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# Circular economy and agriculture: Mapping circular practices, drivers, and barriers for traditional table-olive groves

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ABSTRACT

The Circular Economy (CE) has notable potential for the economic, environmental, and social sustainability of agriculture. However, the literature on the CE has focused on the industrial sector, leaving significant gaps in the analysis of sustainable circular models in agriculture. In the case of traditional table-olive cultivation, which suffers from serious competitiveness problems, the possibilities of the CE are particularly relevant. Given the lack of previous research for the sector, this work aims to map the circular practices carried out in traditional table-olive groves and identify their drivers and barriers. To this end, an exploratory methodology of mixed approaches is proposed that combines desk research, observational fieldwork, focus groups with stakeholders and experts, and farmers' in-depth interviews. This methodology can be generalised to other crops. The results obtained have enabled up to 59 practices to be brought to light throughout all stages of the life cycle of olive cultivation, which cover all the principles and strategies of the CE. Plant covers, the use of eco-efficient techniques, the repair and sharing of machinery and tools, and the management of organic outputs stand out. The collaborative economy and institutional support were identified as the main drivers, while technical-economic barriers and regulatory limitations constitute the main obstacles detected. Based on these results, three groups of recommendations are proposed as a guide to future policies for which certain CE practices are highlighted: increase financial incentives, create a stable legislative framework, and reinforce incentives for the collaborative economy.

## 1. Introduction

The Circular Economy (CE) represents a profound change in the current production and consumption model. It has significant potential to contribute towards the achievement of the 17 Sustainable Development Goals (Ortiz-de-Montellano et al., 2023), which explains that, in the last decade, both government interest and scientific contributions on the topic have grown exponentially (Kirchherr et al., 2023; Lozano et al., 2021). The potential of the CE to achieve environmental, economic, and social sustainability is especially relevant in the agricultural sector (Barros et al., 2020; Velasco-Muñoz et al., 2021, 2022). On the one hand, the direct link between agriculture and natural resources makes it responsible for a major part of the existing environmental problems (large water and energy footprint, impacts on the soil, GHG emissions, loss of biodiversity), but this proximity to natural resources also offers agriculture the opportunity to preserve them and regenerate the environment (Ellen MacArthur Foundation (EMF), 2019; Morseletto, 2020).

On the other hand, agriculture is a strategic sector for food production and, therefore, for the guarantee of food security and health. It is also responsible, however, for a large part of food waste (Ellen MacArthur Foundation (EMF), 2019, 2021). Furthermore, as it constitutes the main economic activity of the rural world, it plays a decisive role in employment, society, and rural culture (Mies and Gold, 2021). Lastly, a substantial part of the agricultural production of the most developed countries is experiencing problems competing on prices in an increasingly globalised environment. In this context, CE strategies become an opportunity to differentiate the product and gain competitiveness while contributing to environmental and social objectives (Castillo-Díaz et al.,

*Abbreviations:* CE, Circular Economy; CAP, Common Agricultural Policy; PGI, Regulatory Council of the Protected Geographical Indication of Manzanilla and Gordal Olives of Seville.

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2023; Falcone et al., 2022). To this end, Velasco-Muñoz et al. (2021: 4) propose a specific definition of the CE related to agriculture, by focusing on its contribution to environmental, economic, and social sustainability. This definition is the one employed herein to support this research: "the set of activities designed to not only ensure economic, environmental and social sustainability in agriculture through practices that pursue the efficient and effective use of resources in all phases of the value chain, but also guarantee the regeneration of and biodiversity in agro-ecosystems and the surrounding ecosystems".

In the specific case of olive cultivation (*Olea europaea* L.), the CE can also become an option for economic, environmental, and social transformation that guarantees its sustainability (Falcone et al., 2022), in a context in which it is seriously threatened. The olive tree is deeply rooted in Mediterranean culture, where its fruit has been cultivated and consumed for more than 6000 years either as oil or as table olives (Barranco et al., 2008; Buitrago et al., 2024). Focusing on table olives, the sharp increase in the costs of production together with the growing international competition is putting the viability of its traditional cultivation at risk, with serious impacts in the south of Spain where almost a fifth of the world production of table olives is concentrated. Specifically, over the last decade, there has been exponential growth in the costs of this type of cultivation in Spain: 162 % in electricity, 70 % in fertilisers, 22 % in phytosanitary treatments, 21 % in fuels, 11 % in salaries, and 15 % in general expenses (Junta de Andalucía, 2023). In the international context, this has translated into a loss of competitiveness of the Spanish table olive. According to the International Olive Council (2024), between 2011–2012 and 2021–2022, Spanish exports have decreased by 10.7 % while there have been increases in those from countries such as Turkey (83.3 %) and Egypt (54.54 %).

Although the CE can contribute to sustainability, not all circular strategies are necessarily sustainable. In fact, critical voices are appearing that demand more research in this regard (Blum et al., 2020; Corvellec et al., 2022). Despite this demand, scientific knowledge regarding the CE and agriculture remains in its initial stage (De Boer and Van Ittersum, 2018), whereby numerous gaps have been identified that need to be covered to achieve a sustainable circular model in the sector. Much of this literature has focused on circular food production, while placing more emphasis on the phase linked to agroindustry than on the cultivation phase (Velasco-Muñoz et al., 2021, 2022). Furthermore, research on the CE in the cultivation phase has been carried out mainly from technical or agronomic approaches, leaving a lack of studies with an integrated circular approach (Velasco-Muñoz et al., 2022). Although several studies have recently been carried out to adapt the theoretical framework of the CE to agriculture (Velasco-Muñoz et al., 2021), there is still no complete understanding, and major gaps remain in aspects such as measurement, the development of methodologies that shed light on and evaluate circular practices throughout the entire life cycle of agricultural production, and empirical studies with comprehensive circular approaches. The gaps in the literature are even greater in relation to olive cultivation, where the few studies are mostly partial case studies that analyse a specific aspect of the circularity of the sector, especially those linked to the industrial phase of olive oil production and/or with the recovery of waste (i.e., Berbel and Posadillo, 2018; Blanco et al., 2022; Ncube et al., 2022). To the best of our knowledge, there is no research that analyses the table-olive grove with a comprehensive circular approach.

This study strives to contribute towards filling this gap in the literature: its objective is to map the circular practices carried out in traditional table-olive groves and identify the existing barriers and drivers for the circularity in the sector. To this end, using an exploratory mixed-method approach, traditional Sevillian table-olive cultivation farms (Seville, Spain) are analysed, which suffer from serious competitiveness problems and where the CE can provide an alternative for their sustainability.

Relevant theoretical contributions and practical implications are derived from the results of this work. On the one hand, it contributes to scientific knowledge regarding the CE and agriculture in a dual way. To the best of our knowledge, this is the first study that addresses the cultivation of table olives with a circular approach throughout its entire value chain, thereby providing new empirical evidence for the agricultural sector. Moreover, a methodological approach is proposed for the identification of circular practices, drivers, and barriers that can be extrapolated to the analysis of other crops. On the other hand, decisive practical implications can be derived from the results of the work for a sector suffering from serious economic problems and on whose future depends, to a large extent, both the ecosystem in which it develops and the local society and culture. Although the CE can provide a viable alternative, that which remains unknown cannot be valued, and hence, this type of study can be useful in guiding public policies at various administrative levels, from the Common Agricultural Policy (CAP) to local initiatives.

The rest of the paper is organised as follows: Section 2 provides a literature review. Section 3 is devoted to the description of the case study and the methodology, while Section 4 presents the results obtained, including the discussion, with Section 5 providing the conclusions and implications.

