgo, despite covering the smallest area has the largest amount of land under vines (29%) followed by the Upper Corgo, the next largest that spreads upstream along the Douro River with 22% of the area under vines. Finally, the biggest sub-region is the Upper Douro with only 9% of land under vines extending to the boundary with Spain [26].

Surrounded by craggy mountains that confer its characteristic Mediterranean-like climate, the region presents a favorable climate for the development of viticulture. For its deep valleys are protected by mountains, the climate in the region is characterized by very cold winters and hot-dry summers. The soil in which the vines are planted is mostly made up of schist with some granite [27]. The average elevation over the entire region is 443 m but ranges from a low near 40 m to a high of just over 1400 m [28]. According to the Centre for the Research, Study, and Advancement of Mountain Viticulture (CERVIM), the Douro region is the largest and most heterogeneous mountainous wine region in the world. Here, there are hillside vineyards, and more than 40% of the vines are planted in plots with a gradient greater than 40%, which hampers mechanization, demands for intensive manual labor, and increments production costs [29].



**Figure 1.** Sub-regions of the DDR.

The precipitation volume varies throughout the region. In terms of the annual rainfall, the total amount of rain decreases as one goes to the Spanish border ranging from 1200 mm in Lower Corgo to 380 mm in Upper Douro [28]. In regard to the amount of sunlight, the north bank of the river is influenced by the dry southerly winds where the highest average annual temperatures are found, mostly along Douro's riverside. The average annual temperatures range from 11.8 °C to 16.5 °C, despite the average temperature of 17.8 °C for growing seasons [28].

The wide range of wine grape cultivars that exist in the Douro Valley and that adapt themselves to different climatic conditions is proof of the region's ability to offer optimal conditions for vines. The varieties are about 78% red and 22% white grape, many of which are indigenous to the region and often chosen according to their compatibility with the characteristics of the planting area [28]. The most noteworthy red varieties are: Tinta Amarela, Tinta Barroca, Tinta Roriz, Touriga Francesa, Touriga Nacional, and Tinto Cão; for white varieties, there are predominantly Malvasia Fina, Viosinho, Donzelinho, and Gouveio. Additionally, the vines in the region are not known for their high yield. The average yield is 4.100 kg/ha even though the maximum production authorized by the regulatory body is 55 hL/ha, or approximately 7.500 Kg/ha [26]. Despite low yields, the Douro region in 2020 produced 20% of the total wine made in Portugal in that year, around 1,264,349 hL [26].

Wine is deeply rooted in the cultural, social, economic, and environmental history of the Douro Valley, its vines being worked today by approximately 20,000 farmers [27]. The average area under vines per farmer is close to 2.0 ha, thus family farms and smallholder farms are still quite representative in the region, mostly in the production of grapes for Port wine [27]. These small- and medium-sized grape growers are mostly members of wine cooperatives. In contrast, roughly 35% of the DDR is owned by less than 4% of the grape growers, the average farm size for this group being ten times higher. Most of these farms belong to wine producers and traders of Port wine [30].

### 3.2. Historical Overview of the Douro Demarcated Region through the Lens of Sustainability

Sustainability has been usually defined considering three dimensions: economic, social, and environmental. Recently, some studies have considered new dimensions such as cultural sustainability and governance. It is common to find reports about sustainability that address each pillar independently. However, this is not possible in real life because sustainability practices always have consequences in all dimensions.



In DDR's story, we can find several examples of the importance of looking for all dimensions. On 10 September of 1756 when Sebastião José de Carvalho e Melo, the future Marquis de Pombal, created the Companhia Geral da Agricultura das Vinhas do Alto Douro (further designated as Companhia) and the DDR, his goal was to delimitate the territory but also to have a legal system that included production control, the implementation of taxation and prices for trade, the classification of wines for exportation, and the prevention of frauds. He aimed to create a sustainable system, from which the economic point of view was successful in the first years of the 19th century. At that time, the Douro wines exports already represented 80% of the total Portuguese wine sales. However, as this strategy only considered the economic dimension, social problems soon appeared due to the lack of consensus in society. Douro farmers, estate owners, and Portuguese merchants supported Companhia policy that was highly contested by British shippers, Porto taverners, and some clergy members of the governmental body, due to their significant loss of power. The combination of freer trade as pressured by the British and a liberal political movement may explain why, until the 19th century, the Companhia was successively reduced, suspended, re-established, and finally dismissed. With the abolishment of the restrictive policies that regulated the Port wine trade, the lack of supervision encouraged the occurrence of frauds and imitations, which affected Douro wine's reputation and economic value. At this time, many new vineyards were planted without control or attention to quality with environmental consequences [31,32].

At beginning of the 19th century, vineyards were destroyed by the epidemics of oidium and phylloxera which forced winegrowers to establish themselves in the Upper-Douro where the devastation was less aggressive, causing an increase in DDR area. At that time, winegrowers were only concerned with solving that specific problem; however, their decision had economic, social, and environmental consequences that still present today: natural and cultural diversity resulting from the aggregation of a new geographic setting; the spread of novel viticultural and winemaking practices; and the loss of biodiversity due to the substitution of endemic vine species as well as excessive use of pesticides [32]. Another example of environmental impacts of winegrowers' decisions is the fact that almost all vineyards in DDR are domestic vines on American rootstocks because this was the solution found to fight phylloxera; North American vines that were being imported were, contrary to Douro vines, immune to the insect. Additionally, the treatment applied against the other two plagues, mildew (downy-mildew) and oidium (powdery-mildew), became mandatory. Those pests greatly affected the farmers in the Douro, and many of them were forced to sell their properties and emigrate. It was the merchants in Porto who benefitted the most as they were able to increase their influence in the Douro by purchasing wine estates or Quintas. New owners built patamares (wide terraces) and established different viticultural practices to fight the viticultural epidemics and to revitalize the production. In 1907, the demarcation system was re-established, which had expanded its supervision towards the Upper Douro [32].

The period between the 1st Republic (1910) and the establishment of the new dictatorship (1926) was the most agitated in the history of the DDR due to the many social inequalities. This period is a good example of how governance and regulatory requirements are important in shaping sustainable winegrowing. In 1932, the Syndicated Federation of Douro Region Farmers (Casa do Douro) was created and one year later, the Port Wine Shippers' Guild was created as a sectorial association that endeavored to discipline the trade. The activities of both entities were coordinated by the Port Wine Institute (IVP), established also in 1933, mandated to supervise quality, guarantee the origin, undertake technical studies, and promote Porto. The IVP controlled the quantity and quality of the appellation's wines by regulating the production and certifying the product based on a strict quality control process. Because of IVP's activity, Port wine production in DDR became highly regulated with economic, social, and environmental consequences. It can be speculated that stricter governance was fundamental to ensure all wineries followed appropriate sustainability practices that led them to where they are today [32].

The time around the Portuguese democratic revolution of 1974 saw profound changes in the Douro. Again, these transformations have dramatically changed both the practices within the winemaking process and the physical territory. A railroad along the river was built, and wine road transportation became viable and was authorized. Almost 80% of all wines traded internally and externally were bottled, contributing to a significant rise in prices. The territory's viticulture was slightly modernized with viable mechanical means. With the financial help of a wide-ranging program of rural development supported by the World Bank, almost half of the DDR was replanted and redesigned to become a mix of *socalcos* (terraces), *patamares* (wide terraces), and *vinha-ao-alto* (vertical vineyards). All these transformations were made to improve the economic dimension and potential of DDR, but the other dimensions were not integrated, with severe consequences for the environment [32].

The second half of the 20th century signaled the revival of Douro's unfortified wines. Douro's dry wines were made either from the surplus of the best grapes reserved for Port wine production or the lowest rated grapes. In 1982, intellectual property rights of the geographical indication CDO (Controlled Designation of Origin) were also granted to dry wines of the region (CDO Douro). Reflecting a new awareness and the responsibility of safeguarding all wines (not just Port wine) within the territory, in 2003, the IVP became the Douro and Port Wine Institute (IVDP).

For all that matters, including the DDR history, it is important to highlight both the main problems and the challenges that are driving wine sustainability today. The DDR's unique characteristics—rough physical conditions, costly production, and low yields—demand that all dimensions are integrated into the sustainability strategy. As the concept of *terroir* includes a set of environmental factors, including farming practices, and other anthropogenic factors that collectively affect the phenotype of a crop, the concept of sustainability includes several dimensions that can collectively affect the future.

### *3.3. Sustainability Issues within the DDR Wine Industry: Environmental Impacts and Sustainable Practices*

Despite an incremental sustainability awareness amongst the global wine industry, currently, there is still a predominant focus either regarding environmental concerns or assessing specific impact categories (e.g., carbon footprint). There is therefore an emerging gap relating to social, cultural, economic, political, and ethical factors [33]. Nonetheless, the reality is that against previous beliefs, the wine industry is finally being held accountable for severe impacts either on the ecosystem or on surrounding communities and territories [34]. Environmentally, the largest concerns frequently reported tend to be related to the amount of waste generated, soil and water contamination due to pesticides use, and peaks of water and energy usage [35]. Packaging materials have also been in the spotlight, as according to previous studies, the wine supply chain contributes 0.3% to the global GHG emissions, a massive contribution when we are only referring to a single type of product [36].

In the next subsections, the industry's main environmental impacts and sustainable winegrowing practices that are already being adopted in DDR are reviewed and discussed.

#### *3.3.1. Practices for Water Reuse and Reduction of Water Use*

Viticulture water footprint, which measures the amount of water needed to produce goods and services, is estimated at 610 L/kg of grapes produced, i.e., 870 L per bottle of wine, considering a global average [37]. In Portugal, very few studies have been conducted to estimate viticulture water footprint. A study showed that 400 to 500 L of freshwater use is associated with the production of one bottle of Portuguese white wine from the Vinhos Verdes region with a total liquid volume of 0.75 L. However, the results were inconclusive as they varied with the assessment method used [38].

