Developing skills for introducing circular business models and digital technologies in olive oil sector

D2.1 National Report on current situation in the olive oil sector

- GREECE -

September 2024

Project management | Identification of olive sector | Holistic circular business | VET curricula | Education programmes | Communication strategy

Croatia I Italy I Greece I Spain I Portugal

02-2024 | 01-2027

WWW.CIRCOLIVE.EU

Consortium

Co-funding

Co-funded by the European Union

Name of the Project	:	Developing skills for introducing circular business models and digital technologies in olive oil sector
Acronym of the Project	:	CIRCOLIVE
Proposal Number	:	101139912
Call	:	ERASMUS-EDU-2023-PI-ALL-INNO
Topic	:	ERASMUS-EDU-2023-PI-ALL-INNO-EDU-ENTERP
Type of action	:	ERASMUS Lump Sum Grants
Granting authority	:	European Education and Culture Executive Agency
Project Duration and start date	:	36 Months - 01 February 2024
Lead partner/coordinator	:	Vakakis S.A. (Greece)
Partners	:	AGRICULTURAL UNIVERSITY OF ATHENS (Greece), ASSOCIAÇÃO CHECK-IN - COOPERAÇÃO E DESENVOLVIMENTO (Portugal), CLUST-ER AGROALIMENTARE (Italy), ISTITUTO FORMAZIONE OPERATORI AZIENDALI (Italy), CAMARA OFICIAL DE COME E INDUSTRIA DE LLEIDA (Spain), FUNDACIO EURECAT (Spain), INSTITUT ZA POLJOPRIVREDU I TURIZAM USTANOVA (Croatia), ALMA MATER STUDIORUM - UNIVERSITA DI BOLOGNA (Italy)
Contact	:	George Vardangalos
Email	:	gvardangalos@vakakis.gr
Website	:	http://circolive.eu/
Title of Deliverable	:	D2.1 - National Report on current situation in the olive oil sector – Greece
Objective of Deliverable	:	*The purpose of National Report is to report results of the research on the current situation in the olive oil sector in Greece as concerns the implemen of circular practices and the main relevant technological gaps, as well as a mapping and review of any existing relevant VET curricula/programmes.*
Deliverable Author/		AGRICULTURAL UNIVERSITY OF ATHENS (Greece)
Names of contributors		Vassiliki Tsagou, Ioanna Rousou AvgiGardeli, Margarita Andreanidi, George Vlahos
Contact	:	George Vlahos
Email	:	gvlahos@aua.gr
Version of Deliverable	:	*v.1*
Date of Submission of Deliverable	:	27 September2024

Publicity Disclaimer

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor the granting authority can be held responsible for them."

National Report on current situation in the olive oil sector - GREECE

Deliverable No. :	D2.1	WP No. :	WP2
Work Package Title	Identification of olive sector circular needs and emerging skills and/or professions for transition of the olive oil sector to a circular econ in the 5 countries		
Status	Final Version 1		
Dissemination Level	PU - Public		
Due Date	30.09.2024		
Submission Date	27.09.2024		

Contributors

Contributor			Date
Deliverable Leader	IPTPO	.	27.09.2024
Work Package Leader	IPTPO		27.09.2024
Final Review & Approval	IPTPO		27.09.2024

History of Change

Release	Date	Reason for Change	Status
Version 1			
Version 2			
Version 3			

Contents

1. Executive Summary

1.1 Background and Purpose

Olives and olive oil are the country's iconic products and constitute an important part of its exports since up to 80% of the production is extra virgin, which is the top-ranked classification category in the world. Olive trees can grow even on arid and rocky soils, while they survive under harsh conditions and strong winds. In Greece, the olive tree is grown in all regions (NUTS2) and most of the regional units (NUTS3) around the country with the vast majority of the groves (approximately 88%) cultivating olives for oil production, while only about 12% of them grow table olives(Figure 1).

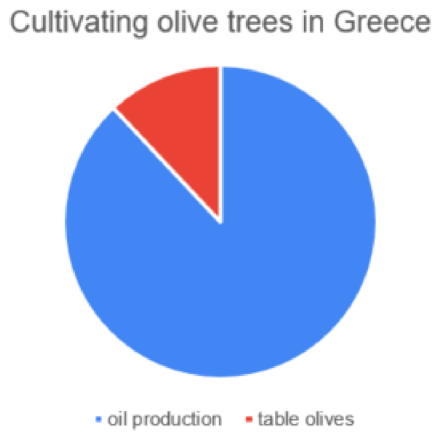

Figure 1: Cultivation of olive trees (red: table olives, blue: olives for oil production) – data. from questionnaires

The present report aims at investigating the current treatment methods and techniques applied for the management of the waste of the olive oil sector in Greece, and evaluating the possibilities of introducing innovative technologies for the valorization of this waste.
The results suggest that the olive sector in Greece, including farming, olive oil mills, olive–pomace oil production facilities, packaging facilities, as well as refinement facilities, is gradually embracing sustainable practices, despite challenges i.e. technological gaps, high costs, legal restrictions and lack of knowledge. Hence, there is room for improvement in olive sector's waste treatment in Greece, since many of the currently applied methods comprise only basic level treatment techniques. The integration of circular economy principles, such as repurposing by-products and maintaining soil health, is evident, with many producers striving to implement more sustainable and efficient methods.

1.2. Key Findings

The results suggest that the olive sector in Greece, including farming, olive oil mills, olive–pomace oil production facilities, packaging facilities, as well as refinement facilities, is gradually embracing sustainable practices, despite challenges i.e. technological gaps, high costs, legal restrictions and lack of knowledge. Hence, there is room for improvement in olive sector's waste treatment in Greece, since many of the currently applied methods comprise only basic level treatment techniques.

The integration of circular economy principles, such as repurposing by-products and maintaining soil health, is evident, with many producers striving to implement more sustainable and efficient methods.

1.3. Recommendations

However, broader adoption is limited by the aforementioned barriers, highlighting the need for greater support and investment in sustainable technologies. General strategies for the adoption of environmentally friendly practices, prevention measures, intensive controls of the production processes and provision of technical assistance and theoretical knowledge to every stakeholder of the sector, are the essential prerequisites for the transition of the Greek olive oil industry to a circular economy model.

2. Introduction

2.1. Overview of the Olive Sector

Olive trees are spread throughout Greece while olives and olive oil are the country's iconic products and constitute an important part of its exports. Olive trees can grow even on arid and rocky soils, while they survive under harsh conditions and strong winds. Up to 80% of the olive oil production is extra virgin, which is the top-ranked classification category in the world. The olive oil sector in Greece includes olive oil mills, olive–pomace oil production facilities, packaging facilities, as well as refinement facilities.

2.2. Objectives of the Report

The main target of this report is to collect data concerning the by-products produced during olive farming and processing, the practices currently applied during farming as well as for the treatment of the wastewater and solid waste derived from the olive processing industry in Greece, the main technological market trends and needs and the existing relevant VET curricula/programs offered on circular business practices. The ultimate goal of this study is the adoption of circular entrepreneurial models for waste and by-product valorization of the whole olive oil value chain and the enhancing of the circular business skills in the olive oil sector in Greece.

3. Methodology

The chapter "Methodology" describes the methods of data collection and their analysis. The aim of the chapter is to inform the reader about the methodology used and the possibility of repeating the study using the same methodology.

3.1. Data collection methods

The data was collected from two data sources: primary and secondary data sources.

Primary data collection involves the process of preparing tools for data collection and

collecting data from a planned sample of respondents. Three data collection instruments were prepared for the purposes of this study: a questionnaire and two interview reminders.

The questionnaire was designed with the aim of collecting quantitative data on a sample of olive grove owners which produce oil in service mills, and a sample of olive mill owners who own or do not own olive groves. The questionnaire (ANNEX 1: Online survey targeting MSMEs in the olive sector) contained multiple-choice questions, closed questions, open questions and questions in the form of a Likert scale. The questions related to numerical production indicators, the use of tillage techniques, the treatment of plant residues in olive groves, methods and capacities of olive processing, the treatment of by-products after olive processing and questions on the circular economy in olive growing. The planned sample size was 20 but data was collected from 22 respondents, namely 17 respondents for the olive grower's category, 2 respondents for the olive grower's and olive mills owners' category and 3 respondent for the olive mill owner category (Table 1). The questionnaires were collected online via Google forms.

Table 1. Decription of the sample of respondents who participated in the online survey (N=22)

Variable	N	Percentage (%)
Gender		
Male	**16**	**72.7**
Female	**5**	**22.7**
Did not answered	**1**	**4.6**
Age		
Up to 36	**7**	**31.8**
37 – 56	**10**	**45.5**
57 and more	**5**	**22.7**
Education		
High school and lower	**7**	**31.8**
Bachelor degree	**11**	**50.0**
Master degree	**2**	**9.1**
PhD	**2**	**9.1**
Enterprise size		
Micro (<10 employees)	**19**	**86.4**
Small (<50 employees)	**2**	**9.1**
Large sized (>250 employees)	**1**	**4.5**
Agriculture is in the household		
The only source of income	**3**	**13.6**
Predominant source of income (>50%)	**4**	**18.2**
Additional source of income (<50%)	**15**	**68.2**

Two interview reminders were also prepared for the qualitative data collection. One interview reminder was prepared for experts in the agri-food sector (ANNEX 2: Structured interview with circular business agro-food experts/professionals). The other one for providers of education in

Greece (ANNEX 3: Structured interview with VET providers). The reminders contained open questions with sub-questions so that the interview could be conducted as efficiently as possible. The planned sample size was 5 respondents for experts in the agri-food sector and 5 respondents for providers of education. Interviews were conducted face-to-face with respondents and through an online meeting. The interviews were recorded and a transcript of the conversation was made. Each respondent has voluntarily and expressly consented to the collection and further processing of personal data and has voluntarily agreed to answer questions for the purpose of research within the CIRCOLIVE project. Each respondent has confirmed this with their signature in the documents: a) Statement related to giving consent for the processing of personal data and b) Information form for participation in research – personal informed consent.

Secondary data are ready-collected data that come from various sources, e.g: statistical yearbooks, available studies, databases, scientific papers, technical literature, etc. When using this data, the source is always cited in the report and the list of references used can be found in chapter 13 of this Report.

3.2. Data analysis methods

After the data collection was completed, the data analysis was carried out.

Quantitative data collected through questionnaires were analysed using descriptive analysis and response frequencies. The data are presented in the form of tables, graphically through graphs and descriptively.

The data collected through the interviews were processed through a content analysis. The interviewees' answers are presented in the form of a description with reference to the type of interviewee in the interview (Interview with education stakeholder; Interview with by-products/waste from olive sector stakeholder; Interview with olive growing and oil production stakeholder).

4. National Context

4.1. Geographic and Climatic Overview

The olive tree is being cultivated in Greece since antiquity. It is the Mediterranean sun combined with the Aegean winds that lend the fruit its unique taste. Greek olive oil is of supreme quality and its uniqueness is mainly due to the climate that the olives are cultivated in. The coastal regions have the perfect climatic conditions needed for the olive trees cultivation and a suitable ecosystem for the trees to grow and bear fruit. Olive groves in Greece are cultivated in the following three climatic zones of Greece:

A) The continental zone of northern Greece, including the mainland of Epirus, Macedonia, and the largest part of Thessaly, where the climate changes gradually from a typical Mediterranean to the colder climates of central Europe.

B)The marine Mediterranean Ionian zone, including the coastal regions of western Greece and the Ionian islands.

C)The Mediterranean mainland zone that includes the southeastern part of Greece up to Thessaly, the Aegean islands and Crete. The climate of this region is similar to the marine Mediterranean, but with lower winter temperatures and longer summer droughts.

Olive groves exist in all regions of Greece and in 50 out of 74 regional units The greatest part of Greece's olive oil is produced in the Region of Peloponnese, followed by Crete, Western Greece, Central Greece, the North and South Aegean and the Ionian islands.

4.2. Historical Development of Olive Cultivation

Dating back to the Minoan civilization, several findings from Knossos appealed that the Cretan economy was based on olive oil (Tsimidou et al 2003). But the discovery of petrified olive leaves in Santorini, of an estimated 50.000 to 60.000 years of age, proves that the enduring relationship between Greeks and olive trees has a remarkably long story. The olive tree became a sacred tree when the goddess of wisdom, Athena, during a competition with the god Poseidon for claiming the city of Cecrops, offered it as a gift. Thenceforth the city adopted the name of Athens (Tsimidou et al 2003; Grego 2022). During the Ancient Olympic Games, the winners were awarded an olive branch in form of a wreath (Grego 2022). According to a legend the wreaths came from a tree planted by Hercules himself in Olympia. Homer referred to olive oil as liquid gold, while Hippocrates noted its healing qualities. In the shadow of tales, traditions and legends olive is still an integral part of life in Greece. Olive oil is used, as part of the ritual, during religious ceremonies, such as baptisms and funerals!

4.3. Regulatory Framework and Government Policies related to olive production by-products

There is no specific regulation concerning the treatment of pruning residues or weeds in Greece. While there has been a strict prohibition for the burning of arable stubble within the Cross Compliance obligations and currently the Enhanced conditionality rules, no such restrictions exist for permanent crops. The only restriction currently applied is that of the prohibition of setting fire outdoors (any kind of fire, hence for burning agricultural residues also) for protection against forest fire (usually from May to October). However, there is a voluntary annual subsidy scheme (ecoscheme) for farmers, who wish to treat pruning residues through composting and applying compost for soil improvement.

