

## Development of a sustainability technical guide for the Italian olive oil supply chain



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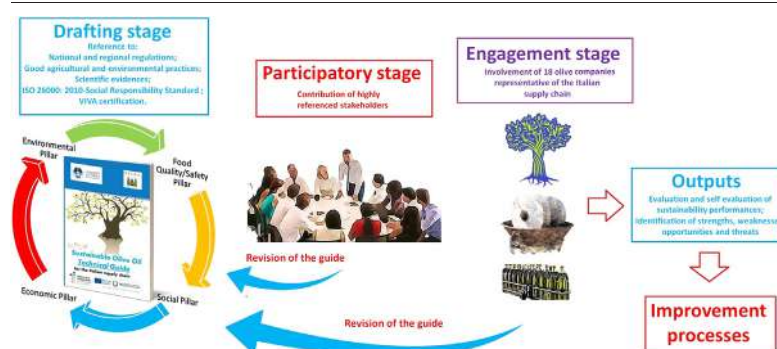
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### HIGHLIGHTS

- Sustainability must increasingly be a central point in olive oil production worldwide.
- The definition of the key elements of “oil total sustainability” is a complex process.
- A technical guide was developed to facilitate the switch to more sustainable production systems.
- The pilot olive companies resulted to be attentive to the issue of sustainability.
- Weaknesses and opportunities for improvement came out from the analysis.

### GRAPHICAL ABSTRACT



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### ABSTRACT

Italian olive growing must aim at the transition to economically and environmentally sustainable management systems, linked to premium quality production and to a recognized and remunerated context of biodiversity conservation in compliance with the provisions of the European Union New Green Deal and United Nations Agenda 2030. To assist and facilitate companies in this step, a sustainability technical guide for the Italian olive oil supply chain has been developed, with reference to the four pillars of sustainability. The guide, consisting of 42 requirements, was submitted to 18 olive farms from 8 different Italian regions participating in this pilot study, to assess their level of total sustainability and to receive feedbacks throughout the drafting process. Taken as a whole, the companies have proved to be virtuous in meeting the requirements provided, with percentages of compliance ranging from 86 to 96% according to pillar and from 70 to 100% according to company and showed a remarkable spirit of collaboration and involvement in the construction of the guide. In this regard, the text is aimed to represent a participatory standard for Italian institutions and for other olive countries.

### 1. Introduction

Sustainability has recently become a central theme in business orientation, in the planning of governments' strategies and in the motivation of purchasing decision around the globe. Nevertheless, the concept of

“sustainability“ is quite complex and broad, having a series of case-specific facets that can be analysed and interpreted from different perspectives (Diesendorf, 2000; Purvis et al., 2019; Kwatraa et al., 2020). Moreover, the well-known (and extremely vague) definition of sustainable development in the Brundtland Report (WCED (World Commission on Environment and Development), 1987; “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”), explicitly links the adjective “sustainable” to economic growth, social equity, food security and natural resources

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protection. The practical application of this open definition, implying the reconciliation of economics and ecology (despite sharing the same Greek etymological root  $\sigma\acute{\iota}\kappa\omicron\varsigma$ : home/family/family's properties), still remains the great challenge of the 21st century. One further problem is that while chemical and physical phenomena concerning sustainability are generally quantifiable, the measurement of qualitative data like some social, cultural, environmental and landscape issues (immaterial values) may be subjective (Koo et al., 2009) and can be affected by particular local conditions.

Regarding the Italian olive-oil sector, the extreme fragmentation of the production structure, the different farming systems, the vast national olive germplasm and the prominent economic, cultural (from gastronomy to medicine, from art to mythology and history), social and environmental value of olive, make it difficult to generically define an univocal model of sustainability. The Italian olive sector includes about 825,000 farms (ISMEA—Institute of Services for the Agricultural and Food Market, 2020b), most of them (97%) are sole proprietorships employing about 95% of supply-chain workforce, but generating only 30% of the olive sector turnover (~4.5 billion euros; ISMEA—Institute of Services for the Agricultural and Food Market, 2020a). 81% of the farms have a size of less than 2 ha (55% less than 1 ha) corresponding to 38% of the total olive grove area (Ismea, 2020a). These data are also linked to the hindering orographic situation of olive groves mostly cultivated in hilly (67%) and mountainous (11%) areas (ISTAT—Italian National Institute of Statistics, 2012), where the olive tree represents an integral and characteristic element of the territory as well as one of the few crop options for agriculture and environmental conservation (Tiò, 1996).

Italian olive growing can be generally split between a majority (63%) of nonprofessional small-holder farms and a smaller, but significant, number of professional farms, competitive at the international level (ISMEA—Institute of Services for the Agricultural and Food Market, 2020b). The former represents a traditional, rainfed, poorly mechanized and low input olive growing often practiced in complex orographic contexts, characterized by steep slopes and terraces, in which workforce is provided by family members and olive oil is generally destined for self-consumption (accounting approximately for 4% of the total oil produced). In this sense, these companies have a preeminent environmental, landscape, historical, cultural and anthropological significance, by preserving local traditions and biodiversity (local varieties) and preventing severe soil erosion (Beaufoy, 2001; Loumou and Giourga, 2003; Brunori et al., 2018). From a sustainability point of view, they have a low environmental impact with high social value, but they are generally unprofitable (i.e. they are based on the undervalorization of family worktime), although the earnings are often shared within small communities and families for which they represent an important (if not the only) source of income (Duarte et al., 2008; Palese et al., 2013). Notwithstanding, extensive, rainfed olive groves in dry areas have been forecasted as the most vulnerable to future climate changes (Mairech et al., 2021).

Competitive farms are represented either by small but strongly market-oriented companies with niche productions or by large companies with intensive and in (sporadic cases) super-intensive production systems. These latter systems have been proven to be economically more sustainable than traditional olive groves due to higher yields per hectare and lower operating costs per kg of product (Godini et al., 2011). However, the increase of plant density emphasize the use of agrochemicals, irrigation and mechanization with a consequent greater environmental impact on a per-area basis compared to traditional systems (Beaufoy, 2001; Tous et al., 2014; Russo et al., 2016; Ben Abdallah et al., 2021). Similarly, some studies report a reduction of biodiversity of vascular plants (DRAPAL – *Direção regional da agricultura*, 2009) and avifauna (Solomou and Sfougaris, 2015; Bouam et al., 2017; Morgado et al., 2020) in response to intensification, as well as a reduction of fish variety and habitat diversity, in water courses in the immediate vicinity of intensive olive groves (Matono et al., 2013). From a social point of view, a direct linkage between intensification and the notion of de-territorialization has been proposed, whereas intensive farming systems are less rooted to traditional knowledges, peculiarities and regional ecologies of the territory and community (Silveira et al., 2018). On the other hand, the carbon sequestration potential of olive orchards has been

described to increase under intensification of planting, albeit with some exceptions, because of the greater biomass produced in response to the higher volumes of water employed for irrigation (Mairech et al., 2020). Eventually, in a comparative study on Water Footprint (WF) intensive and superintensive olive orchards had a lower water demand per hectare and lower values for each of the three components of WF, than those recorded in a traditional orchard (Pellegrini et al., 2016).

