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Review

A Water Footprint Review of Italian Wine: Drivers, Barriers, and Practices for Sustainable Stewardship

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Abstract: Wine constitutes the dominant Italian agricultural product with respect to both production quantity and economic value. Italy is the top wine producer worldwide in terms of volume and the second one below France in terms of national income. As the Italian agricultural production accounts for 85% of the national freshwater appropriation, the country's agricultural sector strains freshwater resources, especially in the central and southern regions, which constitute important winemaking areas in terms of quantity and quality. To this end, we first perform a review of the existing research efforts on wine water footprint assessment to investigate the water dynamics of wine production in Italy compared to the rest of the world. The results indicate a prevalence of studies on the water footprint of Italian wine, emphasising the need for deeper research on the sector's water efficiency. Then, we aim at exploring the major drivers, barriers, and good practises for systematic water stewardship in the Italian winemaking industry, considering the product and territorial characteristics. This research is anticipated to contribute towards providing insights for practitioners in the Italian wine sector to develop water-friendly corporate schemes for enhancing the added value of their products.

Keywords: freshwater resources; water footprint; water management; wine production; winemaking sector; Italy

1. Introduction

The winemaking industry plays a critical role in the economy of the primary sector of the Southern European and Mediterranean regions [1]. Thus, there is an increased pressure towards minimising the environmental impacts of wine production [2] to improve the sustainability of the sector in terms of climate change and natural resources [3]. More specifically, consumers' environmental expectations further motivate winemakers to adopt green technological interventions for efficient water use during irrigation or wastewater reuse [4]. In addition, given that a considerable number of consumers, especially young ones [5], express willingness to pay a premium for a sustainable wine label [6], the production of water-friendly wine could be an ambitious strategy for increasing profitability through quality improvement [7].

The winemaking efficiency in terms of freshwater use can be expressed through the water footprint (WF) concept, which refers to the total volume of freshwater consumed and polluted at national, corporate, or product levels [8]. Specifically, WF is a multidimensional indicator that consists of three components: (i) green water addresses the absorption of rainwater by plants (i.e., the proportion of precipitation that infiltrates into the unsaturated soil zone and is temporarily stored in soil and vegetation canopy [9]), (ii) blue water refers to the consumption of surface or groundwater during irrigation and processing activities, and (iii) grey water constitutes the freshwater quantity used for assimilating pollutants during farming and manufacturing given specific water quality standards [8].

In Italy, agricultural production is responsible for 85% of the country's freshwater appropriation (This percentage is calculated as the ratio of the WF of crop production, grazing, and animal water supply to the total WF of national production in Italy, which are both provided in annual average values during the reference period 1996–2005), of which 81% refers to green WF, 8% refers to blue WF, and 11% refers to grey WF [10]. In the case of the winemaking sector, the average WF of Italian grapes equals to 488 L per kg of fresh fruit, of which 76% corresponds to green water, 7% corresponds to blue water, and 17% corresponds to grey water [11]. In terms of wine, the average WF of a glass (0.125 L) of Italian wine is 88 L [12]. Notably, a considerable number of research papers further quantify the WF of different wine varieties across the regions of the country. Apart from water use, emphasis is further placed on water scarcity issues of the Italian territory. In fact, the national agricultural sector poses considerably high stress on freshwater resources [13], particularly in Southern Italy [14], which constitutes an important winemaking area in terms of wine quantity and quality [15].

Although the water impact of wine is relatively low compared to other agricultural commodities [11], its high production volume and its economic value in Italy render research on the WF of Italian wine essential. In fact, wine constitutes the top national agricultural product in terms both of quantity and value [16]. Compared to the rest of the world in 2017, Italy constituted the first producer concerning wine volume (4.25 billion L, excluding juice and must) [1], and the second one below France regarding economic value (12.1 billion Euro) [17]. In addition, the country came third following the United States and France (2.26 billion L) in respect to wine consumption, while it was second both below Spain in terms of export volume (2.14 billion L) and below France concerning export value (5.87 billion Euro) [1].

Notably, scientific research on the WF assessment of wine is growing rapidly [18]. As water management across supply chains is considered as vital for the long-term sustainability of the winemaking industry [19], this work aims at (i) reviewing the existing WF assessment efforts during wine production to explore how the wine WF research is diffused worldwide (Section 2), (ii) investigating the drivers and barriers of water stewardship in the Italian winemaking sector as an identified global leader in the field of study (Section 3), and (iii) discussing water stewardship policies applicable to the Italian wine production (Section 4). Overall, this paper aims at highlighting the need for water management in the wine industry, especially in water-scarce countries where it constitutes a major economic activity. To this end, we anticipate that this research will contribute towards supporting winemaking practitioners in identifying good practices in water management and launching efficient water-related corporate schemes through overcoming barriers motivated by impelling drivers.