## 2. Literature review

The Circular Economy represents a shift of the paradigm in the current model of production and consumption. In 1966, Boulding pointed out the need to adopt a closed system that took into account the limited resources of the planet, but it was not until the last decade that the presence of the CE in scientific literature has grown exponentially and become a fashionable topic (Kirchherr et al., 2017, 2023; Kalmykova et al., 2018; Lozano et al., 2021). However, significant gaps continue to exist in their scientific knowledge (Corvellec et al., 2022; Korhonen et al., 2018; Martínez et al., 2023).

The multidimensionality and complexity of the CE explains why a precise, widely-agreed-upon definition has yet to be established. There are authors who consider the CE as an umbrella concept that encompasses a series of pre-existing interrelated terms (Blomsma and Brennan, 2017) and others who prefer to focus on the existing *principles and strategies* behind the concept (Korhonen et al., 2018; Martínez et al., 2023). The CE principles are linked to the so-called Rs, ranging from the popular 3 Rs to the broader approaches of Potting et al. (2018), which indicate up to 10 Rs: reject, rethink, reduce, reuse, repair, restore, remanufacture, reuse, recycle, and recover. Kirchherr et al. (2023:194), after reviewing 221 definitions, propose a globalising definition that includes principles, strategies, and drivers of the CE, and highlights its contribution to environmental, economic and social sustainability: "The circular economy is a regenerative economic system which necessitates a paradigm shift to replace the 'end of life' concept with reducing, alternatively reusing, recycling, and recovering materials throughout the supply chain, with the aim to promote value maintenance and sustainable development, creating environmental quality, economic development, and social equity, to the benefit of current and future generations. It is enabled by an alliance of stakeholders (industry, consumers, policymakers, academia) and their technological innovations and capabilities".

The scientific body on the CE has focused mainly on the industrial sector, leaving a major gap in relation to the *agricultural sector*, where scientific advances seem to remain in their infancy (De Boer and Van Ittersum, 2018; Velasco-Muñoz et al., 2021, 2022). In fact, a large part of the studies on the CE and agriculture jointly analyse the agri-food system and focus more on the agri-food industry and distribution phase than on the agricultural production phase (Ellen MacArthur Foundation (EMF), 2019, 2021; Fortunati et al., 2020). Furthermore, research on the agricultural phase mostly consists of case studies from technical or agronomic approaches, which analyse a specific aspect linked to improving the efficiency of the sector. This could be useful for the circularity of the sector, but there remains a lack of studies with an integrated circular approach (Velasco-Muñoz et al., 2022).

In order to advance the circularity of agriculture, it is essential to have our own theoretical framework upon which to support research, since the specificities of the sector mean that the general framework of the CE is not directly applicable (Velasco-Muñoz et al., 2021). Thus, for example, the close link between agriculture and natural resources causes regeneration strategies to make more sense than in other sectors (Ellen MacArthur Foundation (EMF), 2019, 2021). Based on an extensive review of the literature, Velasco-Muñoz et al. (2021) make a proposal that includes not only a specific definition of the CE applied to agriculture, but also the adaptation of circular principles and strategies, and the evaluation of a set of indicators to measure the circular transition in the sector. Thus, Velasco-Muñoz et al. (2021) propose four strategies to develop circular models in agriculture (narrowing resource loops, slowing resource loops, closing resource loops, and regenerating resource flows), within which the principles (R) related to the sector can be framed. These are the principles used herein to support the empirical analysis of this research: Reduce, Reuse, Repair, Repurpose, Recycle, and Recover.

The first strategy, that of narrowing resource loops, includes actions that involve reducing the intensity of resources and/or the environmental impacts generated, and is therefore linked to the principle of Reduction (Kennedy and Linnenluecke, 2022). For the agricultural sector, it is not only about optimising the use of resources but also about adopting an approach based on eco-effectiveness (Braungart et al., 2007; Morseletto, 2020; Velasco-Muñoz et al., 2021). The second strategy, slowing resource loops, includes actions to preserve the value of resources and products over time. In the case of agriculture, these strategies are related to the principles of Reuse and Repair and have a greater application to the inputs used (machinery, tools…) than to agricultural output, since this output cannot be reused (for the same purpose) or repaired. However, there are other ways to extend the useful life of an agricultural product, such as the prevention of food waste and the different food preservation alternatives linked to the agri-food industry (De Boer and Van Ittersum, 2018; Ellen MacArthur Foundation (EMF), 2019). Thirdly, the closing resource loops strategy involves actions that lead to the creation of new value, mainly from the Reuse or Recycling of materials discarded from the value chain. In agriculture, this strategy fundamentally translates into the practices of recycling and reuse of different agricultural materials, including plant cover with pruning remains (Falcone et al., 2022), or energy generation (Barros et al., 2020). Lastly, regenerating resource flows focuses on actions that contribute towards preserving and improving natural capital, which are generally identified with the principle of Recovery. Given its proximity to natural resources, the primary sector is essential for this strategy. In this respect, there are numerous examples linked to the so-called regenerative agriculture (Ellen MacArthur Foundation (EMF), 2021 defines regenerative production as the set of practices that involve healthy and stable soils, better local biodiversity and/or better air and water quality). These four CE strategies, like the principles, are not exclusive, and hence the same action can be included in several strategies and/or linked to several principles (Møller et al., 2023, Velasco-Muñoz et al., 2021).

Empirical research on the CE in the agricultural production phase remains very scarce, especially related to work that jointly considers all stages of its life cycle. The stages of the life cycle of agricultural production range from input management (e.g., seeds, fertilisers, pesticides, energy, fuel, water, tools, and machinery), field preparation (hoeing, sowing, and transplanting), processes to improve production and quality of the fruit (fertilisation, pest control, mulching, irrigation, and pruning), to the management of the output (crop products, by-products, and waste). For each of these stages, Velasco-Muñoz et al. (2022) identify the main contributions made by the literature related to the adoption of circular models and discuss the existing limitations and opportunities. It concludes that the research has focused on the recovery of organic waste, and no studies have been found that analyse the management of inputs from a circular perspective, especially in relation to technical materials. Likewise, there is a lack of methodological work for the study of agriculture from a comprehensive circular perspective.

Certain work on the CE and agriculture focus on the barriers and/or drivers for the adoption of circular models in the sector (Aznar-Sánchez et al., 2020; Barros et al., 2020; Borrello et al., 2016; De Boer and Van Ittersum, 2018; Ellen MacArthur Foundation (EMF), 2019, 2021; Haque et al., 2023; Velasco-Muñoz et al., 2022). In relation to barriers, there seems to be broad agreement regarding aspects such as: regulatory limitations, scarcity of incentives and uncertainty thereof, high costs, lack of technology and knowledge necessary for its application, low awareness on behalf of both producers and consumers, deficiencies in reverse-logistics chains, size and dispersion of farms, and lack of cohesion within the sector.

In coherence with these barriers, the main drivers identified are linked to institutional support and the creation of networks that connect and unite the various stakeholders throughout the entire production chain. Therefore, on the one hand, institutional support is necessary to promote R&D&i and improve access to technologies, expand training and awareness, harmonise legislation, and offer stable incentives (Barros et al., 2020; De Boer and Van Ittersum, 2018; Ellen MacArthur Foundation (EMF), 2019, 2021). On the other hand, agricultural cooperatives and the collaborative economy become an essential element of governance that contribute towards overcoming many of the barriers found (Aznar-Sánchez et al., 2020; Haque et al., 2023; Perdana et al., 2023).