Italian olive oil industry counts 220 companies and over 4000 olive mills. Therefore, 90% of oil mills process less than 1000 tons of olives, equal to 44% of oil production (ISMEA—Institute of Services for the Agricultural and Food Market, 2020a). On the other hand, the capillary presence of olive mills ensures fast olive processing and therefore the hygienic-nutritional quality of olive oil (given the correct management of the previous phases), as well as the production of many oils linked to the territory. This may represent an additional value especially in tourist areas. Supporting local companies and safeguarding autochthonous cultivars for premium quality products play a great importance for consumers as the on-farm or on-mill purchases account to 26% of the total oil sold in Italy (ISTAT—Italian National Institute of Statistics, 2021). Despite this, since Italy is the world's leading olive oil importer, "100% Italian" olive oil represents less than 30% of total bottled production (ISMEA—Institute of Services for the Agricultural and Food Market, 2020a). In assessing the sustainability of this "international" oil, the environmental impact due to transport must therefore also be considered. Furthermore, part of this imported olive oil comes from North-African countries with a weaker system of environmental laws (allowing for instance looser use of agrochemicals), than those enforced in Europe. To date, EU trade agreements do not provide particular sustainability requirements for imported goods (Fuchs et al., 2020), insofar as European Commission is about to present a legislative proposal regarding a Carbon Border Adjustment Mechanism (CBAM), namely a carbon tax applied to imports of certain goods from outside the borders of the European Union.

In this scenario, the identification of the high number of variables that must be taken into consideration in the sustainability assessment/self-assessment process for both the agricultural and the processing phases represents a crucial point for a correct definition of actions and policy. The drafting of a "total" sustainability technical guide is part of this perspective, as it was intended as an operational support for the enhancement and promotion of a sustainable olive-oil supply chain by representing a point of reference for olive oil companies in the definition of a sustainability model and in the systematic implementation of improvement processes. At the same time, it can be a useful tool for policy makers to define the areas of economic intervention in supporting olive companies in a context of environmental and cultural heritage protection, premium quality production, fair income distribution, respect for workers' rights and profitability. Additionally, a sustainability technical guide can represent an aid for small farms in the transition to sustainable forms of agronomic and/or business management in order to access national or European fundings that are traditionally more commonly requested by and granted to large farms.

## 2. Methods

### 2.1. Development of the technical guide

The goal of the technical guide was to obtain a highly inclusive text based on a limited number of requirements whose degree of compliance would have allowed for a general but accurate and comprehensive picture of an olive farm/company sustainability level, taking into account the peculiar characteristics of the Italian olive oil supply-chain. It has been conceived as a practical guide for olive farms/companies for improving the awareness of their own level of sustainability at the environmental, nutritional, social and economic level by considering tangible and intangible assets, for supporting companies in defining a sustainability plan and, consequently, for stimulating a constant process of improvement. In this sense, the sustainability technical guide may serve as a reference in the self-assessment/external evaluation process to verify the consistency and

effectiveness of the improvement approach over time through the definition of specific verifiable objectives, and periodic review. As it was thought of as a starting point for the many companies not involved in sustainability issues, expensive indicators, potentially discouraging small companies, have been excluded at this first stage. Nevertheless, the use of footprint indicators for the quantitative monitoring of the progress and company efforts in terms of sustainability is planned in a second phase of the project. As such, this guide is aimed at representing a first step towards the development of a unique standard of sustainability for the olive oil supply-chain which can be easily conveyed to all the subjects involved.

An imminent practical application of this text may come from the introduction of “eco-schemes” in the Common Agricultural Policy (CAP) post-2020 reform, a fully EU funded instrument in support of selected agricultural practices (European Commission, 2021) to accompany farmers in the switch towards more sustainable management systems in accordance with the “Farm to Fork” and “Biodiversity” strategies that the European Commission adopted, in May 2020, in implementation of the so called New Green Deal.

Eventually, it may serve as a touchstone for other countries. Indeed, considering that over 90% of olive growing is practiced in the Mediterranean basin and, more generally in a rather restricted area (traditionally between the 30th and 45th parallel North and -marginally- South) it is likely to suggest its application, with small “customizations” on a case-by-case basis, in the olive oil supply chains throughout the rest of the world.

Production processes of the agricultural and the olive mill phase have been characterized in terms of environmental sustainability, landscape protection, food safety and quality, ethically and socially responsible behaviour, olive biodiversity and cultural heritage protection, profitability, fair price and the sharing of value on the territory and among stakeholders. This also implied studying the complex network of interactions and relationships the company entwines with the stakeholders involved at different levels (suppliers, customers, local community, distributors, etc.). This aspect is particularly important in evaluating the transparency and rigor implemented during the production processes, especially where several independent companies are involved.

Reference was made to national and regional regulations (in particular to the National Integrated Production Quality System -SQNPI-), good agricultural and environmental practices, scientific evidence derived from the available bibliography, the ISO 26000: 2010-social responsibility standard, the SA8000 standard and the VIVA certification for wine sustainability

## 2.2. Participatory stage

A participatory stage before meeting the companies envisaged the contribution of referenced representatives of the Ministry of Agriculture and Forestry, the Ministry of Ecological Transition and Oleificio Zucchi, for an ongoing sharing of inputs, intentions and knowledge and the creation of a network of highly engaged stakeholders. A mixed methodology based on previous experience (Campling et al., 2021) was applied. Face to face meetings, workshops and remote webinars were scheduled in five steps. The first phase was the drawn of the list of the technological needs and the socio-economic and environmental issues for producing sustainable olive oil: this was discussed in one workshop at regional level where scientists such as pedologists, agronomists, genetists, food engineers, ecotoxicologists were invited in the dialogue. All of them were involved in the project of the EU Rural Development Plan called Terre d'Olivio. Secondly we met the officers of the Sustainable Development Department of the Ministry of Ecological Transition and of the European agricultural ministries of the environment and agriculture respectively. In this phase the political goals for the sustainable development planned in the national strategies (e.g. the National Plan of Resilience and Recovery) were identified, in compliance with the European strategies. The third phase provided the involvement of single representatives of the olive oil industry such as cooperatives of producers, farmers and millers: a mixed approach of meetings and webinars was applied for discussing and listing the requirements and relative benchmarking of the sustainability reliable for the national olive oil production. The fourth phase was the field phase including the survey: a large sample of producers

were invited to participate and the ones who accepted were met face to face, one by one, for answering to the different requirements transposed in questions as usually done in the common standard of certification. The fifth phase was in practice, the validation phase of the requirements screened in the whole participatory activity carried out.

## 2.3. Administration of the technical sustainability guide to several Italian olive companies

The text has gone through a validation phase with the participation of 15 Italian olive farms, a processing company, a benefit corporation -with 9 conferring partners- and a cooperative -constituted by 15 farms- operating in the olive oil sector, to test the effectiveness of the requirements and to build a constructive dialogue. Furthermore, this allowed us to outline an assessment of the sustainability status of the companies involved. The administration of the technical guide took place in the form of *vis-à-vis* interview so to introduce the requirements and to answer any possible questions in real time.

The companies, set up in the form of “company of persons” or “company of capitals” (according to the Italian legislation), are located in 8 Italian regions and constitute a rather exhaustive picture of the different types of olive companies that make up the Italian olive oil scene (Table 1). Aim of this phase was to see the participation of a sufficient number of Italian olive companies, representing the Italian olive oil supply chain in its entirety and the 18 companies that agreed to participate allowed us to meet this goal (as in Table 1), despite a greater number of olive companies was invited to participate to this pilot stage. Actually these 18 companies rely on a higher number of olive farms (including conferring partners and cooperative members) which have been directly involved for the verification of the requirements. Furthermore, their different localization (from 8 different regions) allowed us to consider the possible different characteristics of local olive growing. In particular, 9 companies are located in the three most important Italian olive regions (Apulia, Calabria and Sicily accounts for about 75% of total olive oil production) while the others were chosen for the particular added value acquired by the olive oil produced in these regions (Tuscany, Umbria, Emilia Romagna, Marche and Abruzzo).

