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The new CAP and the challenge of sustainability: a synthetic indicator for the Italian wine sector

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Abstract. Among the keys enabling the actors of the food chain to become more sustainable, the Strategy assigns an important role to knowledge and information. For this reason, the Farm to Fork Strategy aims to make the Farm Accountancy Data Network (FADN) the main data source of sustainable indicators, turning it into a Farm Sustainability Data Network (FSDN). Wine not only represents one of the most important products of the Italian agri-food system (value of turnover and exports), but it is also characterised by a widespread use of traditional certification systems (PDO/PGI, Organic), to which in recent years specific certifications of sustainability have been added, evaluated through its threefold dimension: economic, environmental, and social. Indeed, wine is much ahead of other sectors in the process of sustainability certification both for the process and the product itself. The paper is an effort to test the current set of information included in the FADN and some related computable indicators as a feasible tool for the assessment of sustainability in the wine sector. The goal of this paper is twofold. Firstly, we assess the actual level of sustainability of the wine sector in Italy through an indicator that synthetizes the three dimensions (economic, environmental, and social) of sustainability at the regional level. Secondly, more in general, we test the current capacity of the FADN information to provide a reliable measure of sustainability given the intention of the EU legislator to switch the European data network from FADN to FSDN.

Keywords: sustainability, wine sector, CAP Reform, FADN.

1. INTRODUCTION

The last few years have seen the prevalence of the paradigm of sustainability in all fields of production and development. After the launch of Agenda 2030 in 2015 and the 17 Sustainable Development Goals by the United Nation Organisation, all subsequent public policies were aligned to these main policy goals, including EU policies.

With regards to agriculture, the Food and Agriculture Organization of the United Nations (FAO) had already adopted in 1989 a concept of "sustainable agriculture and rural development" based on environmental conservation (soil, water, and animal and vegetal genetic resources), economic viability, and social acceptance [1], aligned with the sustainable development concept from the Brundtland Report and the three dimensions of sustainable development: environmental, social, and economic [2].

Whitin the Common Agricultural Policy (CAP), elements of sustainability were introduced by Agenda 2000 and since then the concept has gained increasing visibility and relevance. Recently, the Farm to Fork Strategy (2020) has set the goal of making the EU food system a standard for sustainability at the global level [3,4,5]. Among the key factors that enable actors in the food chain to become more sustainable, the Strategy assigns an important role to knowledge and information. For this reason, the Strategy aims to turn the Farm Accountancy Data Network (FADN), already widely used in the economic evaluation of agricultural policies, into the Farm Sustainability Data Network (FSDN), the goal of which will be to collect data for new and more accurate sustainability indicators. The transformation of the FADN will be one of the main future challenges, due the fact that its original purpose was limited to the evaluation of the economic performance of farms. The Italian FADN, however, represents an exception, as it has long since broadened the scope of its dataset and, consequently, the type of variables collected. Thus, the capacity of the Italian FADN to measure sustainability more comprehensively is worthy to be tested[1].

Wine not only represents one of the most important products of the Italian agri-food system (value of turnover and exports), but it is also characterised by a widespread use of traditional certification systems (PDO and PGI) and a significant share of organic production. In recent years specific sustainability certifications have been added, which are evaluated in their economic, environmental, and social dimensions. Moreover, wine is often associated with high profile tourism experiences, which add to the perception of wine consumption as a "full experience", connecting good food, convivial lifestyle, and the enhancement of local territories [6].

The increasing attention to the issue of sustainable production processes has also been reinforced by the International Organisation of Vine and Wine (OIV), which has supported the definition of a common ground of general principles of sustainable wine and vine production, and the adoption of a global vision, taking into account environmental, social, economic, and cultural aspects [7].

For all these reasons, and thanks to the many different sustainability programs launched in Italy – the most popular of which are V.I.V.A. and Equalitas[2] – the Italian wine sector is far ahead of others in the certification of sustainability both for the process and the product itself [8,9].

This work aims to test the extent to which the current set of information included in the Italian FADN is suitable for building a feasible tool for assessing the sustainability of the wine sector at the regional level in Italy. The relevance of sustainability in the Italian wine sector and the advanced stage of the Italian FADN in tracing and measuring sustainability make this study particularly innovative and can support the transition from theory to the practical implementation of the three dimensions of sustainability. In fact, after a test phase in the next few years, in 2026 the implementation roadmap of the new FSDN has scheduled the introduction in the database of additional variables necessary to measure the environmental and social performance of farms at the European level.

To our knowledge, other recent studies assessing the sustainability of the wine sector have successfully focused on various aspects of production through questionnaires to wine producers [10,11,12]. Other research has investigated the sustainability of the chain as a whole, focusing mainly on organic production [13] or on models of sustainable business in the wine sector [14]. No recent studies have sought to build a specific context-related synthetic set of sustainability indicators, as it is proposed here. The present study also constitutes the first ever attempt to include social elements of sustainability in the synthetic measure, according to the "triple bottom line principle" [15].

The objective of this paper is therefore twofold. First, we assess the actual level of sustainability of the Italian wine sector with an indicator that synthetizes the three dimensions of sustainability (economic, environmental, and social), developed through a multi-criteria approach (Sustainability Wine Index – SuWI). This indicator can be used to assess the level of sustainability of Italian regions over time. To render measurements comparable across regions, the variables used to build the indicator take the local context into consideration as much as possible. The second and more general objective is to test the current capacity of the current FADN dataset to pro-

[1] For more information on the Italian FADN, please visit https://rica.crea.gov.it/

[2] There are other interesting sustainability schemes at the national and regional level, such as SOSTAIN in Sicily. However, the present analysis is limited to the two most relevant national programs, which the Ministry of Agricultural, Food and Forestry Policies is working to harmonize.

vide a reliable measure of sustainability, in anticipation of the EU legislator's intention to switch from FADN to FSDN[3]. Based on the FADN dataset, the performance of the wine sector is assessed for Italian Regions according to the three dimensions of sustainability, defining a set of indicators for each of them. We then propose a synthetic sustainability indicator based on the results for each Region in each of the sustainability dimensions, which facilitates more general reflections on the use of the current Italian FADN as a sustainability data network.

2. SUSTAINABILITY IN THE WINE SECTOR

2.1 Background and literature review

The wine sector has been particularly affected by the theory and practice of sustainability, for many different reasons: the sector is associated with high profile, responsible consumption; it affects the state of health of local territories; it characterizes local development in a specific way; and it involves both primary production (vines) and the processing industry (wine factories).

An important boost in the recognition of a sustainability certification has come from the many OIV resolutions, which define the general principles of sustainable wine and vine production, including environmental, social, economic, and cultural aspects [16]. In addition, other initiatives focus on specific issues, such as traceability [17] or greenhouse emissions and carbon footprint in the wine industry [18]. It is interesting to observe that both scholars and policy-makers agree on considering sustainability applied to viticulture and wine-making as something different from organic (or biodynamic) production, given the broader and more holistic value placed on the former [9]. In fact, it is now agreed to interpret sustainability not only as an environmental concern but also as a social and economic one: rather than limiting the approach merely to an environmental dimension [19] a proper consideration of the ecological, economic, and social dimensions of sustainability can lead to a change in the unsustainable modes of production and consumption, thus contributing to protecting and managing natural resources and enhancing a bio-economic and circular approach to development [8,20,21].

It is often argued that sustainable viticulture frameworks are the response by the wine territories to the latent demand from customers and markets for more transparency in terms of processes and environmental impacts; they are also viewed as a way to highlight and systematize current practices or to improve and promote innovation processes [9]. For this reason, many studies have focused on the effects of including sustainability issues in strategies of vine-growing and wine production, as well as on consumer perception of the main differences between conventional and sustainable wine, including organic production, certification of origin, bio-dynamic wines, and "free wines".

Given the complexity of a product such as wine, its identification with its origin, and the steady growth of "sustainable" lines of production, reviews on these matters are always very careful in analysing segments of products as well as segments of consumers, which differ widely according to country, region, habits, and attitudes towards environment and sustainability. Previous studies have attempted to classify and compare different tools and legislation across different producer countries, both from the "old wine world" and "new actors" [22,9,23,24].