Martins et al. [39] performed a sustainability evaluation of Portuguese wines based on the life cycle assessment (LCA) methodology. One of the wines was a "terroir" wine from the Upper Douro Valley region, produced in small quantities using grapes from a single

vineyard associated with the winery where the grapes are processed and fermentation occurs. The other wine was a branded wine, produced in large quantities using grapes from several Portuguese vineyards, mainly located in the north of Portugal but with significant differences in climatic conditions and even agricultural practices. The authors found that the water consumption for the branded wine was more than double the value for the “terroir” wine, using 4.93 and 1.58 L of water/0.75 L wine, respectively. For wastewater, similar differences were observed between the two wines. Moreover, the dominant life cycle stage was different: winemaking (because of the wine desulfitation process) for the branded wine and bottling for the “terroir” wine (bottles rinsing operation) [39].

The effective efficiency of the wastewater treatment system and estimation of its overall impact on the winery water footprint was assessed for a medium-sized winery located in the south of Portugal, Tagus wine region, with a production capacity of 750,000 L. It was found that the winery water footprint ranged from 9.6 to 12.7 L of water per wine bottle of 0.75 L, the wastewater produced being responsible for about 98% [40].

Recently, the water footprint in the wine sector was evaluated from the vineyard to the bottle through the implementation of a methodology based on field experiments and LCA on two Portuguese case studies in the south of Portugal (Lezíria do Tejo and Alentejo). Regarding direct water footprint, it ranged from 366 to 899 L/0.75 L bottle. The study revealed that although more than 97.5% of the water footprint was associated with vineyards, the winery stage was responsible for more than 75% of the global warming potential indicator [41]. Due to climate change projections for DDR that reveal warming and drying trends for the upcoming decades, a yield decrease is expected. One of the possible solutions to face this is irrigation. Even so, DDR yield levels are still projected to decrease with irrigation (70–80% of baseline yields), though to a lesser extent when compared to non-irrigated simulations. This decrease is attributed to the synergistic effect of severe heat and water stresses in the future [42].

Therefore, to attain sustainable viticulture, it is essential to ensure effective water management. It is urgent to increase investigation that provides both tools to estimate vineyards’ water status and strategies to optimize the effective implementation of sustainable water management and irrigation in viticulture. The use of unmanned aerial vehicles (UAVs) to acquire aerial imagery using RGB, multispectral, and thermal infrared sensors in a vineyard located in the DDR enables the multi-temporal characterization of the vineyard development throughout a season through the computation of the normalized difference vegetation index, crop surface models, and the crop water stress index [43]. Recently, a study carried out in DDR (Upper Douro) evaluated the potential of a ground robot (VineScout) to assess and map vineyard water status using thermal infrared radiometry in commercial vineyards under different irrigation treatments. The authors found that this approach could be helpful in decision making concerning precise variable rate irrigation to increase water use efficiency, wine-making sustainability, and yield quality [44].

There are some examples of good water use practices in DDR. In Sogrape vineyards equipped with irrigation, only drip irrigation during the night is used. The water used to wash all packages containing chemical products is reused to dilute spraying chemicals. To reduce water waste, all farming and winery equipment is washed with pressurized water for waste reduction [45]. The increase in the water use efficiency of grapevine can reduce the irrigation need. The foliar application of kaolin suspension (5%) to Touriga-Franca and Touriga-Nacional varieties over two consecutive growing seasons in DDR enhanced water use efficiency and can be used in the future as a sustainable measure to reduce water use [46].

Regarding wine tourism, it is also necessary to decrease water use, which is higher than the residential water use, and evaluate the impact of the generation of wastewater on environment sustainability. For that, it is urgent to carry out studies that evaluate the situation to define a strategy for reduced water use.



### 3.3.2. Practices for Reduction of Pesticides, Fungicides, and Herbicides Use

The use of herbicides, pesticides and synthetic fertilizers have all proven to give rise to problems. Although their toxicity levels vary, all these chemicals can be dangerous to air, water, soil quality, vineyard workers, and neighboring people and animals that share the ecosystem. On the other hand, the implementation of environmentally friendly production methods such as the abdication of chemical pesticides is costly due to enhanced manual labor. The bottom line is that chemical usage issues have provided causes for concerns among the wine industry for presenting a risk of contamination to soil and potentially jeopardizing water sources as well, along with market and policy pressure.

In DDR soils, residues of several pesticides were found with older vineyards showing higher levels of copper and banned insecticides (such as DDT). Therefore, it is important to be aware that some pesticides can remain in soils for several years, or even decades, long after their use [47]. The application of copper-based fungicides and bactericides against downy-mildew are permitted in organic farming due to the lack of alternatives.

Another concern is regarding biodiversity loss due to the inappropriate use of chemical products in viticulture. These can devastate the vineyards' natural defense network by damaging populations of natural predators. In retrospect, biodiversity drop promotes the application of stronger chemicals to protect the vineyard against pests and diseases, having a significant effect on the overall cost per ton of grapes produced [11].

Chemical use is not solely related to wine grape growing processes. It also occurs during the cleaning and maintenance processes for the equipment that is used in the winemaking and bottling stage, as well other side businesses such as wine tourism.

Regarding DDR, more studies are needed to evaluate the contribution of the active ingredients in fertilizers and pesticides used in vines to the carbon footprint. The results of those studies are important to outline strategies to optimize viticulture sustainability by maximizing crop productivity and reducing or preventing soil and water contamination by pesticides. One possible strategy consists of the in situ application of organic residues as organic amendments. This method allows increasing soil organic matter content, and it can be used to control soil and water contamination by pesticides. This promotes the immobilization of pesticides in soil organic matter, enhancing their subsequent biodegradation, and preventing or reducing their potential mobility into water resources. Besides that, it delivers nutrients to the soil by increasing organic matter content, promoting soil fertility and plant growth and stimulating ecological restoration with concomitant benefits for the health of the soil ecosystem. In addition, some organic materials require minimal pre-treatment before their application to the soil because of their biological origin [48].

In Portugal, it is required by law that pesticide applicators have received training for their purchase and use of pesticides. However, the application of pesticides by winegrowers is often not performed according to the regulations. Therefore, a high exposure to these compounds occurs which can have major effects on the health of the farmers. A study carried out to evaluate the effects of pesticides on the acetylcholine pathway in the winegrowers of Upper Douro alerted to the dangers associated with those products and to the importance of security regulations for agricultural activity [49].

Finally, considering the difficulty to convince wine producers to adopt natural approaches towards pest management as a result of the use of synthetic alternatives in conventional agriculture being more economical and less labor intensive, it is crucial that future research find ways to quantify and articulate the economic and environmental benefits associated with natural approaches to viticulture and land management. Research on biodiversity-oriented approaches or ecosystem services valorization based on vineyard management practices is still uncommon [11].

### 3.3.3. Practices for Improving Soil Management

To produce wines of high quality, winegrowers must control vine vigor and vine growth, which depends on appropriate soil management: soil conservation, soil nutrition, water content, biodiversity for pest control, and resource availability regulation. Moreover,

the maintenance of the soil's biological potential increases or maintains soil organic matter content, which contributes to long-term soil preservation [50]. Soil management aims to prevent the degradation of the natural characteristics of soil, enabling its exploitation based on sustainable procedures. However, one must not forget that the unique landscape of the DDR is a combined work of humans and nature over poor soil. Despite its beauty and potential to produce worldwide acclaimed wines, mountain vineyards are naturally prone to erosion processes, mainly due to steep slopes and complex topography as erosion can be triggered by rainfall intensity and slope gradient. Nevertheless, plant cover and land uses are also considered key factors for the intensity of soil erosion, explaining why soil loss is a significant environmental problem in semi-arid agricultural environments of Mediterranean Europe, especially in vineyards. According to Pacheco et al. [51] the main reason for the high erosion rates in these vineyards is because soil is almost bare for a large part of the year. Additionally, cases of soil loss increment are frequently related to deforestation and substitution of forests by crops, meadows, or permanent cultures such as orchards or vineyards [51].

A common and unproductive consequence of soil erosion is hillside instability. This instability of the slopes can cause landslides with important damages to the infrastructure and significant economic losses for the grower. It is estimated that damages caused by landslides can cost up to 14% of annual incomes from the vineyards [51]. Proper conservation practices are therefore needed to guarantee sustainable soil management.

DDR is in mountain or sloping land, where there is a high possibility of erosion risk, which has for long been tackled with traditional soil conservation structures, as is the case of dry-stone walled terraces. In DDR, erosion from a vineyard-dominated watershed was estimated to be  $12.2 \text{ Mg ha}^{-1} \text{ yr}^{-1}$  [17]. This is a relatively high value but acceptable considering being equivalent to regional-scale erosion rates estimated for other vineyard hill slopes in France:  $10.5 \text{ t ha}^{-1} \text{ yr}^{-1}$  in Languedoc and  $2.6 \pm 12.3 \text{ t ha}^{-1} \text{ yr}^{-1}$  in Burgundy. Although, erosion risk in vineyard fields from Spain seems to greatly exceed these numbers with average erosion approaching  $22 \text{ t ha}^{-1} \text{ yr}^{-1}$ , with the lowest soil loss threshold locally assumed to be  $5 \pm 11 \text{ t ha}^{-1} \text{ yr}^{-1}$  and the highest reported to be  $30 \text{ t ha}^{-1} \text{ yr}^{-1}$  in Navarre. Several other case studies developed in sloping vineyards from the Aosta Valley region, in the Italian Alps, proved that the disparity of erosion rates among the different settings is deeply related to changes in the plant cover and land use of a region [52].