The treatment of olive oil mills wastes is regulated by the national legal framework. Specifically, the conditions of the Greek Joint Ministerial Decision (JMD) 15/4187/266/2012 (Government Gazette 1275 B) as they have been amended by the JMDs 135207/1801/2017 (Government Gazette 4333 B) and 127402/2016 (Government Gazette 3924 B) are applied on the Standard Environmental Commitments (SBC) of industrial activities of olive oil mills. It has to be recorded that the provisions of the specific JMD apply to the majority of oil mills in Greece as their daily oil production capacity is significantly lower than 300 tones. Concerning waste water derived from olive oil production, according to condition E3-1 of the JMD oil collection, neutralization or any other equivalent method, sedimentation and finally disposal to open evaporation ponds is the proposed treatment method. According to Condition E3-2 of the JMD olive oil mill wastewater can be used after appropriate pre-treatment process (including oil collection, sedimentation or any other equivalent method) for the irrigation of olive groves or other trees. Concerning the pomace originating from the oil sector according to Z8 condition of the JMD it should be treated at olive pomace facilities.

5. Olive Production Analysis and Olive Oil Processing

5.1. Cultivation Practices and Varieties

Olive trees grow slowly, taking four or five years to yield their first fruits and another 10 to 15 to reach their full capacity. Once established however, the olive trees can live for many years. Every procedure concerning olive farming, from pruning in spring through flowering and harvesting in the late autumn, has a bearing on the quality of the fruit, and thus of olive oil (Lodolini et al. 2023; Saglam et al. 2014). Pruning comes after harvesting to prepare the tree for the next crop. The maturity of the olive plays an important role by affecting both the taste of the fruit and the oil produced (Mele et al. 2018). The olive fruit harvest, via hand-picking, begins in October and goes on for about two months, depending on the type of olive and the place it is cultivated. Green olives are harvested first, followed by the plump black olives that are among the country's best-known snacks: tight-skinned Kalamata olives with their pointy tip and juicy Amfissas olives that come in a variety of browns, blacks and purples. Last to be harvested is the wrinkled black variety, which may be harvested even in March, as it must mature on the branch firstly and then be cured in coarse salt.

Some olives are suitable only as table olives and others are suitable only to produce oil. Olive varieties for olive oilare**: a) Koroneiki** which is considered to be the "queen" of olives. It produces a high quality, low acidity and full-bodied extra virgin olive oil at a yield of approximately 6 to 7 liters/kg. The Koroneiki olives thrive in the rocky, dry areas of the south Peloponnese and of Crete. Kalamata PDO is one of the finest extra virgin olive oils that comes from this variety. b) **Athinolia**, which is a variety of olive that matures slowly and is harvested from the end of December until the beginning of January. By mixing Athinolia and Koroneiki olives a full-body extra virgin olive oil of a balanced and intricate fruity flavor can be produced. c) **Manaki**also matures slowly and its harvest period is from the end of October until the beginning of January. The taste of olive oil that comes from this fruit is softer and its aroma reminds ripe fruits like apple and tomatoes (https://approachguides.com/blog/guide-greek-olives-olive-oil/).

5.2. Olive Oil Extraction Methods

Nowadays olive mills in Greece use two basic oil extraction methods:

1. Traditional pressing, where the ground paste is placed between pressing mats and is subject to pressure to expel the oil mix (mixture of oil and water). This mixture is then poured into a vat or a holding tank to rest until due to gravity and the different densities oil is separated from the water.

2.Centrifugation method: It is conducted by two different types of decanters:

(a) a three phase centrifugation system during which 1 litre of water is added per kilo of paste and is subsequently placed into a horizontal centrifugal machine, where the solid is separated from the oily phase. This phase or unpurified oils then pass into a vertical centrifugal machine, where the oil is separated from the vegetable water. This process results in the production of three streams i.e.

(1) olive oil, (2) wastewater (known as vegetable or fruit water in English, alpechin in Spanish, acque di vegetazionein Italian and katsigaros in Greek) and (3) solid waste (known as pomace in English, orujo in Spanish, sansa vergine in Italian and trifasikoselaiopirinas in Greek). As water is being added during processing total waste produced are increased. The produced pomace is dry and can be used either for obtaining pomace oil or can be treated as a waste.
(b) a two-phase centrifugation procedure, a process that is more advanced. Specifically, it is based on a two-phase decanter and is the same as the three-phase process, but instead of adding water before the horizontal centrifugation, the vegetable water produced is being recycled leading to lower energy costs, less water waste and a higher extraction rate of olive oil (output/input ratio). From this process besides oil, a humid solid waste (known as pomace in English, alperujo in Spanish, sansa vergine in Italian and difasikoselaiopirinas in Greek) are produced. These wastes are not considered as a disposal problem compared to the wastewater produced from a three-phase system. They are usually dried onsite to obtain a pomace with less than 50% of water. However, drying process is costly and greenhouse gasses and fumes are produced (Niaounakis and Halvadakis 2006).

According to a sectoral report of National Bank of Greece (2015) the most commonly used process for oil extraction in Greece at a rate of 80% was the three phase centrifugation system, whereas traditional pressing systems was still used at a percentage of 18%. Since then and according to recent data reported by the Ministry Environment and Energy (https://wfdver.ypeka.gr/el/consultation-gr/2revision-consultation-gr/) the majority of the mills in Greece function through two-phase centrifugation systems. Specifically, in Peloponnese olive oil mills, at a rate of 65%, use two phase centrifugation systems, while only the 35% is producing olive oil through three phase systems. Accordingly, among the respondents of the online questionnaires in the present study, the majority of the olive oil producers (at a percentage of 66%) own a two phase system olive mill with capacities that vary between 1500-12000 kg/hour.

5.3. Cultivation area, Yield Trends and Production Statistics

In Greece, the olive tree is grown in all regions (NUTS2) and most of the regional units (NUTS3) around the country wiith the vast majority of the groves (approximately 88%) cultivating olives for oil production, while only about 12% of them grow table olives. This suggests that olive oil production is the dominant scope of olive cultivation in Greece, which aligns with Greece's status as one of the top olive oil producers globally. However there is not significant difference between the average size of farms with olives for oil production, which is approximately 1.89 hectares, and farms that produce table olives, that are around 1.79 hectares. The overall small size of the farms (around 2 hectares) indicates that olive farming in Greece is primarily conducted by small-scale operations.Similar data came out from our field research, as most of the respondents own small and frequently family-run farms. Additionally, taking into account the total number of olive farms in Greece (up to 382,353) and the total area cultivated with olives (770,564.35 hectares), can be also concluded that olive farming in Greece is highly fragmented with a large number of small farms (2023).Thus, the high number of farms combined with the relatively small average farm size reinforces the notion that the olive sector in Greece is dominated by smallholders. This could pose challenges in terms of scalability and modernization but also indicates a deep-rooted tradition of olive farming across many families and regions.

Concerning the olive oil production sector and according to the Hellenic Statistical Authority (ELSTAT, 2021) there are around 1,887 units occupied in the production of olive oil, most of them of small size (family businesses) with an average annual production capacity of 170 tons (Sectoral Report of NBG, 2015). In 2022 the total cultivated area of olive trees in Greece produced 461,839 tons of edible olives and 2,747,069 tons of olives for oil (ELSTAT, 2022). Moreover, according to International Olive Council data, from 2016 to 2023, an average of 223,500 tons of olive oil were produced in Greece ranking Greece (9%) in the third place of the foremost producers of olive oil in EU after Spain (49%) and Italy (12%). The Peloponnese followed by Crete and the region of Western Greece produce the largest percentage of olive oil and edible olives. The production of olive oil during the 2023-2024 was significantly reduced. Specifically, according to the latest EU data, the olive oil production in Greece between October 2023 and January 2024 was up to 131,500 tons, while the final production of the season is expected to amount to 155,000 tons (MS declarations - Commission Regulation R 2017/1185 Art.12). Finally, according to our field research the amount of the processed olive fruit was higher to all the cases examined in 2022 (900- 6724 tn) than in 2021 (700 - 2652 tn), while in 2023 the respective amount was significant decreased (100 – 3698 tn).

6. By-products and Waste Production in the Olive Sector

6.1. Olive Leaves and Branches

Olive leaves as a waste consists of a mixture of leaves and small branches that are generated from both the pruning of the olive trees, and the harvesting and cleaning of olives prior to oil extraction in the processing plant.

Pruning biomass: The total average annual pruning biomass for olive trees in their mature phase amounts to 0.7803 tons of dry matter per hectare. This biomass represents the branches that are pruned annually for maintaining tree health and fruit productionThey are generally used for direct combustion, animal feed (fresh) and as feedstock for direct combustion or pellet manufacturing.

Specifically, in Greece, concerning pruning biomass treatment (Figure 2):

- **20%** of the pruning biomass is burnt in the field, which releases carbon dioxide into the atmosphere but might also help reduce pests and diseases.
- **70%** of the pruning are used as solid fuel outside the field, indicating a high level of recycling and energy recovery from the pruning, which is environmentally beneficial as it provides an alternative energy source.
- **10%** of the pruning are used for purposes other than burning, which might include composting, mulching, or other agricultural uses.

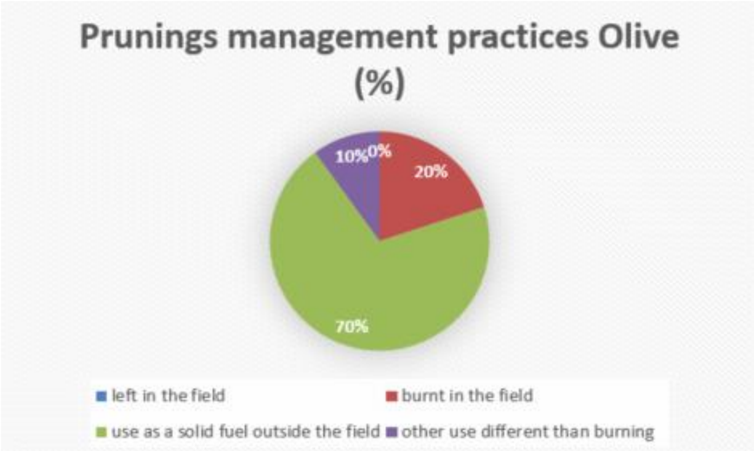

Figure 2: Practices for olive pruning management in Greece (data from questionnaires).

The above statistics indicate a trend in utilizing the pruning biomass for energy (70%), which constitutes a practice that reduces waste and contributes to renewable energy sources. However, burning in the field is a practice that should be eliminated and replaced by more sustainable practices for further minimizing of carbon emissions.

Leaves Biomass:: The fallen leaves contribute to the annual biomass, with each tree shedding an average of 6.21 kg of dry matter per year (Annual biomass (dry matter) of fallen leaves (Olive)). This biomass can be managed similarly to prunings, either left in the field to decompose and enrich the soil, collected for composting, or used as mulch. The fallen leaves represent an additional source of organic material that can be used to improve soil fertility if managed appropriately. Given that evergreen trees like olives renew their leaves roughly every three years, this biomass can be a consistent source of organic material.

The findings of a LIFE CLIMATREE project (CO2RCCT was developed within Action C.4 of the LIFE CLIMATREE project (LIFE14 CCM/GR/000635) suggest the following:

Carbon Content of Fresh Fruits Biomass: The carbon content of the fresh fruit biomass is significant, with approximately 150.9 g of carbon per kg of fresh fruit. This metric is important for understanding the carbon footprint of olive production and can be used in broader analyses of the environmental impact of olive farming. Knowing the carbon content of the fresh fruits helps in calculating the total carbon storage or emissions associated with olive production. It can be a critical factor in assessing the sustainability and environmental impact of the olive oil industry.

Total Biomass Management: The overall biomass management strategy appears to focus heavily on the reuse of organic material (prunings and leaves) either as fuel or for other agricultural purposes. This practice is beneficial for maintaining soil health and providing alternative energy sources.

Carbon Emissions and Sequestration: The carbon content data provides insight into the potential for carbon sequestration in olive orchards. Proper management of pruning and leaves can help sequester carbon in the soil, while minimizing burning can reduce carbon emissions.

6.2. Olive Pits

Olive pits that are usually removed during olive processing, constitute the main solid by-product of the olive industry, as table olives are mainly consumed as pitted products.The woody part of olive pits (a by-product from pomace factories) is a solid and sustainable biomass fuel, and therefore a renewable energy source derived from the process of producing olive oil. They are 100% natural products, free from chemicals and have a high heating power of 5,153 kcal/kg.

According to our field research results the most common practice in Greece in nowdays is the usage of olive pits as an energy source in its original form. Thus, it is generally believed that the amount of olive processing waste can be significantly reduced and a natural, renewable energy source can be obtained. However, the majority of the respondents believe that olive pits have a lower energy value compared to wood. It is also unclear to many of them whether high investments are required for the processing of pits.