Research into the CE in the olive grove remains very limited and, similar to that analysed for the agricultural sector in general, it is acutely focused on the aspects most linked to the agri-food industry. Olives have the peculiarity of not being able to be consumed directly but must be processed either for oil or as table olives. In this case, the literature has focused on olive oil production (Blanco et al., 2022; Berbel and Posadillo, 2018; Ncube et al., 2022; Stempfle et al., 2021), with no work available on table olives from a circular perspective. However, several of the studies that study the olive oil value chain also analyse aspects of the olive cultivation phase, the conclusions of which could largely be extrapolated to the table-olive grove, for example, Falcone et al. (2022) employ a methodology based on Life Cycle Assessment, Environmental Life Cycle Costing, and the Material Circularity Indicator to evaluate the circularity of the production of olive oil.

Nevertheless, most of these investigations are partial studies only focused on the possibilities of valorising the biomass derived from pruning the remains of the olive tree (wood, branches, and leaves) either for the production of various types of energy and biofuels (Berbel and Posadillo, 2018; Crespo-Barreiro et al., 2023; Lo Giudice et al., 2021; Zabaniotou et al., 2015; Manzanares et al., 2017), or as plant cover or biofertiliser (Berbel and Posadillo, 2018; Kavvadias et al., 2018; Rodríguez-Lizana et al., 2023), as animal feed (Berbel and Posadillo, 2018; Lo Giudice et al., 2021; Ncube et al., 2022), for the production of biomaterials (Fico et al., 2022; Lo Giudice et al., 2021; Ben Mabrouk et al., 2023), or even as valuable bioactive compounds for the pharmaceutical and cosmetic industries (Berbel and Posadillo, 2018; Lo Giudice et al., 2021).

Olive cultivation has been studied from the perspective of the sustainability of certain practices. In this case, these are mostly studies that analyse the technical and/or environmental efficiency of different elements linked to this crop, such as irrigation management (Maesano et al., 2021; Sánchez-Rodríguez et al., 2019), the use of plant cover (López-Vicente et al., 2021; Marañón-Jiménez et al., 2022), different weeding options (De Luca et al., 2018), and the possibility of mechanical collection (Sola-Guirado et al., 2018). Although no circular approach is employed, the results of these studies may be useful for the assessment of specific circular practices in olive farms.

The review of the literature performed herein has revealed the need for work that addresses the cultivation of olives throughout all stages of their life cycle with a comprehensive circular approach: from the management of the inputs necessary to carry out production, passing through the different agricultural tasks, to the management of the outputs.

## 3. Materials and methods

With the objective of mapping the current state of the CE in traditional Sevillian table-olive groves, an exploratory methodology of mixed approaches is proposed focused on the study of agricultural holdings belonging to the Protected Geographical Indication (PGI) of Manzanilla and Gordal Olives of Seville.

### 3.1. Case study: traditional Sevillian table-olive groves and the PGI

An overwhelming 98 % of table-olive cultivation is located in the Mediterranean area, with Spain being the primary producing country with a share of 20 % (International Olive Council, 2024). Most of this production is concentrated in the region of Andalusia and, particularly, in the province of Seville, with 61 % of Spanish production in the 2022–2023 campaign (Ministerio de Agricultura, Pesca y Alimentación (Gobierno de España), 2023). For centuries, Seville has led international rankings in the production and marketing of certain varieties of high-quality olives, such as Manzanilla and Gordal, characterised by their traditional cultivation method. The traditional olive grove has an average density of 100 trees per hectare compared to the super-intensive version whose density can reach up to 800 trees per hectare (Junta de Andalucía, 2023). The quality of these varieties explains why, since the end of the 19th century, they have been exported to the most demanding international markets, highlighting the North American market (Barranco et al., 2008). Furthermore, farms dedicated to the cultivation of table olives in the traditional style represent great economic, social, and environmental value for the rural areas in which they are located. Its manual collection with the help of a traditional collection basket, called a "macaco", and a ladder or wooden bench is extremely respectful of the environment and also mobilises a large number of workers for its collection, being a social, economic, and cultural event in the olive-growing municipalities. This traditional way is part of the Intangible Heritage of Andalusia (Instituto Andaluz del Patrimonio Histórico, 2012).

However, the current cultivation of traditional olive groves of Manzanilla and Gordal in Seville is threatened by the proliferation of other olive-growing systems that are more competitive. In the 2021–2022 campaign, the profitability of the intensively irrigated table-olive grove amounted to 0.407€/kg, while in the traditional rainfed olive grove it was −0.049 €/kg (García-Brenes et al., 2024).

In this complex context, the PGI was founded as an organisation that brings together the traditional Manzanilla and Gordal farms of Seville, whose purpose is to guarantee their survival. To this end, they strive to differentiate their products through quality certification and commercial actions aimed at highlighting the contribution of traditional table-olive cultivation to the environmental, economic, and social sustainability of the rural world of Seville. Given that the CE can become a viable alternative to achieve these objectives, the empirical analysis of this research focuses on the farms associated with the PGI.

### 3.2. Methodology

The study employs a mixed exploratory methodology that combines desk research, observational fieldwork, interviews, and focus groups with stakeholders and experts ($n = 8$) and farmers' in-depth interviews ($n = 71$). Following Johnson and Onwuegbuzie (2004), this methodology was chosen since it enables a holistic approach, consistent with the comprehensive approach associated with the CE model, with which to explore in depth and to present findings both within the local context and in the participants' own words. Thus, a methodological strategy structured in four steps is designed that aims to be easily generalisable to other crops in the agricultural sector (see Fig. 1).

#### 3.2.1. Step 1: framework for designing a diagnostic tool

The objective of the first step involves creating the *framework* on which to support the fieldwork to identify the CE actions carried out in the olive grove. In particular, this framework serves as the basis for the design of the *guidelines* that will guide the discussion groups with experts and stakeholders and the farmers' in-depth interviews. These guidelines constitute the main diagnostic tool. Although many of the farmers and stakeholders who participate in the research are not explicitly familiar with the concept of CE, the aim is that, through the guidelines, they can go through the phases of their productive activity and be guided to bring to light the practices that can correspond to the principles of circularity. To this end, based on *desk research*, a reference framework is designed in this first step in the form of a double-entry table in which the rows represent the different elements of the olive grove value chain, and the columns represent the principles of CE (R) that are more directly related to the sector.

In relation to the value chain, the inputs used, the production processes, and the outputs generated are given in detail by relying on the stages indicated by Velasco-Muñoz et al. (2022) for agriculture and by adapting them to the cultivation of olive groves based on the literature review carried out (Berbel and Posadillo, 2018; De Luca et al., 2018; Ncube et al., 2022; Stempfle et al., 2021). On the other hand, by taking as reference the CE strategies adapted to agriculture proposed by

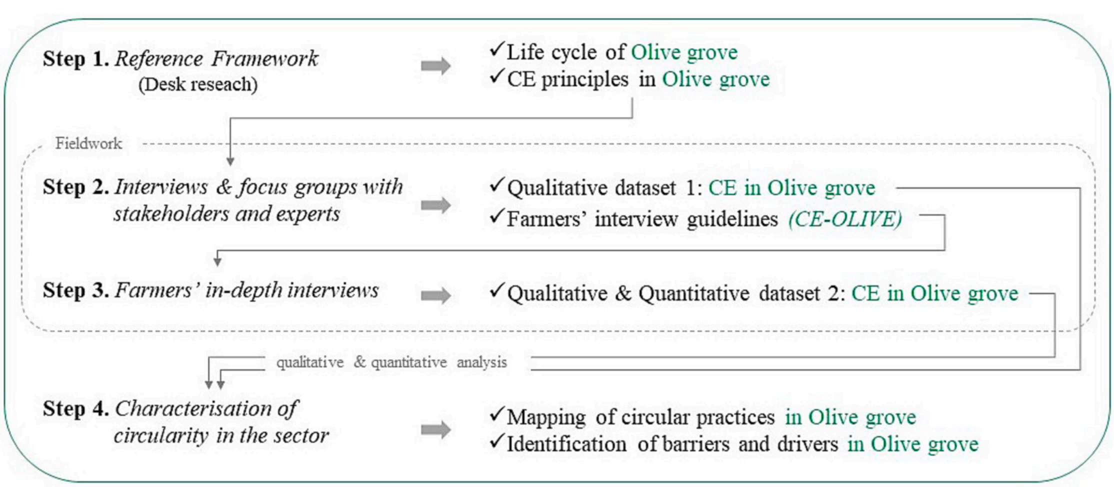


**Fig. 1.** Research design.

Velasco-Muñoz et al. (2021) and the 10 Rs of Potting et al. (2018), we selected the most significant principles for the sector that can be easily identified by farmers: Reduce (R1), Reuse (R2), Repair (R3), Repurpose (R4), Recycle (R5), and Recover (R6). Thus, Fig. 2 details this double-entry table, where the various practices carried out by farmers (CE-$P_{ij}$) can be related to each stage of the olive cultivation phase ($i$) and linked to the principle(s) ($j$) with which it corresponds.