The surfaces of the farms varies between less than 1 and 300 ha of olive groves. Particular mention is deserved by the involved cooperative (Goel bio) formed by companies that oppose to ‘ndrangheta -the organized crime of Calabria- that for this reason have been subjected to intimidation and attacks over the years. It is a further testimony of the difficulties that practicing agriculture can have in some areas of the country.

## 3. Results and discussions

### 3.1. Technical guide: general characteristics

The technical guide has been developed on the basis of a paradigmatic, ideal company covering the entire production cycle, from farm gate to point-of-sale; consequently, it can be even administered to olive farms exclusively dealing with the agricultural phase, olive mills dealing with the stages following primary production and companies exclusively dedicated to bottling, packaging and marketing, despite they cannot be considered the natural recipients of the guide, as they fall outside most of the provisions. For this reason, the non-applicability of a specific requirement is contemplated.

The text has undergone some changes according to comments and suggestions of the companies involved, that were therefore not only passive subjects of this pilot study.

The specification is divided into 42 requirements catalogued according to the four pillars of sustainability: Environmental (20), Food Quality/Safety (6), Social (10) and Economic (6). However, a requirement may have several implications, thus falling into more than one pillar/category. Mandatory actions and indications of (voluntary) good practices are envisaged for each requirement; a requirement is met when all of its provided mandatory actions are met. The answer options are in the “yes”/“no”/“not applicable” form in reference to the mandatory actions only. The technical guide administration took place in person during the visits to the

**Table 1**  
List and characteristics of the olive companies participating in the study.

Company	Region	Type of company	Products
Azienda Agricola Bononi	Emilia - Romagna	Olive farm with jointly owned oil mill producing EVOO under its own brand	Organic certified EVOO
Azienda Agricola Podere la Torre	Emilia - Romagna	Agricultural farm without oil mill producing EVOOs under its own brand	100% Italian EVOOs (as Consortium)
CO.N.VI.	Emilia - Romagna	Nursery with oil mill, conferring partner for the Consortium EVOO "Brisighella" POD and olive miller for third parties (oil mill authorized for organic production)	POD certified EVOO "Brisighella" (as Consortium)
Azienda Agricola Le Battole	Emilia - Romagna	Agricultural farm without oil mill conferring partner for the Consortium EVOO "Brisighella" POD	POD certified EVOO "Brisighella" (under several brands for associated companies)
Finoliva Global Service	Apulia	Company dedicated to collection, packaging and marketing of EVOOs conferred from about 10 thousand producers (individual companies, cooperatives and associations of producers) of Italian origin only. Packaging of EVOOs for own brands and for Private Labels.	-POD certified EVOOs -Organic certified EVOOs -100% Italian EVOOs
Azienda Agricola Fazio Michele	Apulia	Agricultural farm with oil mill producing EVOOs under its own brand	Organic certified EVOOs
Azienda Agricola Fazio Giovanni	Apulia	Agricultural farm with oil mill producing EVOOs under its own brand	Organic certified EVOOs
Azienda Agricola Gaetano Schiavone	Apulia	Agricultural farm without oil mill producing EVOOs under its own brand	- 100% Italian EVOOs
Azienda Agricola Zappa Gianluca	Abruzzo	Olive farm without oil mill producing EVOOs under its own brand	100% Italian EVOOs
Azienda Agricola Lungarotti	Umbria	Agricultural farm without oil mill producing EVOOs under its own brand	POD certified EVOO "Colli Martani"
Società Agricola Rocca delle Macie	Tuscany	Agricultural farm without oil mill producing EVOOs under its own brand	Organic certified EVOOs
Tenuta di Collina	Tuscany	Agricultural farm with oil mill producing EVOOs under its own brand	Organic certified EVOOs -100% Italian EVOOs
Frantoio Agostini	Marche	Oil mill with agricultural farm producing EVOOs under its own brand	-Organic certified EVOO -PGI certified EVOO
Goel Bio	Calabria	Cooperative with associated oil mills	Organic certified EVOOs
Azienda Agricola Virzi	Sicily	Agricultural farm without oil mill producing EVOOs under its own brand	Organic certified EVOO with local development brand "Nebrodi - Sicily"
Azienda Agricola Sallicano Marianna	Sicily	Agricultural farm without oil mill producing EVOOs under its own brand	Organic certified EVOO
Boniviri	Sicily	Benefit corporation (integrating in its corporate purpose, in addition to profit objectives, the aim of having a positive impact on society and the biosphere) with 9 conferring partners and associated oil mills producing EVOO under its own brand	Carbon neutral EVOO (as OP)
Azienda Agricola Agrisana	Sicily	Agricultural farm without oil mill, member of the Agrisana organization of producers (OP) and conferring partner for oleificio Zucchi	100% Italian EVOO Organic certified EVOO PGI certified EVOO

different companies. We interfaced with olive orchard owners, agronomists responsible for the agronomic management of the farms, managers of the olive oil production line and company figures responsible for personnel management, risk management process and relationship with suppliers and customers. Each requirement has been described in detail - and eventually clarified - from the administrator of the questionnaire and each response was reasoned and commented with the interlocutors. Participants were asked to provide data and documents to prove their answers as listed in the guide, or (at this stage) at least to ensure that they are in possession of the documentation, to avoid subjective bias or misinterpretation of the requirements. Nevertheless, as this guide was meant to be part of a future sustainability certification, thereupon, recognized certifiers will be responsible for verifying the truthfulness of the declarations. To facilitate its use and compilation, definitions and evidences are reported for each requirement, as well as data sources where to find the requested information. The user is therefore step by step driven through an overall user friendly self-assessment system. According to this implementation approach, a company is put in the condition of being able to use this guide in autonomy with the mere goal to test/improve its environmental performance, or to be evaluated by a third party professional, whereas the development of a sustainability certification will be realized.

### 3.2. Environmental pillar

The requirements of the environmental pillar concern the management of the agronomic and mill phases in such a way that they have a positive or neutral impact on the environment. Basically, the requirements can be classified into 4 categories (Fig. 1):

- Adoption of good agronomic and environmental practices;
- Biodiversity and cultural heritage protection;
- Landscape protection;
- Improvement processes.

#### 3.2.1. Adoption of good agronomic and environmental practices

With regards to good agronomic and environmental practices, adherence to regional integrated production regulations is required. These regional technical standards indicate the agronomic and pest management practices to be adopted to reduce the impact on humans and the environment, but which allow for economically sustainable production, taking into account the territorial and vocational characteristics of the area. In particular, the rules on integrated production concern: the choice of the cultivation environment and its suitability; management of the agro-ecosystem; the choice of varieties and propagating material, soil, water and plant management; agrochemical use; waste management. This requirement is considered fulfilled whenever the farms/companies possess the SQNPI or organic certification. The SQNPI is a certification scheme recognized at community level (EC Reg. 1974/2006) that aims to enhance the sustainable agricultural productions in compliance with regional integrated production regulations. Since 2016, 826 olive farms have joined the SQNPI, for a total area of about 30,000 ha, which corresponds to an average surface of 36 ha, far above the national average. A collateral objective is therefore also to raise awareness of sustainability certifications among small and medium-sized companies.

As for organic certification, there are over 37,000 organic-certified olive farms, covering about 22% of the entire Italian olive-growing area for an average surface of 6.5 ha; however, the share of organic oil produced in Italy corresponds to less than 10% of the total (~28,000 Mg; Sinab, 2020). This is due to the reduced presence of oil mills authorized for organic production, but also to the failure to deliver the product to the mill (organic certification gives the right, with some restrictions, to access to European Union funding) and marginally to the lower yield of organic olive groves. A limit could be represented by the possibility of labeling as organic, only olive oils belonging to the virgin and extra virgin categories (European Commission, 2019). The paradox is that Italy imports about 18,000 Mg of organic oil per year, almost exclusively from Tunisia.