To reduce soil losses, proposed management measures for common situations often include a superficial tillage using a rotary hoe. Notwithstanding, it is defended that the most effective management practice is the replacement of conventional tillage by soil treatments with cover crops. It has been demonstrated that the use of cover crops in vineyards to prevent erosion is cost effective if all on- and off-site costs are considered, including ecosystem services in the long term [52]. In summary, nature-based solutions against erosion can be effective for soil conservation in vineyards, protecting against splash erosion, reducing runoff, and improving the soil structure.

#### 3.3.4. Waste Management and Minimization Strategies

Solid waste generation is one of the major issues facing sustainable wine production, and the rudimentary ways in which waste minimization strategies have been implemented by many wineries have resulted in an ineffective process for dealing with such a problem [11]. Solid waste can have organic or inorganic origins. While organic waste in the wine production process includes by-products such as grape pomace (62%), lees (14%), stalk (12%) and dewatered sludge (12%), inorganic waste materials comprise different kinds but mostly plastic-based byproducts such as pesticide containers, irrigation lines, old netting, vine guards, packaging waste, and polythene [53]. The methods that wine producers should utilize for waste disposal varies with its origin and composition.

This challenge is further complicated by a lack of winegrowers' knowledge regarding waste production, treatment, and disposal options, leading often to ineffective or even improper solutions [11]. According to many wine countries' laws, industrial waste must be

recycled, valorized, or disposed of, with waste disposal being more often chosen. The two most common types of inorganic waste disposal are incineration or depositing materials in landfills [54].

Despite organic waste usually requiring specific disposal treatments due to contamination and odor issues, some of these wastes are reported to be used as by-products or incinerated or disposed in landfill [53]. Some environmentally friendly technologies have also been more developed for the valorization of winery waste products, or cosmetic or pharmaceutical industries for example, encouraging companies to invest in new technologies that not only allow them to decrease their environmental impact but also to establish new processes that can provide additional sources of income [54]. Several alternatives have also been proposed to recycle and valorize these residues. One of the simplest and functional alternatives, especially for grape pomace or marc, is their use as growing media or organic fertilizers by direct addition into soils or after composting. However, more research on this matter is needed as some negative effects can be observed in the soil when some of these wastes are used as an organic fertilizer, contributing for nitrogen immobilization or nitrogen leaching increment in soils directly amended with residues [55]. Some polluting characteristics of residues and incompatible properties with agricultural requirements require for specific procedures and ways to condition the waste prior to use for agricultural purposes [55]. However, composting has been proposed as the best technically and economically feasible new management procedure for organic wastes. In Ruggieri et al. [53], composting was defended as the best solution for closing the organic matter cycle as costs are almost negligible and it presents one of the best environmental performance and impact, and from an energy standpoint, composting systems involve less energy than other systems based on mineral fertilizers [53]. The bottom line is that there is a considerable lack of knowledge in the wine industry on the composting process from a technical point of view, which supports the traditional disposal of waste directly in landfills or its incineration, both solutions being often neither economically nor environmentally sustainable [53].

### 3.3.5. Carbon Footprint and Practices to Improve Energy Use Efficiency

When looking at mitigation measures toward climate change impacts and global warming, reducing the total amount of greenhouse gas (GHG) emissions being produced either by an organization or product is critical. As aforementioned, this topic is starting to gain incredible attention from the wine industry.

According to Rugani et al. [36], the carbon footprint (CF) for a generic bottle of wine is on average  $2.2 \pm 1.3$  kgCO<sub>2</sub> eq. Overall, viticulture activities, packaging, and end-of-life are the most significant processes [36]. Viticulture activities contribution is estimated to be 17% on average, but possibly reaching values as high as 50%. The biggest issue of this life cycle stage is the use of pesticides and fertilizers, mostly because of their energy and fuel consumption in the production process coupled with transportation activities and application practices due to the large release of N compounds [56]. Regarding winemaking activities, this stage can contribute to the total CF of a generic wine bottle by 10% to 15% on average but can reach 27%. Literature focused on this life cycle stage has reported that energy consumption at the winery, including electricity consumption from the use of air-conditioning systems, is the main issue associated with CO<sub>2</sub> emissions during this production phase [57].

Carbon footprint issues are not only directed concerns for winegrowers but the entire supply and value chain of wine including retailers and consumers, as the logistics involved in wine production and distribution are pointed out as one of the key issues for the intensive CF that the industry leaves in terms of energy use. Studies that examined the wine supply chain found that this area contributes massively to the global GHG emissions [36]. More than 50% of the GHG emissions involved in wine production occurs in the post-production phase. The main affairs identified by the literature are related to packaging processes, mainly because of the glass bottle production and transportation. When analyzing different

wine and spirit packages, it has been often reported that a single-use glass bottle represents the most impacting packaging solution in terms of CO<sub>2</sub> eq emissions. The packaging end-of-life also plays a key role in the final CF value, but there is considerable variability of results due to lack of data quality [57].

In summary, the main environmental practices that are usually identified by wine-makers as being a priority include the reduction of pesticides, fungicides, and herbicides, and water reuse, soil management, and treatment of solid waste companies. These are important sustainability practices but cannot be implemented when considering only the environmental dimension. Implementation must meet some basic criteria that are also directly related to the economic performance of the winery and social inclusion.

#### 4. Designing and Planning Sustainability Initiatives for the DDR

##### 4.1. Wine Tourism in Douro Region

Tourism in Portugal has flourished since 2012 and Portugal is today considered one of the five most visited European countries [58]. Becoming such a popular tourist destination has encouraged the development of wine tourism in most of its 14 wine regions. Wine grape growing is the main agrarian culture in the country and an activity closely associated to the national cultural heritage and traditions, responsible for local economic growth, job creation, and other social effects in rural areas [59]. The wine sector is therefore highly meaningful to the Portuguese economic and social landscape, and wines continue to be one of the main products exported with leading commercial surpluses [60].

As aforementioned, wine tourism can provide a competitive advantage for rural regions with the wine industry, DDR included. This potential advantage is extremely important especially when we are referring to the Douro, a region that apart from being isolated from mass markets, has a low population density, is relatively weak in terms of internal linkages, is subject to ageing and out-migration, and lacking in innovation and entrepreneurship. However, its uniqueness due to the living and evolutionary viticulture was a deciding factor in its designation by UNESCO as a World Heritage Site [19].

Moreover, even though the economic and social evolution of the Douro Valley is intrinsically linked to the production of Port wine, the most widely exported Portuguese wine and a hallmark of the country's identity, Port businesses tend to concentrate tourism flows outside the region mostly in Porto city or Vila Nova de Gaia, the home to the Port wine cellars [61]. According to the Portuguese Port Wine Business Association (AEVP), Porto and Vila Nova de Gaia during pre-pandemic periods (before COVID-19) were receiving more than 1.5 million visitors per year [62]. Regarding such tendencies, it seems indispensable to develop and enhance sustainable wine tourism directives for the region. Nonetheless, such strategies must note and consider the negatives that can emerge with excessive growth in tourism. Despite DDR having some significant improvements in accessibilities in the last decades, wine tourism development must be undertaken with due care and consideration of the locality, ensuring that its natural resources are being protected. Thus, further steps in this regard should consider the local population's perspectives and concerns along with the regions' carrying capacity.

Research analyzing the relationship with sustainable tourism from the perspective of residents has been published. The main concerns raised by participants were often in regard to environmental sustainability and the natural resources that might become under pressure if the wine industry and tourism grows. Rapid urbanization of smaller cities and their surroundings is also mentioned as a potential threat to other rural sectors, along with the phenomenon of formal and informal development that can affect already established regional wine routes [25].

Andrade-Suárez and Caamaño-Franco [62], when studying Vila Nova de Gaia residents' impressions, concluded that wine tourism was favorably perceived as one of the principal sources of income for the local economy, while culturally seen as positive for the improvement of the city's image and cultural exchange. It was also acknowledged that tourism enhances the provision of public services and infrastructures while promoting

the maintenance and restoration of the historic and cultural heritage, linking it with its environment. On the other hand, several aspects were pointed out as threats to the quality of life of the residents and potential worsening of natural resources and the local ecosystem including that tourism leads to changes in and loss of the area's traditional culture and increased levels of rubbish, noise, and pollution.

Regarding the biggest wine tourism tendencies in the Portuguese market, we have wine routes, wine festivals, and some enterprises. About wine festivals, the most well-known is the Wine in Azores festival and the Madeira Wine Festival, one of the oldest European wine festivals held since the 15th century [16]. As for wine routes, such thematic itineraries are today one of the most common that wine tourism offers in Portugal [19]. Wine routes started to be implemented in 1993 with the participation of the country in the Dyonisios European Union Program [63]. In the last decade, all routes have significantly increased their number of adherents, from wine cooperatives and their unions to wine-growers' associations, winegrowers-bottlers, storekeepers, wine shops, wine museums, rural tourism, and country houses, among others. Until recently, Portugal had 12 main wine routes [16]. However, in 2021 the project "Porto and North of Portugal Wine Tourism Routes" was created to help to boost sustainable tourism in the northern region of Portugal. This initiative is described as an interconnection, whether physical or functional, capable of arousing significant networking as a means of creating differentiated wine tourism experiences between four different wine regions: Douro, Vinhos-Verdes, Távora-Varosa, and Trás-os-Montes. This is a relatively recent activity in Portugal, but it is defended because the use of synergies may allow this route to become the biggest tourist attraction in northern Portugal and provide a major contribution to the local economy and regional development (<http://www.portoandnorthwineroutes.pt/> (accessed on 14 March 2022)). Sustainability principles have been considered for participation, as candidates will have to go through several selection criteria of which one of the guidelines suggests the implementation of an integrated development strategy with the assumption of responsibility over the land, the adoption of sustainable practices, consumer education, and the protection of natural resources and heritage (<http://www.portoandnorthwineroutes.pt/> (accessed on 14 March 2022)).