In the recent literature, many works rely on the conceptualisation of sustainability that originated among wine makers, particularly in the United States and Spain. Pullmann et al. [10] compare wineries and food processors in the US in terms of sustainability, highlighting differences in practices and in performance impacts. Their main findings concern the environmental dimension and show how wine producers in the US are far ahead of food processors in addressing sustainability. Pomarici et al. [11] analyse the perception among Californian wine producers of the costs and benefits (both in economic and environmental terms) of joining a sustainability scheme implemented by the State of California. While most farmers interviewed recognised some form of benefit from sustainable practices, some costs we are also acknowledged. However, all agreed on the positive effect of sustainability on quality and vineyard health. Garcia-Cortijo et al. [12] focus on four drivers of sustainability in Spanish wineries: marketing, financial resources, technologies, and innovation. Their main finding is that consumers perceive communication and innovation as more important than financial and technological resources. This kind of analysis is key to draft policies that support the switch to a sustainable approach and to enhance specific sustainability certifications. Finally, Ferrer et al. [14] propose a model of sustainable business in the Spanish wine sector, associating Spanish wineries to archetypic models, identified as either "high sustainability" or "low sustainability". These differ in terms of the type of marketed product, the integration in the supply chain, and the policies required,

[3] With specific annual surveys it will be also possible to use FSDN to measure the evolution of sustainability in wine production, facilitating periodic comparisons both at the farm and the territorial level.

and sustainability is perceived as an increasing element of competitiveness on the internal and external market.

With regard to studies that look more specifically at the Italian market, Broccardo and Zicari [25] explore the role of sustainability in the business model of small and medium farms operating in the wine sector in Italy. They focus on the profitability of family-owned businesses and on sustainability as a vehicle to innovation in the long run. Their paper illustrates how Italian farms operating in the wine sector integrate sustainability in their business models. The Wine sector in Italy is composed mainly of small and medium size family-owned farms, as well as in Spain and France, the main European producers. In Italy, the wine sector has reached high levels of performance, both in terms of production and exports, becoming one of the standards of excellence of the national agri-food sector. Through interviews with wine producers, relevant academic works [26,27,28] have shown that a significant number of farms has become involved in some sort of "sustainability projects" in order to meet specific needs of their customers, both end consumers and intermediaries (Ho.Re.Ca.). The focus of these projects included organic farming, energy saving, and the reduction of chemical inputs. According to Broccardo and Zicari [25], for most of the interviewed farms, sustainability was understood not only from an environmental point of view, but also from a social one, such as work conditions and quality products. Moreover, for younger producers, sustainability was also perceived as a way to increase territorial stewardship and defence. While a broad interest in sustainability is declared by both family and non-family businesses, its practical implications vary substantially. Sustainability is mostly associated with environmental issues, while the combination of environmental with either social or economic issues is less frequent, especially among non-family farms. Firms that are sensitive to sustainability do not always seek to reduce costs; rather, their main goal is to improve customer fidelity through sustainability goals.

The following studies focus on consumers' choices, and specifically on their perception of sustainable production. Capitello and Sirieix [24] analysed Italian and French consumers' perceptions of sustainable versus conventional wine. The study shows how consumers associate different characteristics and beneficial aspects with different categories of sustainable wines, also depending on their level of knowledge of the sector and their personal involvement with wine consumption. A cross-national study conducted in seven wine-producing countries by Szolnoki [22] revealed different understandings of sustainability in the wine industry even between wine producers located in the same region or country. Recent studies have highlighted that different sustainability certifications have appeared in the past decade in many wine-producing regions [9,29,30]. However, the management of sustainability remains underdeveloped in many of the certification frameworks. In a cross-country analysis of several sustainability-assessment frameworks, Flores [9] noted that sustainability frameworks focus on operational issues, while strategic thinking remains underdeveloped. In addition, according to Moscovici and Reed [30], there is a need for more research into the consumer perspective of sustainability certifications. Capitello and Sirieix [24] demonstrate that there is a lot of room to improve the perception of sustainability in wine certifications and that sustainable wine marketers should place a greater emphasis on the level of consumer involvement with wine and the specific associations made by consumers with the sustainable wine category they want to promote.

Several recent studies have shown that consumers are interested in wines produced in an environmentally friendly or socially responsible manner [31,32,33,34]. However, compared with other industries, consumers hold the perception that the wine industry is already relatively 'green', and this creates one of the biggest barriers to the success of the sustainable wine sector [35,36]. Wine is generally perceived as a 'natural' product; thus, unlike for other 'natural' food products, claims of wine being organic have failed to create an important element of differentiation [8,33,36,37]. The sustainable wine market is evolving into a market segment with a vast growth potential and further product differentiation. So, consumer involvement with the quality of sustainable products and efforts in sustainable production practices remain a challenge for the wine industry.

For the Italian sample, the results confirm previous studies on the sustainable wine market [38]. Among the product-attribute associations, Italian respondents attach importance to the environment and ethics, while price of products does not appear to be relevant. Sogari et al. [39] also confirm a direct relationship between positive attitudes towards sustainable wine, stronger belief in environmental protection, and willingness to pay more. This study also brings new insights in relation to consumers' involvement with wine and EMCB (ethically minded consumer behaviour). EMCB does not appear to be sufficient to explain differences in consumers' perceptions of different sustainable wines. Consumers who best differentiate among wines are interested in sustainability to a limited extent, their choices being driven more by the intrinsic quality of the product than by the sustainability of the process.

Another stream of literature focuses on the shift from traditional to sustainable production, such as in the case of the work by Chaminade and Randelli [40]. The authors focus especially on the territorial dynamics of the innovation process and, more specifically, on the role of territorially embedded innovation ecosystems (TEIE) in accelerated sustainability transformations, with a particular focus on the establishment of the biodistrict of Chianti classico.

Another relevant issue, investigated by Merli et al. [41], is that of building solid indicators for measuring sustainability. This topic is particularly relevant when sustainability becomes key in the allocation of public support to the wine sector and to agriculture in general [42]. It also directly involves the FADN in the debate, since it has often been indicated as the relevant dataset for measuring and assessing the level of sustainability of the main agricultural processes and products. The work by Merli et al. [41] stresses once again the need to investigate sustainability not only through environmental indicators but also by including economic and social ones. However, using Life Cycle Assessment (LCA) as the main methodology, it is very difficult to create a common ground for measuring sustainability, because "life cycle" is interpreted in different ways: from farm to product consumption, from farm to gate, and so on. In general, there is a problem with the definition and dimension of sustainability, and with the definition of the life cycle of the product, and this is particularly true for wine. For this reason, there has been a proliferation of methods and standards for sustainability assessment, in the old as in the new wine production world, and each of them, as reviewed by Merli et al. [41], has its own pros and cons. Sustainability indicators should measure the impact of business activities through a scientific, objective, and shared method. This process should be conducted with the support of stakeholders representing different viewpoints. This would improve both consistency of measurements and scientific solidity. The goals set should focus on a common ground leading to strategies for sustainability, acknowledging, at the same time, differences characterizing individual territories, in terms of production and consumption. The identification of shared and comparable tools is essential in building business networks aimed at achieving sustainability in vineyards and wineries. The variety of instruments, indicators and certifications that have been proposed worldwide may lead to confusion for both farms and consumers, who are unlikely to understand the real benefits of sustainable wine production. The authors conclude that it is crucial to develop a common indicator set for sustainable wine production in order to define clear metrics to monitor the industry's environmental, economic, and social impacts.

2.2 The Italian Programs for Wine Sustainability

Outside the academic world, the interest in sustainability of the wine sector in Italy is proven by the wide range of sustainability programs launched in recent years by private producers and consortia. The large number of different strategies, guidelines, and practices is a positive sign of the concern regarding the issue of sustainability in viticulture. However, farmers and producers might not have a clear understanding of the opportunities and benefits deriving from the implementation of a certain sustainability program [8].

As a matter of fact, sustainability has become a key issue for the Italian wine industry. Currently, V.I.V.A. and Equalitas are the two main voluntary wine sustainability certification schemes operating in Italy. Both are based on the three pillars of sustainability (economic, social, and environmental) and apply to the entire life cycle: from the vineyard to the bottle of wine. Moreover, they are both based on a principle of continuous updating of the goals and improvement of the results. Despite some common aspects, the two programs present several important differences.