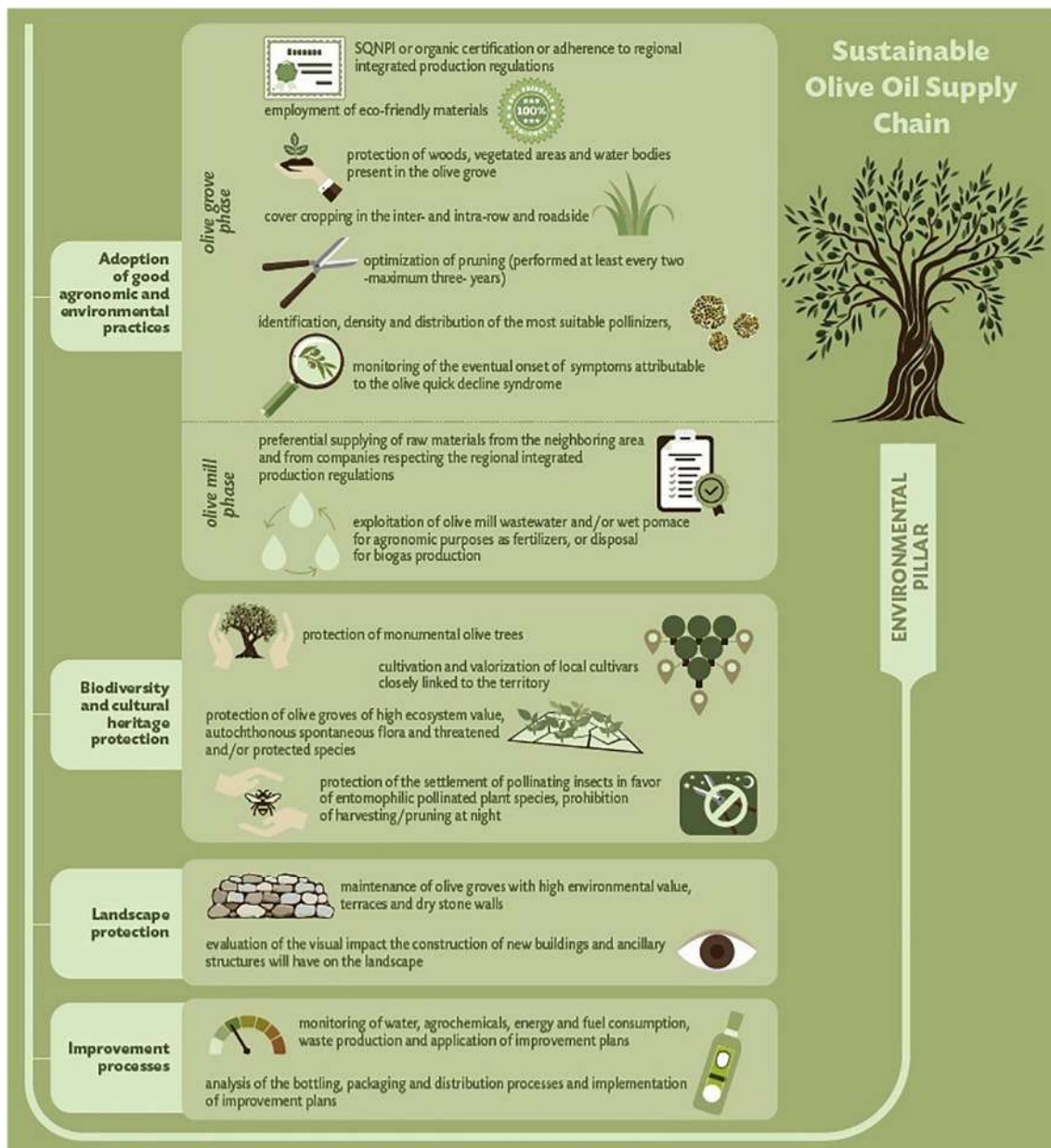


Fig. 1. Schematic representation of the requirements provided for the environmental pillar.

Adherence to the technical sustainability guide could represent an incentive for increasing this percentage.

Possession of other private (e.g. UNI 11233:2009, *Integrated production systems in agricultural food chains*) and regional sustainability standards was provided too.

Further agro-environmental requirements regard the employment of eco-friendly materials and protection of woods, vegetated areas and water bodies possibly present in the olive grove as well as cover cropping in the inter- and intra-row and roadside during autumn and winter, optimization of pruning (performed at least every two -maximum three- years), identification, density and distribution of the most suitable pollinizers, and the monitoring of the eventual onset of symptoms attributable to the principal olive phytopathies, with particular reference to olive quick decline syndrome (OQDS).

The employment of eco-friendly materials represents one of the possible strategies to limit the production of inorganic waste in oliviculture and to speed up the transition towards a sustainable production system.

Woods and forests protection is foreseen by Legislative Decree 3 April 2018, n. 34 in which the woodland and forest heritage is recognized as “an asset of significant public interest to be protected and enhanced for the stability and well-being of present and future generations” (art. 1). Similarly, Legislative Decree 3 April 2006, n. 152 provides measures for the protection of water bodies.

Cover cropping has been proven to be the most suitable soil-management practice to protect the soil surface from erosion, to preserve the environment and to reduce production costs in olive groves. Cover cropping facilitates root development, improves soil drainage, stimulates microorganisms' activity and diversity (Sofu et al., 2014; Lombardo et al., 2019a) as well as arthropod diversity (Carpio et al., 2019), limits the need for external nutritional supplements by preventing the leaching of nitrates and by increasing the organic matter availability in the top layer of the soil caused by the constant renewal of roots of the turf (Kladivko, 2001; Arias-Giraldo et al., 2021) with all the associated positive effects on soil fertility -and, as a possible consequence, plant productivity-. Accordingly, Toscano et al.

(2004) observed that organic matter (OM) content in cover cropped soils raised up to 122% compared to tilled ones. However, adequate herbaceous species should be chosen to ensure a more balanced nutrient availability; in fact cover crops could compete with olive trees for minerals, water and fertilizer if they are not well managed. In this regard, the use of seasonal species or harrowing in the spring and summer to bury the manure and to eliminate weeds, could optimize water resources during the growing season, limiting the loss of water already infiltrated (Pastor et al., 2001). Although several studies report no significant differences in yield between bare and cover cropped soils in both rainfed and irrigated olive orchards (Gómez et al., 1999; Toscano et al., 1999; Hernández et al., 2005; Vignozzi et al., 2018), others highlight a marked reduction in production due to spontaneous permanent cover cropping in mature (Rodrigues et al., 2011; Ferreira et al., 2013; Correia et al., 2015) and young olive trees (from 3 to 7 years after planting) under deficit irrigation (Gucci et al., 2012). Thus the choice and correct management of cover crops are key points to avoid the possible reduction of the harvest. There is some evidence that spring/summer mowing of cover crops is an effective choice to avoid yield reduction (Palese et al., 2014; Sastre et al., 2016), while the employment of cover crop with self-reseeding annual legume species resulted in higher yields compared to ordinary tillage (Rodrigues et al., 2011).