6.3. Olive Pomace (2-phases and 3-phases)

Olive pomace, derived as a by-product of olive oil production, constitutes a raw material for olive–pomace oil production. It is a moderately acidic, semi-solid material. It generally consists of 50–70% water, 2.5–3% residual oil retained in the pulp, significant amounts of cellulose, hemicellulose and lignin, inorganic compounds, and organic matter, including proteins, polyphenols, polyalcohols, pigments, sugars, and fats (Tsantila et al. 2007; Lopez Pineiro et al. 2008). Due to its organic charge it presents phytotoxic properties and thus, it requires special techniques for its treatment (Nunes et al. 2020). Pomace produced from two-phase systems is characterized by higher humidity (up to 62 %) compared to that from 3-phase systems. Regarding pomace handling, it is thoroughly exploited in Greece, since it is utilisedfor the production of olive–pomace oil and pomace wood (Valta et al. 2015). In summary, the method includes: reception and storage of fresh pomace, drying of pomace, extraction of dry pomace, distillation, concentration of hexane-water, separation of hexane-water and storage of olive–pomace oil. In addition to the oil produced, exhausted pomace or pomace wood (orujillo in Spanish, sansa esausta in Italian and pirinoxilo in Greek) is also produced. This is an excellent example of successful valorisation of a by-product, since a waste that is produced from one company can be the raw-material for another. Olive–pomace oil producers buy pomace from olive oil producers and thus, olive oil producers are at the same time consistent with their environmental obligations and have financial benefit at the same time. Indeed a common practice is that pomace oil producers pay olive oil producers with pomace oil or pomace wood instead of money (Valta et al. 2015).

Among the olive oil producers that answered the online questionnaires, the 60% use olive wet or dry pomace in their enterprises for the production of pomace oil and/or pomace wood. Although only the 20% of the respondents use it to produce biofuel, all of them agreed that it is a high-quality renewable energy source and its usage as biofuel is rather useful. Finally, the other 20% of the respondents answered that they dispose wet or dry pomace at a disposal site. Two of the agro-food experts/professionals that were interviewed during our field research own/work in olive waste treatment plants that mainly process pomace (wet or dry) for the production of value added products. Specifically, they collect initially the first oil produced by the mechanical treatment of the pomace (in Greek called “repasolado”) as its value in the Greek market is higher than olive pomace oil. At this stage the product is being dried in order to reduce its moisture, through the addition of dried air into the driers. Moisture is then expelled through chimneys in the form of steam. Afterwards the product is chemically processed in order to produce pomace oil, which weights the 5% of the pomace weight. This oil must be additionally refined in order to be edible. At the end of the procedure as a by-product pomace wood is also produced and can be used as fuel. Overall, from 100 kg pomace, approximately 5 kg of olive pomace oil and 50 kg of pomace wood are produced. The first oil ("repasolado") as well the olive pomace oil are sold at an indicative price of 5€/kg and 2.5-3€/kg respectively. On the contrary, pomace wood is mainly used by the enterprises themselves as a fuel for their burners and driers or is sold to neighboring industrial units or for domestic use (for heating) at the indicative price of 120-160€/tn. Nevertheless, concern was expressed about the lack of information among the consumers regarding the olive pomace oil advantages in relation to other seed oils.

Concerning the treatment of olive pomace through composting the 40% of the respondents agreed that composting is the best available way to use olive pomace, while the 60% did not give any specific answer. The compost produced through such a procedure according the 80% of the respondents constitutes a high-value organic fertilizer that can improve the structure and biological activity of the soil.
Finally, according to an agro-food expert interviewee who specializes in the valorization of by-products and residues from two phase olive oil mills, the residues after the extraction of olive pomace oil can be used for the cultivation of mushrooms and for composting with other agricultural waste for the production of an organic fertilizer.

6.4. Waste Water

The average ratio of the generated wastewater (kg) per olives processed (kg) is greater for three-phase systems (up to 1.23) than that for two-phase systems (up to 0.22) (Valta et al 2015). Waste water from olive oil mills is considered to be one of the the most polluting and least biodegradable industrial effluents with COD up to 220 g/l (Khdair et al. 2019). Its chemical composition depends on the fruit maturity, the cultivar variety (Justino et al. 2010), the climatic conditions, and the method of extraction of olive oil (Khdair and Abu-Rumman 2017). Its disposal and treatment constitutes one of the the most important environmental issues in the industry due to its content of phytotoxic and antibacterial phenolic substances, that shows resistance to biological degradation, and its high organic load (Kounani et al. 2023).

The majority of olive oil mills in Greece face great challenges in affording the cost of wastewater treatment and the implementation of costly waste management methods. From the desk research conducted it emerged that the prevailing waste treatment method that is mostly applied in Greece includes oil collection, neutralisation of acidity, sedimentation and disposal to open evaporation ponds (lagoons). These ponds are widelly used despite the fact that in many cases only the waste volume is reduced by this method, while serious environmental problems occur. They are rarely in the appropriate size and usually have a permeable base, leading to frequent overflow of sewage or their infiltration into the soil, thus affecting the neighboring natural ecosystems (surface and ground water, soil, etc.) (Papadopoulos et al. 2014), as well as the other economically activities of the area, like livestock farming, tourism, and agriculture. It can be thereby claimed that by uncontrollable disposal of wastewater for a long time and lack of the appropriate preservation standards and monitoring, the physicochemical parameters of the nearby ecosystems, maybe altered causing permanent degradation and threatening the environmental sustainability of the region (Kounani et al. 2023). Despite that, the specific treatment method is a low cost method and thus widely applied.

Furthermore, very often untreated wastewater is disposed on the soil and in water recipients uncontrollably (Foteinopoulos and Darakas 2018). This disposal has environmental effects, among which are the reduction or depletion of dissolved oxygen in the water, eutrophication, toxic effects to aquatic species and alterations in the natural soil environment (Danellakis et al. 2011).

According to recent data of the Ministry Environment and Energy (https://wfdver.ypeka.gr/el/consultation-gr/2revision-consultation-gr/) wastes derived from the oil production process in Peloponnese exhibit BOD_5 of 2,200 kg/m^3, total suspended solids up to 0,800 kg/m^3, total nitrogen up to 0,040 kg/m^{3}and total phosphorus up to 0,020 kg/m^3. Moreover phenols up to 580 mg/m^3 are detected, as well as Cu, Zn and Cl_2 at concentrations of 297, 76 and 40 mg/m^3, respectively. These estimations are based on Hellenic Statistic Authority data (ELSTAT, 2019) and on the following assumptions as well:

- 1000 kg of olive fruits lead to the production of 200kg of olive oil.
- At a three-phase oil production system 960 l of water are required per 1000 kg of olive fruits (including the water used for the rinsing of the fruits and the centrifugation process).
- Two-phase centrifugation systems require 110 l of water/1000 kg olives (mainly for the fruits' rinsing).

From the treated industrial wastes that end up to the main rivers drainage basins of the area, a percentage of 50-73 % in Southern and Western, of 18-32 % in Northern and of 6-42% in Eastern Peloponnese come from olive oil mills. According to respective data for Crete the function of 382 in total olive oil mills and the production of 72,080 tons of olive oil in 2019 led to the production of wastes with BOD_5 up to 5,354 tn, polyphenols up to 71 tn, total N up to 690 tn and P up to 301 tn that year. In Thessaly, where quantities of treated industrial effluent end up in the Pagasitikos gulf, the wastewater produced from 60 olive oil production units have BOD_5 equal to 597.05 tn/year and total suspended solids, total N and P up to 5095.57, 48.60 and 2.16 tn/year, respectively. In Epirus, where olive oil mills constitute the 50% of the total industrial units of the area, effluents from the oil production process exhibit BOD_5 and total suspended solid values up to 1302 and 6411 tn/year, respectively. Treated industrial wastes in Western Central Greece mainly end up to Acheloos andcome from olive oil mills at a percentage of 40% with BOD_5 up to 1192 and total suspended solids up to 5716 tn/year. In the Aegean islands 126 olive oil mills have been recorded, 96 of which in the northern Aegean. Among them 40 are functioning with two phase systems and therefore are not related to wastes ending up into rivers or the sea. Out of the total three phase olive oil mills of the area, the 33 have licence according to Condition E3-1 for pretreatment and disposal to evaporation ponds, which means that their wastes do not end up into rivers or seas either, except in the case of leakage or accident.

Acccording to our field research results all of the respondents olive oil producers firstly pretreat through appropriate processes the olive oil mill wastewater and then they use it through different ways, i.e. the 44% use it for irrigation, the 28% recycles it by reusing it in the olive oil processing, while another 28% release it into the environment (Figure 3). Concerning its reusage through the olive oil production procedure most of the respondents agreed that it contributes to the reduction of fresh water consumption, leading thus to decreace of the total olive processing costs and the negative impact of olive processing on the environment. However, there exists a rather confusing situation among the olive oil producers that participated, regarding the costs, the profits and the legal requirements of the specific procedure.

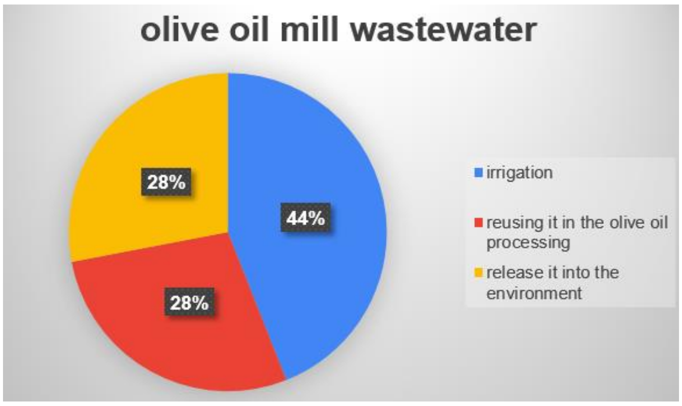

Figure 3: Treatment of olive oil mill wastewater in Greece (data derived from questionnaires).

Among agro-food experts interviewees there was an olive producer and owner of a modern olive oil mill in Zante that produces biological oil through traditional pressing. In his mill the wastewater produced (up to 5 tn at a moderately productive year) is treated with nitrogen fixing bacteria (*Azotobacter vinelandii*) in special tanks. These bacteria possess the enzymatic system (laccases) for the degradation of the phenolic compounds of the wastewater, so as to become appropriate as fertilizer through irrigation.

6.5. Other residues (table olives residues, lampante olive oil, etc.)

Among the solid wastes originating from the olive sector also are: the inappropriate (damaged) olives, the ash from the operation of burners, the dust due to burners operation or due to drying of pomace and the sludge derived from the evaporation, the precipitation and / or septic tanks. Most Greek units use the inappropriate olives for animal feed, or as a soil improver or for the production of biogas, whereas the ash from pomace wood burners is disposed with municipal waste or used as fertilizer (Valta et al. 2014). Sediment material from oil storage tanks (in Greek: mourga) is being sold for further exploitation to soap manufacturing industries. Similarly, the sludge resulting from the treatment of wastewater is collected, dehydrated and used most of the times (83 %) as a soil improver. In olive pomace oil industries dust is usually collected in cyclones and comes from the dryers of omace and from steam boilers. Dust originated from dryers is being initially extracted and then is burned along with pomace wood in dryer burners or steam boilers, while dust from steam boilers is burned with pomace wood.

Since olive fruits can not be consumed directly once collected due to their bitter taste, table olive industry generates significant amounts of wastewater annually derived through the alkaline treatment, fermentation, and washing steps of the olives. These wastewater are characterised by high conductivity and salt content, as well as high organic and biophenol content and due to their composition they can pose worldwide a threat to the environment (Huertas-Alonso et al. 2022). In Greece, olives are usually treated by the „Greek style" and thus, after being collected, are placed directly in brine and left there for months in order their bitterness to be completely removed. By this treatment the level of pollution caused is less and the final products are in full agreement with the trend of consuming as more natural and least treated as possible.

Among the respondents of the field research only the 20% sell by-products and/or the waste obtained by the processes in thein enterprises to customers that are not strictly in the near areas.

7. Sustainability and Environmental Impact

7.1. Sustainable Practices in Olive Farming and Olive Oil Producing

Three final products that could be produced through sustainable practices in Greece from olive tree pruning are: a) separate olive leaves for disposal to pharmaceutical or cosmetics industry, b) compost for agriculture and soil enhancement and c) pellets for energy applications (Charisiou et al. 2014; 2016). Also, the implementation of sustainable farming methods, such as crop rotation, intercropping and organic farming may restrict the use of chemical fertilizers and pesticides, improving thus, the soil health which is important for the olive trees. By installing drip irrigation systems or by using advanced technologies like soil moisture sensors, water management which is vital for an olive groove can be achieved.

The survey indicates a split in the adoption of sustainable practices, with 47% of producers using certified organic farming methods, while 53% continue to rely on conventional technologies. On the other hand, as far as individual practices are concerned, the practice most used is mechanical weeding and mulching since 12 out of 17 producers implement it, while regular use of Organic Fertilizers is adopted by 10 producers (Figure 4). Another, less frequent, sustainable farming practice adopted is incorporation of Pruning Residues into Soil which is practiced by 7 out of 17 producers. Less common practices include pellet production and firewood generation, while most producers do not engage in niche uses like utilizing pruning residues in the pharmaceutical or decorative industries.

Concerning olive pits, they were considered for years to be waste material. However, olive pits have been found to have an energy rating of 8,800 Btu per pound, a value that is higher than that of hard wood, which means that olive pits don't just burn; they burn well. Accordingly, olive pits could be used in combustion, in the same way as any other type of biomass. Moreover, they have also been found to have greater heating capacity than diesel fuel. As specified by the results of our field research many of enterprises involved in the olive sector in Greece use olive pits as a fuel in their original form.

As it has already been mentioned in the above sections of the present report sustainable practices in Greece concerning the use of olive pomace mainly include their further process through chemical treatment for the production of pomace wood and olive pomace oil. Specifically, pomace wood is used by the enterprises themselves as fuel for their own needs.

