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Indicators of sustainability in Mediterranean olive value chains: Building knowledge for the transition to sustainable food systems

Thesis conducted within the frame of the SNF-funded project "*Deliberative diets: Connecting producers and consumers to value the sustainability of Swiss food system scenarios*"

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MSc Agroecology

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Abstract

The olive value chain is a cornerstone of the socio-cultural, economic, and environmental landscape of the Mediterranean region. The industry is a major source of employment and income in rural communities. In recent years, the sector has undergone significant shifts towards mechanized highly intensive cropping and irrigated systems. While there is an increase in profitability, the adverse effects on the environment and the socio-economic aspects of life have been noticeable, bringing into sharp focus issues of sustainability. Numerous studies have been conducted over the last decade to assess the sustainability of varying aspects of the value chain. The challenge is that there is no established mark, critical control point or limit beyond which olive systems are deemed to be 'unsustainable' or a set of indicators that fully characterize the state of sustainability. This is largely due to the context specific nature of sustainability and ongoing debates as to its meaning. This is further hampered by high heterogeneity in the sector. To identify a set of criteria and indicators that adequately addressed sustainability, satisfying both scientific rigor and value chain actors, a two-pronged bottom up and top-down approach was used. A systematic literature review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines was conducted in the region to identify indicators used in sustainability assessments along the value chain. Second, these indicators were compared to key sustainability criteria identified by farmers in the Andalusia region of southern Spain, based on separate research results from the Deliberative Diets project, using the Photovoice method. The literature review isolated 74 papers with 46% focusing solely on the environmental dimension of sustainability. The social and economic dimensions were largely neglected with 1% and 9%, respectively. Around 91% of studies were focused on the agricultural phase of the value chain. In contrast, the Photovoice action research revealed a predominant focus on social issues at the farm level with 41% of the criteria falling in the social dimension whereas only 20% and 9% addressed environmental and economic issues. A reconciliation of the criteria and indicator data sets provided a holistic view of sustainability issues and transformative pathways in the region.

Keywords: sustainability assessment, indicators, sustainability criteria, Mediterranean, olive

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I would also like to thank my teammate Magdalena Zbinden who stuck to the task and ensured that sufficient data was collected to prepare this report and achieve the objectives of the study**.** Screening over 7,000 papers was not for the fainthearted but you made it possible**.** Thursdays were not fun without you (sorry Mike). To Moritz Egger, thank you for sharing your expertise and charting the collection of data for the case study in Spain.

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Last but not the least, to my daughter and dear friend, Victoria and Nihat, thank you for the inspiration, motivation and entertainment during the review and preparation of this report.

Abbreviations

CO_2	Carbon dioxide
FADN	Farm Accountancy Data Networks
FAO	Food and Agriculture Organization of the United Nations
GHGs	Green House Gases
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCSA	Life Cycle Sustainability Assessment
MCDA	Multi-Criteria Decision Analysis
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SAFA	Sustainability Assessment of Food and Agricultural Systems
sLCA	Social Life Cycle Assessment
WCED	World Commission on Environment and Development

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1. Introduction

1.1 Research Background and Rationale

The environmental, social and economic impacts of feeding the Swiss population are immense, and largely fall outside of Swiss borders. Olive oil production in Southern Europe (particularly in Spain) generates substantial environmental impacts and is characterized by mounting socio-economic challenges. Evaluating and implementing improvement measures and identifying transformative pathways for such high-impact value chains are two strategies to improve the sustainability of the Swiss food system. The SNF-funded project "*Deliberative diets: Connecting producers and consumers to value the sustainability of Swiss food system scenarios*" aims to address this gap by developing indicator-based MCA methods to evaluate the sustainability of different tree crop value chains (conventional-industrial to organic-agroecological). The aim is to generate useful information to support decision and policy making and policy process (Schader et al., 2020).

Oil and nut crops produced in Mediterranean regions generate a large environmental impact in the Swiss food system, due to highly intensive production systems and large water requirements in a water-scarce region (Chaudhary et al., 2016; Scherer & Pfister, 2016). Production systems vary greatly which leads to different sustainability profiles (incl. synergies and trade-offs) across different environmental and socio-economic topics (Russo et al., 2016). MCAs involving techniques from the field of MCDA can help to identify preferable options under such conditions (De Luca et al., 2018), but this requires appropriate design in terms of indicator selection, aggregation and stakeholder participation (De Luca et al., 2017). Even among experts, the choice of which topics fall under the term "sustainability" can vary widely (de Olde et al., 2017). Therefore, developing coherent indicator sets that are both scientifically grounded and resonate with the concerns of stakeholders is a key task in order to achieve meaningful improvement and transformation of such systems. However, food systems are highly complex and sustainable transformations ultimately need to be fostered at the scale of value chains and individual operators (Stirling, 2006), helping to coordinate their activities with broader system goals.

1.2 Swiss Food System and Olive Consumption

The "Mediterranean diet" has been promoted extensively as a model of healthy and sustainable food consumption, characterized by a "high intake of extra virgin (cold pressed) olive oil, vegetables including leafy green vegetables, fruits, cereals, nuts and pulses/legumes, moderate intakes of fish and other meat, dairy products and red wine, and low intakes of eggs and sweets" (Davis et al., 2015). It is associated with major health benefits, particularly reduced cardiovascular disease, and also environmental and economic benefits (Germani et al., 2014). As a result, over the past decades, table olives and olive oil have become ubiquitous products on supermarket shelves and kitchen cupboards the world over. In Switzerland, imports of Spanish olive oil rose by 10% per year between 2000 and 2019 (from 2.55 to 4.77 thousand tons based on FAOSTAT Trade Matrix data; (https://www.fao.org/faostat/en/#data/TM). A stronger trend is observed for table olives; 1.12 thousand tons in 2000 versus 3.48 thousand tons in 2019. Both products make an important contribution to Switzerland's environmental and social impacts outside its borders (that is, the sustainability impacts that are "embedded" in imports). In the case of olives, a large water footprint (due to expanding irrigation with vulnerable water resources) combined with high consumption of oily foods in Switzerland, means the product is a major contributor to water-related impacts driven by environmental scarcity and biodiversity loss (Scherer & Pfister, 2016).

1.3 The Food System Concept

Berry (2009) describes eating as "an agricultural act". A closer look at this profound statement exposes the non-linear feedback loops and ripple effect that eating habits and consumer choices have on agricultural production and land use change (Alexander et al., 2015; Gerbens-Leenes & Nonhebel, 2005). In many capitalist economies, consumption trends and patterns often dictate the quality and quantity of fresh produce and value-added products made available to the marketplace. While consumers have significant impact and upstream processes and players, the opposite is also true. The marketing strategies of major processors, distributors and retailers influence consumer behaviour, purchasing habits and trends. These causal relationships create an interconnected web of value chains, activities, resources, and people that are embedded in the wider social, economic, and environmental fabric of the societies within which they operate (Mausch et al., 2020). It is this foundation that underpins the food system concept. On such a backdrop, agri-food systems can be considered as purposeful human activity systems (Kaufmann & Hülsebusch, 2015) where various actors articulate their values, worldviews, and objectives to accomplish specific goals. These often competing human constructs make food systems inherently complex, plagued by ‘wicked’ problems (Salfer, 2023). As with all systems, food systems exhibit the abstract concept of emergence, that is, a specific property that only arises from the interaction of the parts as a whole unit and which is not present in the individual parts (Leeuwis et al., 2021). The main emergent properties of food systems are food production, culture, and sustainability. This systems approach indicates that there are many paths to ‘achieving’ sustainability and any other emergent property and provides a deeper understanding of the possible outcomes of any change or improvement efforts on parts or the whole system.