Optimization of pruning is necessary to maximize the productivity of olive by favoring aeration, lighting, photosynthesis and fruiting. Annual pruning allows lighter and faster interventions and is recommended where particular forms of farming are implemented, but over the years it implies higher costs of specialized labor. The 2–3 year limit appears acceptable. In fact, pruning carried out every 2 or 3 years at the most does not seem to have negative effects on production and oil yield (Rodrigues et al., 2018), while longer pruning intervals result in heavier operations causing significant production drops and significant reduction of riparian vegetation and the hosted avifauna. Vigorous rejuvenation pruning must be carried out to recover non-productive mature plants. The removal of suckers and watersprouts must be done annually to avoid unnecessary competitions for resources. Moreover, properly grinded pruning residues left on the soil's surface have been shown to represent an efficient way to increase the olive groves OM content and to diminish CO<sub>2</sub> emissions (Rodríguez-Lizana et al., 2008; Nieto et al., 2010).

Pruning must be carried out in late winter-early spring, when the reserve substances have already been allocated and to avoid the risk of damage from freezing and in non-rainy periods to reduce the risk of spreading diseases through wounds.

Identification, density and distribution of the most suitable pollinizers are fundamental factors for achieving increased yields. In fact, olive is an andromonoecious anemophilous species whose most varieties display high levels of self-sterility and a certain degree of inter-incompatibility (Lombardo et al., 2019b; Moreno Sanz et al., 2020). Also, the effectiveness of pollination was found to be maximum within a radius of 30 m (Ayerza and Coates, 2004; Sibbett and Osgood, 2005). Moreover, considering that fruit set percentage is generally very low (around 10% of the flowers will bear fruits; Spinardi and Bassi, 2012), the -even small- increase in this percentage generated by the right choice and distribution of pollinizers would lead to considerable higher productions, especially in monovarietal cultivation conditions, also in presence of self-fertile cultivars (Farinelli et al., 2006; Sgromo et al., 2006; Seifi et al., 2015). This choice must take into account the synchronism of the respective flowering phases, and the adaptation of the plants to the given pedoclimatic conditions of cultivation. The identification of pollinators (as well as of cultivated varieties) already present in the olive grove can take place either through the use of molecular markers, or through bio-agronomic characterization. In the case of newly planted plants, farmers must possess the regulatory plant passport provided by the nursery.

The monitoring of the eventual onset of symptoms attributable to the OQD is an extremely contingent activity due to rapid advancement of the outbreak front in Apulia (the most important Italian olive producing

region, where the infection first appeared in 2013, causing the felling of thousands of olive trees and huge losses in oil production) and to the possibility for pathogenic insect vectors of *Xylella fastidiosa* subsp. *pauca*, strain CoDiRO (*Philaenus spumarius*, *P. italoignus* and *Neophilaenus campestris*) to be “hitchhiked” over long distances (Lombardo et al., 2021a).

Compliance with these last three requirements has obviously also positive economic repercussions.

As regards the oil mill phase, the requirements provide for preferential supplying of raw materials from the neighboring area and from companies respecting the regional integrated production regulations and the exploitation of olive mill wastewater and/or wet pomace for agronomic purposes as fertilizers for the nutrients contained therein (Lacolla et al., 2019; Muscolo et al., 2019). The advantages derive from the reduced environmental footprint linked to transport, from the possibility of processing the olives more quickly, thus ensuring the freshness of the product and from the recycling of processing waste that should otherwise be disposed of with additional costs.

### 3.2.2. Biodiversity and cultural heritage protection

Requirements related to olive biodiversity and cultural heritage provide that the farm is committed to protection of monumental olive trees (according to article 7 of National Law 14/01/ 2013 no. 10 and to regional law (R.L.) 06/04/2007 n. 14 of the Apulia Region “Protection and enhancement of the landscape of monumental olive trees in Apulia” and the R.L. 30/10/2012 n. 48 of the Calabria Region “Protection and enhancement of the olive-growing heritage of the Calabria Region”) and to cultivation and valorization of local cultivars closely linked to the territory, with particular reference to cultivars at risk of extinction, falling under Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI) regulations or included among/linked to Traditional Agrifood Products (TAPs). Italy possesses the largest olive germplasm heritage in the world and has the highest number of PDOs (42 for extra-virgin olive oils -EVOOs-, and 4 for olive tables) and PGIs (7), and 75 TAPs (23 olive oil or olives-based typical dishes, 19 cultivars and 33 EVOOs). The consequent cultural importance of this cultivation is also evidenced by the national association “City of (olive) Oil” to which 375 Italian public bodies adhere, aimed at promoting the dissemination of the culture of olive oil. Additionally 5 olive landscapes have been inserted in the “National Register of rural landscapes of historical interest, agricultural practices and traditional knowledge” established with Decree n. 17070 of November 19, 2012.

About this topic, it should be emphasized that agricultural biodiversity is protected by the European directive 2008/62 / EC (“In order to ensure *in situ* conservation and the sustainable use of plant genetic resources, landraces and varieties which are naturally adapted to local and regional conditions and threatened by genetic erosion (conservation varieties) should be grown and marketed even where they do not comply with the general requirements as regards the acceptance of varieties.”) and that super-intensive systems have a detrimental effect on olive biodiversity itself, as they are based, to date, only on three foreign varieties, even if some Italian cultivars have been proposed as suitable (Lombardo et al., 2021b).

Regarding the agro-ecosystem biodiversity defense, mandatory actions provide protection of olive groves of high ecosystem value, autochthonous spontaneous flora (according to the “Habitats” Council Directive 43/92/EEC, implemented by Presidential Decree 8 September 1997 n. 357 and subsequent amendments, and to R.L. n. 47 of 7 December 2009 of the Calabria Region “Protection and enhancement of monumental trees and spontaneous native flora of Calabria”), and threatened and/or protected species that may be present in the olive grove and protection of the settlement of pollinating insects in favor of entomophilic pollinated plant species. A further requirement is the prohibition of harvesting/pruning at night, in particular for super-intensive olive systems where these operations have caused the death of millions of birds sheltering in olive crowns (Da Silva and Mata, 2019); this is in line with the provisions of Directive 2009/147/EC on the conservation of wild birds.

### 3.2.3. Landscape protection

The guide requires the maintenance of olive groves with high environmental value, located in complex orographic contexts, characterized by steep slopes, where they represent an integral part of the landscape and play a key role in the stabilization of the hydrogeological structure of the land. Furthermore, companies are requested to maintain terraces and dry stone walls as shelter for plant and animal species and a useful means to preserve soil structure (Santilli et al., 2011) and to evaluate the visual impact the construction of new buildings and ancillary structures will have on the landscape. In accordance with Council Regulation (EC) 1257/99 on support on rural development (article 22), “the conservation of high nature value farmed environments which are under threat” and “the upkeep of the landscape and historical features on agricultural land” shall be recipients of support, nevertheless this provision lacks specific implementing decrees.

### 3.2.4. Improvement processes

Monitoring of water, agrochemicals, energy and fuel consumption, waste production and application of improvement plans are required steps as well as the analysis of the bottling, packaging and distribution processes and implementation of improvement plans. The farm must draw up an adequate irrigation plan based on the water balance of the crop and the use of efficient irrigation distribution techniques. In this sense, while irrigation has a positive effect on yield, as irrigation levels increase, the free acidity of the oil and the emission of suckers increase, while the total phenol content and resistance to lower temperatures decrease (Dag et al., 2008; El Yamani et al., 2020).

Consistency and effectiveness of the approach must be verified over time, through a self-assessment process based on the definition of specific verifiable objectives and periodic reviews.