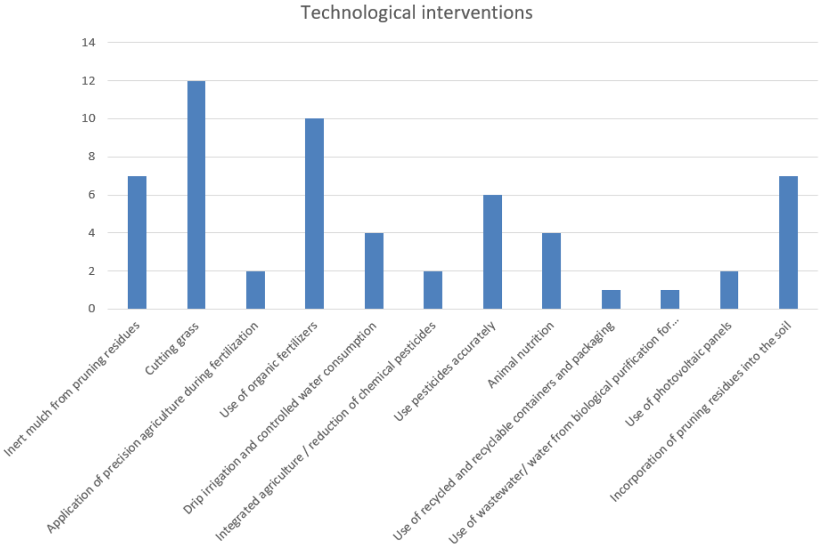

Figure 4: Circular practices applied in the olive sector in Greece (data from questionnaires).

From the evaluation of the data derived from both desk research and field research (questionnaires and interviews) it was obvious that the prevailing waste treatment method of oil mill wastewater that is currently applied in Greece includes oil collection, neutralization of acidity, sedimentation and disposal to open evaporation ponds (lagoons). In many of the enterprisesparticipant in the field research the evaporation ponds constitute the final treatment/disposal step. In general, the evaporation ponds are widely used worldwide although in some cases only waste volume is reduced and serious problems might occur due to leakage of wastewater to soil and/or groundwater.

Due to the environmental effects induced by its disposal olive mill wastewater has been considered as a mater of treatment aiming at the destruction of organic matter and phenolic compounds and hence, the reduction of their chemical oxygen demand and phytotoxicity. The difficulties towards this direction are its high organic loading, the mills seasonal operation, their high territorial scattering and the presence in these wastes of nonbiodegradable organic compounds such as long-chain fatty acids and phenols. Among the various different treatment processes for wastewater except of lagooning or direct watering on fields are cocomposting, physicochemical methods (flotation and settling, coangulation, oxidation by O, and Fenton reagent, flocculation, filtration, sedimentation, dilution open evaporating ponds and incineration), ultrafiltration/teverse osmosis, chemical and electrochemical treatments and manifacture into animal foods Rahmanian et al. 2014).

By categorizing the proposed techniques three categories are denoted:

1. Reduction of the wastes by converting oil production systems from three phase to two phase continuous systems
2. Reduced impact of the polluting load to the recipient via detoxification methodologies.
3. Recovery or recycling of components from olive mill wastes.

The conversion of olive oil production systems would save both energy and water and lead to the production of higher quality olive oil due to its better oxidative stability. However, high investment costs are required (Rocha et al., 2022), especially since olive mills in Greece are mainly small to medium enterprises. Moreover, water consumption needs to be carefully controlled even in the case of two-phase systems, during the washing of the olives. A closed cleaning system which recycles the used water could be the solution, which will also serve in energy savings. For controlling the energy consumption, a number of alternative improvements could significantly reduce the requirements in energy, as well as the corresponding air emissions. Specifically, such interventions could be better insulation, improvements in combustion, use of automations, exploitation of thermal content of exhaust gases and usage of energy saving equipment. Regarding the air emissions, operating conditions of the equipment should be carefully set and maintained regularly, while, the penetration of eco-friendly fuels (e.g. natural gas) in order to minimize the wide use of diesel engines could help for the air emmissions elimination.

Concerning the detoxification methodologies: (a) Physical methods are typically used for the pretreatment of the wastes and the removal of the contained solids, (b) Thermal processes lead to removal of the contained water and condensation of the waste streams, but their operational cost is high, (c) Advanced oxidation methods are effective, but also have remarkably high cost, (d) Biological processes require longer lag phases and (e) Physicochemical processes (eg neutralization, precipitation) do not lead to complete elimination of the polluting load, although they are cheaper methods. Therefore, a combination of these treatments could probably constitute the best solution. A sustainability and benchmarking study of olive mill waste water treatment methods, claimed that the most effective processes in terms of organics reduction are membrane filtration, electrolysis, supercritical water oxidation, and photo-Fenton. Anaerobic digestion, coagulation, and lime processes had the lowest environmental impact, while composting and membrane filtration were the lowest-cost methods, owing to the added-value of composts and phenolic compounds, respectively (Zagklis et al., 2013). Using composts as soil improvers in many crops lead to enhanced yields. From the aspect of wastes' valorization olive mill wastewater could be utilized either as a substrate for the growth of microorganisms (e.g. oleaginous yasts, edible fungi) that will lead to the production of fertilizers, bioproducts and/or animal feed, or as a cheap source for the recovery of compounds like phenols (e.g., hydroxytyrosol, oleuropein, phenolic acids, tannins, flavonols, anthocyanins, etc.) and dietary fiber (e.g., pectin). Phenols have been reported to presend several biological activities such as antioxidant, free radical scavenging, antiinflammatory, anticarcinogenic, and antimicrobial activities, while dietary fiber are currently used as additives in food stuff due to their ability to provide advanced technological properties and health claims to the final product (Souilem et al. 2017). The valorisation of olive mill wastewater for dyeing textile materials, such as wool and acrylic fibers, has also been proposed as they constitute an abundant source of natural dyeing substances. Furthermore, olive mill wastewater due to its substantial sugar, volatile acid, polyalcohol and fat content may be utilized as a substrate for biohydrogen, biomethane and bioethanol production (Valta et al. 2015). Among the rest olive oil by-products, leaves and flowers posess antibacterial activities, while leaves, stems, and fruit pulp have been reported to have collagen-production-promoting activities, giving them thus, the potential to be further developed and used in the skin care industry.

In Greece, according to the results of our field research and in agreement with all that have been already recorded in above sections, the most common sustainable practice for olive oil mill wastewater is its appropriate pretreatment and its thereafter use either for the groves' irrigation, or for co-composting with other agricultural wastes aiming at the production of organic fertilizers, or its utilization as a substrate for edible mushrooms cultivation or at last for its reusage in the olive oil mill instead of fresh water.

Based on the questionnaire results, there are significant barriers to adopting sustainable practices for pruning and farming residue management. The main challenges identified include: a. Technological Gaps: A lack of technology and knowledge prevents many producers from effectively implementing sustainable practices like composting and controlled burning. b. High Costs: The high initial investment and operational costs associated with these practices are a significant deterrent, making it difficult for producers to adopt these methods. Finally another type of barriers is (c) Regulatory Challenges: Legal restrictions and insufficient support further complicate the adoption of sustainable practices in residue management.

The use of pruning residues faces several key challenges such as (a) lack of Technology and Knowledge: Cited by 12 out of 17 producers, this is a major barrier to adopting practices like soil cover, composting, and pellet production. (b) High Initial Investment and Costs: Financial barriers prevent the widespread adoption of practices such as pellet production and composting, noted by 10 producers. (c) Legal Restrictions and Support: Regulatory barriers are mentioned by 5 producers, especially regarding controlled burning and pellet production.Finally (d) 7 producers do not consider the use of pruning residues crucial for environmental protection, indicating a need for greater awareness

Despite these challenges, some producers are actively participating in initiatives like the "LIFE OLIVE" program, which repurposes pruning residues into compost for olive groves. However, the high costs of transportation and processing limit wider adoption of these practices.

8. State of Circular Business Practices in the Olive Sector

8.1. Trends and Preferences

Recent research have revealed opportunities to recover valuable compounds, such as specific polyphenols, phenols, proteins, fats, cellulose and lignin, from olive sector's waste (Madureira et al. 2022; Carmona et al. 2023). By ways based on circular economy and its principles olive waste can be converted into new and higher value-added products,such as biofertilizers, bioenergy, purified water, biobased materials, food and feed additives (Kounani et al. 2023). Following the example of biogas production from livestock waste, anaerobic digestion technology is now emerging as a solution for managing the olive mill wastewater in Greece. In northern Greece for example, a group of olive oil producers (Kyklopas SA in Evros is one of them) are disposing of the toxic material while contributing to the production of green energy via the first biogas plants that process liquid waste produced through olive oil extraction. Biogas plants are being built all over Greece, spreading thus the word and promoting the model of circular economy. However, there are still some challenges involving the low quantities of olive mill wastewater currently feeding the biogas plants in relation to the total amount produced across the country and the seasonal flow of raw material as well. The latest problem could be solved by potentially storing the waste in the premises of the biogas unit to feed supply through the year, but this means that appropriate storage should have been planned during the design of the biogas plant facilities.

The results of the field research conducted suggest that there are mainly social motives in the majority of the people involved in the olive sector in Greece for treating wastes and by-products aiming at the protection of the environment. However, there is a general belief that there should be financial support from the government towards this direction, improvement of the legal framework and greater awareness of all those who are involved about new circular practices. A significant problem that has to be solved is mill owners' frequent resistance to change, maintaining the understandable rationale they have been using for hundreds of years, highlighting thus, some difficulties to adopting new technologies.

8.2. Technological Gaps in the Implementation of Circular Practices in the Olive Oil Sector

To date, sustainable management of olive oil waste is not systematically and effectively monitored, due to many factors, such as the large volume of the waste, the seasonality in its production, and the complexity of the waste composition. Moreover, limited research on the current level of implementation of circular economy in oil industry in Greece has been conducted. Nevertheless, there is an ever increasing interest in finding practices for the immediate integration of the circular economy into the industry.

According to our field research, there is a general belief that there should be financial support from the government towards the direction of the implementation of circular practices, as the cost for such practices is sometimes high, improvement of the legal framework and greater and continuous awareness of all those who are involved about new circular practices. Another one significant problem that has to be solved is mill owners' frequent resistance to change, maintaining the understandable rationale they have been using for hundreds of years, erasing thus, some difficulties to adopting new technologies.

The availability of technology, knowledge, and expertise is crucial for the adoption of more advanced residue treatment methods such as composting and pellet production. Producers who have access to these resources are more likely to become engaged in these practices.

A significant barrier is the lack of technology and knowledge needed to implement advanced practices such as composting and controlled burning. This gap prevents many producers from adopting these methods, which could otherwise contribute to more sustainable farming practices. There is a notable perception among some respondents that the environmental benefits of these practices are not significant enough to justify the costs and efforts. This perception could further hinder the widespread adoption of circular practices in residue management.

8.3. Best Practices of the Implementation of Circular Practices in the Olive Oil Sector

Concerning the olive farmers, including recirculation of waste and by-products strategies, such as valorizing olive tree pruning biomass directly in the olive plantation for compost or (in moderation) as animal feed, would be a very good practice in terms of circular economy. Furthermore, farmers could also collect leaves and dry them for herbal infusions (highly appreciated as antioxidants) as an upcycling opportunity. Olive oil millers in turn should seriously consider a change for more advanced technological solutions concerning their mills (two-phase systems) that will lead to fewer wastewater or olive cake amounts. Olive pomace should continue to be used for the extraction of olive pomace oil, which can be offered to food industry customers or for the production of traditional soaps and pomace wood as well. Also, enterprises that specialize in olive oil waste valorization should be mainly recommended to develop partnerships with research institutes in order to make applicable their innovative ideas or upscale their technological solutions. It is also crucial to raise both producers and consumers awareness by notifying and underlying the importance of circular economy principles, leading their behaviors on more sustainable paths.

9. Technological Advancements

9.1. Innovations in Production and Processing

Greece is at the lower positions in terms of implementation of the circular economy's principles. Concerning the usage of agricultural wastes in the production of biogas in the end of 2015, 83 licenses were issued for biogas plants with a total capacity of 441.4 MW (Kounani et al. 2023). However, among the operating biogas plants three are in landfills, four use agricultural waste for biogas and two generate heat in the food industry (ABI 2018).

The agri-food sector in Greece is characterized by a high potential for implementation of circular economy. Nevertheless, legislative and other interventions, as well as structural changes and resetting of the value chains, are required. Such changes are alterations in the production procedures (extraction of raw materials, design of products and materials), handling and consumption of generated waste and their possible reutilization (as secondary raw materials) in a collaborative approach across the value chain, since circular economy relies solely on the interconnection of processes and networking between the actors and businesses involved.

9.2. Future Technological Trends in the Sector

Future technological trends could derive from recent scientific research on the improvement of treatment methods that are already applied:

●A case study of a gasification unit in the regional unit of Messenia has been reported by Alatzas et al. (2019), highlighting the interesting potential for investment in gasification technologies in Greece. In Messenia the annual olive oil production exceeds 50,000 tonnes and the vast amount of olives trees in the area leads in a biomass energy potential, from tree plantations, up to 3,800,000 GJ. The specific gasification technology can utilize up to 7956 tonnes of biomass per year and produce 6630 MWh of electricity and 8580 MWh of thermal energy. Moreover, such a unit promices to raise the agricultural income, create new jobs, and increase the green footprint at local level.