#### 4.2. Porto and North of Portugal: A Prominent Tourism Destination of Choice

Douro region being characterized as a depressed region in terms of having a low population density, and the fact that its holdings of small parcels are mostly farmed by elderly growers with lower income and education levels seems to sustainance the low attractiveness and the repulsion of the region to younger generations [61]. Notwithstanding, Douro has been considered for centuries as one of the most important wine-producing regions in Portugal due to the production of Port wine and its remarkable weight in the total Portuguese wine exports [27]. Port wine has been sold on the world market for over 250 years, and almost 85% of its production continues to be exported to more than one hundred countries today [13,64].

Furthermore, in spite of wine grape growing in Douro being mainly characterized by small businesses with a family orientation in rural areas which can be challenging for tourism activity [16], the region has also watched in the last ten years an exponential growth in the number of wine-producing estates with the potential to engage in tourist activity. Thus, the DDR fits the terroir model as its economy is mostly based on wine supplemented by tourism [29].

Despite the fact that only 25 estates were serving the tourism market in DDR in 2015 [29], today there are more than 400 wine estates in the region looking to wine tourism as an extremely interesting way of promoting their products and undergoing the process of adaptation to the reality of wine tourism. Some of these wine estates from the RDD are now recognized on a worldwide basis and have earned important international awards [65].



Additionally, the region's status as a World Heritage Sites since 2001 as an evolving and living cultural landscape has supported the Porto city and the north of Portugal becoming a prominent tourism destination of choice, with the whole Douro Valley territory also growing as a tourism destination [13].

In line with this, more than ever, the tourism sector in general represents an important status in Portugal accounting for 9% of the national GDP, and the wine tourism is one of the fastest growing economic exponents and an enhancer of sustainable local development [16]. According to data released by the Secretary of State for Tourism, in 2018 Portugal welcomed 2.5 million tourists traveling for reasons related to wine tourism, with direct cellar door sales contributing for the growth of the Portuguese wine industry by 50% [62]. In this sense, Portugal is understanding wine tourism as an activity that can help the country's economy while generating socio-economic progress in depressed rural regions [16].

However, even though the Portuguese wine tourism sector currently is one of the most dynamic tourism segments in the country with the Douro region as one of the main actors of this trend, only very few wineries were offering wine tourism activities at their estate or providing any form of accommodation until recently. In 2005, the region was responsible for only 1% of Portugal's accommodation capacity, and in 2012, the accommodation sector in the territory only contained 36 hotels with a capacity of 2303 beds, and 101 rural tourism units with 552 beds. Additionally, the domestic market represented about 78% of the total demand, with the remaining visitors mainly from other European countries [29].

With the large number of tourist arrivals, many wine estates are now offering some sort of wine tourism to take advantage of this flow [58]. In a five year period between 2014 and 2019, tourism in Porto and the north of Portugal more than doubled the total number of guests to 5.8 million and the number of overnight stays to 10.7 million. It also practically quadrupled the number of foreign guests to 3 million, gathering 637.8 million euros of overall returns in 2019 [66]. Currently, the northern region occupies the 3rd national position in number of overnight stays and has risen to the 2nd national position in terms of guests [67], with foreigners from Germany, Spain, USA, France, UK, Brazil, Japan, China, and South Korea already representing 60% of total overnight stays in the region [66]. Finally, the northern territory in terms of business dynamics has already exceeded 20,000 tourism business units [67], and according to 2020 data from the Ministry of Economy, 28% of tourism companies are currently in the northern region, corresponding to 31,920 establishments in total of hospitality sectors and employing 23.4% of the population between staff and services [66].

On the other hand, one cannot say that there is over-exploitation of tourism in the Douro Valley, as there are comparatively few long-stay visitors to the metropolitan area of Porto city, today accounting for more than 70% of the number of guests and overnight stays in the region. The city of Porto alone is responsible for more than 50% of guests and overnight stays [68]. Since the 1990s, the Port wine cellars have been one of the biggest tourist attractions of the region, with the most famous Port wine companies including Calém, Porto Ramos Pinto, Burmester, Churchill's, Cockburn's Port, Ferreira, Offley Forrester, Real Companhia Velha, Rozés, Sandeman, W & J. Graham, and C.N. Kopke Taylor's (Fladgate & Yeatman) offering guided tours combined with Port wine tasting sessions [62].

Even though Port wine cellars in Vila Nova de Gaia continue to be the most dynamic driving force in the Portuguese wine tourism sector, the classification of this region as a cultural landscape by UNESCO has also increased its appeal amongst investors and local entrepreneurs, evidenced by the range of other tourism activities that have surged and developed in the last few years. Beyond river cruises, the scenic historic train ride, diverse types of accommodation units, Port wine route, and wine-related events and tasting, there are other relevant points of interest in the area with high potential for tourism, outside the competitive advantage and the appeal of the Port wine market and associated with the region's heritage [27]. A good example is its castles or the shrines and churches known as the stage for pilgrimages in the summer. Additionally, besides being an area surrounded by mountains and natural parks, in Peso da Régua, the Douro museum expresses the identity

of the people who built the landscape of the region and can be visited. Not far away on the south bank of the Douro River is Lamego, one of the most beautiful cities in northern Portugal and known for its immense blue and white tiled flight of steps leading to the Sanctuary of Nossa Senhora dos Remédios. In Pinhão's railway station, right by the river, its ancient tiles are often admired by visitors. Finally, before arriving at Barca de Alva and entering the International Douro Natural Park right on the border between Portugal and Spain, there is the Vale do Côa Archaeological Park, an open-air rock art gallery that is also classified as a World Heritage Site. Its Palaeolithic figures that spread along the margins of the Côa River were the first Palaeolithic rock art discoveries in open-air.

To summarize, Douro Valley has the potential to quickly become a popular worldwide wine tourism destination, with an incremental number of accommodation facilities and modern wine producing Quintas to attract visitors. However, the region is also gaining higher reputation around its inherent natural and cultural heritage attached to its traditions and villages based on traditional family ties, inheritance, dependence on natural resources, rich natural and archaeological heritage, praised gastronomy, and religious background [16,27,69].

For such engaging traits, wine tourism can coexist with other agricultural or complementary activities in the DDR grounded to its cultural heritage. This may also be the solution to boost the average length of stay in the Douro Valley, as it is still quite low when compared with the average stay in Portugal. Even though the region has invested in and improved several infrastructures and the performance of tourism indicators which contributed to enhanced regional development, the progress of tourism in the Douro Valley is still frail in some aspects, with the average stay being around 1.5 nights [27].

In 2018, despite the Porto and the north of Portugal being praised for being the destination with the 3rd longest stay in Portugal (continental Portugal) with 1.77 nights, it was still inferior to the national average of 3.1 nights [13,68]. Such results can be associated with the inability of the Douro region to generate attractions capable of holding tourists for longer periods of time but also with its winding roads which create difficulty of mobility within the region adds to the concentration of tourists in the nearby main urban areas [68].

#### 4.3. Sustainable Wine Tourism Directives

The DDR wines market has experienced great changes in most recent decades which were mainly promoted by the increase in the production of CDO Douro wines and to the change in wine consumer behavior in Portugal. Nowadays, there is an increasing number of consumers curious about consuming sustainable wines. As a result, many wineries and wine regions are seeking to make their wine production more sustainable as a point of the brand and for product differentiation. However, due to the growing environmental awareness within the industry, such concerns have also contributed to the improvement of their overall performance by adopting sustainable practices during the entire production process.

In the agriculture fields, several regenerative agriculture and natural-based solutions are mentioned in the literature such as diversifying crop rotation and crop rotation systems, use of soil bio-resources, mulching, usage of high analysis fertilizers, contour farming, and no-till farming. The option for low emission tractors or promoting tractor sharing initiatives in the area is also suggested. For the winery, there is the consideration of energy production from renewable sources for the generation of electricity through photovoltaic panels or from other sources such as biomass, hydroelectric, solar thermal, etc. Another relevant step is to consider ecologically sustainable packaging and suppliers that share sustainability principles in their business and behavior. Finally, the adoption of the carbon footprint certification of products can also be a means to assess and monitor performance and simultaneously report and communicate to the consumer [70].

Regarding transportation, different transport modes or choices deeply influenced the results of studies calculating the associated energy and carbon emissions. As aforementioned, the wine tourism scenario is seen as the least efficient CF scenario. According to

developed benchmarking analysis, with the boom of wine tourism across the globe, cellar door sales may become the most carbon intensive component across all life cycle stages of wine. Transportation alternatives for purchased wine at cellar doors through networking and collaboration agreements between wineries in the area may be one of the solutions [23]. Another example of efficient transportation is to ship in bulk rather than bottled wine. When considering this choice, the total impact of global warming potential (GWP) can appreciably reduce up to 13% [57].

Even though the wine industry has dedicated increasing efforts to considering its impact on the environment and improving its sustainability performance, the reality is that a significant amount of attention has been focused on the vine and wine production portion of the sector. More comprehensive supply chain and life cycle analyses are needed to better map the industry's impacts from the grape to the wine bottle where packaging, distribution, sales, and consumption scenarios are included. In other words, it is time to take the whole picture of the wine industry when contemplating its efforts towards sustainability, and all side businesses where products or services are provided, including suppliers and wine tourism, must be considered.