### 3.3. Food quality/safety pillar

Regarding the food quality/safety pillar, management of the harvest (on farm phase) and post-harvest phase and traceability and nutritional quality of EVOO (olive mill phase) have been considered (Fig. 2a). The first requirement regards harvesting at an early stage of drupe veraison. Whereas there are other methods to identify the correct olive drupes harvesting period (Tombesi and Tombesi, 2007; Camposeo et al., 2013), harvesting at an early stage of veraison represents a simple and effective strategy to safeguard the quality of the oil, as olives not fully ripened have higher levels of total polar phenols and tocopherols (Bouaziz et al., 2010; Menz and Vriesekoop, 2010; El Riachy et al., 2019; Kafkaletou et al., 2021), among the main responsible compounds for the health properties of olive oil, and consequently greater resistance to oxidation. The other on farm requirements provide indications on harvesting materials and methods, storage and transport of harvested olives. For the olive mill phase, the adhering company must ensure quality, hygiene, safety and traceability along all stages from post-harvest to transport of the finished product. Specifically, a proper management of the post-harvest phase (storage of olives, materials employed, respect of hygienic conditions and multi-residual analysis limits) in order to ensure the safety and organoleptic quality of the olive drupes is described. The drupes must be processed within 24–maximum 48 h from harvest to minimize oxidation and avoid the increase of acidity (Rotondi et al., 2021). The olive mill must apply the regional integrated production regulations during processing, packaging, storage and transport phases. In case of different production lines (e.g. organic and traditional products), separate production spaces with dedicated storage areas or processing cycles set up at different times must be implemented. The produced EVOO must respect the product classification and the company must guarantee the distinctive characteristics of: origin, organoleptic profile, composition and health-nutritional value, through declarations on the label. EVOO bottles must be properly stored as the quality level is maintained only if the storage conditions minimize the oxidative processes due to oxygen and light (Lanza and Ninfali, 2020). Lastly, olive companies are encouraged to exploit the extra virgin olive oil-related health claims (regarding polar

phenols, tocopherols approved by EFSA and contained in the Commission Regulation (EU) No 432/2012.

### 3.4. Socio-economic pillar

For the socio-economic pillar, most of the requirements derive from the ISO 26000: 2010-Social Responsibility Standard and the Territory indicator (Luzzani et al., 2021) of the VIVA certification for sustainable wine (Dammario et al., 2021). Concerning this last point, there is an invitation contained in the decree-law of 19/05/2020 n.34, art. 224-ter. of the Ministry of Agricultural, Food and Forestry Policies to extend this sustainability certification to other agri-food chains. The obligations concern: (Fig. 2b):

- monitoring of accidents and injuries during working hours;
- monitoring of the recruiting methods, contractual and working conditions of employees;
- hours of training provided;
- relationships with all the involved stakeholders, with particular reference to the choice of suppliers and distributors;
- identification of cases of non-compliance with regulations and/or voluntary codes regarding the impact on the health and safety of products in the post-sale phase;
- employment of not misleading communications;
- contribution to the economic and social development of the local community and valorization of the territory and its food and cultural heritage.

Newly added requirements are related to the harmonization of voluntary declarations on sustainability and to attribution of a fair price during the sale or purchase phase.

Regarding the former issue, Legislative Decree 254/16 (implementing the EU Directive 2014/95) provides for the obligation for specific companies and large groups to draw up an individual non-financial statement regarding (Article 3) environmental, social issues relating to personnel money laundering and respect for human rights. The Decree extends (Article 7) to all other companies the possibility of submitting a voluntary non-financial declaration containing information regarding (Article 3, paragraph 2): a) the use of energy resources, distinguishing between those produced from renewable and non-renewable sources, and the use of water resources; b) greenhouse gas emissions and polluting emissions into the atmosphere; c) the impact, where possible on the basis of hypotheses or realistic scenarios even in the medium term, on the environment as well as on health and safety, associated with environmental and health risk factors; d) social aspects; e) respect for human rights. As there are a multitude of environmental certifications, it is not always easy to interpret the real involvement of companies in sustainability issues, so that the risk of green washing is real. The scope of the requirement is to sensitize companies to a harmonization of voluntary declarations on sustainability to introduce a single standard aimed at consolidating the criteria for declaring the sustainability of EVOO covering environmental, nutritional, social and economic aspects.

The issue of the attribution of a fair price in the olive oil sector was first addressed at the Community level in 1966 with Regulation No 136/66/EEC of the Council of 22 September 1966 reporting that: “the marketing of Community crops of these products must ensure producers a fair income, the level of which may be determined by a production target price in the case of olive oil [...] whereas the difference between these prices and prices acceptable to the consumer represents the subsidy which should be granted to attain the desired objective” and (article 10) “Where the production target price is higher than the market target price ruling at the beginning of the marketing year, a subsidy equal to the difference between these two prices shall be granted to producers of olive oil extracted within the Community from olives harvested within the Community”. However, it is still a current problem, so that the requirement imposes the attribution, during the sale or purchase phase, of a fair price that can guarantee a fair profit to the olive grower, the miller and the other actors in the supply chain, in compliance with product quality and environmental and worker standards that takes into consideration the production context, production and transport costs and intangible values.

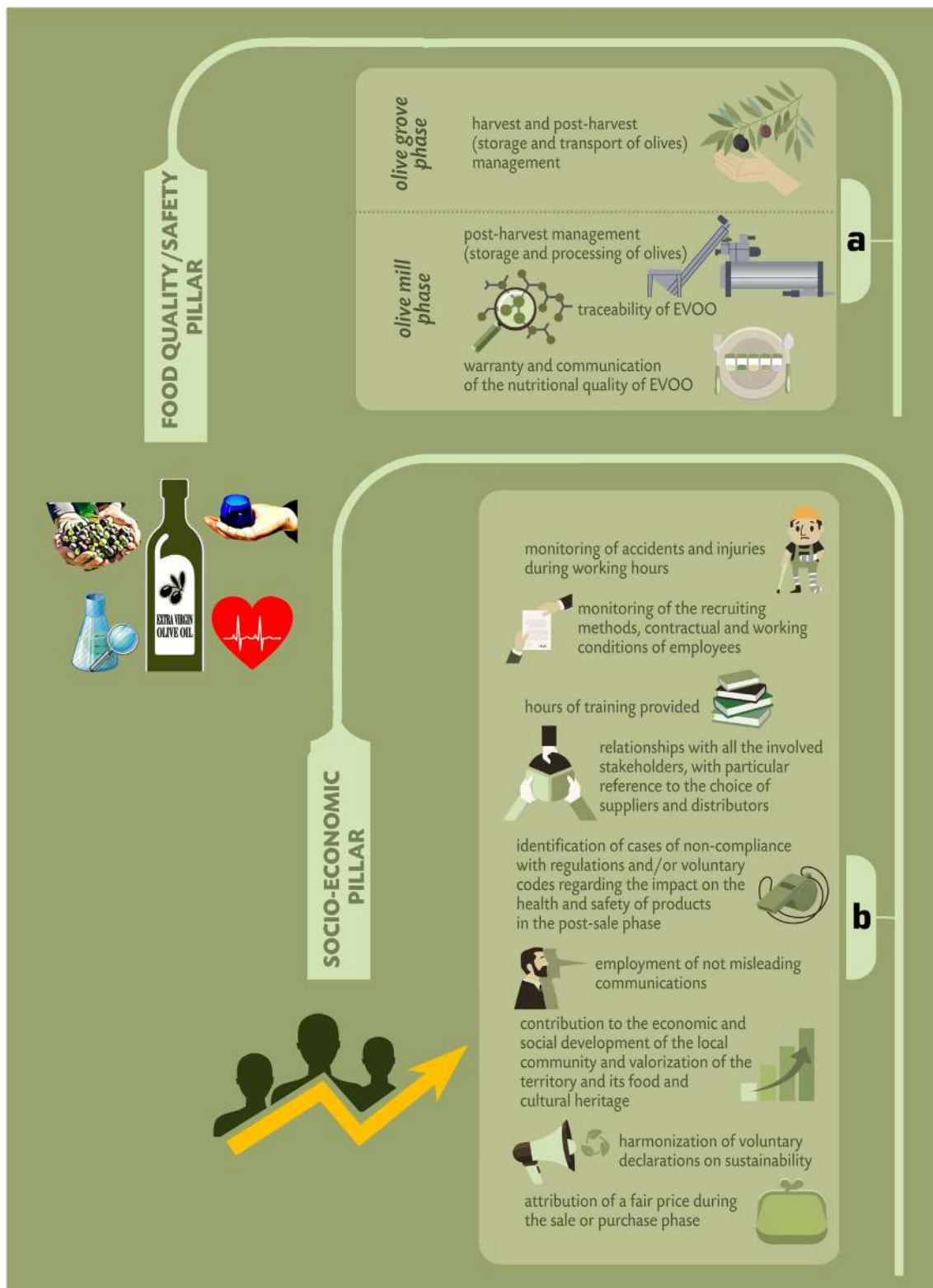


Fig. 2. Schematic representation of the requirements provided for the food quality/safety (a) and socio-economic (b) pillars.