2. Water Footprint of Wine: Literature Background

In this section, we perform a review of the global wine WF literature to identify the position of the Italian case studies in this research field. Within the extant literature, we have identified 20 articles in total that include the terms "water footprint" (or "water management" or "freshwater resources") and "wine" (or "winemaking") in the Scopus and Web of Science databases. Then, we present the major descriptive statistics of the review findings along with a brief discussion. Finally, the taxonomy of the Italian literature provides a detailed analysis of the papers under study in a structured manner.

The WF of a product is defined as the total volume of freshwater used directly or indirectly across its end-to-end supply chain [20]. Figure 1 illustrates the different stages of a wine supply chain, highlighting the viticulture and the vinification phases as the prevalent WF contributors. To quantify the WF of wine, several methodological approaches exist; the WF assessment manual that focusses on the volumetric measurement of water consumption and pollution [8] and the life cycle assessment (LCA) techniques (e.g., the ISO 14046 [21]), further including the impact of water scarcity (which varies spatially and temporally) on the WF indicator [14], constitute the most common ones. Although a comparison among the different WF assessment approaches is considered out of the scope of this research, a more detailed analysis of their unique charasterics is provided by Chenoweth et al. [22].

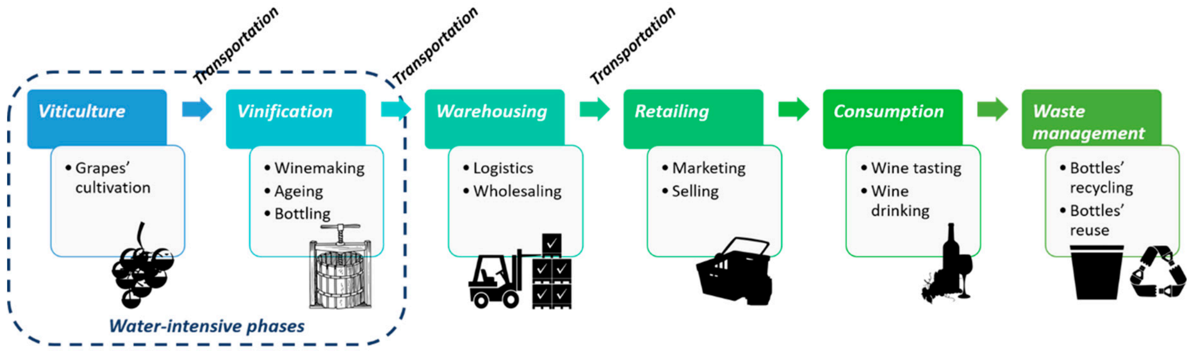

Figure 1. Typical wine supply chain.

2.1. Research Efforts Worldwide

Several case studies on wine WF assessment have been identified in the literature, indicating the increasing academic interest in evaluating the use of freshwater resources in the winemaking sector worldwide. Outside Europe, efforts have been made to quantify the WF of New Zealand's wines. First, a combination of an LCA-based approach and a hydrological water-balance technique was implemented to quantify the volume of water consumed and polluted during wine production in two New Zealand regions [23]. In a later study, the authors extended the WF research of New Zealand's wine by comparing the results obtained using diverse methodologies, further including the traditional WF assessment method, to investigate freshwater utilisation from different perspectives [24]. In North America, a US study assessed the greenhouse gas emissions, the energy use, and the freshwater use across the life cycle of wine produced in California, beginning from the cultivation of grapes up to their delivery at the winery gate, to provide a holistic evaluation of the wine's environmental impact [25]. Moreover, a preliminary research effort was made for assessing the grey WF associated with wastewater produced during the winemaking process in a Canadian winery and co-treated by municipal wastewater treatment plants [26]. In Latin America, a recent study quantified the consumptive blue and green WF of several varieties of grapes for wine production in five Argentinian regions, using different irrigation systems [27].

Within Europe, although the majority of research on wine WF assessment has been documented across southern countries, two publications refer to Northern Europe. In Romania, the WF of a bottled wine produced in a medium-sized winemaking plant was quantified in the stages of viticulture and vinification, further evaluating the socio-economic potential of winemaking and the related water-related schemes within the country [28]. In Hungary, a recent study developed a framework for WF assessment during grapes' cultivation and processing to optimise the consumption of both rainwater and freshwater consumed [29]. Moving to the south, several researchers evaluated the WF of Iberian wines. More specifically, an evaluation of both direct and indirect freshwater use was performed for a Portuguese white wine variety during the viticulture and the winemaking stages, further analysing the related environmental impacts of water use [30]. In addition, a more comprehensive analysis included the LCA of the carbon, water, and energy footprints, as well as the material intensity and solid and water wastes, of a bottle wine during the phases of grapes' cultivation, wine production, bottling and packaging in Portugal [31]. More recently, the water-related ISO 14046 was used to analyse the WF profile of a Spanish grape variety for vinification and to address the impacts due to water scarcity and degradation from a life cycle perspective [32]. Moreover, an indicator of water depletion, mainly due to irrigation during the viticulture stage, was evaluated in the context of a complete LCA of an aged red wine produced in Catalonia, Spain [33].