*3.2.2. Step 2: interviews and focus groups with stakeholders and experts*

The second step consists of carrying out interviews and forming focus groups with stakeholders and experts with a dual objective: on the one hand, to obtain a first vision of the circularity in traditional Sevillian olive groves; on the other hand, to adjust the framework of reference as much as possible to the particularities of the sector to complete the definition of the guideline that will guide the interviews with the farmers. Therefore, 6 individual interviews and 2 focus group meetings are carried out with experts and stakeholders from the sector. The selection of these actors was made whereby they were considered key informants (Bohnsack, 2010) seeking a wide range of points of view and included representatives of associations and cooperatives in the sector, public administration technicians, and university experts. The interviews and discussion groups were carried out in person between October and December 2022 and were structured around the double-entry table designed in the previous step. The elements that constitute the value chain of the Sevillian table-olive grove were therefore specified, circular practices and existing barriers and drivers for its implementation were identified and, finally, possible new actions were discussed (Table S1 in the Supplementary Information provides details of the technical aspects of these interviews and discussion groups).

*3.2.3. Step 3: farmers' in-depth interviews*

Based on the frame of reference and the conclusions of the interviews and focus group meetings with stakeholders and experts, a guideline draft is designed for the farmers' interviews that is tested with four farmers with different characteristics. As shown in Table S2 of the Supplementary Information, the final guideline (CE-OLIVE) is presented in the form of a topic list to facilitate guidance to farmers along the value chain of their productive activity in the identification of associated practices with the principles of circularity. Therefore, CE-OLIVE constitutes the main diagnostic tool with which to map the circularity of traditional Sevillian table-olive groves. Semi-structured interviews were chosen to encourage the natural expression of the farmers' perceptions and perspectives while allowing them to deviate from the initial script when emerging themes of interest for the research arose (Flick, 2023). On the other hand, since the objective was not statistical generalisation, purposive sampling was used (Creswell, 1998). Farms belonging to the different cooperatives associated with the PGI were selected in which the owner played an important role in the management and in which a predisposition to participate in the research was found. A total of 71 interviews were necessary to reach theoretical saturation (Flick, 2023). These interviews, lasting between 40 and 60 min, were carried out telephonically by the authors of the work between February and May 2023, after having made a prior appointment. An action protocol was designed in which the recommendations for good interview practices were followed (Flick, 2023; McGivern, 2006) (Table S3 in the Supplementary Information includes the datasheet).

*3.2.4. Step 4: mapping of circular practices, identification of barriers and drivers, and characterisation of the CE in traditional Sevillian table-olive groves*

The CE practices carried out in the sector are identified, based on the analysis of both the interviews and focus group meetings with stakeholders and experts and of the farmers' in-depth interviews. To this end, the transcripts of the interviews are coded and included in a database designed following the double-entry table shown in Fig. 2. Thus, from the actions reported by the interviewees, those interviews are selected that are associated with the principles of the CE and are coded based on their place in the table-olive grove value chain and the CE principle(s) to which they correspond. In this way, further to identifying the CE practices developed, it is possible to cluster them in order to characterise the circularity of the sector. Furthermore, for each of the CE practices identified, the database includes the drivers and barriers indicated by farmers, stakeholders, and experts. The coding is, first, carried out independently by each of the authors of the work and, subsequently, debated and agreed upon (McGivern, 2006). Lastly, the proportion of farmers who carry out each of the CE practices identified is determined with the objective of delimiting the most and least frequent practices and, based on their drivers and barriers, proposals to continue advancing towards the circularity of the sector are discussed.

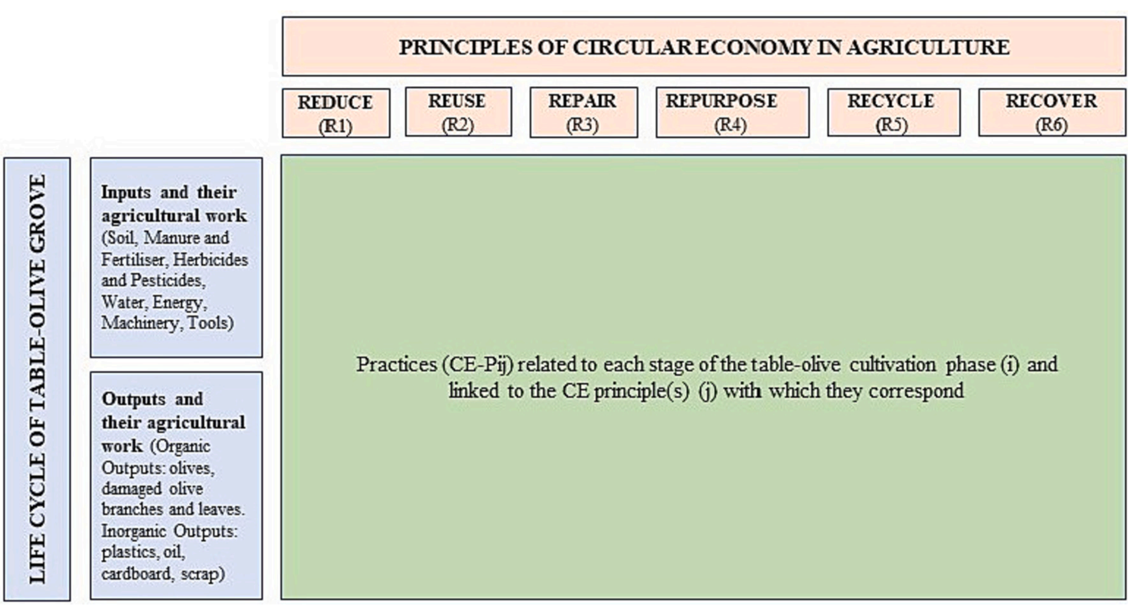


**Fig. 2.** Reference framework for the design of a diagnostic tool for the circularity of the Sevillian table-olive grove.

## 4. Results and discussion

The research carried out has enabled us to identify up to 59 circular practices carried out throughout the entire value chain of traditional Sevillian table-olive groves. Although only 42.25 % of the farmers interviewed had heard of the CE, all had carried out actions that correspond to a number of the CE principles.

The results of the work have been structured into three blocks to strengthen their discussion. The first focuses on circular practices linked to the management of inputs and related agricultural tasks. The second is oriented towards circular practices connected to the outputs generated, including the tasks associated with the collection and marketing of the main production and the management of by-products and waste. Lastly, the barriers and drivers identified for the implementation of circular practices are jointly analysed.

### *4.1. Circular practices related to input management and associated agricultural tasks*

Table 1 shows the identified circular practices that are associated with each of the inputs and their related agricultural tasks, indicating the principle(s) of the CE ($R_i$) with which they correspond and the proportion of farmers who employ them.