●Muktadirul Bari Chowdhury et al. (2014) composted rice husk combined with olive pomace and leaves in comparative pilot experiments at a three-phase olive mill in Amfilochia (Western

Greece). Taking account of the experiments results they designed a complete composting plant for an average Greek olive mill that receives 30 m^3 of olives/day (representative volume of small mills in Greece) for a 90 days operation period (from October to the end of December). During the composting process several physicochemical parameters (such as organic matter, temperature, electrical conductivity, moisture content, pH, total C, N, P, K, Na, and water-soluble phenols) were recorded during various phases of the experiment and the compost producted was tested for phytotoxicity using L. sativum seeds. Accorging the results of the experiments the compost that was produced was of high quality, whereas the time of composting was reduced. The required qrea for the composting of the generated waste in a typical Greek olive mill, is approximately 500 m^2. Hence, composting their wastes is aaustainable manner for the Greek olive oil owners to valorize their waste couraging CE, but also to gain financial benefits (Muktadirul Bari Chowdhury et al. 2014).

●Another comparative study conducted by Galliou et al. (2018) in a three-phase olive mill in Crete, reported a new approach to wastewater treatment for organic fertilizer production via two simple processes, that of composting and that of solar drying in a greenhouse. According to their findings the solar drying process produces a product rich in organic matter and nutrients such as K but also with high concentrations of phytotoxic compounds (phenols). However, after the composting the final product was an organic fertilizer rich in nutrients with low phenol content, as they were significantly removed during the composting process. They also claimed that by the addition of grape marc, in a volume ratio of 1:1, as a swelling agenta more efficient composting was achieved (Galliou et al. 2018). By the use of this process, rational management of olive mill waste is achieved, while marc and manure, two wastes that cause significant degradation of the Greek areas that host these activities, are treated in a sustainable way.

●Finally, Koutrotsios et al. in 2021 examined the suitability for the cultivation of the edible mushroom *Pleurotuscitrinopileatus* of two-phase mill wastes in combination with wheat straw and olive leaves. They concluded that the by-products of the mill are suitable for growing *P. citrinopileatus* mushrooms, as an alternative solution in valorization of olive oil mill waste.

10. Market Analysis

10.1. Market Forces

●Market Dynamics and Waste Product Utilization: In the olive industry, many producers are increasingly repurposing waste materials like pruning residues and olive sludge into compost, which is often used to enhance soil fertility on-site rather than being sold. This practice supports sustainability by recycling waste back into the olive groves. However, the costs associated with processing and transporting these materials remain high, limiting broader market adoption.

●Product Sales and Utilization: By-products such as pomace oil and olive pits are commonly sold in bulk to refineries and used as fuel in industrial and household settings. The rising demand for these by-products has led to significant price increases, particularly for olive pits, which is valued as an economical fuel alternative. In contrast, liquid waste from olive processing is often converted into fertilizer for local use but struggles to fully meet the needs of larger groves.

●Market Evolution and Challenges: The olive industry anticipates legislative changes that may require more extensive recycling of olive waste, encouraging sustainable practices and reducing dependence on commercial fertilizers as their prices rise. Weather conditions present a key risk to raw material availability, while competition from alternative oils and low consumer awareness of products like pomace oil remain challenges. Nevertheless, there is potential for growth in extracting valuable components from olive by-products, despite high associated costs.

●Drivers and Barriers in Pruning Residue Utilization: Interview responses suggest that the main driver for farmers' decision to adopt sustainable farming practices are (a) Sustainability and Environmental Awareness since 8 out of 17 producers cite perceived environmental benefits as the main reason for adoption. The reduction of costs and expected higher income was the second, in order, reason stated by 7 farmers, while availability of technology and access to knowledge was mentioned by 6 producers.

The market dynamics of the olive industry reflect a growing focus on sustainability, driven by the utilization of by-products like pomace oil and pyrene wood. However, technological gaps, high costs, and regulatory challenges hinder broader adoption of circular practices. Legislative changes and increased awareness may drive further advancements, with market forces shaping the industry's approach to sustainable waste management and production practices.

10.2. SWOT Analysis

SWOT Analysis for Olive By-Products and Waste Management Sector was conducted (Table 2). Specifically:

<u>Strengths</u>

Sustainability and Cost Efficiency: A significant strength within the sector is the widespread adoption of composting, which reduces reliance on commercial fertilizers. This not only lowers annual operational costs but also enhances the sustainability of olive farming practices. Companies that engage in composting and other waste repurposing methods are able to position themselves as environmentally friendly, a feature increasingly valued in the market. This sustainability focus serves as a powerful marketing tool, differentiating these businesses in a competitive industry.

Local Relationships and Industry Experience: Many businesses benefit from established local relationships with clients and suppliers, built on years of experience and a strong reputation within the industry. These relationships provide stability and a competitive edge. Additionally, smaller facilities have the advantage of being more flexible and capable of implementing targeted modernization efforts, such as improving energy efficiency, which larger operations may find more challenging.

Zero-Waste Operations: Operating as a zero-waste facility is a major strength, particularly in today's market, where consumers and business partners increasingly prioritize environmental responsibility. Businesses that can minimize waste and turn by-products into valuable resources are well-positioned to capitalize on this growing trend.

Favorable Geographical Locations: Some companies operate in regions with minimal competition, providing a stable environment for business growth. This geographical advantage allows them to expand their market share and solidify their presence in the industry without the pressure of intense local competition.

Weaknesses

Lack of Support for Circular Economy Practices: One of the most significant weaknesses identified is the lack of institutional and financial support for circular economy initiatives. Without adequate funding and a supportive policy framework, many companies struggle to invest in necessary technologies and infrastructure to adopt more sustainable practices. This limits their ability to innovate and fully embrace circular economy principles.

Geographic and Regulatory Challenges: Companies located near protected areas, such as Natura zones, often face strict regulations that limit their ability to expand or modify their operations. This can stifle growth and restrict innovation. Additionally, traditional olive mills, especially smaller ones, may experience fluctuations in production efficiency due to inconsistent waste availability, leading to underutilized processing units during certain times of the year.

High Initial Costs and Technology Gaps: Financial barriers are another critical weakness. High initial investment costs deter many producers from adopting sustainable practices like soil cover, pellet production, and composting. Furthermore, a significant technology gap exists, with many producers lacking access to the necessary technology and knowledge to implement these practices effectively.

Opportunities

Support for Circular Economy Initiatives: There is substantial potential for growth if external programs, subsidies, or incentives were introduced to support circular economy practices within the olive sector. An indication of the importance is the implementation of a successful subsidy scheme introduced under the “ecoscheme” intervention of the Greek Common Agricultural Policy Strategic Plan 2023-2027. This scheme provided for aid to permanent crop farmers to collect the pruning residues and either produce their own compost and apply it to their fields or give them to companies and receive compost ready for application. It has been quite successful since 55,217 farmers with permanent crops (including olive farmers) covering 113,920.71 ha of tree orchards have implemented this scheme. Such initiatives could make businesses more competitive by lowering costs and improving sustainability.

Technological Innovation for Energy Efficiency: Opportunities exist for businesses to innovate through the use of existing resources, such as utilizing steam boilers to generate electricity, which could transform seasonal operations into year-round activities. Additionally, installing photovoltaic panels and collaborating with farmers to enhance efficiency could further reduce operational costs and environmental impact.

Expanding Waste Management Services: The sector could diversify its revenue streams by processing liquid waste from other olive mills and converting it into valuable products like liquid fertilizer. This would not only enhance sustainability but also create new business opportunities in waste management and recycling.

Growth in Low-Competition Areas: Companies operating in regions with little or no competition have a unique opportunity to grow their market share. This stable operating environment allows them to focus on expansion and innovation without the pressure of competing against numerous local businesses.

Threats

High Operational Costs and Intense Competition: The sector faces significant threats from the high costs associated with traditional cultivation methods and the intense competition from more intensive farming operations. Additionally, the aging workforce within the industry may find it challenging to adapt to new technologies and practices, further complicating efforts to modernize and innovate.

Regulatory and Social Challenges: Changes in environmental regulations and the potential for increased social opposition to processing emissions pose significant risks. Complaints from local communities about odors and other nuisances could lead to stricter regulations, increasing operational costs or even resulting in operational restrictions. The current regulatory environment is often seen as unsupportive, which further hinders the sector's ability to adopt sustainable practices.

Environmental Risks from Mismanaged Waste

There is a significant threat posed by the potential environmental impact of mismanaged by-products and waste. If these materials are not processed according to circular economy principles, they could cause considerable environmental harm. This underscores the need for proper waste management practices and the adoption of circular economy strategies to mitigate these risks.

Market and Economic Uncertainties

The broader economic environment, unpredictable weather conditions, and fluctuations in annual production pose additional threats to the sector. These factors can affect raw material availability, operational costs, and overall market stability, making it difficult for businesses to plan and sustain long-term operations.

Table 1: SWOT Analysis for Olive By-Products and Waste Management Sector

SWOT Analysis	
Strengths	**Weaknesses**
- Sustainability and cost efficiency through composting, reducing reliance on commercial fertilizers. - Strong local relationships and industry experience provide stability and a competitive edge. - Zero-waste operations are highly valued in the market, promoting environmental responsibility. - Favorable geographical locations with minimal competition, allowing for business growth.	- Lack of support for circular economy practices, both financial and institutional. - Geographic and regulatory challenges limit expansion in protected areas. - High initial investment costs and technology gaps prevent broader adoption of sustainable practices.
Opportunities	**Threats**
- External support and subsidies for circular economy initiatives could drive growth. - Technological innovations for energy efficiency (e.g., photovoltaic panels, steam boilers for electricity generation) can reduce operational costs. - Waste management services, such as liquid fertilizer production, offer opportunities for diversification. - Growth potential in regions with little competition.	- High operational costs and intense competition from more intensive farming operations. - Regulatory and social challenges, such as stricter environmental regulations and community complaints about processing emissions. - Environmental risks from mismanaged waste, if not handled according to circular economy principles. - Economic uncertainties, unpredictable weather, and annual production fluctuations.

10.3. Regulatory Challenges and Barriers

The olive by-products and waste management sector is a critical part of sustainable agriculture, yet it faces numerous regulatory and legislative challenges that hinder its development. Insights gathered from industry questionnaires highlight significant obstacles that affect the ability of producers to implement circular economy practices effectively.

Regulatory Challenges

One of the most pressing issues is the restrictive legal framework governing the processing of olive by-products, such as olive pomace. Current regulations often prevent producers from processing their own by-products, complicating efforts to close the loop in the production process and fully embrace circular economy principles. This is particularly challenging in areas where local legislation does not support smaller or region-specific operations.

Additionally, there is a notable lack of organized systems and infrastructure to support sustainable practices like composting and pellet production. For instance, many producers reported that their regions do not have established composting systems, making it difficult to implement these environmentally beneficial practices. The absence of regulatory support for these systems further complicates efforts to manage pruning residues and other by-products effectively.

Financial constraints are a significant barrier to adopting sustainable practices in the olive by-products sector. High initial investment costs for processing facilities and the ongoing operational expenses are major deterrents. Many producers struggle to finance these investments, especially in the absence of adequate subsidies or financial incentives. This financial burden is further exacerbated by delays in receiving government funding, often due to broader economic crises or administrative bottlenecks. These delays force producers to rely on bank loans, increasing their financial vulnerability.

A recurring theme among producers is the lack of access to necessary technology and knowledge, which is crucial for implementing circular economy practices. The high costs associated with adopting new technologies further limit the sector's ability to innovate and improve efficiency. Many producers express frustration over the insufficient dissemination of information regarding innovative practices and technologies, highlighting a need for better support and education within the industry.

Social resistance, often stemming from a lack of environmental awareness, also poses significant challenges. Local communities frequently express concerns about issues like odors from processing facilities, particularly during peak production periods. This resistance can lead to fines and increased operational costs, further complicating the business environment for producers. Additionally, there is a need to shift long-standing cultural attitudes towards waste management and environmental responsibility, which remains a significant barrier to the broader adoption of sustainable practices.

The olive by-products and waste management sector is faced with a complex array of challenges that impede its growth and innovation. Regulatory restrictions, high costs, technological gaps, and social resistance are significant barriers that need to be addressed to enable the sector to fully realize its potential in implementing sustainable practices.

11. Vocational Training (VET)

11.1. Existing VET on Circular Business Practices in the Olive Sector

In general, the field of circular practices and entrepreneurship is not sufficiently developed throughout the Greek educational system.

According to the results of the research during the present study, there are not undergraduate courses in the Agricultural University of Athens that focus entirely on circular practices in the olive sector, but there are several post-graduate courses on this field by the School of Applied Economics and Social Sciences. During several under graduate courses though, such as “Olive Cultivation“, there are often two-hours lasting lectures devoted to circular economy practices, while during the “Environmental Microbiology” course methods for the valorization of agro-food wastes (including olive wastes), such as composting, treatment as substrates for the cultivation of edible mushrooms or plant growth promoting microorganisms etc., are analyzed.

As it was mentioned during the VET interviews, in the Hellenic Mediterranean University in Crete courses concerning Agroecology are taught and practices that include agro-food wastes treatment through pyrolysis for the production of biochars (with organic fertilizers as end-products) are applied.

The non-profit organization “New Agriculture - New Generation”, in collaboration with the Region of Western Macedonia, have offered a free training and counseling program for agrocircularity and its applications on farming. The program consisted of four distinct training modules, one of which was on fruit-tree and olive farming. Moreover, “New Agriculture – New Generation” in collaboration with the Municipality of Northern Kynouria and the Chamber of Arcadia (NUTS3), conducted during the summer of 2024, the “Open Olive Academy” training program. The objective of this program was to strengthen the olive cultivation sector in the wider area of Northern Kynouria by transferring knowledge on the olive and olive oil sector. This series of short courses will cover the entire value chain, i.e. cultivation, production, and marketing and will also include experiential education. By attending the short course cycle, participants will gain basic knowledge in areas, such as preparation - establishment of an olive grove, olive physiology, cultivation practices, plant protection & climate change, quality, processing and marketing.