2.2. Italian Case Studies

An increased number of case studies on wine WF has been mapped across the Italian territory. Lamastra et al. [34] proposed a new WF quantification approach (Valutazione Impatto Viticoltura sull'Ambiente – V.I.V.A. tool) to improve the WF assessment manual technique [8], emphasising in detail the calculation of the grey WF of six different wine varieties of a Sicilian winery. Bonamente et al. [35] quantified the direct green, blue, and grey WFs of a typical red wine produced from a blend of grape varieties by a medium-sized winery in Umbria, based on the V.I.V.A. tool [34] and following the ISO 14046 principles [21]. In a later study, the authors performed a combined carbon and WF assessment in the life cycle of the Italian red wine using the same dataset and methodological approach [36]. In the same vein, Rinaldi et al. [37] performed a cradle-to-grave analysis for juxtaposing the carbon and WF indicators of a red and a white wine of an Umbrian producer, using the same system boundaries, functional unit, and input data, based on the relevant ISO guidelines [21]. In Umbria again, Bartocci et al. [38] calculated the carbon, ecological, and WF, along with several LCA-related environmental impacts, for two different varieties of grapes during cultivation, wine production, vinegar ageing, and bottling, following the ISO approach [21]. Recently, Borsato et al. [39] compared the WF outcomes of a volumetric (i.e., the V.I.V.A. tool [34]) and two LCA-based approaches (i.e., Available WAter REmaing – AWARE [40] and Water Scarcity Index [14]) during the production of a white wine variety in Northeast Italy to improve water management. Miglietta et al. [41] investigated the WF of two types of wines indicated with designation of origin whose vineyards are situated in Northern (Piedmont) and Southern (Sicily) Italy to compare the geographical impact of grapes' cultivation on freshwater consumption and pollution. More recently, Miglietta et al. [42] quantified the water efficiency (i.e., the ratio of total wine WF to total wine production) and the economic water productivity (i.e., the ratio of wine price to wine WF) of all Italian wines indicated with appellation of origin. In addition, Miglietta and Morrone [43] studied the virtual water flows and economic water productivity of wine trade between Italy and Balkan countries. The latter three research efforts were conducted based on the WF assessment manual estimates [8].

Figure 2 illustrates the distribution of the case studies on wine WF assessment by country. Notably, Italy dominates the wine WF research (i.e., nine out of 20 studies), confirming (i) the leading role of the Italian winemaking industry both within the country [16] and abroad [1], and (ii) the increased water scarcity concerns in the region [14], followed by New Zealand, Portugal, and Spain (i.e., two out of 20 studies each). Notably, there is an apparent absence of WF studies for French wines, despite the major economic impact of the country's winemaking sector worldwide [17], which is potentially due to lower water scarcity indices compared to Italy [14]. In addition, Figure 3 depicts the distribution of the studies by year of publication. In fact, the research on wine WF assessment has received a rather constant interest during the last 6.5 years (i.e., the first paper was identified in 2013), exhibiting an average of 2.9 studies per year worldwide and 1.2 studies annually in Italy.

Finally, Table 1 provides a taxonomy of the literature in the field of wine WF assessment in Italy. More specifically, the type of the study, the period in which the data were collected, the location of the study, the wine variety examined, the winemaking phase considered, the WF assessment method used, as well as the type and volume of the WF quantified, are documented to provide detailed information in the field of wine WF assessment in a supplementary manner. Notably, a comparative analysis of the studies could be challenging due to significant differences concerning the (i) methodological approaches implemented, (ii) databases utilised, (iii) assumptions articulated, and (iv) temporal or spatial characteristics considered. However, as the diverse WF assessment approaches exhibited vary with respect to the manner that they quantify water use [22], it is not infeasible to compare WF results derived from different methods, even though the calculations are performed using the same dataset [44]. In fact, Bonamente et al. [36] confirm this statement through providing different results compared to Bonamente et al. [35], although they use the same input data. Even by applying the same methodology, the different wine variety types [34], as well as the diverse climatic and geographical conditions of the Italian regions from North to South [41], influence the wine WF assessment findings. Nevertheless, in general, green water emerges as the typical source of water for wine production, even in semi-arid environments such as Central Italy.