3.5. Identification of strengths and critical points of the companies participating in the study in terms of sustainability

A collateral starting point for reflection was provided by the 12 farms/companies that, when personally contacted, -illegitimately- refused to join this study. Possession of environmental certifications and lack of interest

in the subject were recurring reasons for refusal. This was symptomatic of how widespread a certain indifference or misinformation towards the broader meaning of sustainability is and how much it is only partially understood. Institutions should pay particular attention to this aspect/indication, and promote specific interventions such as targeted funding and training courses.



The farms that participated in this pilot study, despite not always having clear sustainability-oriented strategies, globally showed virtuous behaviours towards the four pillars of sustainability with percentages of compliance with the requirements ranging from 86 to 96% according to pillar (Fig. 3a) and from 70 to 100% according to company (Fig. 3b). The percentages reported in Fig. 3 contain a two-level information: 1) the degree of a company's total sustainability and 2) where the company should intervene to improve its global sustainability level. This latter aspect is particularly important as the primary objective of the technical guide, at this stage, was to represent a mean to increase the self-awareness of companies' sustainability, to identify the major weaknesses and eventually to understand how to ameliorate their sustainability performances, in a continuous improvement process. For this reason, a limited but exhaustive (corroborated by accurate studies and bibliographical research) number of requirements within every company's reach (whose satisfaction did not imply excessive efforts and costs on the part of companies) was chosen to reach this goal.

However it should be emphasized that this guide was conceived as an integrative tool in a future sustainability certification process together with footprint measurements and, as such, compliance with all the meetable requirements in the mandatory provisions, will be mandatory. Consequently, all the requirements have been foreseen to have the same relevance.

Analyzing the results more specifically, 11 out of 18 companies had organic certification (Table 1), while the others turned out to comply with regional integrated production regulations. No farm resulted to be SQNPI certified for olive groves. Possession of other certifications has also been registered. All the farms cultivated local varieties (6 of them had POD or IGP certifications) and declared to protect monumental olive trees, woods, native flora, endangered species, vegetated areas and areas of high ecosystem value -where present- and to practice cover cropping between tree rows. This last issue is provided among the potential agricultural practices that eco-schemes could support (European Commission, 2021). A derogation from this requirement was naturally granted to the

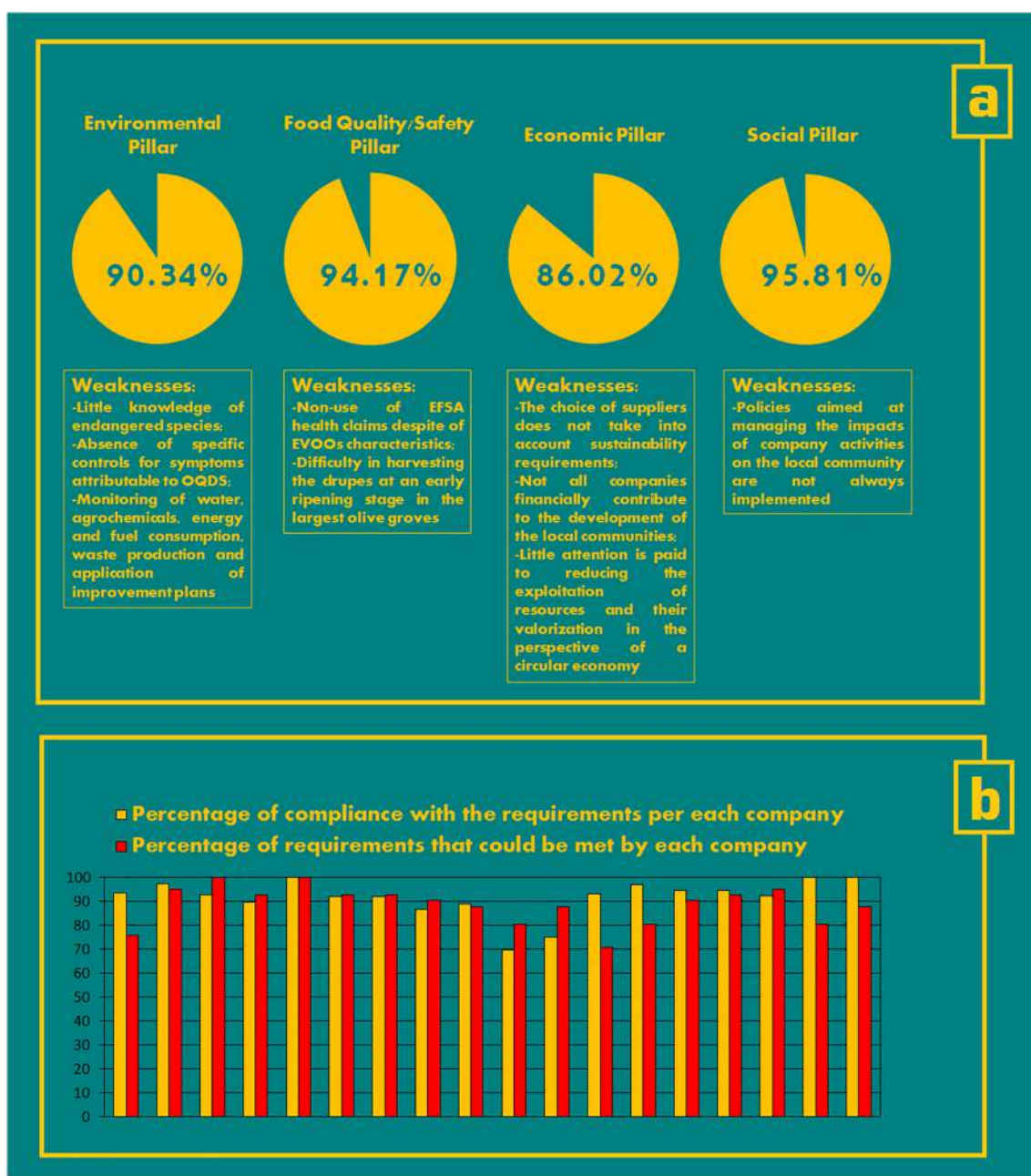


Fig. 3. Percentage of compliance with the requirements at global (a) and company (b) level.

cooperative members who carry out the mechanical tillage of the soil as it hinders the spread of fire in an olive grove, having been several times victims of arsons.