The ”Institute of Agricultural Sciences – IGE” that is supervised by the Ministry of Rural Development and Food has organized several seminars addressed to olive producers or pensioners who want to return to their birthplace and be engaged to olive production.

“ELGO-DIMITRA”, an organisation supervised by the Ministry of Rural Development & Food (a legal entity under Private Law), operates 6 Schools of higher agricultural training and 28 centers that provide training throughout the country on the modernization of the agriculture sector in Greece. Courses exclusively on circular entrepreneurship in the olive sector are not yet offered by the organization. In the context of entrepreneurship, some lectures occur during relative courses.

However, there is a special program on olive farming aiming at young farmers with duration of 150 hours. During this program, brief lectures on subjects of sustainability and circular economy are conducted, while some visits to olive groves or olive oil mills occur.
Finally, several short courses and conferences on olive farming are often organized by farmers' cooperatives and regional agricultural authorities. During these seminars lectures about sustainable practices on the treatment of olive sector's wastes are sometimes conducted.

11.2. Training Methods and Techniques, Recognition Paths/Qualification Validation Methods Used

In the Agricultural University of Athens, all the relative with this field lectures conducted include power point presentations, educational videos and experiential education.

The training program conducted by "New Agriculture - New Generation" and the Region of Western Macedonia was addressed to established farmers (between the age of 18-45), as well as to unemployed and young professionals who wish to work in the agrifood sector and other related professions. Each module of the program targeted a group of 20 people, through a training course that covered topics such as: innovative approaches to plant cultivation and protection in the context of sustainable farming, processing and standardization of agricultural products, utilization of agricultural waste, working together with end users, making use of funding tools, new policies on a European and national level, innovative business models, promotion and dissemination etc. Each module's training program covered 62 hours of training, with 31 hours being devoted to lectures and 31 hours to hands-on training on the field as well as counselling for planning and implementing business ideas.

The "Open Olive Academy" training program that is conducted by "New Agriculture – New Generation" in collaboration with the Municipality of Northern Kynouria has 52 hours duration and aims at olive growers, either professional or supplementary, who are active in the Municipality of Northern Kynouria. Additionally, professionals from the entire value chain of olive oil and olives, such as olive mill owners, processors, and traders, can participate in the seminars, with priority given to professional young producers under 45 years old, followed by professional producers of any age, after evaluating the applications. At the end of both programs a Certificate of Attendance was given to participants.

The seminars that have been offered by the "Institute of Agricultural Sciences" had six month duration and were mainly conducted by oral lectures, power point presentations, educational videos and experiential education. At the end of the seminars Certificate of Attendance was given to the participants.

11.3. Best Practices Identified Regarding the Education Programs on Circular Business Practices in the Olive Sector

Among the respondents to the online questionnaires, only the 18% has already taken a course of circular economy in the olive sector (in the form of seminar), but all of them stated that are willing to attend a training course focused on how to valorise olive by-products and waste. Regarding the way they prefer such a course to be conducted, half of them prefer an online course, 20% of them by presence, while the 30% prefer a hybrib mode that includes both methods. Findings of the VET interviews suggest that the best way for such seminars to be conducted should engage theory, practice and educational visits to olive groves and/or olive oil mills as well.

The answers during the VET interviews reveal a clear support of the idea that courses on circular entrepreunership should be incorporated into the undergraduate curriculum of Greek agronomic higher education institutes. Moreover, it is believed that the Centers of Education and Lifelong Learning of the Universities should offer relative, shot-term programs that would be not particularly specialized and thus, better understandable by participants with no studies on agriculture.

The conduction of seminars on circular entrepreneurship was also suggested to engage farmers cooperatives that could allocate some fields for experiential education, where the circular management of the by-products/wastes could be implemented. Thus, farmers might be easier convinced about the benefits of proper management and the improvement of the soil and trees' status.

Regarding the instructors that should be occupied in such seminars, it is believed that should be a synthesis of scientists with expertise on different scientific fields but also qualified with technological experience. Indicatively, short courses on farming practices and techniques or the management of the wastes of the olive sector shouldbe taught by agronomists, techniques such as pyrolysis should be conducted by engineers, circular economy practices should be taught by experts on ecology and organic agriculture, while on circular entrepreneurship seminars economists should be engaged.

As far as the required skills and background of the attendants basic knowledge in the field of agriculture should be required, while it would also be desirable the participants to be professionally occupied in the olive sector.

Short courses on circular entrepreneurship should occur in such ways that will lead to the development of skills in the field of application. Specifically, participants of such courses should gain knowledge on the technological developments in circular economy, acquire the know how to take advantage of the skills and technological knowledge offered and have skills regarding the economic analysis of such opportunities and models on circular entrepreneurship. Each participant after the end of the course should be able to focus on the method or product that fits best to his/her needs or interests and apply circular practices for the production of value added products. It was also suggested that in order to take attendance certificates that will have greater recognition, participants should be evaluated after the end of the courses.

11.4. Potential Institution that Could Offer Courses on Circular Business Practices in the Olive Sector

The Center of Education and Lifelong Learning of the Agricultural University of Athens, which offers several training programs concerning the olive sector, has not conducted any circular entrepreneurship program, so far. However, there could be such a program in the future.

Moreover, "ELGO-DIMITRA", that aims at the development and support of actions for the modernization and development of the country's agricultural sector, the improvement of production processes, the certification of the quality of agricultural products and the establishment and certification of correct agricultural practices. The organization could possibly in the future organize a program on circular entrepreneurship, as there is the required experience, the qualified personnel and the appropriate infrastructure for seminar lectures.

Furthermore, Co-operatives in collaboration either with Universities or with ELGO-DIMITRA or with other organizations could organize short courses in the field of circular entrepreneurship in the olive sector. Also waste management units or composting companies, or companies that produce organic fertilizers could also have interest in conducting such courses/conferences in circular entrepreneurship education in the olive sector.

12. Conclusion

12.1. Summary of Key Insights

Summarizing, although the olive oil industry is a highly developed sector in Greece, as evidenced by the considerable number of olive growers and olive mill owners and the amounts of waste generated, the business activities of olive mill waste and by-product valorization are minimal. On the basis of the evaluation of our data, it was obvious that mechanical weeding/mulching and direct application of pruning residues are the main sustainable farming practices while the prevailing waste treatment method currently applied in Greece includes oil collection, neutralization of acidity, sedimentation and then, disposal to open evaporation ponds. In both production stages, farming and processing, the techniques used are plain and could cause environmental problems.

Despite the fact that waste valorization technologies and the circular economy practices are constantly updated through the advances in the academic research, they are often not combined with business innovation, or they are not implemented on an industrial scale. Although by-product streams have potential economic value they are not always exploited through their utilization by sustainable ways, e.g. as fertilizers or soil improvement products after their pretreatment and composting. There are several problems or gaps according to those that are engaged professionally in the olive sector that have to be overcome towards this direction. Among these difficulties are the improvement of the legal framework and the financial support from the government that will encourage the professionals of the sector to implement circular practices.

Olive farming in Greece is primarily conducted by small-scale operations. and is highly fragmented with a large number of small farms.Thus, the high number of farms combined with the relatively small average farm size reinforces the notion that the olive sector in Greece is dominated by smallholders. This could also pose challenges in terms of scalability and modernization but also indicates a deep-rooted tradition of olive farming across many families and regions that has to be faced up.

12.2. Recommendations for the implementation of circular practices in olive sector

Alternative more advanced treatment options should be applied leading to better environmental protection along with other benefits, e.g. composting, bioenergy etc. Concerning the solid waste management, the valorization of pomace through its processing for olive pomace oil and pomace wood production, is an excellent example for a waste generated from one industrial unit to constitute raw material for another. Furthermore, alternative treatment options, such as production of adsorbents, antioxidants, biopolymers, enzymes and dyeing textile materials, which have recently received a great deal of research attention, have to be further studied and developed so as to increase their economic feasibility towards their industrial use,

In order Greece to be able to move towards a circular economy model, firstly emphasis should be given on minimizing the waste generated but also on the more efficient use of water and energy, in order to eliminate the total environmental impact. For the control and the reduction of the water consumption during the production process and the related generated wastewater, the use of two-stage centrifugation systems is the most efficient technology. Thus, the Greek olive oil mills should continue to turn their function into this type of centrifugation systems.

Overall, general strategies for the adoption of environmentally friendly production practices, prevention measures, and intensive controls of the production processes is the basic assumption for the transition of the Greek olive oil industry towards a circular economy model. Moreover, encouraging the decrease of the water consumption through practices such as, the use of ecological sewers, the more rational waste management system in the olive oil mills, the use of oil-water separators to recover the olive oil residues and accomplish reduce of pollution loads in the environment is required. Taking in account all the above, it can be concluded that it is crucial to provide all the technical assistance and the theoritical knowledge, to every stakeholder of the sector, in order to encourage them to apply and maintain the principles of the green olive oil processing.

12.3. Policy Implications and Recommendations

Although in Greece, olive cultivation constitutes a significant part of the Utilised Agricultural Area, the Primary secort GDP and exports, the average size of olive groves, olive oil mills and the rest of the facilities occupied in olive and olive oil production are of medium to small and very small size. To consider the valorization of by-products and waste as a profitable economic activity, a significant volume of them is needed. Consequently, in order to efficiently implement circular economy principles and practices in the olive oil sector, there is a need for new business models. Towards that end, it seems imperative to apply common legislation and rules, grants, and strategies adapted to the size and capacity of the enterprises engaged and strategies that will focus in raising the awareness of both professionals involved in olive oil production, as well as consumers for paying for more environmentally friendly products.

13. References

Association of Businesses and Industries (ABI) (2018) Yes to the circular economy (no to the recycling of wrong policies). Economy and Business (Weekly bulletin for the Greek economy), 122, 21 pages. (In Greek)

Carmona, I., Aguirre, I., Griffith, D. M. &Gaecia-Borrego, A. (2023). Towards a circular economy in virgin oliveoil production: Valorization of the olive millwaste (OMW) „alpeorujo“ through polyphenol recovery with natural deep eutectic solvents (NADESs) and vermicomposting. *Science of the Total Environment, 872, 162198.*

Charisiou, N.D., Paraskeva, C.A., Goula, M. A. & Papadakis, V. G. (2014). Techno-economical & sustainability analyses for multilateral exploitation of olive tree cultivation residues. *Journal of Environmental Science and Technology Research, 1, 1-6.*

Charisiou, N. D., Konstantakou P. P. &Papadakis, V. G. (2016). Exploitation of olive tree prunings as raw material for the production of high quality compost. *Environmental Engineering and Management Journal, 15, 2709-2717*.

Danellakis, D., Ntaikou, I., Kornaros, M., &Dailianis, S. (2011). Olive oil mill wastewater toxicity in the marine environment: alterations of stress indices in tissues of mussel, Mytilus galloprovincialis. *AquaticToxicology, 101, 358–366.*

ELSTAT (2019). Production of some secondary products by Region and Regional Unit. Available at: https://www.statistics.gr/el/statistics/-/publication/SPG06/2019
ELSTAT (2022). Tree crops. Number of trees and production of the main tree crops, by Region and Regional Unit. Available at: https://www.statistics.gr/el/statistics/-/publication/SPG06/-

Foteinopoulos, I. &Darakas, E (2018). Olive mill waste management: the case of the prefecture of Messinia. *Hydrotechnics27, 15–28.*

Galliou, F., Markakis. N., Fountoulakis, M.S., Nikolaidis, N. & Manios, T. (2018). Production of organic fertilizer from olive mill wastewater by combining solar greenhouse drying and composting. *Waste Management, 75,305–311*.