1.4 Agriculture and Food System Sustainability

Ehrenfeld (2008) describes sustainability as an “essentially contested concept”, controversial in its meaning, quantification, qualification, and the degree to which it can be attained. One of the earliest definitions of sustainability was presented by the famous 1987 Brundtland Report of World Commission on Environment and Development (WCED). The report defines sustainability (in the context of sustainable development) as the ability to “meet the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987, p.16). This definition can be considered vague as it does not provide any details about the components or aspects and the exact description or characteristics of sustainability that should emerge from an inherently complex and somewhat unstable food system.

A more pointed definition of sustainability in the food system context is provided by the Food and Agriculture Organization of the United Nations (FAO). Here, a sustainable food system is defined as one that “provides food security and nutrition in a way that does not comprise environmental, social, and economic bases for now and future generations” (FAO, 2018). This definition conveys the triple bottom line concept of sustainability commonly applied in literature, where there is balance between the environmental, social, and economic dimensions. While this approach may prevail, there are scholars who believe that it is ill conceived, and a greater weight or emphasis should be placed on environmental sustainability. Hill (1998) and Lewandowski et al. (1999) support the notion that sustainability should be defined in terms of ecosystem and community initiatives. In this scenario, environmental resources (air, water, land, and nutrients) are viewed as ‘absolute’ requirements or limiting factors to the maintenance of life on the planet. On the other hand, economics is viewed merely as an instrument to fulfill higher societal values but not essential for core survival. This approach lends to the illustration of sustainability as a 'wedding cake', in a nested hierarchy where the environmental dimension forms the base upon which social and environmental dimensions rest.

1.5 Sustainability Assessment of Food and Agriculture Systems

As systems vary, sustainability becomes a highly contextual and site-specific property bound by temporal and spatial scales. The paths and factors that are indicative of sustainability thus become different. Further, the question will often remain as to when sustainability is achieved and what are the characteristics or indicators of this 'achievement' or lack thereof. Often, this is determined by participants in the system and their own desires and views. Maffia et al. (2020) points out the "problem of expressing sustainability judgements in agriculture, since there are no established standards that sets limits beyond which agricultural production is no longer sustainable". This has made it difficult to develop univocal sustainability assessment methods, frameworks and tools.

Over the years, several sustainability assessment methods and tools have been developed based on context and the definition of sustainability accepted by stakeholders (Lampridi et al., 2019). In response, the FAO has since developed the Sustainability Assessment of Food and Agricultural Systems (SAFA), a holistic sustainability assessment framework adaptable to various contexts and expectations (FAO, 2014). SAFA includes many sustainability assessment methods such as the popular Life Cycle Analysis (LCA) approach, moving beyond product assessment to incorporate processes, management, and social components.

SAFA provides a cascading framework of guiding principles or criteria and themes under four dimensions: environmental integrity, economic resilience, social well-being, and good governance. Each thematic area is supported by an example set of quantifiable and in some instances, subjective indicators that characterize a sustainability outcome. The fact that there is no defined set of SAFA indicators, and the subjectivity or ambiguity of some indicators (e.g. 'target' based indicators and several indicators of social wellbeing) creates challenges for standardized implementation. The continued exchange of materials and information across an ever-changing, open food system and how this process evolves the definition of sustainability, also remains a limitation for operationalizing the framework, as no updates have been released following the first version of the SAFA guidelines. Nonetheless, SAFA remains applicable to a wide range of food and agriculture systems and is one of the only explicit sustainability frameworks for agriculture that has been promoted by the FAO.

1.6 Aim and Objectives of the Study

To date, a comprehensive review of the sustainability of the olive sector in the Mediterranean context using both an inductive and deductive approach in one study has not been conducted. The study is even more unique as it examines the value chain form farm to fork and provides an opportunity to inform the further development of sustainability frameworks such as SAFA as well as paths for sustainable transitions in the sector.

Overall, this study aimed to identify an indicator set that satisfies scientific rigor as well as fulfills the expectations of value chain participants. To achieve this, the following objectives were met:

- Identify and classify indicators used in literature to assess and compare the sustainability of olive and olive oil production systems and value chain configurations.
- Identify the coverage of main sustainability themes, based on the established SAFA framework, and highlight any gaps in knowledge.
- Identify key topics that are important to value chain actors in Southern Spain, and compare topics and indicators found in the literature.
- A recommended selection of indicators that are both scientifically grounded and cover the needs of producers.
- Recommend paths for sustainable transitions of olive value chains.

2. Materials and Method

2.1 Methodological Framework

The methodological approach of the study was divided into three major parts (Figure 1). In the first stage, a systematic literature review was conducted to identify and ascertain the prevalence of indicators used to assess the sustainability of olive value chains in the Mediterranean. Secondly, a case study was conducted in southern Spain to identify locally and culturally relevant sustainability criteria. In the final stage, the results were analyzed and used to develop indicator sets that best described and represented sustainability issues in the region.

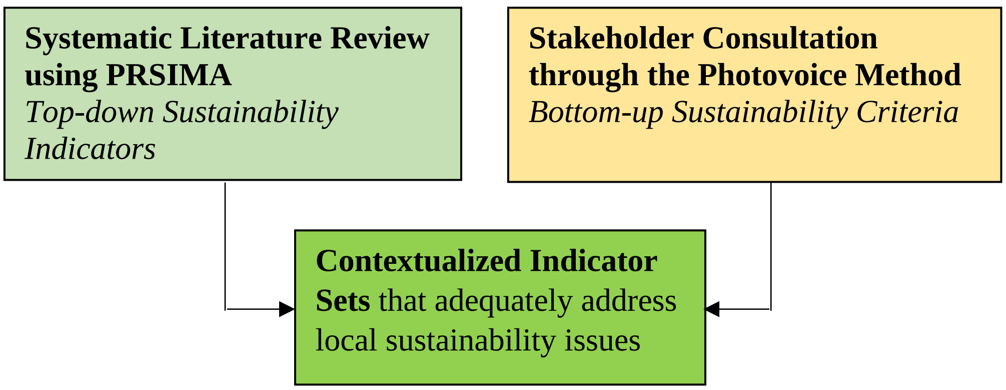


Figure 1 Methodological framework of the study

2.2 Scope of Study

2.2.1 Geographic Scope and Description

This study focused on the 23 olive and olive oil producing countries bordering the Mediterranean Sea (Figure 2). The Mediterranean region is the largest producer of olives and olive oil, accounting for approximately 93% of the worlds' output in 2018 (Maffia et al., 2020). Spain is the world's largest producer with olive production reaching 8,256,550 tons in 2021, followed by Italy (2,270,630), Turkey (1,738,680), Morrocco (1,590,504) and Portugal (1,375,750) rounding out the top five (FAOSTAT, 2023a). Greece is also regarded as a top producer, producing 3,240,063 tons in 2019 (FOASTAT, 2023b). Similarly, these countries are the largest producers of olive oil.