#### *4.1.1. Olive trees, soil, manure and fertilisers, and herbicides and pesticides*

All the agricultural holdings are olive groves of extensive traditional cultivation, which implies a density of 100 olive trees per hectare (distance between olive trees 6–10 m). This type of cultivation has been identified as a CE practice since it allows an increase in the useful life of olive trees (R2) and enables less soil erosion by involving less aggressive agronomic management (R6). Furthermore, each olive tree has a greater volume of soil to satisfy its water needs. Likewise, the lower density of olive trees allows for a more sustainable tree replacement system. Since there is distance between olive trees, the farmer can plant new trees in the middle of the rows and only when they reach 10–12 years old are the oldest ones removed (R1, R6).

The main barrier to maintaining extensive traditional crops is economic in nature since olive production is greater in intensive farms. In fact, in the province of Seville, 32.5 % of Manzanilla olive trees and 26.6 % of Gordal olive trees are already intensive (Junta de Andalucía, 2021). However, the existence of associations, such as the PGI, constitute a powerful driver for the maintenance of traditional crops by highlighting their environmental, social, and economic contributions.

In relation to the soil and its maintenance, 73.24 % of the farmers interviewed maintain adventitious wild plant cover almost all year round in order to reduce soil erosion, prevent the formation of a superficial crust, and improve the retention and availability of nutrients (López-Vicente et al., 2021; Marañón-Jiménez et al., 2022; Velasco-Muñoz et al., 2022). However, a smaller percentage of farms have also been found in which inert plant cover is utilised as a result of incorporating into the soil the fine remains of pruning and crushed cuttings of new shoots (60.56 %) or herbaceous cuttings (42.25 %). These actions correspond to the principles of circularity of Reduction (R1), Repurpose (R4), and Recover (R6) and coincide with practices identified in other studies on olive groves (Berbel and Posadillo, 2018; Kavvadias et al., 2018; Rodríguez-Lizana et al., 2023).

On the other hand, the rapid advance in technology and its adoption by cooperatives enables the extension of precision agriculture practices on the farms analysed. Of those interviewed, 46.48 % use these techniques to ascertain the exact quantities of water, nutrients, fertilisers, herbicides, and pesticides that are necessary in each area of the farm and at a specific time. In this way, precision agriculture enables the consumption of inputs to be rationalised (Marañón-Jiménez et al., 2022; Velasco-Muñoz et al., 2022), thereby contributing towards achieving eco-efficient farms and, therefore, being identified as a circular practice associated with the Reduction principle (R1).

**Table 1**
Circular practices in traditional Sevillian table-olive groves relative to inputs and their related agricultural work.

| Input | CE practice | CE principles(1) | % of farmers(2) |
|---|---|---|---|
| Olive tree | I1. Traditional/extensive cultivation (Longer useful life of the olive tree) | R1; R2 | 100 % |
| | I2. Progressive reset | R1; R6 | 100 % |
| Soil | I3. Traditional/extensive cultivation (Erosion reduction) | R1; R6 | 100 % |
| | I4. Living plant cover (Decrease erosion/Improve nutrient fixation) | R1; R6 | 73.24 % |
| | I5. Inert plant cover from chopped pruning and weed cuttings | R1; R4; R6 | 60.56 % |
| | I6. Inert plant cover from cut grass | R1; R4; R6 | 42.25 % |
| | I7. Precision agriculture (Rationalisation of nutrient contributions) | R1 | 46.48 % |
| Manure and fertiliser | I8. Use de organic fertilisers (Reduction of chemical fertiliser consumption) | R1; R4 | 42.25 % |
| | I9. Use of ashes from controlled burning of fine pruning remains and weed cuttings | R1; R4; R6 | 7.04 % |
| | I10. Incorporation of fine pruning remains and chopped weed cuttings | R1; R4; R6 | 60.56 % |
| | I11. Incorporation of the remains of cut grass into the soil | R1; R4; R6 | 42.25 % |
| | I12. Precision agriculture (Reduction of chemical fertiliser consumption) | R1 | 46.48 % |
| Herbicides and pesticides | I13. Living plant cover (Reduction of chemical herbicides/pesticides consumption) | R1; R2; R6 | 73.24 % |
| | I14. Weed consumption by livestock (Reduction of chemical herbicide consumption) | R1; R4 | 12.68 % |
| | I15. Precision agriculture (Reduction of herbicide/ pesticide consumption) | R1 | 46.48 % |
| | I16. Integrated agriculture (Reduction of chemical pesticide consumption) | R1 | 7.04 % |
| Water and irrigation | I17. Vegetation cover (Better use of rainwater) | R1; R6 | 73.24 % |
| | I18. Use of wastewater/purified water for irrigation | R1; R4; R5; R6 | 9.86 % |
| | I19. Storage, recovery, and use of stormwater | R1; R2; R6 | 12.68 % |
| | I20. Scheduled irrigation and intermittent cuts (Reduction of water consumption) | R1 | 60.56 % |
| | I21. Drip irrigation and controlled deficit irrigation (Reduction of water consumption) | R1 | 80.28 % |
| | I22. Precision agriculture (Reduction of water consumption) | R1 | 46.48 % |
| Energy | I23. Use of photovoltaic panels | R1; R6 | 30.99 % |
| | I24. Use of hybrid motors (Reduction of fossil-fuel consumption) | R1 | 7.04 % |
| | I25. Use of biofuels (Reduction of fossil-fuel consumption) | R1; R5 | 11.26 % |
| | I26. Machinery planning (energy savings) | R1 | 28.16 % |
| Machinery and transport | I27. Repair and maintenance of machinery | R1; R3 | 100 % |
| | I28. Sharing of machinery | R1; R2 | 50.70 % |

(*continued on next page*)

**Table 1** (*continued*)

| Input | CE practice | CE principles(1) | % of farmers(2) |
|---|---|---|---|
| | I29. Replacement with more efficient machinery and/or less fossil-fuel consumption | R1 | 25.35 % |
| | I30. Trailer with coated and perforated sides to prevent deterioration of olives | R1 | 100 % |
| Tools and gadgets (3) | I31. Repair and maintenance of tools | R1; R3 | 100 % |
| | I32. Sharing of some tools/ equipment (precision agriculture technology) | R1; R2 | 46.48 % |
| | I33. Purchase of tools on the local market | R1 | 67.61 % |
| | I34. Long-life products (e.g., traditional collection baskets “macaco”) | R1; R2 | 100 % |
| Containers and packaging | I35. Use of recycled and recyclable containers and packaging | R1 | 100 % |
| | I36. Reuse of part of containers and packaging | R1; R2 | 100 % |
| Auxiliary infrastructure | I37. Use of natural elements to delimit farms (Reduction in the use of synthetic resources) | R1; R4 | 100 % |

***Notes:*** (1) R1 = Reduce; R2 = Reuse; R3 = Repair; R4 = Repurpose (Reuse for other purpose); R5 = Recycle, R6 = Recover. (2) % of farmers interviewed who carry out CE practice. (3) Tools and equipment include: Ladder, Brush Cutter, Scissors, Pruners, Pruning debris shears, Compactor roller, Herbicide bar, Atomiser guns, Irrigation tubes, and traditional collection baskets.

For manure and fertilisers, in addition to the incorporation of plant cover and the use of precision agriculture techniques, other actions linked to the principles of circularity have been found: 42.25 % state that they use organic manure and have reduced the amount of chemical compounds applied (R1) and 7.04 % incorporate into the soil ashes as fertiliser from the controlled burning of remnants derived from both pruning and the clearing of new shoot cuttings (R1, R4, and R6).