Grego, S. (2022). The Olive Tree: A Symbol. IntechOpen. doi: 10.5772/intechopen.102827

Huertas-Alonso, A. J., Gonzalez-Serrano, D. J., Hadidi, M., Saldago-Ramos, M., Orellana-Palacios, J. C., Sánchez-Verdú, M. P., Xia, Q., Simirgiotis, M. J., Barba, F. J., Dar, B. N. & Moreno, A. (2022). Table olive wastewater as a potential source of biophenols for valorization: a mini review. *Fermentation*, *8*, *215*. https://doi.org/10.3390/fermentation8050215

International Olive Council: World olive oil figures: http://www.internationaloliveoil.org/estaticos/view/131-world-olive-oil-figures

Justino, C., Marques, A.G., Duarte, K.R., Duarte, A.C., Pereira, R., Rocha-Santos, T. & Freitas, A.C. (2010). Degradation of phenols in olive oil mill wastewater by biological, enzymatic, and photo-Fenton oxidation. *Environmental Science and Pollution Research, 17, 650–656.*

Khdair, I.A. & Abu-Rumman, G. (2017). Evaluation of the environmental pollution from olive mills wastewater. *Fresenius Environmental Bulletin, 26(4),2537–2540.*

Khdair, A.I., Abu-Rumman, G.& Khdair, S.I. (2019). Pollution estimation from olive mills wastewater in Jordan. *Heliyon, 5(8), e02386.*

Kounani, A., Pavloudi, A.&Aggelopoulos, S. (2023). Circular Economy in Olive Oil Industry: The case of Greece. In : W. Leal Filho , A.M. Azul, F. Doni,& A.L. Salvia (Eds.), *Handbook of Sustainability Science in the Future(pp. 1399-1424*. Springer, Cham. https://doi.org/10.1007/978-3-030-68074-9_166-1

Koutrotsios, G., Tagkouli, D., Bekiaris, G., Kaliora, A., Tsiaka, T., Tsiantas, K., Chatzipavlidis, I., Zoumpoulakis, P., Kalogeropoulos, N. &Zervakis, G.I. (2021). Enhancing the nutritional and functional properties of *Pleurotuscitrinopileatus* mushrooms through the exploitation of winery and olive mill wastes. Food Chemistry, 370, 131022. https://doi.org/10.1016/j.foodchem.2021.131022

Law on Standard Environmental Commitments (SBC) of industrial activities (15/4187/266/2012 Greek Joint Ministerial Decision) , Official Gazzete, no. B΄1275/2012. Available at: https://search.et.gr/el/fek/?fekId=474447

Law on Standard Environmental Commitments (SBC) of industrial activities (1st amendment of no. 15/4187/266/2012 Greek Joint Ministerial Decision), Official Gazzete, no. B΄3924/2016. Available at: https://search.et.gr/el/fek/?fekId=535574

Law on Standard Environmental Commitments (SBC) of industrial activities (2nd amendment of no 15/4187/266/2012 Greek Joint Ministerial Decision), Official Gazzete, no. B΄4333/2017. Available at: https://search.et.gr/el/fek/?fekId=548894

LIFE CLIMATREE (CO2RCCT was developed within Action C.4 of the LIFE CLIMATREE project (LIFE14 CCM/GR/000635)

Lodolini, E.M., Polverigiani, S., Giorgi, V., Famiani, F. &Neri, D. (2023). Time and type of pruning affect tree growth and yield in high-density olive orchards. *ScientiaHorticulturae, 311, 111831.* https://doi.org/10.1016/j.scienta.2023.111831

Lopez-Pineiro, A., Albarran, A., Nunes, J.R. & Barreto, C. (2008). Short and medium-term effects of two-phase olive mill waste application on olive grove production and soil properties under semiarid Mediterranean conditions. *Bioresouser Technology, 99, 7982–7987.*

Madureiira, J., Mardaça, F. M. A., Santos-Buelga, C., Ferreira, I. C. F. R. Cabo Verde, S. & Barros, L. (2022). Applications of bioactive compounds extracted from olive industry wastes: A review, *Comprehensive Reviews in Food Science and Food Safety, 21, 453-476.*

Mele, A. M., Islam, M. Z., Kang, H.-M. &Giuffrè, A. M. (2018). Pre-and post-harvest factors and their impact on oil composition and quality of olive fruit.

Monthly EU Olive oil Production (2023-2024). Available at: https://www.agronegocios.es/wp-content/uploads/2024/04/olive-oil-monthly-production_en.pdf

Muktadirul Bari Chowdhury, A.K.M., Michailides, M.K., Akratos, C.S, Tekerlekopoulou, A.G., Pavlou, S. &Vayenas, D.V. (2014). Composting of three phase olive mill solid waste using different bulking agents. *International Biodeterioration Biodegradation, 91, 66–73*. https://doi.org/10.1016/j.ibiod.2014.03.012

Niaounakis, M.&Halvadakis, C.P. (2006). Olive processing waste management: literature review and patent survey. In: *Waste managemen, Series 5t* second ed. Elsevier, Amsterdam.

Nunes, L.J.R., Loureiro, L.M.E.F., SaLeticia, C.R. & Silva Hugo, F.C. (2020). Evaluation of the potential for energy recovery from olive oil industry waste: thermochemical conversion technologies as fuel improvement methods. *Fuel, 279, 118536.* https://doi.org/10.1016/j.fuel.2020.118536

Papadopoulos, N.G., Soupios, P., Kim, J.H., Simyrdanis, K., Kirkou, S. &Tsourlos, P. (2014). Mapping of olive oil mills' wastes (OOMW) through ERT: a case study from alikianos site in Eastern Crete (Greece). In: Conference proceedings, Near Surface Geoscience 2014– 20th European Meeting of Environmental and Engineering Geophysics, September 2014, vol 2014, pp 1–5. https://doi. org/10.3997/2214-4609.20142055

Rahmanian, N,, Jafari, S.M., & Galanakis, C.M. (2014), Recovery and removal ofphenolic compounds from olive mill wastewater *Journal of American Oil Chemists Society, 91(1), 18*.

Rocha, C., Soria, M.A. & Madeira, L.M., (2022). Olive mill wastewater valorization through steam reforming using multifuctional reactors: challenges of the process intensification. *Energies, 15 (3), 920.* https://doi.org/10.3390/en15030920

Saglam, C., Tuna, Y. T., Gecgel, U. & Atar, E.S. (2014). Effects of olive harvesting methods on oil quality. *APCBEE Procedia, 8, 334-342.*

Sectoral report of National Bank of Greece, "Olive oil Establishing the Greek brand„ (2015). https://www.nbg.gr/-/jssmedia/Files/nbgportal/reports/migrated-data/files/greek/the-group/press-office/e-spot/reports/documents/olive-oil_2015.pdf?rev=71f89216387a41959153c7916af3ad2f

Souilem, S., El-Abbassi, A., Kiai, H., Hafidi, A., Sayadi, S. & Galanakis, C.M. (2017). Olive oil production sector: environmental effects and sustainability challenges. In: C.M. Galanakis (Ed.) *Olive mill waste recent advances for sustainable management.* Academic Press, chapter1.

Tsantila, N., Karantonis, H.C., Perrea, D.N., Theocharis, S.E., Iliopoulos, D.G., Antonopoulou, S. & Demopoulos, C.A. (2007). Antithrombotic and antiatherosclerotic properties of olive oil and olive pomace polar extracts in rabbits. *MediatorsofInflammation, 2007(1),36204.*

Tsimidou, M. Z., Blekas,G.&Boskou, D. (2003). Olive oil. Encyclopedia of Food Science, Food Technology and Nutrition, 4252-4260.

Valta, K., Aggeli, E., Papadaskalopoulou, C., Panaretou, V., Sotiropoulos, A., Malamis, D., Moustakas, K. &Haralambous, K.-J. (2015). Adding value to olive oil production through waste and wastewater treatment and valorisation: The case of Greece.Waste Biomass Valorization, 6, 913-925. https://doi.org/10.1007/s12649-015-9373-4

Zagklis, D.P., Arvaniti, E.C., Papadakis, V.P. & Paraskeva, C.A. (2013). Sustainability analysis and benchmarking of olive mill wastewater treatment methods. *Journal of Chemistry Technology* and Biotechnology, 88 (5), 742-750.

14. Appendices

14.1. Glossary of Terms

Olive Grove: A plantation where olive trees are grown, primarily for producing olives used in oil extraction.

Olive Mill: A facility where olives are crushed and processed to extract virgin olive oil.

Pomace: The solid residue left after the extraction of olive oil, consisting of olive skins, pulp, seeds, and stems.

Two-Phase Centrifugation: A method of olive oil extraction with minimal addition of technological water that separates the oil from the residues, resulting in two phases: oil and wet pomace.

Three-Phase Centrifugation: A method of olive oil extraction with addition of significant amount of technological water that separates the oil, from the residues, resulting in three phases: oil, dry pomace and the residual liquid phase, also called wastewater from the olive mill, constituted mostly from technological and vegetable water.

Liquid olive pomace: The solid by-product from the two-phase centrifugation process, with a high moisture content.

Dry Pomace: The solid by-product from the three-phase extraction process, containing less moisture than wet pomace.

Olive Pit: The hard stone inside an olive that contains the seed. It is often separated after the oil extraction process and can be used for various purposes like energy production.

Biogas: A type of biofuel that can be produced from organic materials, including olive pit, through anaerobic digestion.

Organic Fertilizer: A natural fertilizer made from organic matter such as composted olive pomace and used to enrich and increase soil fertility.

Composting: The controlled aerobic process of decomposing organic matter with the help of microorganisms leading to the creation of a nutrient-rich product, which is used as fertilizer.The process of decomposing organic matter, such as olive pomace, to create nutrient-rich compost for soil amendment.

Circular Economy: An economic system aimed at eliminating waste and the continual use of resources, often implemented in olive oil production by reusing by-products and minimizing environmental impact.

Mulching: A technique where organic materials, like olive pruning residues, are spread over the soil surface to improve moisture retention, soil fertility, and reduce weed growth.

Pellet Production: The process of compressing organic materials, such as olive pits or pomace, into small, dense pellets used as fuel.

Olive oil refining plant: A plant that processes low quality olive oil or pomace oil, producing edible refined oils from olives or olive pomace.

14.2. Survey Questionnaires and Interviews

14.2.1.ANNEX 1: Online survey targeting MSMEs in the olive sector

ANNEX 1: ONLINE SURVEY TARGETING MSMEs IN THE OLIVE SECTOR

QUESTIONNAIRE ABOUT METHODS AND POSSIBILITIES OF USING OLIVE BY-PRODUCTS AND WASTE IN OLIVE SECTOR

This survey is launched as the first consultation activity of the project ***"Developing skills for introducing circular business models and digital technologies in olive oil sector (CIRCOLIVE)"***, a three-year project co-funded by the European Union under the Erasmus+ Programme.

The project aims to support the EU transition to the Circular Economy by improving/enhancing the circular business skills in the olive oil sector in Spain, Italy, Greece, Portugal and Croatia, in order to promote the adoption of circular entrepreneurial models for waste and by-product valorisation of the whole olive value chain.

The answers to this survey will help us in developing of skills for introducing circular business models and digital technologies in olive oil sector.
In this survey definition of ***Circular Economy*** presents methods and possibilities of using olive by - products and waste in olive sector.

The survey takes **about 10 - 20 minutes**. Responses will be treated **anonymously**and the results will be used for **CIRCOLIVEproject purposes only**.

Your answer is valuable to us and we thank you in advance for your time and effort.

- questions for olive producers

1. Volume and characteristics of olive production on the enterprise
   - Total area under olive groves ________ ha
   - Total number of olive trees by age
     - o Olive groves until 5 years _______________ trees
     - o Olive groves between 5 to 20 years _____________ trees
     - o Olive groves older than 20 years ______________trees

2. Technology used in your olive grove (one answer)
   a) Conventional
   b) Ecological with eco-label
   c) Other

3. Which technological interventions related to circular economy you apply in olive grove:

	Yes-No
Inert plant cover from chopped pruning	
Incorporation of the remains of pruning into the soil	

	Yes-No
Inert plant cover from cut grass	
Grass cutting	
Livestock nutrition	
Use organic fertiliser	
Precise incorporation of mineral fertiliser	
Integrated agriculture /reduction of chemical pesticide	
Precise pesticide application	
Storage, recovery and use of stormwater	
Use of wastewater/purified water for irrigation	
Drip irrigation and controlled of water consumption	
Precise irrigation	
Use of photovoltaic panels	
Use of hybrid motors	
Use of biofuels	
Use of recycled and recyclable containers and packaging	
None of the above	

4. Type of soil management in your olive grove
   a) Soil cultivation
   b) Mulching (mulching permanent grassland and pruning residues)
   c) Combination of the first two ways
   d) Other:

5. Intensity of winter pruning in your olive grove
   a) Every year
   b) Every couple of years
   c) None

6. Intensity of summer pruning in your olive grove

a) Every years

b) Every couple of years

c) None

7. Select the procedure with olive pruning residues in your olive grove (multiple answers is possible)

Procedure

a) Mulching (mulching permanent grassland and pruningresidues)

b) Controlled burning with or without returning the ashes to the olive grove

c) Composting

d) Firewood

e) Production of firewood pellets

f) Livestock nutrition

g) For pharmaceutical and food industry

h) Production of useful and decorative items (furniture, jewellery, dishes, etc.)