Figure 2 Geographic scope of the review

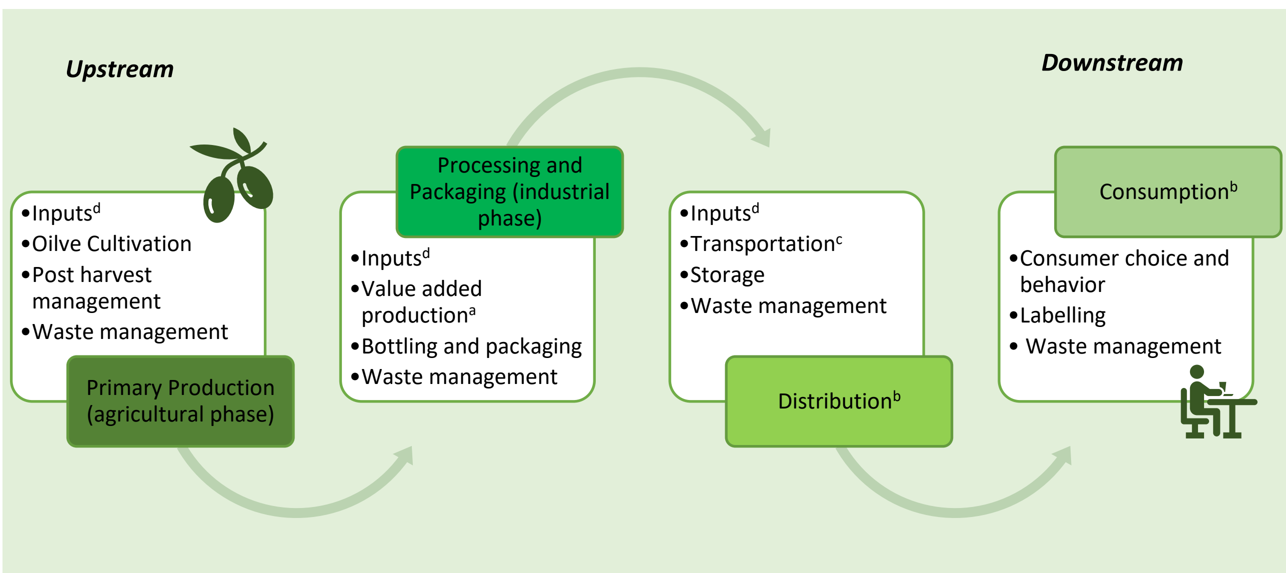
Olive production thrives in the region largely due to the favorable climatic conditions and the adaptability of the olive tree. The Mediterranean basin is characterized by mild winters and hot summers with temperatures in the range of 15-25^{o}C (59-77^{o}F) in the growing seasons (ENI CBC Med, 2023; Fotia et al., 2021). This temperature range is ideal for the phenotypic development of olive trees which typically exhibit a decrease in fruit yield at temperatures above 30^{o}C (Koubouris et al., 2009).

In recent years, the region underwent two major shifts in the management of olive production. As a direct response to climate change and more frequent and severe droughts, there has been a steady increase in the conversion of traditional rainfed olive orchards to irrigated systems to maintain yields (Mairech et al., 2021). In addition, the increased global food demand, decline of agrarian labour and other socio-economic constraints have encouraged a gradual but significant shift from traditional low-density systems (<100 trees ha^{-1}) to intensive (>200 trees ha^{-1}) and highly intensive (>800 trees ha^{-1}) cropping systems characterized by high levels of mechanization. (Abdallah et al., 2022; Fraga et al., 2020). This trend is well pronounced in olive producing countries such as Spain (Romero-Gámez et al., 2017), Sicily, Italy (Maesano et al., 2021) and Tunisia (Elfkih et al., 2022). High-density planting systems are also forcing the adoption of irrigation to supply the increased demand for water, especially in drier months.

Despite the benefits, in particular, employment creation and value added to many rural economies, these shifts have created a myriad of environmental and socio-economic challenges primarily associated with the application of higher doses of agrochemicals (fertilizers and pesticides) and increased water and energy consumption. The mid to long-term implications (natural resource depletion, emission of GHGs, biodiversity loss, soil erosion and land and water pollution) have garnered both academic interest and policy intervention in the region.

2.2.2 Value Chain Boundaries

The study covered the four main aspects of the value chain, from farm to fork: primary production, processing, distribution, and consumption (Figure 3). A review of the sustainability of waste management systems or methods was not conducted except where they were included in studies on one or more value chain segments. The research team agreed that the scope for inclusion of waste management into this study would be too broad but acknowledged that this would be a relevant topic for future investigations.



[a] Value-added production includes processed and prepacked products such as olive oil and variations of olive fruit preparations and preservation.
[b] Distribution and consumption segments originate within the Mediterranean region but may terminate in other countries.
[c] Transportation of value-added products.
[d] Includes all processes such as procurement, production, and transportation of raw material inputs to that segment as reported by the authors of the included studies.

Figure 3 Olive value chain

2.3 Data Collection

2.3.1 Systematic Literature Review

Identification of Studies

The identification of studies for the review was particularly interesting given the complex and multidimensional nature of sustainability as a concept and how it is represented and applied by different scholars. After a preliminary search of the literature, the research team developed a search code that covered key elements of the scope of the study. This included the crop name, location, value chains or systems, forms of assessment and publication period. Keywords representative of each element were searched for jointly, thus each element had at least one representation in the outcome. The search was applied using the title, abstract and keywords of potential records in Web of Science Core Collection (WoS) and Scopus search engines without restriction to publication type and journal.

In WoS, the following search code was applied using the A*dvanced Search Query Builder*:
(TS=(olive OR "olive oil" OR Olea OR "Olea europaea" OR "O. europaea"))*
AND
(TS=(Mediterranean OR Gibraltar OR Spain OR France OR Monaco OR Italy OR Malta OR Slovenia OR Croatia OR "Bosnia and Herzegovina" OR Montenegro OR Albania OR Greece OR Turkey OR Cyprus OR Syria OR Lebanon OR Palestine OR Israel OR Egypt OR Libya OR Tunisia OR Algeria OR Morocco))
AND
(TS=(agricultur OR agro* OR agri* OR crop* OR food* OR product* OR "production system*" OR "cropping system*" OR plot* OR field* OR farm* OR "value chain*" OR "supply chain*" OR "supply network*" OR "food network*"))*
AND
(TS=(assessment OR account OR indicator* OR "multi-criteria" OR "multi criteria" OR multicriteria OR performance OR comparison OR appraisal OR evaluation OR valuation OR analysis OR tool OR "impact assessment" OR "cost-benefit analysis" OR "triple bottom line" OR "life cycle" OR LCA OR "three pillars" OR sustainab*))*
AND
(PY=(1987-2023))

Using the *advanced search* option in Scopus, the following search code was applied:

TITLE-ABS-KEY(olive OR “olive oil” OR Olea OR “Olea europaea” OR “O. europaea”)*

AND

TITLE-ABS-KEY(Mediterranean OR Gibraltar OR Spain OR France OR Monaco OR Italy OR Malta OR Slovenia OR Croatia OR “Bosnia and Herzegovina” OR Montenegro OR Albania OR Greece OR Turkey OR Cyprus OR Syria OR Lebanon OR Palestine OR Israel OR Egypt OR Libya OR Tunisia OR Algeria OR Morocco)