In the farms studied, the use of chemical herbicides is very residual since, as indicated above, 72.24 % of the farmers maintain intrusive grass as wild plant cover and are only eliminated when they come into competition for water with the olive trees themselves (in summer). By maintaining this cover the consumption of chemical pesticides is also reduced (R1) since they contribute towards pest control. Another circular practice that enables the reduction of chemical herbicides involves grazing, that is, the introduction of livestock onto the farm to feed on the grass that competes with the olive trees (R1 and R4). This practice is not widespread (12.68 %) since the livestock in the area is largely made up of goats, which tend to eat olive branches. Lastly, there are practices that reduce the consumption of chemical pesticides through the adoption of new agricultural techniques, such as precision agriculture (46.48 %) and integrated agriculture (7.04 %).

#### *4.1.2. Water, irrigation and energy*

In relation to water and irrigation, despite the fact that the olive grove is a mainly dry crop, 80.28 % of the farms interviewed complement rainwater with various irrigation systems to obtain greater productivity. However, in the majority thereof, in line with previous literature (Maesano et al., 2021; Sánchez-Rodríguez et al., 2019), actions are carried out aimed at reducing and rationalising water consumption.

On the one hand, Repurpose (R4), Recycle (R5), and Recover (R6) practices have been identified linked to the use of rainwater (12.86 %) or wastewater once purified (9.86 %). On the other hand, these farms use consumption reduction practices (R1) such as drip irrigation and controlled deficit irrigation (80.28 %), programmed irrigation and intermittent cuts (60.56 %), or even precision agriculture systems to identify the moments and places where an additional irrigation contribution is necessary (46.48 %). In this case, the principal driver is farmers' awareness of the need to rationalise water consumption in an area with low and irregular rainfall.

The traditional cultivation method of these farms explains why they are barely mechanised and therefore present low energy consumption. Circular Economy practices linked to the use of renewable energies (R5 and R6) and energy savings (R1) are identified, with both their drivers and barriers of a technical-economic nature. Of those interviewed, 30.99 % use photovoltaic panels, which allows them to obtain electricity easily and cheaply in electrically isolated areas. However, one major barrier, is that of theft. Although residual in number, several farms were found in which hybrid engines are being introduced (7.04 %) and/or the use of biofuels (11.26 %), thereby reducing the consumption of fossil fuels.

As in the case of water, energy saving is firmly present in the consciousness of these farmers. This is illustrated in the planned use of machinery facilitated and managed by the cooperative (28.16 %), thus allowing greater efficiency regarding both machinery and fuel (R1).

#### *4.1.3. Machinery and transport, tools and appliances, containers and packaging, and auxiliary industry*

As Velasco-Muñoz et al. (2022) point out, the previous literature on the use of this type of technical input from a circular perspective in agriculture is very limited, especially regarding olive groves (Falcone et al., 2022), and hence the results of this section constitute an innovative contribution.

Both in the case of machinery and transport and in tools and appliances, the most common circular practice in the sector is that of Repair (by themselves or through experts) to extend the useful life (R1, R3), followed by shared use (R1, R2), and purchasing in local markets (R1).

All those interviewed stated that they repaired whenever they could, despite encountering technical and economic barriers such as obsolescence, high repair costs, and the impossibility of finding spare parts. Irrigation systems, pumps, and minor repairs to machinery and tools constitute the most frequent repairs on the farm itself.

Half of the farmers interviewed share machinery, mainly through the cooperative to which they belong. They also share the sensors and the rest of the technology necessary to develop precision agriculture, but it remains impossible to share all the tools due to legal limitations arising from the possibility of spreading infestations.

Purchasing in local markets is a widespread practice, especially in relation to tools and belongings (67.61 %), which allows us to reduce the carbon footprint by minimising transportation costs and promoting the local economy and culture. However, the main barriers to purchasing in local markets are that the product required is not sold in these markets and that its price is uncompetitive. The case of the “macaco” (a traditional basket used in olive harvesting) is worthy of note: this is mostly made with recycled and recyclable materials, is manufactured and marketed through local circuits, and forms part of local tradition across generations.

The purchase of machinery and transport of a more efficient nature that is less dependent on fossil fuels (R1) is beginning to be considered as an option (25.35 %) when old machinery and transport have to be replaced. Furthermore, all those interviewed use trailers with coated and perforated sides to transport the olives, thereby preventing their deterioration.

On the other hand, Circular practices linked to containers and packaging carried out by those interviewed are very frequent, either because they are made with recycled materials (R5) or because they are reused by the farmer for various tasks (R2). In the case of containers of chemical products (fertilisers, pesticides), following current legislation, they are manufactured with recycled products, and, once used, it is mandatory that they be properly managed to give them the required environmental treatment.

Lastly, in relation to auxiliary infrastructure, all farms use natural elements for their delimitation, thereby reducing the synthetic materials used on other types of farms (R1).

### 4.2. Circular practices linked to outputs and their related agricultural work: products, by-products, and waste

In Table 2, a summary is presented of the circular practices associated with the outputs generated and their related agricultural work, the CE principles to which they correspond, and the proportion of farmers who carry out each practice.

#### 4.2.1. Organic outputs: olives

The main product of these farms is the Sevillian manzanilla and gordal table olives, which are marketed through nearby cooperatives for their subsequent processing (washing, sweetening, dressing, and packaging). The majority of cooperatives carry out this transformation themselves or have associated local companies that are dedicated to this processing, which significantly reduces (R1) the environmental footprint of this phase and boosts local employment. Likewise, the fact that this type of crop is consumed in a transformed state extends the life of the product and reduces food waste (R1).

Furthermore, throughout the production process followed by those interviewed, practices have been identified that reduce the volume of damaged olives (R1), such as manual harvesting and the use of transport specially prepared for this purpose. One element that characterises traditional table-olive groves is the manual harvesting of the olives, which not only preserves their quality, but also reduces the impact generated by machinery on the soil and trees and reduces the consumption of fossil fuels. On the other hand, this type of harvesting provides socio-economic benefits in the area by providing employment and maintaining trades linked to local culture. However, the main barrier that this practice encounters is the high cost in comparison to that of their competitors, and constitutes one of the main problems farmers currently face that threaten their future viability (Sola-Guirado et al., 2018).

The olives that ultimately fail to reach the level of quality necessary for marketing as table olives are sold for oil in the same cooperatives (R1, R5). This practice is carried out by all those interviewed, and its main drivers are the economic profitability achieved along with the possibility of selling oil easily through the cooperatives to which they belong.

#### 4.2.2. Organic outputs: branches, leaves and herbaceous cuttings

Similar to the conclusions obtained in other work (Berbel and Posadillo, 2018; Kavvadias et al., 2018; Rodríguez-Lizana et al., 2023), a large part of the organic remains derived from both pruning and the clearing of new shoots and the cutting of intrusive grass, is reused by farmers for a variety of purposes either on the farm itself or by transfer for use by third parties (R1, R4, R5, and R6).

Thus, the branches and leaves obtained from pruning and the clearing of new shoots are usually divided into two parts. The thick branches are used as firewood (21.13 %), both for the farmers' own consumption and for sale or donation (R4). For the twigs and leaves, several circular practices have been found: 7.04 % carry out controlled burning to incorporate the ashes into the soil as fertilisers, 60.56 % chop them up and incorporate them into the soil as a source of nutrients, and 5.63 % donate them as livestock feed to nearby farms. These last two practices are also carried out with the cuttings from intrusive grass (42.25 % and 4.23 %, respectively).