A main strength that can be extrapolated from the responses of the companies was directly related to the high quality of the product. All the interviewees, in fact, agreed in ensuring an excellent quality of the produced EVOOs with typical organoleptic profiles and made with the highest hygienic-quality standards throughout the agronomic and transformation stages. Accordingly, all companies answered to have never been notified of any non-compliance cases. Above-average managerial skills have emerged: the companies, even if family-run, asserted to manage to charge a fair price for the sale of their EVOOs and to guarantee a fair price for their suppliers in the purchase of raw materials. Fair compensation for employees was a direct consequence, as well as a selling price of EVOOs even 5 times higher than the average of the Italian market. Only one company, complained a weak bargaining power in the definition of the sale price because of the competition with other producers. This latter is a real common threat for the sector, as small producers are exposed to aggressive competition from national large olive oil importers and international producers. This is why strongly market-oriented companies with niche productions, betting on quality and the link with the territory, are able to have significant revenues. In fact, in marginal realities, it may happen that farmers derive most of their income off the farm. Accordingly, the territorial and dimensional marginality of these farms results in an economic marginality, that, together with the increasing aging of landowners (about half of the company owners are over 65 years old; ISMEA—Institute of Services for the Agricultural and Food Market, 2020a), has often led to scarce innovation capacity, reduction of investments, drastic reduction of expensive cultivation practices (pruning, fertilization, tillage) with associated loss of production, increased summer fruit drop, marked phenomenon of “on” and “off” years, and, in extreme cases to the abandonment of olive groves. As a proof of this, on average (2008–2018 period) the percentage of product left in the orchard corresponds to 7% of the total yield -this datum drops to 2.8% for the total agricultural production- with peaks of 12–14% (CREA, 2020), and olive oil production that just halved in the last 20 years (from 672,600 Mg in the 200–2005 period to 313,000 Mg in the 2016/2021 years) (IOC—International Olive Oil Council, 2021). Eventually, these are the conditions in which it is easier to resort to undeclared work and in which the hygienic-sanitary rules during olive harvesting and oil production are not always respected, with negative repercussions on the quality of the product. For all these reasons, the efforts that the interviewed companies make to focus on quality and sustainable products must be appreciated and recognized even more.

Returning to the results of the evaluation, all of the companies have been shown to be attentive to personnel management, to comply with the relevant regulations in this regard and to have never resorted to undeclared work. Most companies are involved in organizing training courses for employees, but only a few organize specific courses on sustainability issues. As might be expected, the larger companies resulted to be more prone to participate to the economic and social growth of the local community through donations and financing of works and initiatives.

As for the defense against the onset of symptoms attributable to the Olive Quick Decline Syndrome, the farms implement a generic system for controlling the phytosanitary state of the plants, but, apart from one case, they do not implement specific controls against *Xylella fastidiosa*, which is indeed seen as a non-contingent problem in the other regions other than Apulia.

An opportunity is represented by olive tourism, even if at the moment it is not considered a central element for most companies, which only occasionally organize olive oil tasting experiences or activities linked to the local food and wine heritage. Nevertheless, they all agreed in seeing in the experiential tourism a key factor for the enhancement of the olive oil supply chain, with a nod to the value that the tourism sector has in Italy.

Companies have proved to be inclined to a process of harmonization of voluntary sustainability declarations, so as to provide clearer and more uniform information and to reduce confusion for consumers. Companies with

mills preferentially confer the pomace for the production of biogas, while only in one case it is used for fertilization purposes. This is part of a circular economy plan, in which waste is considered as a resource. Similarly, the burying of shredded pruning residues is widely practiced; only rarely they are burned in situ.

Difficulties arise when farmers were asked for certifications or certain identification of cultivated varieties as most companies cultivate groves belonging to their families over several generations, with mature olive trees commonly older than 50 years of age. This is in keeping with the national data, according to which 61% of the olive surface is made up of trees older than 50 years; this is even due to national law prohibiting the felling of more than five olive trees every 2 years, except for serious phytosanitary reasons. A direct consequence is that about 48% of the farms have less than 140 trees per hectare, 47% between 140 and 399 trees and only 4% over 400 trees per hectare (Eurostat, 2021).

Other weaknesses were represented by the lack of control on energy, water, fuel and agrochemicals consumption and by the failure to prepare and periodically revise improvement plans. Some uncertainty was understandably highlighted regarding the knowledge of protected or endangered species; this aspect must necessarily be part of the farms' improvement processes as agriculture together with aquaculture is a major threat for ~13,000 of the ~23,000 endangered and critically endangered species included in the International Union for Conservation of Nature (IUCN International Union for Conservation of Nature, 2021) “Red List”.

Although all the companies declared the produced extra virgin olive oils to fall within the expected parameters, only one of them answered to report the pertinent EFSA health claims on their labels and, in any case, only for the content of polyphenols. Really, some companies were not aware of the possibility to use EFSA approved health claims for extra virgin olive oil. In general, in the face of good environmental performances, communication of the applied good practices and the obtained results (namely communication of sustainability) seems to be a weak point for most of the companies consulted. An exception was represented by the benefit corporation Boniviri which periodically prepares a quality and sustainability protocol shared with its members. Precisely in this mean the guide can represent an effective and zero-cost tool in an extensive self-assessment and improvement process and a concrete help in the drafting and standardization of sustainability reports for a clear and thorough communication with the stakeholders.

#### 4. Conclusions

Sustainability is a consolidated decision-making lever for consumers, who are increasingly attentive to environmental, social and food quality issues. These aspects are particularly strategic in the case of extra virgin olive oil, where the nutritional value, the link with the territory, the environment and social responsibility are added values and a marketing tool to attract and protect consumers. However, the definition of the key elements of sustainability declined in economic, environmental and social terms is subject to the identification of a high number of variables depending on production sector, company size and characteristics, environmental conditions, technological level, national and regional regulations, local traditions and culture, number of stakeholders involved etc.

In this sense, the drafting of a sustainability program for the olive-oil supply chain is aimed at providing a technical support for the Italian olive growers during the switch to environmental, socio-economic and cultural sustainability practices. In particular, this technical regulation is proposed as:

- A means of obtaining an accurate representation of the degree of sustainability of an Italian olive company;
- A support for companies in defining a sustainability plan and to draft a sustainability report;
- A first step towards a “total” sustainability certification based on indicators for the measurement of relevant benchmark established by the responsible decision makers.

Of course the future policy implementation should state the need for further exchange of information and data between the various sindacate, politicians for the enforcement of instruments and structures to supply development in fields. New meetings and workshop have been planned in the Italian Parliament and Agricultural Ministry to reach this objective.

The different types of companies participating in this phase of a step-wise approach, representative of the complex olive oil production chain described in the introduction, turned out to be quite adherent to the provisions contained in the technical guide and strongly aware of the importance of “sustainable thinking” in this particular historical phase. From this perspective, they probably do not fit into the profile of most part of olive farms/companies, but just because of their interest in sustainability, they were the most suitable ones to test our technical guide and those most qualified to provide valuable suggestions. Additionally, the goal of the study was not to assess the sustainability level of the olive oil supply chain as a whole, but to provide a tool for the individual olive company in a process of continuous improvement.

Finally, although the guide was calibrated on the Italian olive sector, it can also be confidently transferred, with small adjustments, to other olive growing countries, given the various parallels existing with the different olive oil supply chains in the rest of the world.

### CRedit authorship contribution statement

Conceptualization LL, CF, EC; Data curation LL, CF, EC; Formal analysis LL, CF, EC; Funding acquisition EC; Investigation LL, CF, EC, ST, EN; Methodology LL, CF, EC, ST, EN; Project administration EC; Supervision EC; Roles/Writing - original draft LL, CF, EC; Writing - review & editing LL, CF, EC, ST, EN.

### Declaration of competing interest

The authors have no competing interests to declare.

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