AND

TITLE-ABS-KEY(agricultur OR agro* OR agri* OR crop* OR food* OR product* OR “production system*” OR “cropping system*” OR plot* OR field* OR farm* OR “value chain*“ OR “supply chain*” OR “supply network*” OR “food network*”)*

AND

TITLE-ABS-KEY(assessment OR account OR indicator* OR “multi-criteria” OR “multi criteria” OR multicriteria OR performance OR comparison OR appraisal OR evaluation OR valuation OR analysis OR tool OR “impact assessment” OR “cost-benefit analysis” OR “triple bottom line” OR “life cycle” OR LCA OR “three pillars” OR sustainab*)*

AND

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The WoS was accessed through a subscription of the Research Institute for Organic Agriculture (FiBL) on 13 April 2023 and resulted in 3,421 records. On 18 April 2023, Scopus was accessed through a subscription of the Swiss Federal Institute of Technology (ETH) Zürich yielding a total of 4,558 records. The datasets were exported in Research Information Systems (RIS) format from the respective search engines into Rayyan (Ouzzani et al., 2016) for screening.

Screening

Following the removal of duplicate records as a result of combining the datasets, records were screened independently by three researchers in three stages. In the first screening, records were eliminated after skimming the titles, abstracts, and keywords per the established eligibility criteria in Table 1. In the second screening, remaining records were further skimmed to identify references to sustainability or any of its dimensions. In the final screening, full texts were retrieved and reviewed. Only articles that documented sustainability assessment or sustainability performance measurements were included in the review. The inclusion/exclusion of records at each stage of the screening process required and received the agreement of at least two researchers.

Table 1 Eligibility criteria

Criteria	Inclusion Criteria	Exclusion Criteria	Notes
Publication Type and Status	Published journal articles	Books, book chapters, conference papers and reports, academic thesis, and dissertations	
Type of Research	Empirical data, including data from FADN	Literature reviews	
Publication Year	Articles published from 1987-2023	Articles published outside the inclusion period	1987 coincides with the first definition of sustainability by the Brundtland Report (WCED, 1987)
Language of Publication	English language	Languages other than English	Potential limitations to the inclusion of studies from non-English speaking countries in the geographic scope
Access to Publication	Full text available	Articles where only titles or abstracts are available or articles that cannot be located	
Geographic Scope	Sovereign countries bordering the Mediterranean Sea	Any country outside the inclusion region	
Crop/Food Type	Olives and olive oil	Any other crop	Studies with multiple crops including olives were included
Research Area	Sustainability Assessments	Any other focus	

For the purposes of this study, a sustainability assessment was defined as any process that evaluates or measures the sustainability of a system in one or more of the three dimensions (environmental, social, and economic) or that which develops context-specific indicator sets or frameworks or tools for such assessments. Additionally, the included papers must be identified by the author as having an aim to assess or reference sustainability.

The process of data collection (identification, screening, selection) followed the PRISMA 2020 protocol and was documented in the PRISMA flow chart (Figure 4).

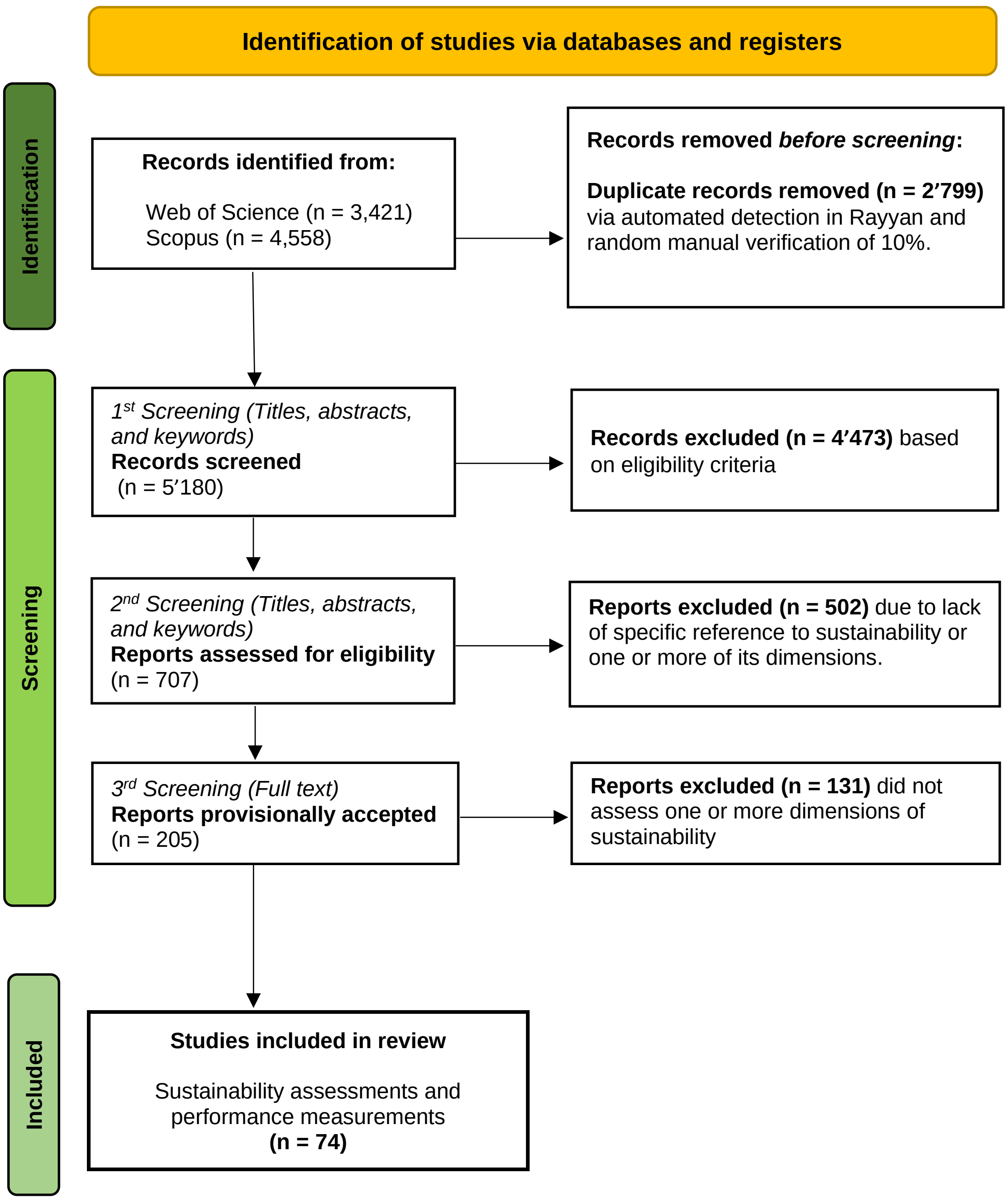


Figure 4 PRISMA flow chart showing data collection processes

Data Synthesis (extraction and analysis)

The bibliographic data, location, sustainability assessment methods, value chain aspects, sustainability dimension, corresponding indicators and system configurations detailed in the articles were extracted into a spreadsheet in Microsoft Excel (v16.0). Indicators with similar description and intent were then standardized into a single indicator name and categorized according to SAFA themes (FAO, 2014). The categorization of sustainability assessment methods was guided by Lampridi et al. (2019). Microsoft Excel was then used to analyze the data.