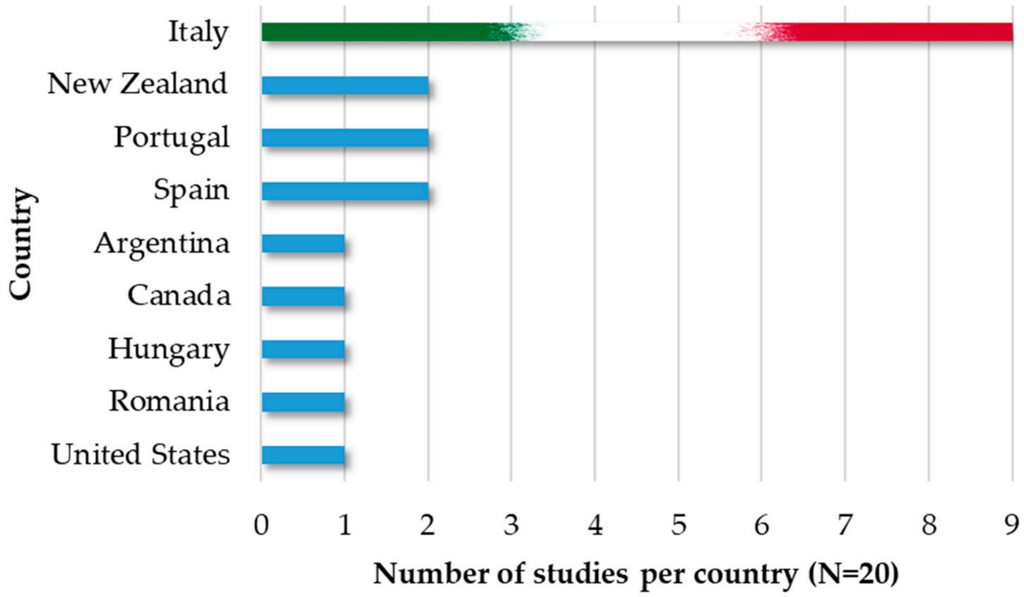

Figure 2. Distribution of studies on wine WF assessment by country.

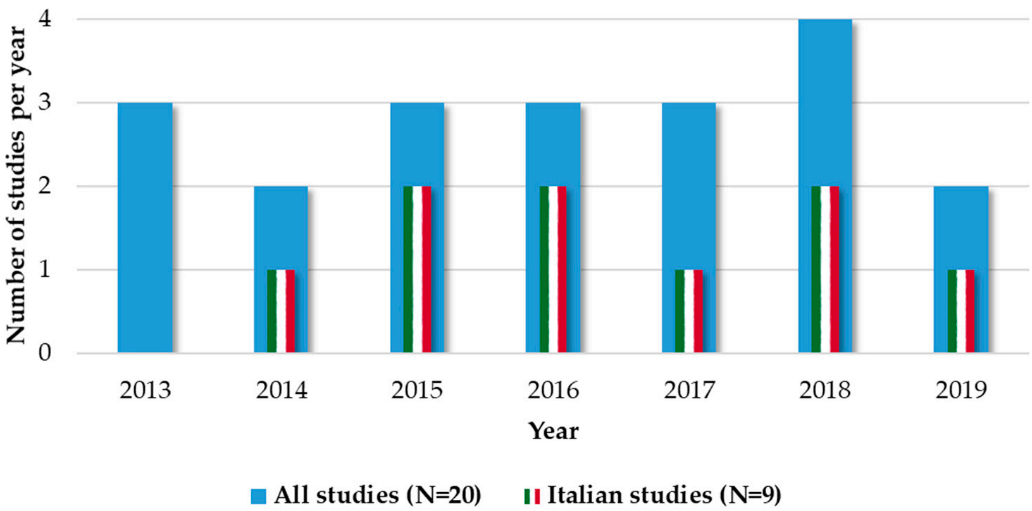

Figure 3. Distribution of studies on wine WF assessment by year.

Table 1. Taxonomy of wine WF research in Italy.