Regarding economic sustainability, one of the biggest challenges is combating the strong competitive tendency in the wine market that demands a continued emphasis on quality products, distinctive branding or positioning, and effective marketing to specific target segments [14]. Wineries are focusing their efforts on exploiting commercial opportunities via tourism also with the purpose of overcoming such difficulties. Besides cellar door sales, strengthening links and networks with foreign residents or visitors can be a strategy to follow by some small-size producers, in particular if opting for non-aggressive wine distribution channels [22].

Other major benefits that are derived from wine tourism are the development of brand equity and the chance to add value, either on internally (shareholders) or externally, as it can be an important contributor to rural regional development and regional branding. However, these opportunities do not arrive without new challenges. The inherent seasonality of wine tourism has been noted as being another difficult problem to overcome. This seasonality of demand can present both the problem of congestion in peak season and financial stress for businesses and host communities in the slow seasons [14].

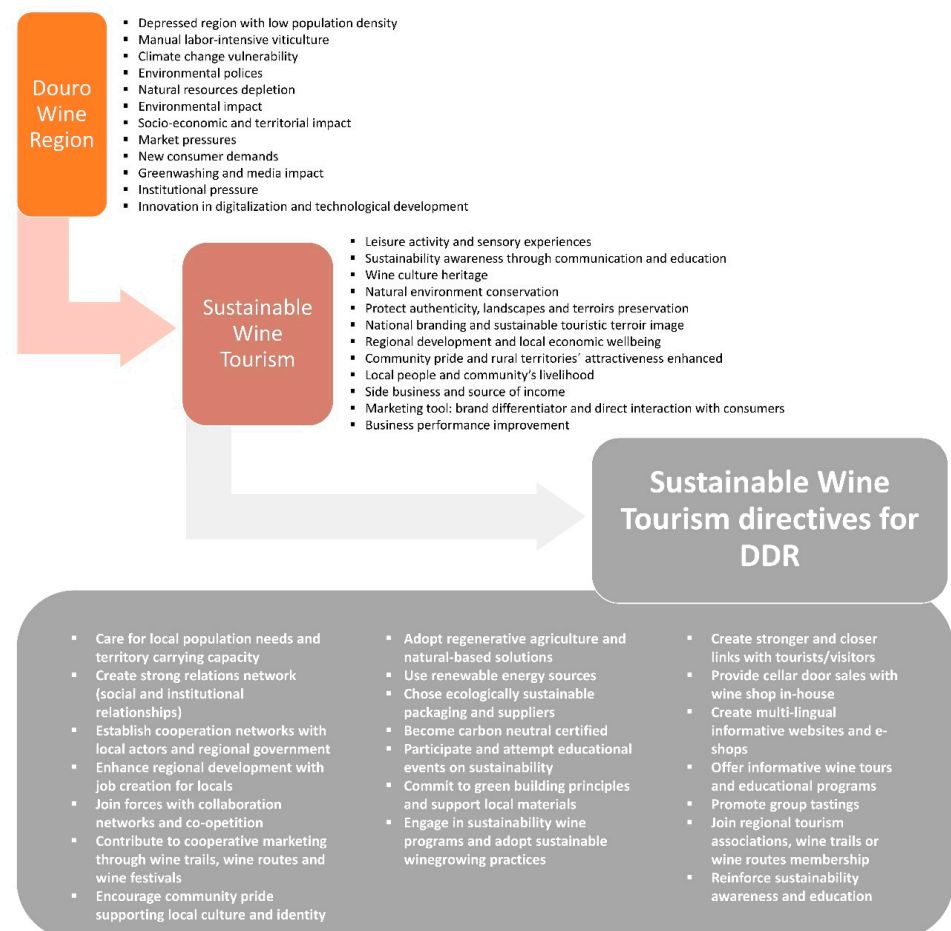
Becoming part of regional wine trails or wine routes may help these businesses to be more involved with tourism opportunities. Other suggestions include becoming members of the local visitor center and local tourism identities or tourism associations for better promotion and marketing. Establishing a network with the operators may encourage more visits and group tastings. Additionally, networking a wide range of cooperative behavior between otherwise competing organizations is an important component for both successful regional economies and maximizing individual businesses' goals [71].

The bottom line is that wine tourism can be used to demonstrate commitment and bring benefits to the community and regional development if such is managed according to sustainability principles and businesses can proactively deal with potentially negative impacts. Thus, wine companies must not solely consider sustainable land usage but also community interests. This may be one of the key social challenges from the point of view of the individual wine producers—the capacity to tangibly demonstrate their commitment to environmental sustainability while preserving the local landscape [11]. Moreover, many of the wine producers being business people and marketers, a different mindset from the locals may lead to or support potential tensions [22]. The distribution of wealth might be another sensible and complex issue regarding this matter when external capital dominates the wine business and locals feel excluded. Furthermore, it is well reported that residents do not get too excited if only low-paying, part-time, or seasonal jobs, are all that are offered. Particularly in remote wine regions, there is a need for employment that can keep breadwinners and the next generation in the area [14].

Finally, even though the development of wine tourism is one good initiative to revive rural areas if promoting the regional brand, event participation, employment and education for the locals, and increasing the quality of life in the community, it must be taken into account that increased prices for rural properties have challenged rural communities experiencing rapid and successful development of their local wine industry. Thus, to be in line with general sustainability principles, the development of wine businesses or new tourism facilities and services should also benefit residents, which requires that any initiative must be evaluated based on local needs and conditions are imposed to ensure affordability and accessibility for residents. If not, local resentment is likely [14]. Thus, looking at all major challenges associated with the wine industry and the fact that they may be magnified by wine tourism or new ones may even emerge, SWT asks for careful planning and management with the need to incorporate all interested parties and consider their needs, in particular residents who may be forced to bear the related environmental, social and economic burdens [14].

#### 4.4. Practical Recommendations and Business Strategies

Cascading down toward recommendations and practical implications to embrace sustainable principles in wine tourism settings at the DDR (Figure 2), adopting behaviors to decrease the winery's carbon footprint is probably the most important next step for the industry. The reality is that tourism actors can have a key role in reducing direct emissions and enhancing and promoting education. Besides assessing CO<sub>2</sub> emissions and seeking to remove unnecessary emissions, several marketing strategies must also be adapted even with carbon offsets, such as luxury wine tourism flying a camera drone and projecting the real-time views instead of offering helicopter rides.



**Figure 2.** Recommendations and strategies for sustainable wine tourism in the DDR.

Giving preference to green energy suppliers so that all the electricity used on the estate comes from renewable energy sources, and monitoring energy consumption regularly for continuous improvement is also important. Another consideration is changing to walking, cycling, or low-consumption electric vehicles for wine tours at the estate, or even committing to fleet electrification. Another option, especially considering new work trends accelerated by the COVID-19 pandemic, is to promote some days working from home to avoid unnecessary travels. Activism for infrastructure that supports regional sustainable choices such as public transports or bicycle routes is also encouraged, as well as limiting individual packaging in favor of refillable, biodegradable, or compostable packaging. Other environmentally major activities may include a commitment to more sustainable grape production, certified wine products and sustainability programs, and other programs against deforestation, fair trade, etc.

Socially speaking, businesses should be proactive in strengthening ties with their staff, promoting job satisfaction, justice, equality, and job pride. Hiring staff from the region and employing younger generations is also relevant to enhance regional development. Culturally, interest in emphasizing the localness or regionalism of products is relevant, such as pairing wine tasting with local food, bread, cheese, or other local delicacies for the visitors. Wineries can also work towards self-sufficiency in food production for their restaurant, as the role of food and local cuisine is well recognized as a key part of tourism. Being an instrumental part of local culture and creating interest and awareness in local products can reinforce local culture and identity and encourage community pride with clear implications for socio-economic sustainability [20].

As for economic sustainability, most elements encompassing environmental, social, and cultural pillars are inevitably connected to it through cost savings. Offering tours is also relevant, as well as having wine shops in-house to sell at the cellar door. Wine tours that include valued educational activities along with other education programs such as winemaking seminars, cooking classes, or museum tours are effective ways of achieving service satisfaction for wine tourists. Combining tourism and education is also considered essential to control the long-term effects of sustainable development [72].

To have and make sales through an e-shop can also be important for direct selling, especially after the COVID-19 pandemic and the increase in electronic sales worldwide. Additionally, it would help to accept credit cards to facilitate purchases, either electronically or on-premises. Another remark is the need to provide information regarding the services offered through modern and informative sites translated in at least two languages [73]. Furthermore, other key elements for SWT development include building stronger collaborations and receiving more support from the public sector such as regional government agencies by paying attention to environmental and carrying capacity issues of the region. Developing new and better infrastructures, or increasing and strengthening existing ones, is also fundamental in developing SWT. To commit to green building principles and support local building materials is also important.

Concerning collaboration, the significance of alliancing is intrinsically related to dynamic capabilities; therefore, it is often emphasized as a source of competitive advantage [25]. Wine festivals have proven to be the second most valuable promotional activity, following only wine tastings. Festivals together with wine routes present an interesting collaborative and market opportunity for wineries for encouraging visitors to spend the night in the wine region and increasing cellar-door sales [73]. In addition to direct visitation, cooperative marketing through wine trails and wine routes optimizes the economies of scope when promoting the wines of the region. It also gives wineries a chance to work collaboratively in the competitive wine market. It is a form of clustering, and a strong tourism facilitator with these factors frequently receive community support and government funding [74].

It is also necessary to establish appropriate legislative actions to facilitate a variety of business procedures and partnerships. Local governments play a decisive role in establishing such an environment and promoting mutually beneficial interactions among the residents, wine businesses and tourists. A positive and healthy branding associated with



consumption in moderation is also critical in the wine tourism businesses to increase the association of the industry to healthy lifestyles and beverage cultures in reducing the potential harm of alcoholism. It is also critical to balance the ecological footprint and economic benefits of wine tourism. For such balance, a logical legislative framework and support from the local government are fundamental to assure proper geographical zoning, not only of vineyards but also of infrastructural development for wine tourism such as streets, hotels, parking areas, and restaurants. Wine tourism must not follow the international model of exploiting all-natural resources [72].