2.2.2 Empirical Case Study in Southern Spain

With support from our partner university, Universidad Pablo de Olavide (UPO), Sevilla, Photovoice action research processes were conducted in two structurally distinct localities in the Andalusia region of Spain. Historically, Andalusia is known as the most important olive producing region and currently accounts for roughly 80% of total Spanish olive oil production (Gómez-Limón et al., 2020; Parra-López et al. 2007).

The case studies, each with a duration of three weeks took place between 17 April to 2 June 2023. The first case group consisted of 17 almond and olive farmers (7 females and 10 males) who were all members of the cooperative Oleand Manzanilla Olive. The cooperative is located in La Puebla de Cazalla near Sevilla, and participants predominantly operated highly mechanized and intensive olive and almond production. The second group of similar composition, 17 almond and olive farmers (7 females and 10 males) was situated in the Alpujarra region, which consists of the mountainous areas below the Sierra Nevada in the hinterlands of Granada and Almeria. Due to the difficult terrain and steep slopes in this region, the process of mechanization and industrialization was only adopted to a limited extent, and the participating farmers rather engaged in agroecology practices and alternative marketing schemes for their products.

The research process involved four stages: (i) Participants were selected with support from our partner institution by distributing clear and comprehensive information about the research process, including the conditions and compensation involved. (ii) The Photovoice process started with introductions about the project, followed by the co-creation of ground rules, and initial individual or group exercises about using cameras and photographic skills. (iii) Farmers were introduced to the topic of sustainability by showcasing a video demonstrating different sustainability perspectives (https://youtu.be/xfdN6yJ9vy0) and asking them to take pictures about what sustainability meant for them as olive producers. Subsequently, images were printed, interpreted in written form by the authors, and presented as well as discussed in small groups of five to seven participants to identify key criteria of sustainability. (iv) Finally, the research team and participants worked for two days on the co-creation of guidelines on how to use the material created and organized Photo exhibitions to allow the participants to showcase their work to local authorities, families, and friends.

It must be noted that this photovoice action research and results generated were provided from an ongoing case study in the Deliberative Diets project (Moritz Egger, pers. comm.), and not conducted within the direct scope of this MSc thesis.

3. Results

3.1 Systematic Literature Review

3.1.1 Distribution of Studies

The literature review identified and selected articles published within the period 1987 to 2023. The year 1987 was particularly significant as it marked the release of one of the first definitions of sustainability (in terms of sustainable development) by the Brundtland Report (WCED,1987). It is reasonable to assume that further conceptual developments and studies around sustainability, in that framing, emerged from this time to guide sustainability assessment studies.

The results indicated that publication of sustainability assessment studies on olive and olive oil production in the Mediterranean appeared to have begun around 2007 with a gradual upward trend over the years (Figure 5). This increase is possibly linked to growing awareness of the environmental and socio-economic issues associated with food and agriculture and the acceptance and application of sustainability concepts.

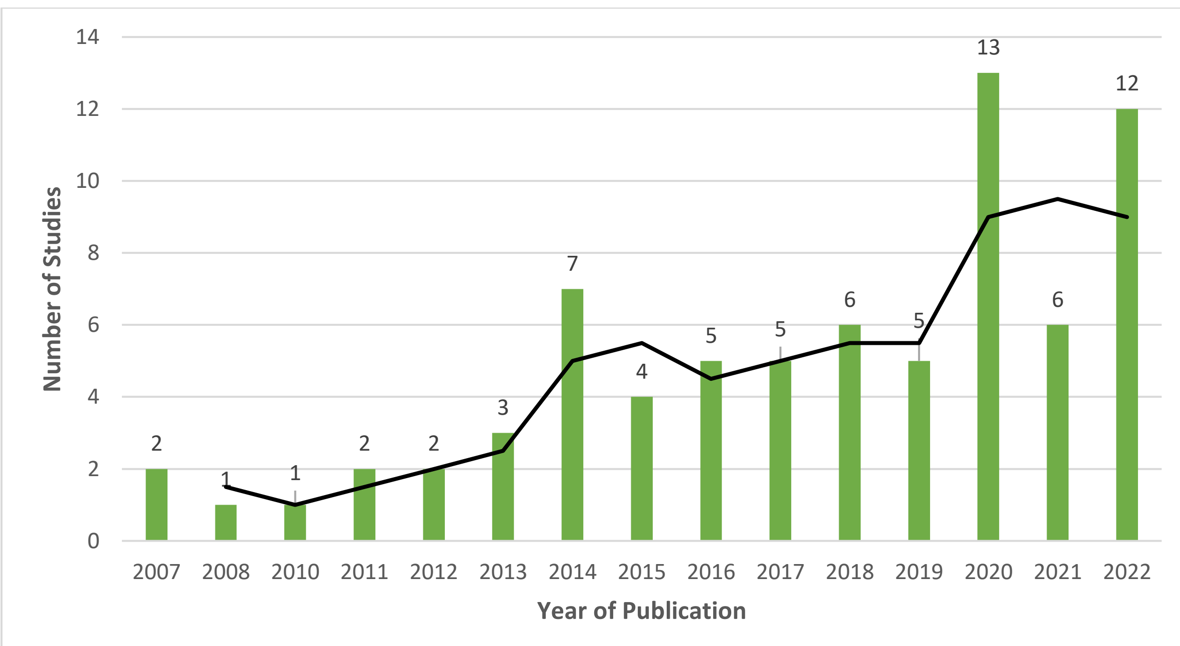
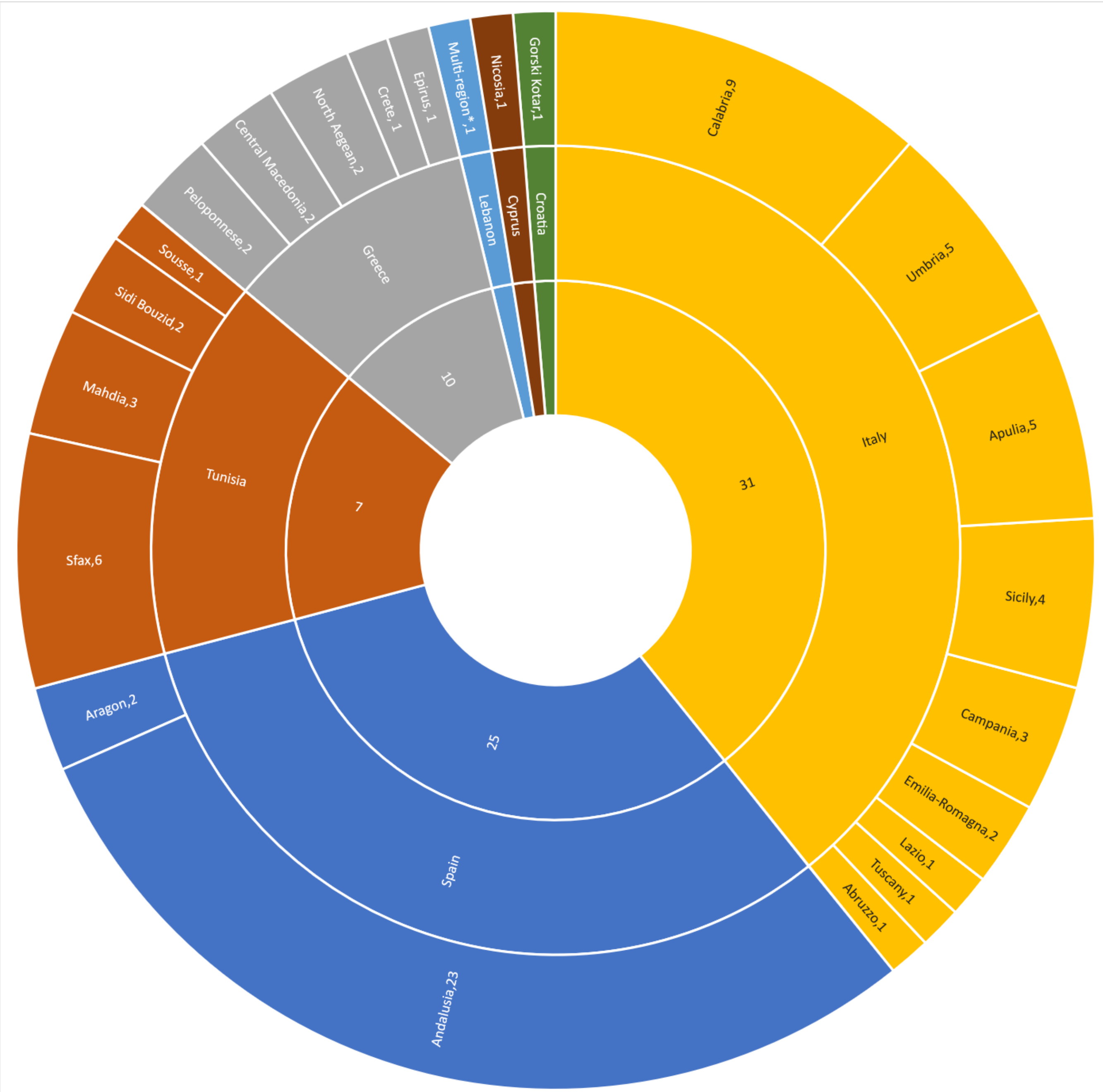