V.I.V.A. is a public certification established in 2011 by the Ministry of Environment, in cooperation with two Research Centres, Opera of the University "Cattolica del Sacro Cuore" and Agroinnova of the University of Torino. In joining this scheme, winegrowers and winemakers accept to follow certain guidelines and to measure their performance using a well-defined set of international standards, referring to four different significant indicators: 1) air, measured through the carbon footprint applied to the life cycle of a wine bottle; 2) water, measured through the direct water scarcity footprint and the non-comprehensive direct water degradation footprint; 3) vineyard, measured mainly via quantitative and qualitative analysis of the impacts produced on water resources, soil, and biodiversity; 4) territory, taking into account the issue of the landscape (abandonment of vineyards, eco-sustainable materials and native species) and also socio-economic aspects.

The social aspects refer mainly to the relationships established with the local community, the staff (training and salary) and the relationship with the consumers, whereas economic aspects refer to the investments made, the adoption of methods of a green or circular economy, and the acknowledgment of a fair remuneration for the different actors in the value chain. Participation in the scheme is communicated with a label and

a QR code that allow consumers to identify the score for the single wine bottle and for the whole organization. Recognition of this labelling in foreign markets is still in progress. To date, about 40 wineries (number steadily increasing) and more than 60 different wines have joined this certification program.

Equalitas is a private certification, established in 2015 thanks to the initiative of Unione Italiana Vini, Federdoc, with the participation of Gambero Rosso, CSQA and Valoritalia. The scheme is addressed to the needs of the entire supply chain: from small producers, to cellars and bottlers, up to cooperatives. Within Equalitas, sustainability refers not only to the three traditional dimensions – environmental, social, and economic – it also includes two additional pillars: socio-environmental and communication. Participation in the program involves the adoption of virtuous behaviors, compliant with specific requirements periodically updated and tiered as major, minor and recommendations, combined with the use of verifiable and measurable Indicators, certified by a third-party entity. Equalitas is characterized by a gradual approach to sustainability goals, and the results achieved are monitored by an annual Sustainability Report. The certification can be obtained by a single producer or by a territory and refers to three different dimensions: the organization standard, the product standard, and the territory, when it involves at least 60% of a specific PDO/PGI. To date, more than 60 wineries (including 2 in Spain, thanks to an agreement with the Federación Española del Vino) and about 40 different wines are certified.

The differences in the sustainability initiatives in the wine sector are an opportunity for the sector as a whole; however, overlapping methodologies and results which can lead to confusion should be avoided. According to Corbo et al. (2014), a common notion of sustainability should be shared and promoted in the Italian wine sector with the cooperation of academic scholars, institutions, and stake holders. This would provide consumers with greater awareness and a clearer knowledge of the benefits and costs of sustainability. Moreover, a common language and framework is needed, in order to better understand and solve shared problems in vine-growing and the wine industry. Finally, a single and shared sustainability framework and brand could enhance the competitiveness of Italian wine on foreign markets, particularly on those promoting sustainable products, which are where Italian wine is mostly positioned.

In this spirit, the Italian Ministry of Agricultural Policies, Food and Forestry (MiPAAF) introduced in 2020 a legal framework (law 77/2020) to reach a common sustainability standard that would harmonize the two protocols V.I.V.A. and Equalitas, using as starting point the "Sistema di Qualità Nazionale di Produzione Integrata" – SQNPI (National Integrated Production Quality System), which is a voluntary certification programme for agricultural and agri-food products generated using integrated production techniques. For the wine sector, the SQNPI was supposed to be supplemented with additional sustainability requirements, taken from the two aforementioned certifications, which remain autonomous and operational. In this way, Italy will be the first EU Member State to have a national system, shared by the wine chain, to acknowledge and assess the performance of sustainability, that the law itself requires to relate to the new FADN.

The two Italian voluntary sustainability certification programmes are comprehensive and of high methodological value. At the same time, due to the importance of the FADN for the European Farm to Fork Strategy and the Italian law, its ability to assess the sustainability of the wine sector is worth to be tested. However, due to the type of variables and indicators available within the FADN, it is currently impossible to compare farms included in it and those participating in the V.I.V.A. and Equalitas programmes, as the latter are based mainly on international standardised indicators which cannot be calculated via the FADN. Nevertheless, the FADN is able to assess the sustainability of the wine sector in line with the following definition, adopted by the OIV *"Global strategy on the scale of the grape production and processing systems, incorporating at the same time the economic sustainability of structures and territories, producing quality products, considering requirements of precision in sustainable viticulture, risks to the environment, products safety and consumer health and valuing of heritage, historical, cultural, ecological and landscape aspects."* [7].

3. DATA AND RESEARCH METHODOLOGY

The data for the present analysis of sustainability in the Italian wine sector are based on an FADN sample. More precisely, the sample consists of 3,995 units of which 2,983 are farms specialized in vine-growing and 1,012 are farms specialized in wine-making[4]. The two groups have been analysed separately – keeping a distinction between farms that only produce grapes for wine and farms that also directly produce wine own – in order to take into account the considerable differences in the structural equipment and in the consequent eco-

[4] More precisely, within the FADN, a farm is considered specialised when the majority (about three quarters) of the production value is due to vine-growing or wine-making.

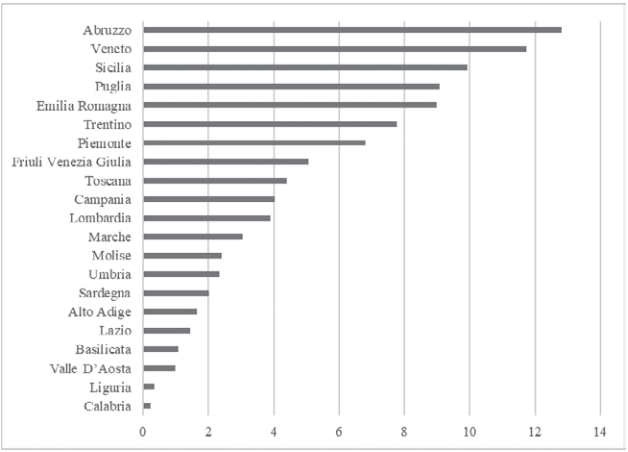

Figure 1. Italian FADN: distribution of vine-growing farms by regions (%). Source: Our elaborations on FADN data 2017-2019.

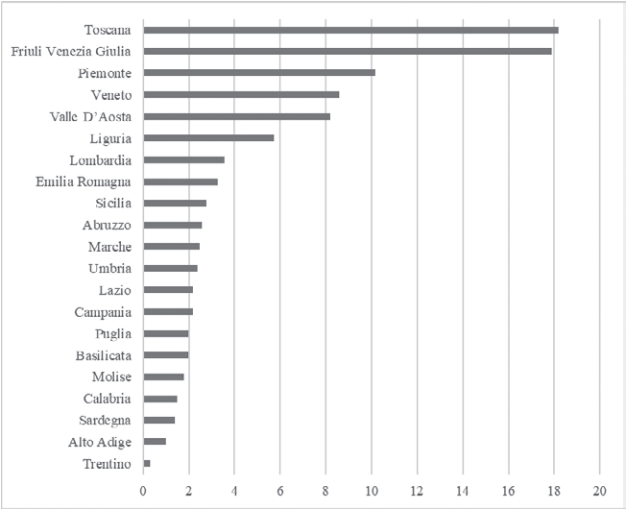

Figure 2. Italian FADN: distribution of wine-making farms by regions (%). Source: Our elaborations on FADN data 2017-2019.

nomic profiles of farms in the two groups [43][5]. The following figures show the regional distribution of farms in the FADN sample that either only produce grapes for wine (Figure 1) or are also engaged in wine processing (Figure 2)[6].

A selection of variables from the FADN, referring to the sample organised in the two subgroups indicated, was used as the basis for the calculation of the wine sector sustainability indicator. The methodology used to calculate the SuWI follows the methodology of the Sustainable Farm Index– SuFI [45], which was developed as a variant of the Agri-Environmental Footprint Index approach methodology [46].