Reference	Study Type	Study Period	Location	Wine Variety	Winemaking Phase	WF Assessment Method	WF Type and Volume		
							Green	Blue	Grey
Lamastra et al. [34]	Real case study	Not specified	Province of Palermo, Region of Sicily (13.49° N, 13.51° E)	Cabernet Sauvignon; Chardonnay; Nero d'Avola; White Pinot; Grecanico	Viticulture; Vinification	WF assessment manual [9]; V.I.V.A. tool [34]	694.5–902.9 (WF manual); 689.5–915.9 (V.I.VA.) L/L of wine	2.6–42.5 L/L of wine (Same for both methods)	0–228.6 (WF manual); 0–389.8 (V.I.V.A) L/L of wine
Bonamente et al. [35]	Real case study	2012	Region of Umbria	Sangiovese with small percentages of Merlot and Cabernet Sauvignon	Viticulture; Vinification	V.I.V.A. tool [34]; ISO 14046 [21] (only as a framework)	621.4 L/bottle of 0.75 L	3.4 L/bottle of 0.75 L	7.4 L/bottle of 0.75 L
Bonamente et al. [36]	Real case study	2012	Region of Umbria	Sangiovese with small percentages of Merlot and Cabernet Sauvignon	Viticulture; Vinification	ISO 14046 [21]	450.6 L/bottle of 0.75 L	7.1 L/bottle of 0.75 L	120.4 L/bottle of 0.75 L
Rinaldi et al. [37]	Real case study	2012	Region of Umbria	Red wine; white wine (specific variety not specified)	Viticulture; Vinification	ISO 14046 [21]	450.6 (red); 496.6 (white) L/bottle of 0.75 L	10 (red); 9.8 (white) L/bottle of 0.75 L	43.5 (red); 44.6 (white) L/bottle of 0.75 L
Bartocci et al. [38]	Real case study	2012	Province of Perugia, Region of Umbria	Grechetto; Sarantino	Viticulture; Vinification	ISO 14046 [21]	830 (Grechetto); 592 (Sarantino) L/L of vinegar	446 (Grechetto); 301 (Sarantino) L/L of vinegar	616 (Grechetto); 439 (Sarantino) L/L of vinegar
Borsato et al. [39]	Real case study	2017	Northeast Italy (45.87° N, 12.70° E)	White wine (specific variety not specified)	Viticulture; Vinification	V.I.V.A. tool [34]; AWARE [40]; Water Scarcity Index [14]	0.988 m^3/ bottle of 0.75 L (V.I.V.A.)	0.181 m^3/ bottle of 0.75 L (V.I.V.A.)	0.024 m^3/ bottle of 0.75 L (V.I.V.A.)
							1.44 (AWARE); 0.01 (Water scarcity index) m^3/ bottle of 0.75 L (No type categorisation)		
Miglietta et al. [41]	Secondary data analysis	Not specified	Region of Piedmont; Region of Sicily	Barolo; Moscato di Pantelleria	Viticulture	WF assessment manual [8]	487–548 L/L of wine (Sum of all types)		
Miglietta et al. [42]	Secondary data analysis	2011–2015	Whole Italian territory	65 varieties with appellation of origin	Viticulture	WF assessment manual [8]	3.03–6.68 m^3/ha of vineyard (sum of all types)		
Miglietta and Morrone [43]	Secondary data analysis	2007–2016	Whole Italian territory (Average)	All varieties (average)	Viticulture	WF assessment manual [8]	460 m^3/ton of wine	40 m^3/ton of wine	101 m^3/ton of wine

3. Water Stewardship in the Italian Wine Industry: Drivers and Barriers

The food and beverage industry's contribution to global freshwater withdrawal is well documented in the extant scientific literature, while freshwater resources are dwindling at an alarming rate [18]. As satisfying the supply of food products requires a sufficient and consistent availability of freshwater resources, collaborative and harmonised interventions across supply chains are essential in order to ensure sustainable and efficient water use [45]. Considering that the Italian wines exhibit substantial WFs especially in water-stressed areas, we discuss the main drivers and barriers of water management in the wine sector based on the existing Italian research efforts. Table 2 summarises the identified drivers and barriers along with a taxonomy of the citing articles.

Table 2. Drivers and barriers of water stewardship in Italy.

Type	Description	References
Drivers	Linkage between water-related environmental aspects to space–temporal pressures	Lamastra et al. [34]; Bonamente et al. [35]; Miglietta et al. [42]; Miglietta and Morrone [43]
	Global trade and makers' attentiveness to sustainable wine supplies and sustainable marketing	Bonamente et al. [35]; Bartocci et al. [38]; Borsato et al. [39]; Miglietta et al. [42]; Miglietta and Morrone [43]
	Consumers' profitable purchasing behaviours towards sustainable wine supplies, particularly when linked to particular territorial culture and history	Bartocci et al. [38]; Miglietta et al. [42]
	Correlation between freshwater quantity/quality and wine quality	Lamastra et al. [34]; Miglietta et al. [41]
	Proliferation of the literature with studies and methodologies on water management allowing for benchmarking	Bonamente et al. [36]; Rinaldi et al. [37]
	Institutional policies and funding schemes supporting water management initiatives	Borsato et al. [39]; Miglietta et al. [41]
	Production effectiveness deriving from water stewardship, particularly from an end-to-end supply chain perspective	Bonamente et al. [36]; Bartocci et al. [38]; Miglietta et al. [42]; Miglietta and Morrone [43]
Barriers	Lack of standardisation of system boundaries to apply and assess the impact of water management policies and practises	Bonamente et al. [36]; Rinaldi et al. [37]; Borsato et al. [39]
	Limited contextualisation of water management operations, particularly with reference to the economic water productivities	Lamastra et al. [34]; Miglietta et al. [42]
	Structural and computational diversification of methodologies assessing the impact of water management policies and practises	Bonamente et al. [35]; Bonamente et al. [36]; Borsato et al. [39]; Miglietta et al. [41]
	Variations in functional characteristics of wine production setting (e.g., local climatic conditions, production processes, etc.)	Bonamente et al. [36]; Borsato et al. [39]; Miglietta and Morrone [43]
	Proliferation of eco-labelling options limiting business differentiation possibilities	Miglietta and Morrone [43]