Figure 5 Distribution of studies within the search period 1987 - 2023 (*n = 74*)

Of the 74 articles identified (Appendix 1), 31 were studies conducted in Italy followed by Spain, Greece, and Tunisia with 25, 10 and 7 studies, respectively. Lebanon, Cyprus, and Croatia were least represented with one study each (Figure 6). Countries with the largest number of sustainability assessments studies conducted were also among the largest producers of olive and olive oil in the Mediterranean. Notably, only seven of the 23 countries in the scope of the study were represented in the results. This is perhaps partly due to English being an inclusion criterion.



*A single study was conducted over multiple regions in Lebanon; Beqaa, Baalbak-Hermel, Mount Lebanon, North and South Lebanon

Figure 6 Distribution of studies by country and region

The sustainability assessments conducted in the countries identified in Figure 6 were primarily concerned with the environmental dimension of sustainability. As presented in Figure 7, 46% of articles focused solely on the environmental integrity of the different value chain aspects studied whereas 9% focused on economic resilience and 1% on social welfare. About a quarter of the studies simultaneously assessed all three dimensions.

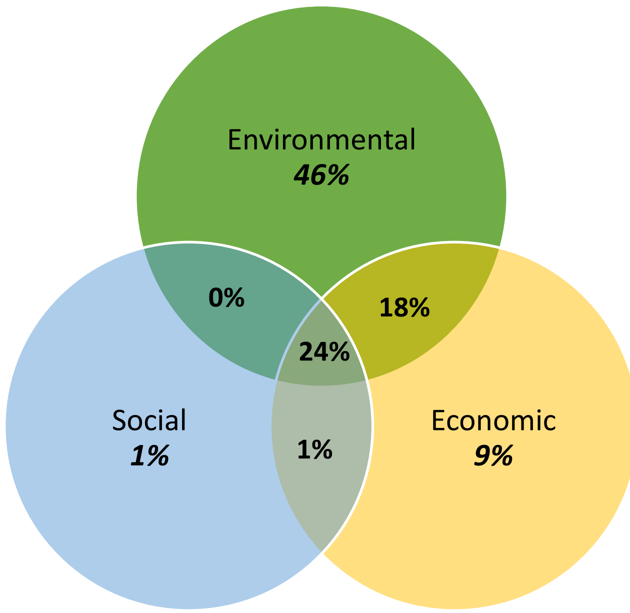


Figure 7 Distribution of studies across the dimensions of sustainability

As most of the studies focused on the environmental dimension of sustainability, it was not unusual that of the 36 assessment methods identified, LCAs (LCA, LCC, sLCA and SLCA) and other environmental assessments methods such as carbon and water footprint assessments and soil erosion analysis were commonly applied (Table 2). For every application of an assessment method across the included studies, 48% were LCAs with 36% focused on environmental performance (LCA). The frequency of the LCC and sLCA to assess the economic and social dimensions were less at 8% and 2%, respectively. The prevalence of LCAs is perhaps indicative of growing environmental issues in major producing countries as well as the method's reputation as a solid approach for assessing environmental sustainability (Fernández-Lobato et al., 2021).

Table 2 Sustainability assessment methods used across studies

Sustainability Assessment Methods and Tools	Frequency (%)
Economic Assessment	**11**
Activity Based Costing (ABC)	1
Cost Based Analysis	1
Harvesting Cost Methodology	1
Land Cost of Agrarian Sustainability (LACAS)	1
Production Cost Analysis	2
Profitability Analysis	2
Technical Productivity Analysis	2
Environmental Assessment	**12**
Agricultural Energy Assessment	1
Carbon Footprint Assessment	3
Eco-efficiency Analysis	1
Energy Returned On Energy Invested (EROI)	1
Multicriteria Environmental Accounting Framework	1
Soil Erosion Analysis	2
Water Footprint Assessment	2
Indicator Set	**4**
Context Specific Indicator Development *	2
Market (Consumer) Survey and Analysis	2
LCA	**48**
LCA	36
LCC	8
LCSA	2
sLCA	2
Multi-criteria Analysis (MCA)	**10**
Analytic Hierarchy Process (AHP)	4
Analytical Network Process (ANP)	1
Data Envelopment Analysis (DEA)	1
ELimination et Choix Tra-duisant la REalité (ELECTRE III)	1
Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	1
Principal Component Analysis (PCA)	1
Simulation	**3**
Crop Specific Decision Support Tool (CO2MPUTOLIV1.0)	1
System Dynamic Modelling (STELLA)	2
Social Assessment	**1**
Market (Consumer) Survey and Analysis	1
Sustainability Assessment Framework	**6**
Context Specific Technical Guide Development *	1
Driving Force-Pressure-State-Impact-Response (DPSIR)	1
Indicateurs de Durabilité des Exploitations Agricoles (IDEA)	1
SAFA	2
Sustainability Assessment of Farming and the Environment (SAFE)	1

Sustainability Assessment Methods and Tools	Frequency (%)
Sustainability Index	**2**
Initiative for Sustainable Productive Agriculture (INSPIA)	1
Social Profit Method	1

* Studies focused on developing a new set of indicators, framework, or tool within a specific geographical context

The MCA approach and methods were also fairly common with 10% applications across the studies. Except for one, all studies utilizing MCA methods simultaneously assessed all three dimensions of sustainability. This could possibly be due to the ability of MCA methods such as the AHP to weight and integrate multiple dimensions and indicators in an assessment using both qualitative and quantitative data (Abdallah et al, 2022).