Finally, policies that are centered on the territory and not sectorial divided (winegrowing vs tourism sectors) are fundamental. If combined, both can benefit from the implementation of innovative projects, sustained by public and private institutions, research centers, municipalities and public institutions, associations and other organizations, and companies. The SWT initiatives currently being pursued by the DDR with three other wine regions including the project “Porto and North of Portugal Wine Tourism Routes” are certain steps towards coordinating sustainable tourism development in the northern region of Portugal. Support from organizations including the government, local agencies, and industry associations is requested to assist this recent tourist activity in Portugal and promote the use of synergies. It is through such collaborative marketing efforts to enhance regional heritage branding that the wineries in remote regions can survive and thrive.

To conclude, new attitudes and behaviors are necessary on the part of producers and tourism agents that involve more cooperation, articulation, and support. Educational and motivating events are fundamental to highlight the advantages of using sustainable practices and multifunctional business management. Finally, more studies and concrete proposals with innovative ideas are also welcomed to better explore cultural, environmental, and territory values [19].

#### *4.5. Emerging Trends Shaping SWT: Proposals for DDR*

Given SWT challenges, trends, and opportunities, it might be important to develop a regional or multi-regional strategic plan with practical guidelines for the promotion of wine tourism as part of a value chain concerned with sustainability issues and their impact on the community. For such, it is important to invest in collaboration networks and cooperative marketing. Ongoing development is also needed in technical knowledge of sustainable winegrowing, culture, and heritage value, as well as behavioral intentions of the wine tourist.

Regarding the role and impact of wine tourism, a comprehensive and organized effort is needed to assure and maintain quality, authenticity, and cultural and heritage value while protecting natural, cultural, and historic resources. This is why it is desirable to first formulate a community-based vision for wine tourism that is framed by SDGs and sustainability principles. Thus, DDR residents should be consulted first regarding their concerns about the proposed policy and development. This strategic plan must also be fully integrated with other regional planning functions including the community plan, agriculture, local economy, regional development, wine industry, and tourism in general. It should identify existing opportunities for wine tourism development as well as barriers to prevent exploitation and future resentment between businesses and residents.

For such, assessment frameworks to monitor sustainability performance, tourism development, and the impact on the local population are essential. Therefore, it is necessary to develop sustainability frameworks with guidelines to assist local actors where overall wine industry and wine tourism impact assessment can be conducted and monitored for continuous improvement. This approach has already been implemented in some wine tourism regions through sustainable wine programs. One good example is Chile’s national sustainability program certification scheme created in 2011. The code of conduct was initially designed to set out requirements and standards over the three main areas of the wine production process (vineyard, winery, and business/human resources), but in 2021, the Wines of Chile launched the first-ever Sustainability 365 campaign highlighting the

commitment of local wineries in all areas of sustainability, wine tourism included. Presently, the Wines of Chile sustainability program already has four certifiable areas: vineyards, processes, social, and tourism. The goal is the creation and promotion of a national green image. While working closely with traders to educate about sustainability issues, wineries can already certify in SWT, as certification enhances the reputation of the company and the regional and national brand.

Future sustainable development directions for wine tourism in DDR may be based on such initiatives; however, we must first identify sustainability indicators adequate for national and regional contexts. Benchmarking reports should be promoted in the wine sector and in the region to find opportunities and improve processes, despite the fact that effective benchmarking can be limited by insufficient and inconsistent data.

##### **5. Final Remarks: Collaboration and Co-Operative Networks Are Key**

No doubt remains that SWT has a strong connection to the culture, traditions of rural areas, and distinctive features of the local community and place. With increased demand and greater competition among wineries offering touristic experiences, managers must reflect on how to enhance their image to be profitable but at the same time assure sustainability principles to preserve cultural patrimony. Such considerations may be the greatest allies against touristic massification responsible for the lack of quality and de-characterization of rural areas.

Wine tourism can be linked to territorial sustainability if there is a commitment and coordination of stakeholder objectives in line with the territories' development needs. But such requires the application of strategies such as the "Porto and North of Portugal Wine Tourism Routes" to generate cooperation networks based on sustainability principles. Therefore, SWT calls for the involvement of all stakeholders including on an institutional level, marketing and tour operators, wine producers, local trade, tourists, and residents [62]. Synergies between local government, wineries and organizations dealing in hospitality or with other sectors including craft brewing or culinary tourism are critical for its development [25]. This process of interactions between wine firms and local actors can create a regional and organized setting based on several partners connected to the region. In this sense, wine tourism can be an opportunity to diversify the local economy of the wine producers and local actors [16].

According to the literature, networking refers to a wide range of cooperative behavior between otherwise competing organizations linked through economic and social relationships and transactions. Such interactions can be an important component of both successful national economies and highly performing regional economies and may offer potential contributions for economic restructuring in rural areas [71]. If SWT implementation in the region is flexible with a strong social network that offers information and knowledge to the collective learning, any strategy based on interactions and partnerships can generate a widespread collection of the positive tourism impacts and better manage the negative outcomes [16].

Wine tourism potential benefits are diverse for each local actor, but overall, it establishes the opportunity for businesses to sell and market their products, educate consumers and young generations, add value to the destinations' image that leads to increased tourist flows and expenditure, and raise job accessibility and employment quality contributing to the development of rural areas in general [27]. Thus, for SWT strategies to create value and accomplish business success connected to territorial development, a win-win relationship between all stakeholders is necessary. Integrated planning and management must then be anchored to co-competitive networks as a business situation in which independent and competing parties cooperate and coordinate their activities to reach a mutual goal [21].

In summary, there are several environmental sustainability drivers for the wine industry such as personal preferences, market demands, and compliance with regulations [17]. However, when considering implementing sustainable wine tourism practices, there are relevant benefits associated with economic and social value creation beyond environmental

orientations. Undoubtedly, there is a strong link between embracing social, cultural, and environmentally sustainable practices with economic sustainability, either through revenue generation, cost reduction, or potential value-adding. Additionally, the need for partnership and innovative models of collaboration as well as local community engagement and empowerment was highlighted, particularly when discussing wine and SDGs. One must consider not only the overall role of winegrowing in our societies but also the need to promote responsible consumption and production throughout the wine value chain [75]. However, due to the dynamic nature of the wine sector, and as wine tourism continues to develop, the need for a better understanding of consumer behaviors regarding wine regions as well as the factors that enhance their overall experiences is critical [27]. When behavioral intentions of wine tourists in Porto were examined, personal involvement, product involvement, destination emotions, and place attachment were predicted as major antecedents. Involvement, destination emotions, and place attachment were also positively related to the behavioral intentions of the wine tourist [15]. However, when exploring the relationships between two antecedents among wine tourism in Porto and Vila Nova de Gaia—wine brand prestige vs. wine consumer experience—the effect of wine brand prestige was considerably larger than that of wine consumer experience on consumer satisfaction. Thus, wine brand prestige is more effective in enhancing consumer satisfaction than the wine consumer experience itself. Douro wineries should better manage and enhance their relationship quality as consumer satisfaction has positive effects on both wine brand image and word-of-mouth recommendations [76]. Moreover, a better understanding of the emotional aspects of the destination experience as well as the extent to which visitors are personally involved in the wine experience and attached to the wine cellar is still necessary [76].

Moreover, by understanding the different types and motivations of tourists that explore Douro wine tourism, the effect that experiences have on brand image, satisfaction, and even tourist loyalty may have direct implications and contributions to the creation of a consistent sustainability wine-related image. Beyond the strong tendency to link the quality of wines to the landscapes from which they originate [19], attaching this sustainable orientation and image to wine tourism may also offer important contributions to the region's promotion and to bring added value to the Douro and Port wines. Thus, besides the much needed growing interest in producing wine more sustainably, there are also parallel drivers associated with using sustainable practices as a point of the brand and product differentiation in such a highly competitive market [11]. This is even more relevant in remote rural areas with several small- to medium-sized growers and wineries.

The adoption of other initiatives such as sustainability wine programs or certification schemes is also valuable for their ability to be used in the promotion of wine products and brands [11]. However, economies of scale are critical to the implementation of such sustainable practices, as only larger wineries usually have the resources and financial means to pursue locally based sustainability programs. Institutional support from local governments is fundamental to enable smaller grape and wine producers who are less financially empowered to adopt such practices. Thus, social processes of innovation, cultural change, and cooperation are fundamental to raising the adoption rate of sustainable practices within a particular region [11]. Moreover, beyond the need for this kind of initiative to be framed around sustainability, their value statements must also be capable of encouraging participants to expand their concerns and involvement in the environment and surrounding communities [14]. However, it is necessary to first improve research on this issue and include the core elements of the SDGs to better understand how tourism can contribute to sustainable development, in particular regarding remote rural areas. As aforementioned, even though the interest in wine tourism has grown, the sustainability of this activity has received little scientific attention. Sustainability itself is still perceived as a complex and ambiguous concept, and there is only a limited number of studies regarding its relationship with wine tourism. Assessment frameworks to measure wine tourism impacts that shed light on the various aspects surrounding this issue are even scarcer due to the

lack of consensus surrounding selected sustainability indicators [62]. In this sense, this study also pointed out the importance of identifying the right indicators and monitoring strategies adequate for the DDR context capable of evaluating the overall sustainability of these initiatives, where SWT impacts are considered and the progress towards achieving SDGs is continuously measured.