3.1. Drivers

From an environmental point of view, the elevated global water stress levels foster the adoption and application of water management policies and practices in the wine industry [19]. More specifically, wine quality is correlated to grapes' quality, thus motivating the wine industry to investigate irrigation practises [34]. In particular, a wine's identify is defined by grape maturation, aroma, and coloration [46], which are attributes that are amenable to the vine's geographical location and climate conditions that determine the chemical composition and sensory characteristics of grapes [47].

As freshwater appropriation is characterised by space–temporal dimensions, the adoption of advocated practises in the winemaking industry is eminent to mitigate water stress phenomena at both local and global freshwater bodies [33,35,43]. This need is even more pronounced in regions where the nexus of water scarcity, vineyards, production seasonality, and climatic conditions' severity aggravate water consumption. In this regard, targeted institutional and state-specific policies and directives (e.g., European Program of Sustainability, New Zealand Winegrowing Program, Italian initiative on Valutazione dell' Impatto in Vitivinicoltura sull' Ambiente) motivate circular economy and water-use minimisation in wine [39], while they further support investments in related infrastructure to protect water quality and quantity [41]. Furthermore, the plethora of research studies and corporate reports pertinent to water consumption across the wine supply chains operations allows benchmarking [36,37], thus further enabling the continuous improvement and proliferation of water management policies and practises among industry stakeholders.

From a socio-economic angle, water security has a prominent role in the United Nations Sustainable Development Goals, as it is recognised as a key determinant to the delivery of a viable ecosystem to future generations and a critical factor towards ensuring continuity to food manufacturing operations [48]. In particular, securing freshwater resources' sustainability allows winegrowers to improve economic water productivity of their wine supply chains (i.e., monetary value attained per cubic meter of water used), hence ensuring high-quality winery products at a low level of water use [42]. In addition, the implementation of water management policies and practises (e.g., water reuse) allows grape growers and wine manufacturers to reduce the resources' scarcity burden linked with their production [35,36]. To a greater extent, reducing the utilisation of freshwater as a production material results in operational cost savings for companies [43].

From a market perspective, consumers' awareness and attentiveness over the sustainability impact of wine products drive demand growth in the sector, especially in case water-related eco-certification is provided [39]. Indicatively, Rugani et al. [49] critically analysed LCA and carbon footprint-based studies on the wine-making industry and stressed that carbon footprint labelling in wines provides a market differentiation element that could influence consumers' purchasing behaviour. Moreover, wine produced with sustainable techniques has a greater export potential [42], while customers have a willingness to pay a premium price for environmentally friendly wine products [38]. Specifically, given that around 80% of wine sales occur in-store, clear communication of sustainably produced wine is deemed critical for increasing sales [50]. Therefore, as sustainable marketing has nowadays a dominant role in consumer purchasing behaviour and market sales, the communication of the water-related identity of wines could be an additional driver for approaching water-sensitive market segments. To some extent, consumers and policy-makers should also become aware of the virtual water flows, particularly blue water, embedded in international wine trade, considering that agri-food trade greatly influences water appropriation in a country [43]. To this end, national initiatives and businesses in the wine sector actively engage multispectral WF mitigation initiatives to reduce operating costs and communicate the water stewardship of their products to increase consumer value. In particular, better communication to consumers could be achieved via calculating a single-score indicator for labelling purposes [5,51].

In the case of the Italian wines, which are traded under the "controlled designation of origin" and "controlled and guaranteed designation of origin" labels, the adoption of water management policies can deliver a compelling marketing narrative linked to the territorial culture and history of each specific production wine site, promote the valorisation of local freshwater resources, and ultimately drive rural development [41]. Notably, on average, young wine consumers in Italy value water saving labelled wines and demonstrate a willingness to pay a premium price for such product offerings; determinats include wine consumption frequency, environmental-friendly attitude, label use, and label trust [5]. Therefore, as young consumers represent the most common market segment regarding wine consumption, policy-makers could act as a driving force for supporting the winemaking industry to adopt more environmental-friendly production methods (e.g., the Common Agricultural Policy of the EU [52]).