The calculation of the index is based on a multicriteria approach specified from an assessment criteria matrix (ACM) based on the three dimensions of sustainability – environmental, economic, and social – linked to the farm management of the sample selected. More precisely, the ACM is formed by column vectors that indicate the three dimensions of sustainability, while the row vectors indicate the set of indicators used within the farm management to calculate the SuWI. The indicators were extracted from variables available in the FADN on the grapevine sector for the accounting years 2017-2018-2019 and have been observed at the regional level. In Table 1, the selected indicators are listed and described, and the reason they were chosen (contextualization) in relation to the three dimensions of sustainability is explained.

It should be noted that the indicators have been selected according to the specific characteristics of the wine-producing and vine-growing sectors, rather than basing them on the territorial context of each region. However, this level of approximation is compatible with the objectives of the present research, the main goal of which is to test the current and the potential functionality of the FADN to conduct large-scale sustainability analyses. Future research could incorporate the territorial dimension in a more structured way.

Once identified, indicators were normalized to make them comparable and to proceed with the calculation of the farms' sustainability indices by adding the weighted scores for each of the levels within the evaluation matrix. To this end, indicators were converted into scores according to the relationships between indicator values and level of sustainability. The relationships observed can be linear, or non-linear, and scaling can be categorical or binary (Mortimer et al., 2009). For non-dichotomous indicators, the score was predominantly assigned by dividing the observations into quartiles; on the contrary, for dichotomous indicators the score assigned was equal to 10 and 5 (respectively, presence or absence)[7]; finally, for other indi-

[5] It is worth noting that, for an even more accurate sustainability analysis, the FADN sample should have been separated into four sub-groups, in order to take into account the quality of the grapes and wines produced. However, the small size of the sample did not lend itself to such detailed segmentation.

[6] The two groups in the FADN sample, jointly considered, have been compared with other official statistical sources (National Institute of Stastistics - ISTAT). The distribution of the farms in the FADN is generally in line with the overall distribution of the Italian farms with grapevines, with small differences due the sample characteristics (minimum economic dimension) [44] and the presence of farms with grapes not for wine in some southern regions.

[7] For example, this is the case for organic farming. All farms certified as organic were considered equally committed to environmental pro-

Table 1. Indicators used in the development of the sustainability index and their contextualization.

Indicator	Description	Contextualization
Economic dimension		
Net added value per hectare of utilized agricultural area	Represents the productivity of the land net of current costs, depreciation, provisions, taxes and duties and gross of subsidies.	Well assessed profitability indicator
Net added value per labour unit	Represents labour productivity net of current costs, depreciation, provisions, taxes and duties and before subsidies.	Well assessed profitability indicator
New investments	Represents the new investments that are made by the farm over the course of a year	Economic viability of the farms in the long term
Current costs on revenues	Ratio of costs incurred for current management to revenue	Well assessed profitability indicator
Income from Other Gainful Activities	Revenues from complementary activities to agricultural ones such as agritourism, active Contracting, Active Rentals, other Complementary revenues	Farm diversification is an indicator of additional income
Environmental dimension		
Nitrogen content per hectare of Utilized Agricultural Area	Represents the quantity (quintals) of nitrogen present in fertilizers used per hectare of agricultural area.	Indirect indicator of the level of intensity linked to fertilization
Incidence of toxic pesticide expenditure on the total pesticide expenditure	Represents the incidence of farm expenditure for toxic and very toxic pesticides on the total pesticide expenditure	Impact indicator on natural and antagonistic entomofauna
Agro-climatic-environmental payments	Indicates whether the farm has received agro-climatic-environmental payments	Reports farms eligible for RDP agro-environment payments
Organic farming	Indicates the presence of organic farming practices	Reports farms that follow organic production therefore with a high degree of environmental sustainability
Altitude	Represents the location of the farm (plain, hill, mountain)	Enhances the ecosystem services related to high altitude viticulture (e.g. hydrogeological stability, carbon storage, etc.)
Social dimension		
Farmer's age	Represents the age of the farm' handler	Innovation propensity and maintenance of agricultural activity
Family labour unit per hectare of Utilized Agricultural Area	Represents the ratio of family labour units per hectare of agricultural area	Family employment potential
Labour unit per hectare of Utilized Agricultural Area	Represents the ratio of labour units per hectare of agricultural area.	Local employment potential
Certifications (PDO/PGI)	Represents the presence of farm certifications	Social capital indicator, due to the beneficial effects for the local community
Farmer's education	Represents the level of education of the farmer	Higher level of knowledge allows for better farm management
Farmer's gender	Represents farmer's gender	Gender equality provides social value

cators, scores were assigned on the basis of specific evaluations (e.g. farmer's age and farmer's education).

According to this methodology, both the selected indicators and the scores assigned to each of them were carefully tested through a specific questionnaire submitted to a qualified group of stakeholders: experts in wine sector, the FADN, and sectoral policy from academic and technical-scientific world. The result of the score scaling process is shown in Table 2.

Prior to aggregating the normalised indicators, a weight was assigned to the indicators selected within each dimension (the sum of the weights at the dimension level is = 1). Within each dimension, the indica-

tection, obtaining a score of 10. The score was assigned regardless of whether farms receive CAP support. Indeed, the resources for organic farming in Italy are not sufficient for all applications, so the presence/absence of support cannot be considered a discriminating factor. In addition, the identification of the organic method does not consider possible technical issues, but only looks at the participation or not in a certification system defined by the most recent EU strategic documents, and this merely indicates that it is sustainable in comparison with conventional methods.

Table 2. Scaled scores of selected indicators.

Indicator	Unit	Scaling	Score
Net added value per hectare of utilized agricultural area	€/ha	< 0	0
		I quartile	2
		II quartile	4
		III quartile	7
		IV quartile	10
Net added value per labor unit	€/LU	< 0	0
		I quartile	2
		II quartile	4
		III quartile	7
		IV quartile	10
New investments		No	5
		Yes	10
Current costs on revenues	€	I quartile	10
		II quartile	7
		III quartile	4
		IV quartile	2
Income from Other Gainful Activities		No	5
		Yes	10
Nitrogen content per hectare of Utilized Agricultural Area	Q./ha	I quartile	10
		II quartile	7
		III quartile	4
		IV quartile	2
		Not valued	5
Incidence of toxic pesticide expenditure on the total pesticide expenditure	%	0	10
		>0 and <25%	3
		>25% and <50%	2
		>50% and <75%	0
		>75%	0
Agro-climatic-environmental payments		No	5
		Yes	10
Organic farming		No	5
		Yes	10

Indicator	Unit	Scaling	Score
Altitude		Plain	5
		Hill	8
		Mountain	10
Farmer's age	year	<70	2
		60 a 70	4
		50 60	6
		40 50	8
		<40	10
Family labour unit per hectare of Utilized Agricultural Area	lu/ha	I quartile	2
		II quartile	4
		III quartile	7
		IV quartile	10
Labour unit per hectare of Utilized Agricultural Area	LU/ha	I quartile	2
		II quartile	4
		III quartile	7
		IV quartile	10
Certifications	N.	0	2
		1	6
		>1	10
Farmer's education		no degree / elementary school license	2
		middle school license	4
		professional diploma / high school diploma	8
		short degree / degree / specialization	10
Farmer's gender		female	10
		male	5

Source: Our elaborations on FADN data 2017-2019

tors were assessed as being of equal importance[8]. The final aggregation procedure then led to the calculation of the sustainability index where the SuWI obtained is expressed on a scale of values between 0 (low level of sustainability) and 10 (high level of sustainability).

Summarising, for each farm in our FADN sample the multidimensional sustainability index is given by the weighted average of the scores assigned to the same farm linked to the indicators belonging to each of the three dimensions considered. Therefore, the SuWI of each farm represents the weighted average of the three sustainability index categories: economic, environmental, and social. Finally, single data referred to all farms in the two groups are reaggregated to obtain a value of the SuWI at the regional level. Table 3 and the following show the results of these calculations.

The last step in this assessment is a sensitivity analysis, which allows comparisons of farms in each Region by considering different scenarios[9]. More precisely, we

[8] The weights assigned to the indicators belonging to the economic dimension is equal to 1/5 (as we have identified five indicators in the economic dimension); the weights assigned to the indicators belonging to the environmental dimension is equal to 1/5 (as we have identified five indicators in the environmental dimension); the weights assigned to the indicators belonging to the social dimension is equal to 1/6 (there are six indicators).