Again, we identify membership in cooperatives as the main driver since these cooperatives provide the technical advice necessary to execute such practices. As barriers to carrying out practices that involve transfer to third parties, those interviewed cite, among others: the difficulty in contacting potentially interested parties, deficiencies in distribution channels (reverse logistics), high costs and low income obtained, and the scarcity of nearby livestock farms. These barriers

**Table 2**
Circular practices in traditional Sevillian table-olive groves related to the outputs and the associated agricultural tasks.

| Output | CE practice | CE principles(1) | % of farmers(2) |
|---|---|---|---|
| *Organic* | | | |
| Olive | O1. Manual harvesting (Reduction of environmental impact, Reduction of damaged olives) | R1 | 100 % |
| | O2. Use of specific transport to reduce damage to olives | R1 | 100 % |
| | O3. Joint marketing for table olives through local cooperatives | R1 | 100 % |
| | O4. Sale of damaged olives for oil | R1; R5 | 100 % |
| Branches and leaves (pruning remains and weed cuttings) | O5. Firewood: for own use, sale, or donation (Coarse remains) | R1; R4 | 21.13 % |
| | O6. Chopped and incorporated into the soil as a source of nutrients: inert plant cover (Fine remains) | R1; R4; R6 | 60. 56 % |
| | O7. Controlled burning for incorporation of ash into the soil as fertiliser (Fine remains) | R1; R4; R6 | 7.04 % |
| | O8. Donation/sale as livestock feed (Fine remains) | R1; R4 | 5.63 % |
| | O9. Transfer to companies for subsequent use as biomass | R1; R5 | 18.31 % |
| Herbaceous cuttings (Weed cuttings) | O10. Chopped and incorporated into the soil as a source of nutrients (inert plant cover) | R1; R4; R6 | 42.25 % |
| | O11. Donation/sale as feed for livestock | R1; R4 | 4.23 % |
| *Inorganic* | | | |
| Plastics | O12. Reduction of plastic waste through the repair and reuse of irrigation systems | R1; R2; R3 | 80.28 % |
| | O13. Reduction of plastics through the reuse of containers and packaging of non-phytosanitary products | R1; R2 | 100 % |
| | O14. Transfer to the recycling point (Plastics not derived from packaging of phytosanitary products) | R1; R5 | 18.31 % |
| | O15. Adherence to a Phytosanitary Agricultural Container Management System and transfer to the specific recycling point (Phytosanitary Containers) | R1; R5 | 100 % |
| Used oil | O16. Reduction in oil use (Greater efficiency of machinery) | R1 | 100 % |
| | O17. Transfer to a recycling centre (or workshop) for its recycling | R1; R5 | 21.13 % |
| Cardboard | O18. Transfer to a recycling centre | R1; R5 | 18.31 % |
| | O19. Incorporation into the soil as a source of nutrients | R1; R4; R6 | 2.82 % |
| Scrap metal | O20. Transfer to a recycling centre | R1; R5 | 4.23 % |
| | O21. Incorporation into the soil as a source of nutrients (Iron) | R1; R4; R6 | 1.41 % |
| | O22. Sale/donation | R1; R5 | 25.35 % |

**Notes:** (1) R1 = Reduce; R2 = Reuse; R3 = Repair; R4 = Repurpose (Reuse for another purpose); R5 = Recycle; R6 = Recover. (2) % of farmers interviewed who carry out the CE practice.

explain why, in recent years, 18.31 % of those interviewed have gone to specific plant waste management companies for their removal and subsequent conversion into biomass (R5). No farms have been found that manage these organic remains for other uses, such as the production of biomaterials, and compounds for pharmaceutical or cosmetic industries (Ben Mabrouk et al., 2023; Berbel and Posadillo, 2018; Fico et al., 2022; Lo Giudice et al., 2021).

#### 4.2.3. Inorganic outputs

The farms analysed generate a small volume of inorganic outputs, that represent, on average, between 10 and 15 % of the total waste generated. These inorganic outputs can be classified into 4 groups: plastics, used oil, cardboard, and scrap metal and others. Following the recommendations of the EU (European Commission, 2020), a large proportion of farmers claim to carry out practices to promote their Reduction (R1), their transfer to recycling points established for Recycling (R5), and, when possible, their Reuse (R2) and Repurpose (R4), either on the farm itself or by transfer to third parties (sale/donation).

In compliance with the obligations regarding waste from agricultural packaging of phytosanitary products (Law 11/97 and Royal Decree 1416/2001),). One hundred percent of those interviewed take them to a recycling centre run by *SIGFITO*. *SIGFITO,* a non-profit company of which the cooperatives are members, is responsible for the collection and appropriate environmental treatment of these containers (R1, R5). Most of the containers and packaging for other non-phytosanitary products are reused by the farmer, thereby reducing the generation of this as waste (R1, R2).

The rest of the inorganic output generated is also transferred to recycling points (R5), but in a lower proportion: 21.13 % used oil, 18.31 % cardboard, and 4.23 % scrap metal. The main barriers identified that explain these low percentages are the distance to the collection points together with the lack of awareness. Lastly, although they are residual practices (according to Maffia et al., 2020), the Reuse (R2) and Repurpose (R4) actions have been identified from inorganic output, specifically waste derived from cardboard (2.82 %) and scrap metal (1.41 %) has been incorporated as a source of nutrients into the soil. In the case of scrap metal, it is also common (25.35 %) to transfer it to third parties through sale and/or donation for recycling (R5). It is not possible to compare these results with those of previous studies since no previous literature has analysed the management of inorganic outputs on agricultural farms from a circular perspective.

### 4.3. Drivers and barriers for the adoption of circular practices in the traditional Sevillian table-olive grove

Tables 3 and 4 summarise the main drivers and barriers identified for the implementation of circular practices in traditional Sevillian table-olive groves.

#### 4.3.1. Drivers

As analysed herein, in traditional Sevillian table-olive groves, a significant number of circular practices are carried out that are driven by a set of factors that present a balance between tradition and innovation. These circular practices are sometimes the result of ancient traditions while, on other occasions, they are possible thanks to the adoption of new knowledge and technologies.

In a sector in which small farms predominate, in which it is difficult to take advantage of economies of scale and to render large investments profitable, the main driver identified (see Table 3) is associated with the Collaborative Economy, which corroborates the conclusions reached for the agricultural sector in general (Aznar-Sánchez et al., 2020; Haque et al., 2023; Perdana et al., 2023). All the farms analysed belong to a local cooperative that provides them with access to the technologies, means, and knowledge necessary to develop circular practices. These cooperatives provide technical advice, enable the shared use of technologies, machinery, and tools, facilitate access to training and awareness of farmers on this matter, and allow the joint marketing of products and by-products, and advise on waste management. They facilitate access to local suppliers and provide a direct link with the next phase of the production chain (the framing and packaging of the olives), and act as interlocutors and managers of public aid. Another example of a collaborative economy is the PGI, which plays a major role in the marketing of traditional table olives, and places value on the economic, environmental, and social contribution of the practices carried out.

In line with other research focused on the agri-food sector (Barros et al., 2020; De Boer and Van Ittersum, 2018; Ellen MacArthur Foundation (EMF), 2019, 2021), institutional support was also identified as another of the most important drivers, although in this case it was recognised more by the stakeholders and experts than by the farmers themselves. In this regard, the role of EU policies stands out, ranging from its influence on the CAP, which has been promoting agricultural

**Table 3**
Drivers for the adoption of circular practices in traditional Sevillian table-olive groves.

| Drivers | % of farmers[(1)] |
|---|---|
| **Economical** | |
| Cost savings (shared use, cheaper resources, resources of greater efficiency) | 100 % |
| Higher income (Additional income from by-products, increased sales, increased price from differentiation) | 100 % |
| **Political-Legal-Institutional** | |
| Legal obligations | 100 % |
| Systems of certification | 25.35 % |
| Institutional support (aid and incentives, others) | 60. 56 % |
| **Innovation and technology** | |
| Technology | 80.28 % |
| Knowledge | 25.35 % |
| Training | 42.25 % |
| **Social** | |
| More sustainable awareness/practice | 60. 56 % |
| Social benefits/Social cohesion | 42.25 % |
| Culture-Tradition | 100 % |
| Collaborative economy (Cooperatives, PGI, SIGFITO) [(2)] | 100 % |

***Note:*** (1) % of farmers interviewed who carry out the CE practice. (2) PGI: Protected Geographical Indication of Manzanilla and Gordal Olives from Seville; SIGFITO: a non-profit company in charge of the collection and appropriate environmental treatment of agricultural packaging including phytosanitary products, fertilisers, seeds, etc.