3.2. Barriers

Notwithstanding the pronounced need to apply water management policies and practises in the winemaking industry [46], dominant barriers hinder their adoption and maturity. The greatest peril in this process regards the poor alignment between water and agricultural policies [43], which is supported by the existence of different views among scientists regarding the system boundaries to apply water management policies (e.g., indirect WF from raw materials, transportation, end-of-life processes, etc.) [36,37,39]. Indicatively, Italian wines are associated with a lower WF exclusively due to the particular production specifications to guarantee designation of origin (i.e., irrigation and fertilisation are prohibited) [41]. To that effect, WF assessment methodologies generate different results even in the case that the same water management techniques are considered [35].

To a greater extent, established methodologies used for the ex ante evaluation of manufacturing operations' water impact (e.g., LCA) myopically leverage secondary data sources and neglect geographically related characteristics, such as diverse climatic conditions and applied production techniques [36,39]; thus, inconsistencies and discrepancies in the derived results are possible, but they have a detrimental effect on specific regions considering the localised supply of the embedded production inputs. At a more granular level, an evident gap in existing databases regarding indirect water consumption (e.g., green water) further raises evaluation challenges [36]. The lack of detailed data input further inhibits the contextualisation of the results in real-world operations [34], subsequently affecting the decision-making over the investments in related practises.

Furthermore, most water management-related studies focus on the academic merit of the applied methodological approaches in the pursuit of accuracy and precision of calculations. However, business stakeholders, who in principal operationalise water mitigation policies, cannot make inferences about the associated economic water productivities [42]. Moreover, the diverse alternative eco-labels for certifying the adoption of good practices for freshwater utilisation does not always provide businesses with an opportunity to differentiate from the competition [43].

4. Discussion

Food production and consumption are considered to have a rather detrimental impact on the environment [39,53]. Particularly, in the winemaking industry, sustainability is a key driver for competitiveness, market differentiation, and process innovation [4]. WF could become a meaningful indicator in sustainability initiatives for wines (as lower water consumption is also connected with a better wine quality and taste [41,42]); thus, the winemaking industry is exploring practises to improve the related environmental impact.

At a national level (e.g., Chile, Australia, New Zealand), frameworks to inform sustainability in the winemaking industry exist. Flores [3] reviewed the process-based winemaking frameworks in six countries and reported three categories where common water management practises are recognised: (i) soil management—protection of water resources from pollution, (ii) water management—registration of water use, selection of irrigation system, and control of water quality, and (iii) wastewater—monitoring of effluents and treatment of winery wastewater. Focussing on wastewater treatment, in countries such as France, Italy, and Spain, where the wine cellars are generally located close to urban areas, the use of advanced biological processes is crucial [54].

At a more granular level of operations and to cultivate grapes that result in high-quality wines, agricultural practices are required to enable the control of particular properties of grapes, such as the concentration of phenols, which determine the taste, color, and mouthfeel of wine. From a WF point of view, regulated deficit irrigation at the phenological stage is applied to increase the phenols' content [27]. Alongside the different quality of the cultivated grapes for winemaking, irrigation systems and practises are also dictated by the edaphoclimatic and related infrastructure conditions at each region. Indicatively, in the province of Mendoza, Argentina, 88% of the vineyards are irrigated through surface irrigation (i.e., gravity-based systems), whereas the remaining vine-growing area is irrigated through pressurised systems (e.g., dripping) to grow wine grapes of different qualities [27]. Moreover, the selection of good practices in water management for the winemaking industry could be influenced by the assessment methodology applied [39]. Overall, this selection depends on a range of decision-making constituents. More specifically, alternative irrigation options (e.g., drip, deficit) [55,56] and wastewater treatment techniques (i.e., aerobic, anaerobic, or their combination) [54] result in different levels of water savings. In addition, the implementation of digital technologies (e.g., sensors used during viticulture) [57,58] or holistic approaches for water-friendly activities across the whole wine supply chain [59] can further support an advanced and complete water stewardship plan. An indicative list of WF mitigation practices in the winemaking industry is tabulated in Table 3.

Table 3. Indicative good practices for water stewardship in the winemaking industry.