[9] The word "scenario" is used here to represent alternative definitions of sustainability, each giving more importance (weight) to one specific dimension.

first created what we called a "balanced" scenario, in which each dimension of sustainability assumes the same relevance in the creation of the synthetic indicator (each weighing 33.3%); then, we built three additional different scenarios, each of them characterized by different levels of importance assigned to each dimension: what we called the economic, environmental, and social scenarios. In these scenarios, the dominant dimension accounts for 50% of the total weight, while the other two 25% each. To assign a higher weight to each of the three dimensions allows us to rank the performance of each of the two different groups of farms from a specific point of view (or scenario), and subsequently to identify the most performing regions according to each analysed dimension. Therefore, the SuWI has also been calculated under the three additional scenarios.

4. DISCUSSION OF RESULTS

4.1 The SuWI in the balanced scenario

The analysis moves from the "balanced" scenario, in which the three dimensions of sustainability are weighted equally. Overall average scores roughly ranged from just over 5 to nearly 8 in both vine-growing farms and wine-making farms, although the index itself could vary between 0 and 10. The average value of SuWI is equal to 5.97 for the first group and to 6.30 for the second, confirming the good level of diffusion of sustainability practices within the national wine sector (Table 3)[10]. This result is not surprising given the high attention devoted in the wine sector to the sustainable practices and quality labels previously described. However, although the variability in the scores is not large, the differences in the mean values are statistically significant both within the groups and between the different regions (F_{2980} = 39.331 for vine-growing farms and F_{1010} = 18.670 for wine-making farms; p-value <1%).

Analysing the results at the regional level it emerges that in the case of vine-growing farms the best results are achieved by Valle d'Aosta and Trentino-Alto Adige, while the lowest performances are found in the case of Sardegna, Emilia-Romagna and Marche, although the values do not differ much from the national average. In the case of the wine-making farms similar features are displayed, with Trentino-Alto Adige and Valle d'Aosta among the best performing regions, while Sardegna, Puglia and Molise are the regions with the lowest scores.

To better understand these results, it is helpful to look at the partial scores obtained for each sustainability dimension. Indeed, it must be recalled that SuWI is a synthetic and complex index composed of weighted indicators within each dimension (Table 4 and Table 5). In the case of Trentino-Alto Adige and Valle d'Aosta, the fact that farms are located in mountain areas grant them a sort of environmental advantage, according to the construction of the evaluation matrix. This result can in part be justified by the importance that viticulture could have in these contexts in terms of providing ecosystem services related, for example, to hydrogeological stability, landscapes with tourism value, the conservation of biodiversity, and above all the maintenance of agricultural activity in disadvantaged territories.

By contrast, this aspect could penalize other regions in achieving a good environmental index if farms are mainly located in lowland areas, where viticulture is more likely to be focused on quantity rather than quality, which also has repercussions in terms of crop intensification. In this regard, it should be noted that the region with the best environmental performance is Calabria,

Table 3. Balanced scenario: SuWI by type of farm and by Italian region.

Vine-growing farms		Wine-making farms	
Regions	**SuWI**	**Regions**	**SuWI**
Valle d'Aosta	7.22	Alto Adige	7.87
Alto Adige	7.14	Valle d'Aosta	7.35
Trentino	6.47	Trentino	6.98
Lombardia	6.32	Veneto	6.73
Umbria	6.23	Liguria	6.47
Veneto	6.19	Friuli Venezia Giulia	6.36
Liguria	6.15	**Italia**	**6.30**
Calabria	6.12	Campania	6.29
Lazio	6.05	Umbria	6.25
Friuli Venezia Giulia	6.03	Toscana	6.23
Abruzzo	5.98	Lazio	6.22
Italia	**5.97**	Sicilia	6.14
Piemonte	5.95	Lombardia	6.11
Campania	5.95	Calabria	6.01
Toscana	5.93	Piemonte	6.00
Molise	5.87	Abruzzo	5.91
Puglia	5.69	Basilicata	5.90
Basilicata	5.68	Marche	5.84
Sicilia	5.66	Emilia Romagna	5.79
Marche	5.63	Molise	5.43
Emilia Romagna	5.58	Puglia	5.31
Sardegna	5.57	Sardegna	5.23
$F_{(2980)}$	39.33	$F_{(1010)}$	18.67
p-value	< 1%	*p-value*	< 1%

Source: Our elaborations on FADN data 2017-2019.

[10] A preliminary comparative analysis was also carried out referring to other specializations. In particular, a comparison with permanent crops confirms the relatively higher performance of the wine sector. This justifies and supports the choice made for this explorative exercise through the FADN and, at the same time, reflects the advanced level of sustainability achieved by the wine sector, thanks to the well-structured certification currently in place.

Table 4. Vine-growing farms: economic, environmental, social indices in the balanced scenario.

Regions	Economic index	Regions	Environmental index	Regions	Social index
Trentino	6.68	Calabria	7.83	Alto Adige	7.63
Friuli Venezia Giulia	6.68	Valle D'Aosta	7.55	Valle D'Aosta	7.63
Valle D'Aosta	6.48	Umbria	7.52	Liguria	6.72
Alto Adige	6.38	Alto Adige	7.42	Trentino	6.70
Veneto	6.36	Lazio	7.09	Abruzzo	6.45
Emilia Romagna	6.03	Lombardia	7.04	Veneto	6.15
Puglia	5.96	Sicilia	6.91	Campania	6.13
Lombardia	5.95	Campania	6.74	Piemonte	6.08
Umbria	5.90	Marche	6.67	Lombardia	6.07
Italia	**5.83**	Toscana	6.58	**Italia**	**5.78**
Liguria	5.82	Molise	6.32	Friuli Venezia Giulia	5.74
Molise	5.81	**Italia**	**6.31**	Lazio	5.73
Piemonte	5.79	Basilicata	6.14	Calabria	5.55
Toscana	5.69	Veneto	6.06	Toscana	5.52
Abruzzo	5.44	Piemonte	6.05	Basilicata	5.49
Basilicata	5.41	Abruzzo	6.04	Molise	5.47
Marche	5.32	Puglia	6.04	Sardegna	5.39
Lazio	5.32	Trentino	6.03	Umbria	5.25
Sardegna	5.31	Sardegna	6.00	Sicilia	5.12
Campania	4.98	Emilia Romagna	5.96	Puglia	5.06
Calabria	4.97	Liguria	5.92	Marche	4.90
Sicilia	4.96	Friuli Venezia Giulia	5.66	Emilia Romagna	4.75

Source: Our elaborations on FADN data 2017-2019.

thanks to its high incidence of organic farms within the regional FADN sample and the consequent absence of the use of toxic pesticides.

Trentino-Alto Adige and Valle d'Aosta show high scores also for other dimensions, especially for the social dimensions in both groups of farms. This may be partially linked to the fact that the farms belonging to these regions are generally highly specialised in quality wines, having achieved many different certifications, which would imply a greater number of social relationships, as well as the important share of female entrepreneurship in the sample.

On the other hand, for the economic dimension a polarization in performance emerges, with the North-East Regions prevailing over the southern ones. This result is in line with expectations, considering the strategic importance of the wine sector in the agricultural economy of these Regions [47]. It is worth noting that some important Regions with a high vine-growing vocation and tradition nevertheless show lower economic sustainability indices than the national average (Sicilia and Puglia only for wine-making farms). This may be due to the composition of production in terms of prevailing quality types (wines with or without certifications), which is still quite diverse among Italian geographical areas[11].

In addition, the results achieved by the indicator in the economic dimension are only in a few cases aligned with those obtained in the other two dimensions. This is the case of Sicilia, which, while obtaining a good positioning of the environmental index in both groups (the organic farms in Sicilia are widespread with a low consumption of nitrogen and toxic pesticides), is on the contrary penalized by the results in the economic

[11] Other studies based on the Italian FADN sample have showed a generally higher performance for the farms specialised in the production of quality wines [43,44].

Table 5. Wine-making farms: economic, environmental, social indices in the balanced scenario.