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## References

- Gómez, M.; Pratt, M.A.; Molina, A. Wine tourism research: A systematic review of 20 vintages from 1995 to 2014. *Curr. Issues Tour.* **2018**, *22*, 2211–2249. [[CrossRef](#)]
- Brochado, A.; Stoleriu, O.; Lupu, C. Wine tourism: A multisensory experience. *Curr. Issues Tour.* **2019**, *24*, 597–615. [[CrossRef](#)]
- Santini, C.; Cavicchi, A.; Casini, L. Sustainability in the wine industry: Key questions and research trends. *Agric. Food Econ.* **2013**, *1*, 9. [[CrossRef](#)]
- Eyring, V.; Gillett, N.; Achutarao, K.; Barimalala, R.; Barreiro, M.; Bellouin, N.; Cassou, C.; Durack, P.; Kosaka, Y.; McGregor, S. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2021.
- Cichelli, A.; Pattara, C.; Petrella, A. Sustainability in mountain viticulture. The case of the Valle Peligna. *Agric. Sci. Procedia* **2016**, *8*, 65–72. [[CrossRef](#)]
- Dibari, C.; Padovan, G.; Merante, P.; Leolini, L.; Santos, J.; Bindi, M.; Moriondo, M. Transferring scientific knowledge of climate change impact on European viticulture: The Clim4Vitis project. In Proceedings of the ADAPT2CLIMA 2nd international conference, Heraklion, Crete, 24–25 June 2019.
- Santos, J.A.; Gratsch, S.D.; Karremann, M.K.; Jones, G.V.; Pinto, J.G. Ensemble projections for wine production in the Douro Valley of Portugal. *Clim. Chang.* **2013**, *117*, 211–225. [[CrossRef](#)]
- Flores, S.S. What is sustainability in the wine world? A cross-country analysis of wine sustainability frameworks. *J. Clean. Prod.* **2018**, *172*, 2301–2312. [[CrossRef](#)]
- Keichinger, O.; Thiollet-Scholtus, M. SOECO: Socio-economic indicators for viticulture and innovative cultural systems. In Proceedings of the 40th World Congress of Vine and Wine, Sofia, Bulgaria, 29 May–2 June 2017; Volume 9, pp. 1–6.
- Pomarici, E.; Vecchio, R. Will sustainability shape the future wine market? *Wine Econ. Policy* **2019**, *8*, 1–4. [[CrossRef](#)]
- Baird, T.; Hall, C.M.; Castka, P. New Zealand Winegrowers Attitudes and Behaviours towards Wine Tourism and Sustainable Winegrowing. *Sustainability* **2018**, *10*, 797. [[CrossRef](#)]
- Hall, C.M.; Prayag, G. Wine tourism: Moving beyond the cellar door? *Int. J. Wine Bus. Res.* **2017**, *29*, 338–502. [[CrossRef](#)]
- Correia, R.F.; Brito, C.M. Mutual influence between firms and tourist destination: A case in the Douro Valley. *Int. Rev. Public Nonprofit Mark.* **2014**, *11*, 209–228. [[CrossRef](#)]
- Poitras, L.; Donald, G. Sustainable Wine Tourism: The Host Community Perspective. *J. Sustain. Tour.* **2006**, *14*, 425–448. [[CrossRef](#)]
- Ramos, P.; Santos, V.R.; Almeida, N. Main challenges, trends and opportunities for wine tourism in Portugal. *Worldw. Hosp. Tour. Themes* **2018**, *10*, 680–687. [[CrossRef](#)]
- Santos, F.A.D.N.; Vavdinov, N.; Martinez, L.F. Avances y perspectivas para la investigación del turismo del vino en Portugal. *PASOS Rev. De Tur. Y Patrim. Cult.* **2020**, *18*, 159–170. [[CrossRef](#)]
- Montella, M.M. Wine Tourism and Sustainability: A Review. *Sustainability* **2017**, *9*, 113. [[CrossRef](#)]
- OIV. *OIV General Principles of Sustainable Vitiviniculture—Environmental-Social-Economic and Cultural Aspects*; OIV: Bento Gonçalves, Brazil, 2016.
- Lavrador da Silva, A.; João Fernão-Pires, M.; Bianchi-de-Aguiar, F. Portuguese vines and wines: Heritage, quality symbol, tourism asset. *Ciênc. E Téc. Vitiviníc.* **2018**, *33*, 31–46. [[CrossRef](#)]
- Johnson, G.; Hall, C.M.; Mitchell, R.; Longo, A.M. Wine tourism around the world: Development, management and markets. In *Wine Tourism in New Zealand*; Butterworth-Heinemann: Oxford, UK, 2000; pp. 150–174.
- Salvado, J.; Kastenzholz, E. Sustainable wine tourism eco-systems through co-opetition. *Rev. Tur. Desenvolv.* **2017**, *1*, 1917–1931.



22. Alonso, A.D.; Northcote, J. Small Winegrowers' Views on their Relationship with Local Communities. *J. Wine Res.* **2008**, *19*, 143–158. [[CrossRef](#)]
23. Sun, Y.Y.; Drakeman, D. Measuring the carbon footprint of wine tourism and cellar door sales. *J. Clean. Prod.* **2020**, *266*, 121937. [[CrossRef](#)]
24. Duarte Alonso, A.; Bressan, A.; Kiat Kok, S.; O'Brien, S. Filling up the sustainability glass: Wineries' initiatives towards sustainable wine tourism. *Tour. Recreat. Res.* **2021**, 1–15. [[CrossRef](#)]
25. Duarte Alonso, A.; Kok, S.; O'Brien, S. Sustainable wine tourism development through the lens of dynamic capabilities and entrepreneurial action: An exploratory four-region perspective. *Tour. Recreat. Res.* **2020**, *45*, 401–419. [[CrossRef](#)]
26. IVDP Characteristics of the Region. Available online: <https://www.ivdp.pt/en/viticulture/region/characteristics-of-the-region/> (accessed on 14 March 2022).
27. Correia, A.I.; Cunha, R.; Matos, O.; Fernandes, C. Wine Tourism Experiences and Marketing: The Case of the Douro Valley in Portugal. In *Wine Tourism Destination Management and Marketing: Theory and Cases*; Sigala, M., Robinson, R.N.S., Eds.; Palgrave Macmillan: Cham, Switzerland, 2019; pp. 203–220.
28. Prata-Sena, M.; Castro-Carvalho, B.M.; Nunes, S.; Amaral, B.; Silva, P. The terroir of Port wine: Two hundred and sixty years of history. *Food Chem.* **2018**, *257*, 388–398. [[CrossRef](#)] [[PubMed](#)]
29. Lourenço-Gomes, L.; Pinto, L.M.C.; Rebelo, J. Wine and cultural heritage. The experience of the Alto Douro Wine Region. *Wine Econ. Policy* **2015**, *4*, 78–87. [[CrossRef](#)]
30. Rebelo, J.; Caldas, J. The Douro wine region: A cluster approach. *J. Wine Res.* **2013**, *24*, 19–37. [[CrossRef](#)]
31. Villa Maior, V.D. *O Douro Ilustrado: Album do Rio Douro E Paiz Vinhateiro*; Livraria universal de Magalhães & Moniz: Porto, Portugal, 1876.
32. Pereira, G. A Evolução Histórica. In *Viver E Saber Fazer: Tecnologia Tradicional Na Região do Douro. Estudos Preliminares*; Teresa Soeiro, C.C.P., Rui, C., Eds.; Fundação Museu do Douro: Peso da Régua, Portugal, 2003; pp. 103–127.
33. de Olde, E.M.; Oudshoorn, F.W.; Sørensen, C.A.G.; Bokkers, E.A.M.; de Boer, I.J.M. Assessing sustainability at farm-level: Lessons learned from a comparison of tools in practice. *Ecol. Indic.* **2016**, *66*, 391–404. [[CrossRef](#)]
34. Christ, K.L.; Burritt, R.L. Critical environmental concerns in wine production: An integrative review. *J. Clean. Prod.* **2013**, *53*, 232–242. [[CrossRef](#)]
35. Silverman, M.; Marshall, R.S.; Cordano, M. The greening of the California wine industry: Implications for regulators and industry associations. *J. Wine Res.* **2005**, *16*, 151–169. [[CrossRef](#)]
36. Rugani, B.; Vazquez-Rowe, I.; Benedetto, G.; Benetto, E. A comprehensive review of carbon footprint analysis as an extended environmental indicator in the wine sector. *J. Clean. Prod.* **2013**, *54*, 61–77. [[CrossRef](#)]
37. Mekonnen, M.M.; Hoekstra, A.Y. The green, blue and grey water footprint of crops and derived crop products. *Hydrol. Earth Syst. Sci.* **2011**, *15*, 1577–1600. [[CrossRef](#)]
38. Quinteiro, P.; Dias, A.C.; Pina, L.; Neto, B.; Ridoutt, B.G.; Arroja, L. Addressing the freshwater use of a Portuguese wine ('vinho verde') using different LCA methods. *J. Clean. Prod.* **2014**, *68*, 46–55. [[CrossRef](#)]
39. Martins, A.A.; Araujo, A.R.; Graca, A.; Caetano, N.S.; Mata, T.M. Towards sustainable wine: Comparison of two Portuguese wines. *J. Clean. Prod.* **2018**, *183*, 662–676. [[CrossRef](#)]
40. Saraiva, A.; Rodrigues, G.; Mamede, H.; Silvestre, J.; Dias, I.; Feliciano, M.; Oliveira, E.S.P.; Oliveira, M. The impact of the winery's wastewater treatment system on the winery water footprint. *Water Sci. Technol.* **2019**, *80*, 1823–1831. [[CrossRef](#)] [[PubMed](#)]
41. Saraiva, A.; Presumido, P.; Silvestre, J.; Feliciano, M.; Rodrigues, G.; Silva, P.O.E.; Damasio, M.; Ribeiro, A.; Ramoa, S.; Ferreira, L.; et al. Water Footprint Sustainability as a Tool to Address Climate Change in the Wine Sector: A Methodological Approach Applied to a Portuguese Case Study. *Atmosphere* **2020**, *11*, 934. [[CrossRef](#)]
42. Fraga, H.; Atauri, I.G.D.; Santos, J.A. Viticultural irrigation demands under climate change scenarios in Portugal. *Agric. Water Manag.* **2018**, *196*, 66–74. [[CrossRef](#)]
43. Pádua, L.; Marques, P.; Adão, T.; Guimarães, N.; Sousa, A.; Peres, E.; Sousa, J.J. Vineyard Variability Analysis through UAV-Based Vigour Maps to Assess Climate Change Impacts. *Agronomy* **2019**, *9*, 581. [[CrossRef](#)]
44. Fernández-Novales, J.; Saiz-Rubio, V.; Barrio, I.; Rovira-Más, F.; Cuenca-Cuenca, A.; Santos Alves, F.; Valente, J.; Tardaguila, J.; Diago, M.P. Monitoring and mapping vineyard water status using non-invasive technologies by a ground robot. *Remote Sens.* **2021**, *13*, 2830. [[CrossRef](#)]
45. Graça, A.R.; Simões, L.; Freitas, R.; Pessanha, M.; Sandeman, G. Using sustainable development actions to promote the relevance of mountain wines in export markets. *Open Agric.* **2017**, *2*, 1. [[CrossRef](#)]
46. Bernardo, S.; Dinis, L.T.; Luzio, A.; Machado, N.; Goncalves, A.; Vives-Peris, V.; Pitarch-Bielsa, M.; Lopez-Climent, M.F.; Malheiro, A.C.; Correia, C.; et al. Optimising grapevine summer stress responses and hormonal balance by applying kaolin in two Portuguese Demarcated Regions. *Oeno One* **2021**, *55*, 207–222. [[CrossRef](#)]
47. Patinha, C.; Duraes, N.; Dias, A.C.; Pato, P.; Fonseca, R.; Janeiro, A.; Barriga, F.; Reis, A.P.; Duarte, A.; da Silva, E.F.; et al. Long-term application of the organic and inorganic pesticides in vineyards: Environmental record of past use. *Appl. Geochem.* **2018**, *88*, 226–238. [[CrossRef](#)]
48. Köninger, J.; Lugato, E.; Panagos, P.; Kochupillai, M.; Orgiazzi, A.; Briones, M.J.I. Manure management and soil biodiversity: Towards more sustainable food systems in the EU. *Agric. Syst.* **2021**, *194*, 103251. [[CrossRef](#)]