Good Practice	Description	Aims	References
Application of drip irrigation	Drip water slowly to the roots of plants, either above the soil surface (via micro-spray heads) or below the soil surface (via buried dripperline or drip tape)	■ Minimise evaporation ■ Improve water-use efficiency ■ Save nutrients	Borsato et al. [39]; Christ and Burritt [55]
Application of deficit irrigation	Irrigate during drought-sensitive growth stages of a crop and leverage available rainfall in other crop cycles	■ Improve water-use efficiency ■ Control vegetative vigour and production quality of grapevines	Civit et al. [27]; Chaves et al. [56]
Application of partial root-zone drying techniques	Irrigate about half of the root system of a crop and leave the other half to dry	■ Improve water-use efficiency	Christ and Burritt [55]
Digitalisation of irrigation system	Monitor water requirements and use via sensors	■ Monitor evapotranspiration, precipitation, soil/leaf water content ■ Improve water-use efficiency	Aiello et al. [57]; Tsolakis et al. [58]
Treatment of winery wastewater	Use aerobic or anaerobic techniques to biodiograde organic compounds, remove nitrogen, phosphorous, heavy metals, and pathogens	■ Monitor effluents ■ Purify industrial water ■ Promote water reuse (e.g., for irrigation purposes)	Bolzonella et al. [54]
Training of employees and application of water-friendly processes along the production line	Apply process changes and reuse water during wine processing	■ Reduce industrial water consumption in cleaning, disinfecting, cooling, and heating operations ■ Monitor/mitigate effluents	Oliver et al. [59]

5. Conclusions

The Italian wine industry constitutes a global leader in terms of production quantity and quality. Within the country, the economic scale of winemaking renders the industry as the key production component of the Italian agrifood sector related to respective freshwater appropriation. To that end, the investigation of water use needs during viticulture and vinification is imperative to support water stewardship within the country's wine sector. According to the scientific literature, Italian wine dominates the research efforts with respect to WF assessment, thus validating the important role of economic and environmental sustainability in the national winemaking industry. To a greater extent, given the consumers' awareness and positive purchasing behaviour towards water-efficient wines, the sustainability profile of the Italian wines could further link to the designation of origin and receive international market's appreciation.

As research regarding water management in the winemaking industry is limited, this paper acts as an initial mapping that captures the major drivers and barriers of water stewardship considering the unique geographic and socio-economic characteristics of the Italian landscape. Our research findings indicate that the environmental, socio-economic, and market drivers outperform the existing, mainly technical and methodological, barriers. This proliferation of drivers and the identification of good practises in the industry motivate the development of operationalisable water stewardship frameworks for the Italian wine sector.

5.1. Practical Implications

Based on the literature evidence, it is critical that the practitioners of the Italian wine industry should act towards the direction of water management to support the preservation of freshwater resources and enhance the economic water productivity of their products. This research validates that water management policies and practices should be systematically applied in the Italian winemaking industry, from an end-to-end supply chain perspective, to enhance the sustainable brand image of the national production and foster its trade potential and market appreciation.

At an operational level, this research suggests that vine growers and winemaking practitioners should focus on water management interventions at three levels, including (i) soil management, (ii) freshwater management, and (iii) wastewater treatment [3]. In particular, we propose that the type of irrigation systems and practises to be applied should also consider the edaphoclimatic and related infrastructure conditions at each winemaking region to increase the efficiency of water resources appropriation [27]. Regarding wastewater treatment, aerobic processes (e.g., membrane bioreactors [60]) could offer an efficient and easy-to-use solution compared to anaerobic ones that constitute a more economic option [54].

To a greater extent, we propose the digitalisaiton of the wine supply chain, particularly at the farming echelon. In this regard, sensor technologies are reported to support the decision-making process concerning the water stewardship of agrifood commodities [57], which could also be pertinent to the case of the wine supply chain. The use of sensors in grapes' farming for monitor freshwater use and other related parameters (e.g., soil moisture) is an indicative digital intervention that relates to the quality of the wine production. The introduction of advanced technologies can assist in (i) mitigating methodological errors in water-use estimations, (ii) gathering field-level data, (iii) calculating water consumption in viticulture in a more accurate way, (iv) extrapolating information with regard to the WF of their supply chain, and (v) devising sound marketing strategies to engage with consumers [61].

5.2. Future Research

With regard to future research directions, both researchers and practitioners of the winemaking production field may focus on developing analytical and computer-based tools for multi-objective analysis and simulation to solve freshwater resource planning and operational problems. To that end, Aivazidou et al. [7] suggest a framework that guides the ex ante evaluation of applied water management policies through developing a pertinent simulation model that enbables the assessment of water utilisation on the supply chain financial performance. Notably, the modelling effort captures the concept of consumers' environmental sensitivity with regard to blue WF efficiency as a supply chain profitability factor. In addition, the economic evaluation of the green WF to the overall production value of wine, as inspired by the study of Grammatikopoulou et al. [9] for the case of cereals, is highly recommended considering that the majority of wine grapes across the Mediterranean are grown under rainfed conditions. To a greater extent, the economic water productivity could be combined with water scarcity indicators to account for the inter-annual variability of the green and blue WFs at a regional level to improve the management of grapes' production, supply, and wine trade in the winemaking sector [62].

To wrap up, based on the environmental, economic, and technical managerial insights obtained by the analysis of the major drivers, barriers, and good practises, it is crucial that industry stakeholders should systematically focus towards developing a concrete water management scheme in the Italian winemaking sector for fostering its sustainability.

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