Regions	Economic index	Regions	Environmental index	Regions	Social index
Alto Adige	7.92	Calabria	8.23	Alto Adige	7.92
Veneto	7.28	Trentino	8.20	Valle D'Aosta	7.41
Valle D'Aosta	6.87	Valle D'Aosta	7.96	Trentino	7.33
Friuli Venezia Giulia	6.64	Alto Adige	7.76	Liguria	6.98
Toscana	6.15	Umbria	7.58	Lazio	6.48
Italia	**6.15**	Campania	7.47	Veneto	6.30
Emilia Romagna	6.07	Sicilia	7.30	Lombardia	6.27
Piemonte	5.99	Basilicata	6.82	Abruzzo	6.21
Liguria	5.90	Lazio	6.75	Campania	6.15
Sicilia	5.54	Sardegna	6.67	Toscana	6.13
Umbria	5.54	**Italia**	**6.65**	**Italia**	**6.13**
Lombardia	5.54	Veneto	6.61	Friuli Venezia Giulia	6.10
Marche	5.49	Liguria	6.52	Marche	5.78
Abruzzo	5.48	Lombardia	6.51	Basilicata	5.75
Lazio	5.43	Toscana	6.40	Calabria	5.71
Trentino	5.40	Molise	6.34	Piemonte	5.67
Puglia	5.25	Piemonte	6.33	Umbria	5.64
Campania	5.25	Friuli Venezia Giulia	6.33	Sicilia	5.58
Molise	5.22	Emilia Romagna	6.30	Puglia	5.14
Basilicata	5.14	Marche	6.26	Emilia Romagna	4.98
Sardegna	4.37	Abruzzo	6.05	Molise	4.71
Calabria	4.11	Puglia	5.55	Sardegna	4.65

Source: Our elaborations on FADN data 2017-2019.

and social dimensions. Similarly, Emilia-Romagna and Puglia, despite good economic performance in the vine grape sector (less so in the wine sector), are penalized in the social and environmental dimension, which in part can be attributed to the high intensity of the farms. Campania, Toscana and Piemonte are in line with the national average, being regions traditionally suited to viticulture, while, in the case of wine-making farms, Toscana and Piemonte are placed below the national average. In the case of Toscana, the economic and social dimensions reduce the global result of the SuWI, probably due to the high average age of the farmers, the low recourse to waged workforce as well as the persistence of economic difficulties. The most relevant scores for Piemonte are the quantity of pesticides used, which is an indicator of a high degree of intensity of the farming activity, together with a low level of education of farmers (compared to the national average) and a reduced number of new investments.

In sum, these results confirm that the current structure of the FADN is still mainly oriented to capturing economic aspects and less suited to explaining the interactions between the different dimensions of sustainability in a comprehensive and contextual manner. Additional improvements and integrations need to be put in place, especially in terms of social and environmental statistics, in order to fruitfully turn the accounting network (FADN) into a reliable data bank for sustainability (FSDN).

4.2 The SuWI in the alternative scenarios

As mentioned above, a further analysis was carried out on three different scenarios, each emphasising one of the three dimensions of sustainability. This simulation aims to test the robustness of the multidimensional sustainability index for the vine-growing and wine-making farms in identifying the effects of various policies that may enhance one or the other of the dimensions of the

Table 6. Vine-growing farms' sustainability performance in the alternative scenarios.

Economic scenario	SuWI	Enviromental scenario	SuWI	Social scenario	SuWI
Valle D'Aosta	7.03	Valle D'Aosta	7.30	Valle D'Aosta	7.32
Alto Adige	6.95	Alto Adige	7.21	Alto Adige	7.27
Trentino	6.52	Umbria	6.55	Trentino	6.53
Veneto	6.23	Calabria	6.54	Liguria	6.29
Lombardia	6.22	Lombardia	6.48	Lombardia	6.26
Friuli Venezia Giulia	6.19	Trentino	6.36	Veneto	6.18
Umbria	6.14	Lazio	6.31	Abruzzo	6.10
Liguria	6.07	Veneto	6.16	Campania	5.99
Italia	**5.94**	Campania	6.15	Piemonte	5.98
Piemonte	5.90	Liguria	6.09	Umbria	5.98
Toscana	5.87	Toscana	6.09	Calabria	5.97
Lazio	5.87	**Italia**	**6.06**	Lazio	5.97
Molise	5.85	Abruzzo	6.00	Friuli Venezia Giulia	5.95
Abruzzo	5.85	Molise	5.98	**Italia**	**5.93**
Calabria	5.83	Sicilia	5.97	Toscana	5.83
Puglia	5.76	Piemonte	5.97	Molise	5.77
Campania	5.71	Friuli Venezia Giulia	5.94	Basilicata	5.63
Emilia Romagna	5.69	Marche	5.89	Puglia	5.53
Basilicata	5.61	Basilicata	5.79	Sicilia	5.53
Marche	5.55	Puglia	5.78	Sardegna	5.52
Sardegna	5.50	Emilia Romagna	5.68	Marche	5.45
Sicilia	5.49	Sardegna	5.68	Emilia Romagna	5.37

Source: Our elaborations on FADN data 2017-2019.

index. For example, one could wonder what the effects of "deep green" measures imposed by a European or a National policy could be on the vine-growing and the wine-making farms.

The three simulated scenarios confirm, to a certain extent, the results of the "balanced" scenario, with the only exceptions of Calabria in the South and Friuli Venezia Giulia, in the North, for both groups of farms (Table 6 and Table 7), while Campania differs only for the vine-growing farms. Calabria's environmental performance is very good, but its economic and social performance is definitely poorer. On the contrary, Friuli Venezia Giulia features a satisfactory economic performance but the environmental one is much poorer, which implies a rather high level of intensiveness in the farm management and the technical performance.

Comparing the different scenarios, in the case of vine-growing farms in the economic scenario, the number of regions above the national average value (5.94) is lower (8) than in the other two scenarios (respectively 11 for environmental and 13 for social). Moreover, the top group of regions for the economic index includes only regions from the North-East plus Umbria, whereas the other two groups over the average are much more heterogeneous. It should be noted that the north-eastern regions and, to a lesser extent Umbria, are quite specialised in vine-growing and wine-making, with a high share of the sectoral value added.

Table 7. Wine-making farms' sustainability performance in the alternative scenarios.

Economic scenario	SuWI	Enviromental scenario	SuWI	Social scenario	SuWI
Alto Adige	7.88	Alto Adige	7.84	Alto Adige	7.88
Valle D'Aosta	7.21	Valle D'Aosta	7.47	Valle D'Aosta	7.36
Veneto	6.87	Trentino	7.28	Trentino	7.07
Trentino	6.58	Veneto	6.70	Veneto	6.62
Friuli Venezia Giulia	6.43	Campania	6.59	Liguria	6.60
Liguria	6.33	Umbria	6.58	Friuli Venezia Giulia	6.29
Italia	**6.26**	Calabria	6.57	Lazio	6.29
Toscana	6.21	Liguria	6.48	**Italia**	**6.26**
Umbria	6.07	Sicilia	6.43	Campania	6.26
Campania	6.03	**Italia**	**6.39**	Toscana	6.21
Lazio	6.02	Lazio	6.36	Lombardia	6.15
Piemonte	6.00	Friuli Venezia Giulia	6.35	Umbria	6.10
Sicilia	5.99	Toscana	6.27	Sicilia	6.00
Lombardia	5.96	Lombardia	6.21	Abruzzo	5.99
Emilia Romagna	5.86	Basilicata	6.13	Calabria	5.94
Abruzzo	5.81	Piemonte	6.08	Piemonte	5.92
Marche	5.76	Marche	5.95	Basilicata	5.87
Basilicata	5.71	Abruzzo	5.95	Marche	5.83
Calabria	5.54	Emilia Romagna	5.91	Emilia Romagna	5.58
Molise	5.38	Molise	5.66	Puglia	5.27
Puglia	5.30	Sardegna	5.59	Molise	5.25
Sardegna	5.02	Puglia	5.37	Sardegna	5.09

Source: Our elaborations on FADN data 2017-2019.

Moving to wine-making farms, there seems to be a little less variability in the values achieved by each Region in the three dimensions. Only 6 Regions show a higher-than-average value (6.26) in the economic scenario, while this figure rises to 9 for the environmental scenario (average score 6.39) and 7 for the social one (average equals 6.26). Once again, it is especially north-eastern regions (Trentino, Alto Adige, Veneto) and mountainous regions (Valle d'Aosta and Liguria) that place high in the ranking in all the scenarios considered. All in all, in the case of wine-making farms, there seems to be a higher homogeneity and contiguity in the three scenarios presented. This is definitely a topic worth investigating in the future with proper instruments.