**Table 4**
Barriers for the adoption of circular practices in traditional Sevillian table-olive groves.

| Barriers | % of farmers[(1)] |
|---|---|
| **Economic** | |
| High initial investment | 60. 56 % |
| Higher costs (Problems in taking advantage of economies of scale) | 100 % |
| Lower profitability | 100 % |
| **Political-legal-institutional** | |
| Regulatory limitations (Lack of homogeneity, problems in certification) | 46.48 % |
| Lack of institutional support and insecurity regarding incentives and aid | 80.28 % |
| **Innovation and technology** | |
| Obsolescence | 100 % |
| Little development and/or access to technologies | 84.5 % |
| Lack of technical knowledge | 70.42 % |
| **Social** | |
| Lack of environmental-social awareness | 46.48 % |
| Culture-Tradition | 80.28 % |
| Deficiencies in collaborative economy networks | 4.23 % |
| **Other** | |
| Lack of reverse logistics | 42.25 % |

***Note:*** (1) % of farmers interviewed who carry out the CE practice.

associations and the development of sustainable practices for decades, to the recent Green Deal and CE Action Plans (European Commission, 2015, 2019, 2020). Furthermore, the new CAP 2023–27 includes a stronger link with the environmental objectives of the EU (European Commission, 2021). However, as discussed in the following section, the institutional framework is also identified by the agricultural workers as a barrier.

#### 4.3.2. Barriers

As shown in Table 4, the majority of the barriers identified are of a technical-economic nature. On the one hand, all the farmers interviewed pointed out the higher costs and/or lower profitability that some of these practices offer compared to competitors (extensive dry farming, manual harvesting, purchases in local markets) and 60.56 % pointed out the barrier of the high initial investment that is necessary to undertake for certain actions (e.g., replacement of machinery with a more efficient version). On the other hand, all of those interviewed stated that they repaired everything that could be repaired, although technical problems, such as obsolescence or lack of parts, explain why this is not always possible. In this respect, the proposal of the European Commission for a Directive on common rules promoting the repair of goods constitutes a major advance in this direction (European Commission, 2023).

Coinciding with the literature (Haque et al., 2023; Velasco-Muñoz et al., 2022), another group of barriers exist in the form of regulatory limitations and insecurity regarding public incentives. In this respect, in the table-olive grove, the lack of homogeneity regarding regulations has been highlighted, which includes quality requirements to obtain a certification that differ widely in Europe from those in the United States (one of the main destinations for processed olives). Likewise, in the focus group meetings with the stakeholders it emerged that organic farming practices were not carried out since they could not qualify for certification or aid due to the treatment that the olives have to go through to sweeten them. The lack of institutional support to establish suitable reverse-logistics channels was also noted as one of the barriers, especially in relation to waste management.

And lastly, although among the olive growers interviewed there has been widespread environmental awareness on issues related to water, energy, and organic outputs, there has been less awareness in relation to the management of inorganic waste. In fact, 46.48 % stated that, given that the amount of inorganic waste generated on their farms is small, they considered its recycling or reuse to be irrelevant for the environment.

The main limitation that this research has had to face is the lack of previous literature, which has limited the discussion of the results since it impossible, in many aspects, to compare the results obtained from the analysis of the 71 farms considered with other areas, types of cultivation, and even with other types of olive groves, such as intensive and super-intensive groves.

This is, therefore, a first exploratory study that, having mapped the circular practices in the Sevillian table-olive groves, aims to serve as a starting point and driver for future research in which in-depth study into not only the quantification of the level of circularity of the sector, but also the economic, social, and environmental impacts of circular actions, and the role of public policies at various administrative levels.

## 5. Conclusions

In summary, this research contributes to the knowledge of the state of the EC along the value chain of the Sevillian table-olive grove. A total of 59 circular practices have been identified in all phases of the life cycle of olive cultivation and for all EC principles and strategies. Bringing to light the circular practices carried out in this sector constitutes the starting point for them to be highlighted and for the product obtained to be differentiated, thereby contributing to the economic, environmental, and social sustainability of a sector that has been experiencing serious difficulties in competing on prices.

Based on the results of the research carried out, 3 groups of recommendations are proposed to address the barriers identified and to move towards circularity in the sector. Since the majority of the barriers are interconnected, each set of recommendations can contribute to overcoming several barriers.

1. Increase financial incentives so that these farmers can continue to strengthen their commitment to the circular economy, especially with those circular practices that involve higher costs. As pointed out above, the sector currently faces a serious problem for survival derived from increasing production costs together with the increase in imports with much lower prices. In this context, traditional table-olive groves cannot undertake actions that involve higher costs if they are not accompanied by aid from the various administrative levels.

2. Create a stable legislative framework by reducing uncertainty in a sector where insecurity is already present in a major part of its decisions. In this respect, three areas can be underlined in which action is considered a priority. Firstly, the harmonisation of legislation must be strengthened, as must quality standards and certifications. Although much progress has been made in the context of the European single market, cooperation must be strengthened with third countries to which table olives are exported (e.g., USA). Secondly, import control must be improved to ensure that products entering the EU meet the standards required of community producers, thereby preventing situations of unfair competition. This is especially relevant in the context of the new CAP, which plans to establish stricter mandatory requirements. And thirdly, it is necessary to continue advancing in regulations and measures to promote and facilitate the repair and reuse of machinery, tools, and equipment.

3. Strengthen financial incentives and institutional support for collaborative economy initiatives (e.g., agricultural cooperatives and regulatory councils) and reinforce both training and awareness to achieve a cohesive and empowered sector in which farmers are active protagonists of their own future.

The new CAP 2023–27, by aligning with the environmental objectives of the EU, has included part of these recommendations. Thus, for example, financial incentives for agricultural practices and approaches that respect the climate and the environment are increased (at least 25 % of direct payments and 35 % of rural development aid), the budget is increased for research and innovation (especially for bioeconomy), and cooperation between producers is reinforced. However, the key is in its implementation, and, on this occasion, the Member States play a leading role through their CPA National strategic plans. They have the opportunity and responsibility to adapt the general measures proposed by the Commission to the reality of their territories, crops, and farmers.

At the level of scientific knowledge, this research contributes towards enriching the scarce existing literature on circularity in agriculture, by proposing a methodological approach with which to explore circularity in various crops and by providing new empirical evidence. However, this work constitutes only the first step towards a sustainable circular model in agriculture and, in particular, in the cultivation of table olives. Hence, numerous lines of future research are opened. On the one hand, based on the proposed methodological approach, circularity can be explored in other types of crops (including intensive and super-intensive olive groves) and in other geographical areas, and their results can be compared. On the other hand, future research could delve into the quantification of the circularity of table-olive cultivation, both through a set of specific indicators for the different areas and through a synthetic indicator that summarises the state of the sector and enables comparisons. Likewise, more research is needed that delves into the economic, environmental, and social impacts of each of the circular practices identified in order to design a truly sustainable circular future. Lastly, linked to the above, another interesting line of future research is found in the in-depth analysis of the agricultural policies developed at various administrative levels, especially in the CAP, with the aim of assessing how the identified challenges can be incorporated so that the agriculture can move towards a sustainable economic, environmental, and social circular model.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.spc.2024.02.036.

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