49. Teixeira, A.; Oostingh, G.; Valado, A.; Osório, N.; Caseiro, A.; Ferreira, A.; Figueiredo, J.P. The impact of pesticides on the cholinesterase-activity in serum samples. In *Occupational Safety and Hygiene VI*; CRC Press: London, UK, 2018; pp. 319–323.
50. Bender, S.F.; Wagg, C.; van der Heijden, M.G.A. An Underground Revolution: Biodiversity and Soil Ecological Engineering for Agricultural Sustainability. *Trends Ecol. Evol.* **2016**, *31*, 440–452. [[CrossRef](#)] [[PubMed](#)]
51. Pacheco, F.A.L.; Varandas, S.G.P.; Sanches Fernandes, L.F.; Valle Junior, R.F. Soil losses in rural watersheds with environmental land use conflicts. *Sci. Total Env.* **2014**, *485*, 110–120. [[CrossRef](#)]
52. Stanchi, S.; Zecca, O.; Hudek, C.; Pintaldi, E.; Viglietti, D.; D'Amico, M.E.; Colombo, N.; Goslino, D.; Letey, M.; Freppaz, M. Effect of Soil Management on Erosion in Mountain Vineyards (N-W Italy). *Sustainability* **2021**, *13*, 1991. [[CrossRef](#)]
53. Ruggieri, L.; Cadena, E.; Martinez-Blanco, J.; Gasol, C.M.; Rieradevall, J.; Gabarrell, X.; Gea, T.; Sort, X.; Sanchez, A. Recovery of organic wastes in the Spanish wine industry. Technical, economic and environmental analyses of the composting process. *J. Clean. Prod.* **2009**, *17*, 830–838. [[CrossRef](#)]
54. Devesa-Rey, R.; Vecino, X.; Varela-Alende, J.L.; Barral, M.T.; Cruz, J.M.; Moldes, A.B. Valorization of winery waste vs. the costs of not recycling. *Waste Manag.* **2011**, *31*, 2327–2335. [[CrossRef](#)] [[PubMed](#)]
55. Bustamante, M.A.; Moral, R.; Paredes, C.; Perez-Espinosa, A.; Moreno-Caselles, J.; Perez-Murcia, M.D. Agrochemical characterisation of the solid by-products and residues from the winery and distillery industry. *Waste Manag.* **2008**, *28*, 372–380. [[CrossRef](#)]
56. Villanueva-Rey, P.; Vazquez-Rowe, I.; Moreira, M.O.T.; Feijoo, G. Comparative life cycle assessment in the wine sector: Biodynamic vs. conventional viticulture activities in NW Spain. *J. Clean. Prod.* **2014**, *65*, 330–341. [[CrossRef](#)]
57. Muthu, S.S. *Environmental Carbon Footprints: Industrial Case Studies*; Butterworth-Heinemann: Oxford, UK, 2017.
58. Woldarsky, V.; Geny-Denis, L. Development of a best practice manual in wine tourism in Portugal. In Proceedings of the 41st World Congress of Vine and Wine, Punta del Este, Uruguay, 19–23 November 2018; Volume 12, p. 03001. [[CrossRef](#)]
59. Faria, S.D.S.; Lourenço-Gomes, L.S.D.M.; Gouveia, S.H.C.D.; Rebelo, J.F. Economic performance of the Portuguese wine industry: A microeconomic analysis. *J. Wine Res.* **2020**, *31*, 283–300. [[CrossRef](#)]
60. Machado, L.P.; Ribeiro, D. A dinâmica do Turismo do Porto e do Norte de Portugal e a relação com o Vinho do Porto. *Rev. Tur. Desenvolv.* **2017**, *1*, 1013–1022.
61. Pessoa, A. Tourism and regional competitiveness: The case of the Portuguese Douro valley. *RPER* **2008**, *18*, 55–75.
62. Andrade-Suárez, M.; Caamaño-Franco, I. The Relationship between Industrial Heritage, Wine Tourism, and Sustainability: A Case of Local Community Perspective. *Sustainability* **2020**, *12*, 7453. [[CrossRef](#)]
63. Simões, O. Enoturismo em Portugal: As rotas de vinho. *Pasos Rev. De Tur. Y Patrim. Cult.* **2008**, *6*, 269–279. [[CrossRef](#)]
64. Gouveia, S.; Rebelo, J.; Lourenço-Gomes, L. Port wine exports: A gravity model approach. *Int. J. Wine Bus. Res.* **2018**, *30*, 218–242. [[CrossRef](#)]
65. TPNP. Wine Tourism Routes: Porto & North of Portugal. Available online: <http://www.portoandnorthwineroutes.pt/> (accessed on 14 March 2022).
66. TPNP. *Plano de Atividades e Orçamento 2021–2025*; Turismo do Porto e Norte de Portugal, E.R.: Viana do Castelo, Portugal, 2020.
67. TPNP. *Plano de Atividades e Orçamento 2020–2024*; Turismo do Porto e Norte de Portugal, E.R.: Viana do Castelo, Portugal, 2019.
68. TPNP. *Plano de Ação e Orçamento de 2019*; Turismo do Porto e Norte de Portugal, E.R.: Viana do Castelo, Portugal, 2018.
69. Fernandes, T.; Cruz, M. Dimensions and outcomes of experience quality in tourism: The case of Port wine cellars. *J. Retail. Consum. Serv.* **2016**, *31*, 371–379. [[CrossRef](#)]
70. Barisan, L.; Lucchetta, M.; Bolzonella, C.; Boatto, V. How Does Carbon Footprint Create Shared Values in the Wine Industry? Empirical Evidence from Prosecco Superiore PDO's Wine District. *Sustainability* **2019**, *11*, 3037. [[CrossRef](#)]
71. Hall, C.M.; Cambourne, B.; Macionis, N.; Johnson, G. Wine tourism and network development in Australia and New Zealand: Review, establishment and prospects. *Int. J. Wine Mark.* **1997**, *9*, 5–31. [[CrossRef](#)]
72. Amarando, M.; Assenov, I.; Visuthismajarn, P. A systematic review of sustainable wine tourism research in Asia 2000–2018. *Afr. J. Hosp. Tour. Leis.* **2019**, *8*, 1–24.
73. Karagiannis, D.; Metaxas, T. Sustainable Wine Tourism Development: Case Studies from the Greek Region of Peloponnese. *Sustainability* **2020**, *12*, 5223. [[CrossRef](#)]
74. Villanueva, E.C.; Moscovici, D. Sustainable wine tourism development in burgeoning regions: Lessons from New Jersey and Connecticut. *Int. J. Econ. Bus. Res.* **2016**, *12*, 313–333. [[CrossRef](#)]
75. Filopoulos, S.; Frittella, N. Designing Sustainable and Responsible Wine Tourism Experiences. In *BIO Web of Conferences*; EDP Sciences: Les Ulis, France, 2019; p. 03006.
76. Loureiro, S.M.C.; da Cunha, N.P. Wine prestige and experience in enhancing relationship quality and outcomes Wine tourism in Douro. *Int. J. Wine Bus. Res.* **2017**, *29*, 434–456. [[CrossRef](#)]