These analyses confirm the power of the FADN as a tool for evaluating and monitoring farms' overall performance. However, as regards sustainability, the necessity to further develop the FADN has been confirmed. The main goal, as indicated by the Commission itself, will be collecting additional information with an adequate level of detail, both at the farm and the territorial level. Clearly, this must be a long-term adjustment process that will take some time and effort throughout the European FADN network, with the crucial support of the Commission and research offices, which will need to be involved in impact assessments and territorial analyses.

Another key point is that of the representativeness of the FADN sample and its robustness. Particularly relevant for the analysis of sustainability in the wine sector is the exclusion – due to the EU regulations 79/56 and 1217/2009 – from the sample of micro farms (EDU < 8,000 euro) which constitute a significant portion of all farms in Europe and particularly in Italy, especially in marginal territories and in specific production sectors,

including the cultivation of wine grapes. Such a feature of the Italian FADN sample might, for example, affect the overall assessment of social and environmental sustainability. In the move from the FADN to the FSDN, some statistical rethinking and adjustment of the construction of the sample would be appropriate and advisable.

On the whole, our SuWI shows encouraging results when applied to the wine sector. However, it is necessary to select proper homogeneous groups of farms (vine-growing and wine-making) to make the analysis fit better to the sectoral characteristics. Moreover, it reveals some critical issues in the use of the FADN database for a global sustainability analysis – in its threefold dimension – due to its current structure.

5. CONCLUSIONS

In the framework of the new CAP 2023-2027, in which support to farmers is increasingly coupled to specific desirable behaviours, the creation of a synthetic indicator including all three dimensions of sustainability, and applicable to specific sectors, is becoming one of the main challenges [48,49]. To this end, contributions for the construction of synthetic indicators of sustainability are appropriate and even necessary. Many recent works have tested a wide range of synthetic measures of sustainability, but there are no previous studies that have used the FADN for this purpose. Nevertheless, in a few years the FADN should become, according to the EU Commission itself, the main source of data on and measurements of desirable farming behaviours aimed at enhancing sustainability.

The exercise through the FADN has highlighted some relevant challenges. The most important of these are the representativeness of the samples, the replicability of the measures, the generalisation of the indicators, the statistical robustness, and the effectiveness in identifying specific connections between an observed action and the level of sustainability achieved. Our exercise focused on the wine sector, one of the most advanced production systems in terms of certification of sustainability in Italy, so it is interesting to see how it actually performs with regards to sustainability in its three dimensions, based on a series of simple but rather effective indicators originating from the FADN and aggregated in a single indicator like the SuWI. The wine sector is interesting as a case study because it is ahead of other sectors in Italy and other European and non-European countries in the matter of sustainability labels and quality acknowledgment by consumers. A high number of recent papers, as mentioned above, have reported on the awareness of the consumers, the efforts of the producers to become more sustainable, and the advancements in the policy design to combine, alongside the recent strategies of the EU, production goals with environmental and social concerns.

This is the first attempt to apply this methodology to the wine sector and, while it has been quite effective in reflecting the full complexity of the concept itself and in comparing performances in space and possibly in time too, it does not allow one to describe in absolute terms how sustainable a farm, or a group of farms, or a specialised territory is. More work is needed in this respect.

With regard to the composition of the index proposed here, it implies necessarily a sort of compromise amongst the three dimensions considered: the economic, environmental and social dimensions of sustainability. This "average" value of performance could help overcome the idea of possible trade-offs amongst the three dimensions, so that the environmental (natural resources) and social (labour) dimensions of sustainability would no longer be considered constraints, but rather as opportunities to maximise economic values (profits and revenues) [11,50]. Future developments in the method of calculating the SuWI, using appropriate methodologies, could also take into consideration the evaluation of the reciprocal effect (adjunctive or diminutive) among indicators within the different dimensions and between the three pillars of sustainability. However, both innovative policies and new micro and user-friendly technology (digital technology and precision farming) have contributed to reducing the traditional trade-offs among sustainability goals, so that economic goals can be boosted within a more general framework of social and environmental sustainability.

With regards to the performance of the Italian regions as measured by the SuWI, the regional ranking shows significant differences in the position of the Italian regions according to the two groups of farms. Among the wine-making farms, the SuWI shows a greater variability of scores; furthermore, a smaller number of regions achieved a result that was above the Italian average, suggesting that the most sustainable wine-making farms are concentrated in a few regions.

This study also explains the current potential of the Italian FADN for use in sustainability analyses. From this preliminary assessment of the wine sector, some interesting recommendations emerge, aimed at increasing the capability of the FADN for the analysis of sustainability, and more in general in the agricultural sector, as indicated in the Farm to Fork Strategy and confirmed in the roadmap for the construction of the new FSDN.

With regards to data, the main shortcoming identified is the lack of or weakness of some information, which has been overcome here with the use of proxies, which, however, make the link between the variables chosen and the specific dimension of sustainability rather unstable and weaker than they should be. However, it must be said that the analytical structure of the FADN has historically been optimized on the economic dimension of farms, while the environmental and social dimensions have only recently begun to be regularly observed, recorded, and enhanced. The analytical structure of the Italian FADN, which provides for the allocation of costs to individual production processes, makes it possible to indirectly measure the quantities of some technical inputs (e.g. nitrogen and phosphorus) with a good degree of approximation. On the contrary, in the case of pesticides it is not yet possible to identify variables that consider the quantity used and the degree of toxicity. But it is above all in the social dimension that improvements are needed to obtain more precise and solid indicators, so that when the FADN turns into the FSDN, it can indeed have a powerful and reliable set of data for the global assessment of sustainability.

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REFERENCES

[1] FAO, 1997. Guidelines for the Integration of Sustainable Agriculture and Rural Development into Agricultural Policies (Agricultural Policy and Economic Development series 4).

[2] United Nations, 1987. Our Common Future: Report of the World Commission on Environment and Development, New York (NY, USA).

[3] European Commission, 2019. The European green deal, COM(2019) 640 final, Brussels, 11.12.2019.

[4] European Union, 2020. Farm to Fork Strategy. For a fair, healthy and environmentally-friendly food system, Brussels.

[5] European Commission, 2020. How the future CAP will contribute to the EU Green Deal, Brussels.

[6] Santos V., Dias A., Ramos P., Madeira A., Sousa B., 2022. The influence of wine storytelling on the global wine tourism experience, Wine Economics and Policy, 11(1), 3:13.

[7] OIV, 2016. Resolution CST 518/2016-OIV General Principles of Sustainable Vitiviniculture – Environmental – Social – Economic and Cultural Aspects. Bento Gonçalves, Brazil.

[8] Corbo C., Lamastra L., Capri E., 2014. From environmental to sustainable programs: A review of sustainability initiatives in the Italian wine sector. Sustainability, 6: 2133-2159.

[9] Flores S.S., 2018. What is sustainability in the wine world? A cross-country analysis of wine sustainability frameworks. *Journal of Cleaner Production*, 172: 2301-2312.

[10] Pullmann, M.E., Maloni, M.J., Dillard, J., 2010. Sustainability Practices in Food Supply Chains: How is Wine Different?. Journal of Wine Research, 21 (1): 35-56.

[11] Pomarici E., Vecchio, R., Mariani, A., 2015. Wineries' Perception of Sustainability Costs and Benefits: An Exploratory Study in California. Sustainability, 7: 16164-16174; doi:10.3390/su71215806

[12] García-Cortijo M.C., Ferrer J.R., Castillo-Valero, J.S., Pinilla V., 2021. The Drivers of the Sustainability of Spanish Wineries: Resources and Capabilities, Sustainability, 13, 10171. https://doi.org/10.3390/su131810171

[13] Baiano A., 2021. An Overview on Sustainability in the Wine Production Chain. Beverages, 7, 15. https://doi.org/10.3390/beverages7010015

[14] Ferrer J.R., García-Cortijo M.C., Pinilla V., Castillo-Valero J.S., 2021. The business model and sustainability in the Spanish wine sector. Journal of Cleaner Production, 330, 129810. https://doi.org/10.1016/j.jclepro.2021.129810

[15] Elkington, J., 1999. Cannibals with Forks: The Triple Bottom Line of 21st Century Business, Capstone Publishing, Oxford.