Regarding the distribution of studies across the value chain (Figure 8), 91% of studies focused on the agricultural phase while 26% assessed processing and an even smaller number, 7%, assessed downstream segments such as distribution and consumption. Only one study, Mafia et al. (2022), assessed all segments of the value chain within scope of this review.

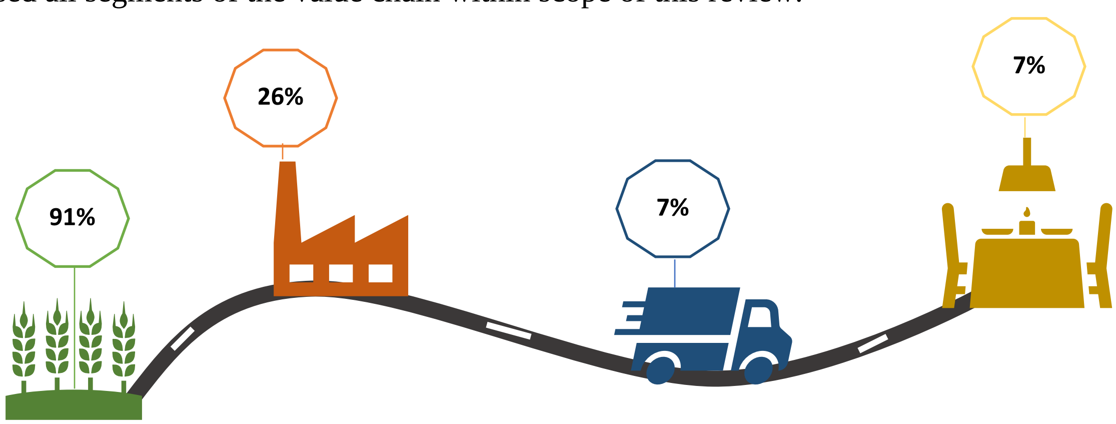


Figure 8 Distribution of studies by value chain segment

At the primary production segment of the value chain, many of the studies reviewed were comparative, assessing the sustainability of different farming system configurations (Table 3). Twenty-five (25) studies compared the sustainability of organic and conventional systems, 13 focused on rainfed versus irrigated systems and nine on varying levels intensification. The large number of studies comparing organic and conventional systems was likely due to the global push for more sustainable agricultural practices amidst the adverse environmental impacts of conventional farming practices. At the processing phase, three studies compared the sustainability of different extraction processes and one study focused on different packaging options. One study compared transportation options at the distribution phase.

Table 3 Distribution of Studies by comparative focus

Type of Comparison	Number of Papers
Organic, Integrated and Conventional Systems	25
Rainfed and Irrigated Systems	12
Intensification Levels	9
Farm Configuration, Cropping and Agricultural Practices*	7
2-Phase and 3-Phase Extraction Processes	3
Harvesting Systems	2
Circular and Linear Production Systems	2
Crop Comparison	2
Packaging	1
Distribution(transportation)	1
Soil Erosion Levels	1
Assessment Methods	1
No Specific Comparison	22

* Eight single studies grouped under a common theme

3.1.2 Indicators of Sustainability along the Value Chain

A wide range of indicators were used to assess the sustainability of the olive value chain and in many instances were selected and applied based on context. Context was the combination of spatial (geographic location) and temporal factors and the prevailing socioeconomic and environmental conditions. The selection and application of indicators in the studies were also largely influenced by stakeholder views and desires of sustainability. As a result, there was high variability in the indicators used. After standardization and categorization using SAFA guidelines, 48 indicators were found to have been applied in at least 5% of the selected studies. These indicators were summarized in Table 4.

Of the 48 indicators isolated, 31 assessed the environmental dimension. They were primarily midpoint indicators applied during LCA based assessments at the agricultural, processing and distribution phases of the value chain. Only the climate change indicators were applied up to the consumption phase, highlighting the systematic contribution of food and agricultural activities to climate change. The most frequently applied indicators were those relating to biodiversity, climate change, land use, human toxicity, freshwater ecotoxicity, acidification and water consumption, each occurring in at least 25% of studies. The prevalence of these indicators is perhaps echoing wide scale environmental challenges in the region.

As there were far less studies focusing on the economic and social dimensions of sustainability, it followed that there were fewer indicators, albeit with similar variability. The results revealed that only five social indicators occurred in at least 5% (and up to 10%) of the studies. These social indicators were applied at the agricultural and processing phases. Employment creation was solely applied at the agricultural phase, possibly an indication of the importance of olive cultivation to employment within the region.

Twelve (12) economic indicators were identified, with three indicators occurring in up to 15% of the studies. These three indicators were net present value, net income and product quality, safety and compliance. Product quality, safety, and compliance as an indicator in economic sustainability assessments was likely connected to the pricing of extra virgin olive oil and other olive products based on organoleptic quality and origin. The economic indicators were applied at both the agricultural and processing phase.

The lesser number of studies and indicators focused on the economic and social dimensions as well as downstream segments of the value chain were indicative of gaps in the literature and the need for further studies to be conducted to address the deficiency.

Table 4 Application of sustainability indicators across the value chain

Sustainability Dimension/ SAFA themes	Standardized Indicators	Typical Units		Primary Production	Processing	Distribution	Consumption
Environmental							
Biodiversity	Biodiversity	dimensionless	● (brown)	+			
Atmosphere	Climate change	kg CO_2 eq	● (brown)	+	+	+	+
	Ozone layer depletion	kg CFC-11 eq	● (dark blue)	+	+	+	
	Photochemical ozone formation	kg NMVOC eq	● (green)	+	+		
	Photochemical oxidation	kg C_2H_4 eq	● (green)	+	+	+	
	Ionizing radiation HH / E(interim)	kBq U235eq; CTUe	● (dark blue)	+	+		
	Particulate matter	kg PM2.5 eq	● (light blue)	+	+		
Water	Freshwater ecotoxicity	kg 1,4-DCB	● (red)	+	+		
	Freshwater eutrophication	kg P eq	● (light blue)	+	+		
	Water consumption	m^3/ha	● (red)	+	+		
	Marine aquatic ecotoxicity	kg 1,4-DCB	● (light blue)	+	+		
	Marine eutrophication	kg N eq	● (light blue)	+	+		
	Water resource depletion	m^3 H_2O eq	● (green)	+	+		
	Water footprint	m3/kg; m3/L	● (yellow)	+	+		
Energy and Minerals	Energy consumption	MJ	● (light blue)	+	+		
	Abiotic depletion (minerals and metals)	kg Sb eq	● (yellow)	+	+		
	Fossil resource scarcity	kg oil eq	● (yellow)	+	+		
	Energy intensity /efficiency/ratio	MJ/kg; dimensionless	● (yellow)	+	+		