None of the above

i) Other (specify):

8. Choose your motives and barriers for utilisations of pruning residues

		Types of procedure						
		a)	b)	c)	d)	e)	f)	g)
Motives for implementation	Lower costs and/or higher incomes							
	Legal obligation and/or support							
	Available technology, knowledge and experience							
	Awareness of sustainability							

Barriers For implementation	High initial investment and costs
	Legal restrictions or insufficient support
	Lack of technologies and knowledge
	Lack of social and environmental awareness

9. Rate your agreement with the following statements about the advantages and disadvantages of mulching pruning residues in an olive grove:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
The most cost-effective way of using pruning residues	1	2	3	4	5
A positive effect on the structure and content of organic material in the soil	1	2	3	4	5
Useful because it prevents the growth of weeds and erosion and conserves moisture in the soil	1	2	3	4	5
Disease development and pest attack are encouraged	1	2	3	4	5
Increases the danger of fire outbreaks	1	2	3	4	5
Negative impact on soil pH value	1	2	3	4	5

10. Rate your agreement with the following statements about the advantages and disadvantages of burning pruning residues:

	I don't	I don't agree	Neither agree nor	I agree	I fully agree

	agree at all		disagree		
The plant residues burning is in accordance with the principles of good agricultural practice	1	2	3	4	5
Useful because pests and disease are controlled	1	2	3	4	5
Extracting the branch from the plantation requires a lot of work	1	2	3	4	5
It is not useful because valuable organic material is lost	1	2	3	4	5
It is harmful to the air and the local ecosystem	1	2	3	4	5

11. Rate your agreement with the following statements about the advantages and disadvantages of composting pruning residues:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Organic waste in landfills is reduced	1	2	3	4	5
The obtained compost is a quality organic fertilizer	1	2	3	4	5
Composting is a demanding procedure that needs knowledge that I do not have	1	2	3	4	5
There is no organized composting system in the area	1	2	3	4	5
The composting process is very long and requires a lot of space	1	2	3	4	5
Composting creates unpleasant odors and attracts insects	1	2	3	4	5
Improper composting can result in the spread of disease in the plantations	1	2	3	4	5

12. Rate your agreement with the following statements about the advantages and disadvantages of producing firewood pellets from pruning residues:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Pellets have a high energy value	1	2	3	4	5
Pellets are an ecological energy source	1	2	3	4	5
Equipment for pellets production is expensive	1	2	3	4	5
The production of pellets requires a large consumption of energy, so their production is not ecologically justified	1	2	3	4	5
There is no organized system for the production of pellets in the area	1	2	3	4	5
The price of pellets is high compared to other energy sources	1	2	3	4	5

- questions for olive mill owners

13. Installed olive mill capacity:___________ kg/hour

14. Amount of processed olive fruits in the last 3 years:

2021 year - _______________ olive fruit tons

2022 year - ______________ olive fruit tons

2023 year - ______________ olive fruit tons

15. Which technology is used in the olive oil extraction process in your olive mill:

a) Two-phase centrifuge system (oil + wet pomace)
b) Three-phase centrifuge system (oil + olive mill wastewater) + dry olive pomace)

Other_________

16. Is the extraction of pits carried out in your olive mill?

Yes - No

17. In which phase are pits being separated?

a) Before milling the fruits
b) After oil extraction, from dry or wet pomace
c) Not applicable

Other_______

18. How is olive wet or dry pomace used or disposed of in your enterprise?

a) It is scattered on agricultural soil immediately after processing
b) Heap composting
c) As biofuel
d) For production of ecological products.
e) For the production of construction materials.
f) Livestock nutrition
g) Is disposed of at a waste disposal site

Other (specify):______________________________

19. If is implemented in your enterprise, how long does the composting process last

___________ months

20. Rate your agreement with the following statements about the advantages and disadvantages of composting olive pomace:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Composting is the best available way to use olive pomace	1	2	3	4	5
The obtained compost is a high-value organic fertilizer	1	2	3	4	5
Compost improves the structure and biological activity of the soil	1	2	3	4	5

Olive pomace decomposes slowly, so composting takes at least 12 months	1	2	3	4	5
Due to the low content of organic acids and phytotoxins soil amendment with olive pomace compost is not an issue of environmental risk	1	2	3	4	5
The legal regulation of olive compost application in agriculture is complex	1	2	3	4	5

21. Rate your agreement with the following statements about the advantages and disadvantages of using olive pomace as biofuel:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Pomace is a high-quality renewable energy source	1	2	3	4	5
Pomace has a low energy value	1	2	3	4	5
The process of using pomace as biofuel is expensive and unprofitable	1	2	3	4	5

22. How is used olive mill wastewater in your olive mill?
   a) Recycling and reuse in the olive processing
   b) For production of biofuel (biomethane)
   c) Purification and reusing (irrigation)
   d) Purification and release into the environment
   e) Other (specify):_______________________________

23) Rate your agreement with the following statements about the advantages and disadvantages of using olive mill wastewater for recycling and the potential use

	I don't agree	I don't agree	Neither agree nor disagree	I agree	I fully agree

	at all				
Olive processing costs are reduced	1	2	3	4	5
Reducing fresh water consumption contributes to ecological sustainability and reduces the negative impact of olive processing on the environment	1	2	3	4	5
Recycling olive mill wastewater is expensive and unprofitable	1	2	3	4	5
The disposal/use of recycled olive mill wastewater is subject to strict legal requirements	1	2	3	4	5
It is useful to purify vegetable wastewater for irrigation	1	2	3	4	5
It is useful to extract valuable compounds, such as polyphenols, from vegetable wastewater	1	2	3	4	5

24) For which purpose are olive pits used in your olive mill?
   a) Energy source in its original form
   b) For the production of pellets or briquettes
   c) For the production of biomaterials. Organic fertilizer
   d) Other (specify):______________________________

25) Rate your agreement with the following statements about the advantages and disadvantages of using olive pits as an energy source:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
The amount of waste from olive processing is significantly reduced	1	2	3	4	5
A natural, renewable energy source is obtained, for which is an increasing	1	2	3	4	5

demand					
Pits have a lower energy value compared to wood	1	2	3	4	5
High investments are required in a pits processing	1	2	3	4	5

26) Do you sell olive by-products and/or waste obtained in the olive sector?

No – Yes, _

Please list all the products you sell and mention as first the most important one according to your opinion.

27) (If the previous answer is YES) Rate your agreement with the following statements related to the placement and sale of the previously mentioned first product:

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
I have no problem with the placement of this product	1	2	3	4	5
I am satisfied with the selling price	1	2	3	4	5
I plan to increase production	1	2	3	4	5
Most of the customers are within a radius of 50 km	1	2	3	4	5
The domestic market does not yet recognize this product	1	2	3	4	5
I need to improve the production technology of product for the market	1	2	3	4	5
It is necessary to educate customers about the benefits of the product	1	2	3	4	5
I have to invest a lot in	1	2	3	4	5

marketing and publicity

28) Rate your agreement with the statements about the opportunities and threats of the circular economy in the olive sector

	I don't agree at all	I don't agree	Neither agree nor disagree	I agree	I fully agree
Public subsidies stimulate olive growers to apply circular economy measures	1	2	3	4	5
The processing of olive by-products and waste requires large capital and labor investments	1	2	3	4	5
Olive by-products and waste from the olive sector pose a threat to the environment if they are not processed according to the principles of the circular economy	1	2	3	4	5
There is no organized olive by-products and waste processing system in the area	1	2	3	4	5
The legislative framework limits the development of circular economy in olive sector	1	2	3	4	5
It is necessary to raise awareness about the benefits of implementing circular economy in olive sector	1	2	3	4	5

Questions for both groups: Socio-economic characteristics of respondents

29) Respondent's gender
    a) Male
    b) Female

c) I don’t want to answer

30) Respondent's age ____________ year

31) Enterprise location

Country ________________

Region _________________

32) Respondent's education

a) High school and lower
b) Bachelor degree
c) Master degree
d) PhD

33) Education in the field of agriculture

Yes - No

34) Do you completed a course, training or education of circular economy in olive sector and/or agriculture?

Yes - No

35) If YES, enter the following information about education:

a. Education name ____________________________________
b. Organization in charge (Vocational Education and Training (VET) provider).
____
c. Duration ____
d. Method of implementation

Online

In presence

Hybrid mode

e. Obtained title ____

36) Enterprise size:

1. Micro (<10 employees)

2. Small (<50 employees)
3. Medium sized (<250 employees)
4. Large size (>250 employees)

37) Agriculture is for my household

a) The only source of income
b) Predominant source of income (> 50%)
a) Additional source of income (< 50%)

38) I am interested in attending a training course focused on how to valorise olive by-products and waste

Yes - No

39) Select the preferred method for attending a training course focused on how to valorise olive by-products and waste

a) Online

b) In presence

c) Hybrid mode

40) Dear responded,

Thank you for your time and contribution to Circolive project

41) I consent to have the information stated above used by the CIRCOLIVE project partners solely for meeting the purposes of this survey.

Yes – No

In case you want receive information about the project and activities, please enter your e-mail

14.2.2.ANNEX 2: Structured interview with circular business agro-food experts/professionals

ANNEX 2: Structured interview with circular business agro-food experts/professionals

Date:

Location:

Enterprise name:

Enterprise email address (in case you want receive further information about the Circolive project):

Enterprise size:

1. Micro (<10 employees)

2. Small (<50 employees)

3. Medium sized (<250 employees)

4. Large size (>250 employees)

Type of enterprise (possible multiple choice):

1. Olive producer

2. Olive mill owner

3. Olive by-products/waste recycle facility owner

4. Other: ______________

Interviewees' business role:

1. Executive

2. Manager

3. Operations and production

Interviewees' years:

Interviewees' educational level:

1. Main information about your enterprise.

- length of business, number of employees,

- description of olive production (total number of olive trees, production area etc…)

- total amount of processed olive fruits per year

- oil mill capacity per hour

- all types of olive by-products/waste being processed

- all types of products obtained

- years of experience of by-products and waste processing

- total amount of each type of olive by-products/waste processed per year

- Other information

2. Describe the olive processing technology

- Describe the olive by-products and waste processing technology also if you know future technology trends if you know
- Describe the normative of each olive by-products and waste obtained from 100 kg of olive fruits (percentage of olive oil, wet/dry pomace, olive mill wastewater, pits)
- In case you use just one type of olive by-products and waste please explain the reason why you didn't use other olive by-products and waste

3. How are the obtained product/products from olive-by products and waste being used?

- Reusing by the enterprise or in the field, selling on the market, other
- If you sell on the market, describe the marketing mix 4P (price, product, place, promotion for each new product/products)
- Identify the major producers and industry players in the olive waste sector
- Try to predict market development of olive waste products (risk/challenges and opportunity/potential)
-

4. Which is your motives/drivers/preferences for processing olive by-products/waste?

- Social motives (more sustainable awareness/practice, social benefits/cohesion, culture/tradition, collaborative economy)
- Economical (cost savings – shared use, cheaper resource, resource of greater efficiency, higher income – additional income from products, increased sales, increased price from differentiation)
- Political-legal-institutional (legal obligations, systems of certification, institutional support)
- Innovation and technology (technology, knowledge, training)

5. Did you have any barriers or gaps when starting the olive by-products/waste business?

- Social (lack of environmental – social awareness, culture -tradition, deficiencies in collaborative economy networks)

- Economic (high initial investment, higher costs, lower profitability)

- Political-legal-institutional (regulatory limitations, lack of institutional supports and insecurity regarding incentives and aid)

- Innovation and technology (obsolescence, little development – access to technologies, lack of technical knowledge)

6. Describe the current situation in the context of barriers or gaps?

- Comment off all barriers from the previous question.

7. Do you plan remaining in olive by-products/waste business in the future?

- Expand business - increase the amount of olive by-products/waste processing capacity, add new types of olive by-products/waste processing or reduce/give up…)

8. Which is the Strengths, Weaknesses Opportunities, and Threats and for further developing the olive by-products/waste business?

Strengths (Strengths describe what an organization excels at and what separates it from the competition)

Weaknesses (Weaknesses stop an organization from performing at its optimum level)

Opportunities (Opportunities refer to favorable external factors that could give an organization a competitive advantage)

Threats (Threats refer to factors that have the potential to harm an organization)

- Can you identify any other best practices in your country regarding circular economy in the olive sector?

9. Do you have any education in the field of circular economy?

If yes, who is the provider of this education, duration of education, way of conducting the education (In presence, online, hybrid mode)

If no, do you plan participating in an educational program on the circular economy in the olive sector?

10. Are you interested in participating in the educational program on the circular economy in the olive sector which will be final results of the CIRCOLIVE project?

Which way of conducting the education (In presence, online, hybrid mode) you prefer?

14.2.3.ANNEX 3: Structured interview with VET providers

ANNEX 3: Structured interview with VET providers

Date:

Location:

VET name:

VET email address (in case you want receive further information about the CIRCOLIVE project):________

Type of VET:

1. University
2. Polytechnic
3. Institute
4. Public Open University
5. Private provider
6. Other (specify):____________________

Interviewees' role:

1. Executive
2. Manager
3. Lecturer
4. Other____________

Interviewees' years:

Interviewees' educational level:

1. Main information about VET provider
    - Length of business
    - Number and type of employees by role (teaching, training, administrative…)
    - Area of provided education (agronomy, forestry, economy, other)
    - Other information

2. Do you offer courses on circular business practices in the olive sector?

If - YES (question no. 3), If – NO (question no. 4)

3. Main information about available educational courses related to circular business practices in the olive sector:
    - Name and number of courses per year
    - Duration of each course in hours
    - Average number of participants who successfully passed the courses (per courses and per year)
    - Method and techniques used for training
    - Obtained title after course finishing
    - What are the recognition paths/qualification validation methods used by the offered trainings?
    - According to your knowledge, is the concept of circular business practices in the olive sector taught in other Institutions (regular (higher) education programs, in vocational training (VET) or in adult training in general)?

4. Which institutions offer courses on circular business practices in the olive sector (Universities, VET providers, adult training institutions, private institutes/schools, etc.)?
    - If there isn't any, which institutions could potentially offer courses on circular business practices in the olive sector in the future (universities, vocational education and training providers, adult training institutions, private institutes/schools, etc.)?

5. What training methods and techniques are mostly used and are suitable for circular business agro-food professionals' training? Theory + practices, Practices + educational visits, combination or something else, please describe.

6. What are the identified best practices in your country regarding the education programs in the context of circular business practices?

- offered trainings, training methods, recognition paths/qualification validation methods

7. In your opinion, which lecturer profiles (specialties) should have an institution offering courses on circular business practices? - agronomy (or a specialist in olive growing), ecology, food technology, economist, others

8. Do participants of the circular economy course in the olive sector need any prior specific degree or knowledge/skills?

9. If yes, which ones?

10. What skills the participants will have after passing the circular economy course in olive sector, and where they can apply their knowledge.

Co-funded by
the European Union

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency. Neither the European Union nor the granting authority can be held responsible for them."

CircOlive

WWW.CIRCOLIVE.EU

Consortium

CHECK-IN

CLUST-ER AGRIFOOD

ifoa Sapere utile

eurecat

Institute of Agriculture and Tourism

Co-funding

Co-funded by the European Union