[16] OIV, 2020, Resolution OIV-VITI 641-2020 OIV - Guide for the implementation of principles of sustainable vitiviniculture. Paris videoconference, 26th November.

[17] OIV, 2007. Resolution CST 1/2007-Traceability Guidelines in the Vitivinicultural Sector. Paris, France.

[18] OIV, 2015. Resolution CST 503AB/2015-greenhouse Gases Accounting in the Vine and Wine Sector e Recognised Gases and Inventory of Emissions and Sequestrations. Mainz, Germany.

[19] Maicas S., Mateo J.J., 2020. Sustainability of wine production. Sustainability, 12, 559.

[20] Corrado S., Sala S., 2018. Bio-economy contribution to circular economy, in Benetto E., Gericke K., Guiton M. (eds.), Designing sustainable technologies, products and policies. From science to innovation, Springer pp. 49-59, ISBN 978-3-319-66981-6 (eBook) https://doi.org/10.1007/978-3-319-66981-6.

[21] Obi C., Vergamini D., Bartolini F., Brunori G., 2020. The impact of change in regulatory and market environment on sustainability of wine producers: a structural equation model, Wine Economics and Policy 9(1): 51-61.

[22] Szolnoki G., 2013. A cross-national comparison of sustainability in the wine industry. Journal of Cleaner Production, 53: 243-251.

[23] Merli R., Preziosi M., Acampora A.,2017. Sustainability experiences in the wine sector: toward the development of an international indicators system. Journal of Cleaner Production, 172: 3791-3805.

[24] Capitello R., Sirieix L., 2019. Consumers' perception of sustainable wine: An exploratory study in France and Italy. Economies, 7(2), 33.

[25] Broccardo L., Zicari A., 2020. Sustainability as a driver for value creation: a business model analysis of small and medium enterprises in the Italian wine sector. Journal of Cleaner Production, 259, 120852.

[26] Galati A., Crescimanno M., Rossi M., Farrugia D., Tinervia S., 2014. The determinants affecting the internationalisation of the Italian SMEs producing sparkling wines: an empirical study on the RBV of the firms. International Journal of Globalisation and Small Business, 6(2): 100-118.

[27] Galati A., Tinervia S., Crescimanno M., Spezia F., 2017. Changes in the international wine market competitiveness. International Journal of Globalisation and Small Business, 9(4): 277-293.

[28] Pomarici E., Corsi, A., Mazzarino, S., Sardone R., 2021. The Italian Wine Sector: Evolution, Structure, Competitiveness and Future Challenges of an Enduring Leader. Italian Economic Journal, 7: 259-295, Springer, https://doi.org/10.1007/s40797-021-00144-5.

[29] Martins A.A., Araújo A.R., Graça A., Caetano N.S., Mata T.M., 2018. Towards sustainable wine: Comparison of two Portuguese wines. Journal of Cleaner Production, 183: 662-76.

[30] Moscovici D., Reed A., 2018. Comparing wine sustainability certifications around the world: History, status and opportunity. *Journal of Wine Research* 29: 1-25.

[31] Ginon E., Ares G., dos Santos Laboissière L.H.E., Brouard J., Issanchou S., Deliza R., 2014. Logos indicating environmental sustainability in wine production: An exploratory study on how do Burgundy wine consumers perceive them. Food Research International 62: 837-845.

[32] Pomarici E., Vecchio R., 2014. Millennial generation attitudes to sustainable wine: An exploratory study on Italian consumers. Journal of Cleaner Production 66: 537-545.

[33] Remaud H., Sirieix L., 2010. Consumer perceptions of eco-friendly vs. conventional wines in Australia. Paper presented at the 5th International Academy of Wine Business Research Conference, Auckland, New Zealand, February 8-10.

[34] Schäufele I., Hamm U., 2018. Organic wine purchase behaviour in Germany: Exploring the attitude-behaviour-gap with data from a household panel. Food Quality and Preference, 63: 1-11.

[35] De Salvo M., Capitello R., Begalli D., 2018. How CS can be used for gaining info about consumers and the market? In C. Santini and A. Cavicchi (eds.), Case Studies in the Wine Industry. Sawston: Woodhead Publishing, ISBN 9780081009444.

[36] Sogari G., Mora C., Menozzi D., 2016. Factors driving sustainable choice: The case of wine. British Food Journal, 118: 632-646.

[37] Cisilino F., Madau F. A., Furesi R., Pulina P., Arru B., 2021. Organic and conventional grape growing in Italy: a technical efficiency comparison using a parametric approach, Wine Economics and Policy, 10(2): 15-28.

[38] Mariani A.C., Vastola A., 2015. Sustainable winegrowing: Current perspectives. International Journal of Wine Research, 7: 37-48.

[39] Sogari G., Corbo C., Macconi M., Menozzi D., Mora C., 2015. Consumer attitude towards sustainable-labelled wine: An exploratory approach. International Journal of Wine Business Research, 27: 312-28.

[40] Chaminade C., Randelli F., 2020. The role of territorially embedded innovation ecosystems accelerating sustainability transformations: a case study in the transformation to organic wine production in Tuscany (Italy). Sustainability, 12, 4621.

[41] Merli R., Preziosi M., Acampora A., 2017. Sustainability experiences in the wine sector: toward the development of an international indicators system. Journal of Cleaner Production, 172: 3791-3805.

[42] Pomarici E., Sardone R., 2020. EU wine policy in the framework of the CAP: post-2020 challenges. Agricultural and Food Economics, 8, 17 (2020), Springer, https://doi.org/10.1186/s40100-020-00159-z.

[43] Malorgio G., Pomarici, E., Sardone R., Scardera A., Tosco D., 2011. La catena del valore nella filiera vitivinicola. Agriregionieuropa, 7 (27): 14-19.
[44] Scardera A., Tosco D., 2014. Redditività e costi di produzione della viticoltura attraverso il campione RICA. In Pomarici E., Tosco D. (eds), Redditività e costi della viticoltura: dal campione RICA un quadro in chiaroscuro. Edizioni Scientifiche Italiane, Napoli.
[45] Longhitano, D., Bodini, A., Povellato, A., Scardera, A., 2012. Assessing farm sustainability. An application with the Italian FADN sample. Paper presented at the 1st AIEAA Conference 'Towards a Sustainable Bio-economy: Economic Issues and Policy Challenges, Trento, Italy, June 4-5, 2012.
[46] Mortimer, S.R., Park, J.R., Mauchline, A.L., Haysom, K.A., Westbury, D.B., Purvis, G., Louwagie, G., Northey, G., Finn, J.A., Knickel, K., Kasperczyk, N., Primdahl, J., Vejre, H., Vesterager, J., Kristensen, L., Teilman, K., Podmaniczky, L., Balázs, K., Vlahos, G., Christopoulos, S., Kröger, L., Aakkula, J., Yli-Viikari, A., Peltola, J. 2009. The Agri-environmental Footprint Index: User's Manual. (Available from URL: http://www.footprint.reading.ac.uk/en/publications_en.html).
[47] CREA, 2021. Annuario dell'agricoltura italiana 2020, Volume LXIV, Centro di Politiche e bioeconomia, Roma.
[48] Cabello J.M., Navarro E., Prieto F., Rodriguez B., RuizF., 2014. Multicriteria development of synthetic indicators of the environmental profile of the Spanish regions, Ecological Indicators, 39: 10-23. https://doi.org/10.1016/j.ecolind.2013.11.013.
[49] Picone C., Henke R., Ruberto M., Calligaris E., Zucaro R., 2021. A Synthetic Indicator for Sustainability Standards of Water Resources in Agriculture, Sustainability, 13(15), 8221. https://doi.org/10.3390/su13158221
[50] Jourjon, F., Chou, H., Gezart, A., E. Kadison, A., Martinat, L., Pomarici, E., Vecchio, R., 2016. Wineries Evaluation of Costs and Benefits of Sustainability Certification Program: The Case of Terra Vitis in France, Recent Patents on Food, Nutrition & Agriculture, 8 (2): 138–147; doi:10.2174/2212798408666160524141500