Sustainability Dimension/ SAFA themes	**Standardized Indicators**	**Typical Units**		**Primary Production**	**Processing**	**Distribution**	**Consumption**
Land	Land use	m^2 *a eq	🟤	+	+		
	Terrestrial acidification	kg SO_2 eq	🟡	+	+		
	Terrestrial ecotoxicity	kg 1,4-DCB	🔵	+	+	+	
	Terrestrial eutrophication	molc N eq	🟡	+			
	Soil fertility	dimensionless	🟡	+			
	Soil protection	dimensionless	🟡	+			
	Soil erosion	t/ha/year	🟢	+	+		
	Nitrogen balance	kg N/ha	🟡	+			
	Pesticide use	kg active matter / ha/year	🟡	+			
	Pesticide risk	kg rat/ha/year	🟡	+			
Land/Water/Air	Eutrophication /eutrophication potential	kg PO_4^{3-} eq	🔵	+	+	+	
	Human toxicity (cancer/non-cancer effects)	kg 1,4 DCB; CTUh	🟤	+	+	+	
	Acidification	kg SO_2 eq	🔴	+	+	+	
Social							
Decent Livelihood	Employment creation	dimenionless; score	🟡	+			
	Level of training and education	dimensionless; score	🟡	+	+		
Human Safety and Health	Worker safety and health	dimensionless; score	🟡	+	+		
Labor Rights	Labor (type)	Score; persons/year	🟡	+	+		
Rule of Law	Community involvement	dimensionless; score	🟡	+	+		

Sustainability Dimension/ SAFA themes	Standardized Indicators	Typical Units		Primary Production	Processing	Distribution	Consumption
Economic							
Investment	Net present value	€/kg; €/ha	[green]	+	+		
	Net income	€; €/ha	[green]	+			
	Total costs	€	[yellow]	+	+		
	Gross margin	€/kg	[yellow]	+	+		
	Profitability	€; €/ha	[yellow]	+			
	Production output	kg olive/ha; L olive oil/ha; €/ha/year	[yellow]	+			
	Labor productivity	€/labour unit; kg/hr/worker	[yellow]	+	+		
	Production costs	€/ha	[yellow]	+			
	Yield (crop)	kg/ha; ton/ha	[yellow]	+			
Product Quality and Information	Product quality, safety, and compliance	dimensionless; score	[green]	+	+		
Vulnerability	Internal rate of return	%	[yellow]	+			
	Autonomy (financial and external inputs)	dimensionless; score	[yellow]	+	+		

Key: Number of studies [brown] ≥ 30% [red] ≥ 25% [dark blue] ≥ 20% [light blue] ≥ 15% [green] ≥ 10% [yellow] ≥ 5%

High Frequency Indicators

Frequently occurring standardized indicators such as biodiversity, climate change, and land use were expressed in several variations in the studies (Figure 9).

Biodiversity Indicators
- Biodiversity structures
- Index of biological diversity,
-Species richness
-Olive grove genetic diversity (olive varieties)
- Habitat/ landscape (ecosystem) diversity
- Biodiversity loss
- Buffers, natural and security areas

(a)

Climate Change Indicators
- Global warming potential
- Climate change (with/without biogenic C)
- GHG emissions/balance
- Emissions of fossil CO_2 to air
- Emissions of SO_2 to air
- Carbon footprint
- Carbon balance

(b)

Land Use Indicators
- Land use occupation
- Land use transformation
- Land use (soil organic matter with units kg C deficit)

(c)

Figure 9 Composition of frequently applied standardized sustainability indicators

Biodiversity

The frequency of biodiversity indicators in sustainability assessment studies underscores the importance of biodiversity conservation to the long-term viability and sustainable development model of the olive industry (Egea & Pérez, 2016). The "diversity of plants and animals and the genetic varieties of olive trees contribute to the economic income, minimize climatic or health risks, increase soil fertility and protect the soil from erosion" (Abdallah et al., 2018). Additionally, plant and animal diversity are integral to reducing or eliminating costly agricultural inputs such as fertilizer (Elfkih et al., 2022). Unfortunately, some of these benefits were not being fully realized in major producing regions such as Andalusia, Spain due to the adverse effects of conventional agricultural practices and intensification on species richness and beneficial insects (Gómez-Limón et al., 2020; Parra-López et al., 2007).

Biodiversity is a complex and variable indicator, evident by the difference in applications (Figure 9a) throughout studies at the farm level. Regardless of the application, its use is often defined and spread over three levels: genetic, biological and ecosystem diversity. Triviño-Tarradas et al. (2020) applied the term 'biodiversity structures' as an indicator of functional agrobiodiversity- a reflection of the three levels of biodiversity. In the same study, the establishment of security areas and buffers (margins) was an indicator of biodiversity as they enhance species richness of pollinators and natural pests. The presence (or absence) and abundance of certain species are indicative of the environmental impacts of management practices and changes in agricultural systems. Sousa et al. (2020) calculated the richness of butterflies (*Lepidoptera Papilionoidea*) in olive groves as a bioindicator of the quality of the agrarian system in use. Butterflies are highly sensitive to environmental stressors such as pollution and climate change (Chowdhury et al., 2023). Lopez-Pintor et al. (2108) determined biodiversity at the landscape scale using an interspersion and juxtaposition index as a spatial diversity index. With GIS software, the study calculated the relative abundance of edges between pairs of land cover types, which gave an indication of the level of species interchange in the area. Biodiversity was also used as a composite indicator (index of biological diversity) accounting for several weighted agricultural practices including the maintenance and control of soil cover, presence of leftover olive fruit on trees post-harvest and piled branches after pruning as well as the use of subsurface drip irrigation, without fertigation. (Beltrán-Esteve et al., 2013; Gómez-Limón et al. 2020). These practices protect and provide food and habitat for animal and plant species. Notably, studies using biodiversity indicators were mostly conducted in Andalusia, Spain and to a lesser extent Tunisia.

Climate Change

Climate change indicators (Figure 9b) were the most frequently occurring indicator across the studies. These indicators were commonly used in LCA based assessments as well as other sustainability assessment studies with an environmental performance component such as Triviño-Tarradas et al. (2020) and Tzouramani et al. (2020). The carbon footprint indicator aggregates the direct and indirect emissions (and removals) of GHGs from processes and products along the value chain. It is often expressed as kg CO_2 $ha^{-1}y^{-1}$, tCO2eq ha^{-1} at the farm phase and kg CO_2 / kg olive oil at the industrial phase (Fernández-Lobato et al., 2021; Lopez-Bellido et al., 2016; Proietti et al., 2014). Emissions typically considered were carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), nitrogen oxides (NO_x), and sulfur dioxide (SO_2). Non-CO_2 GHGs were converted into one unified indicator of CO_2 equivalents (same amount of CO_2 that would create an equivalent amount of warming) using standard and established characterization factors to derive its global warming potential over a specified time, expressed as kg CO_2 eq.

Climate change indicators were applied in studies that spanned the entire value chain within scope of this study. This indicator was prevalent in almost all activities at the farm level, confirming the well-established contribution of agricultural activities on climate change and the need for mitigation strategies to lessen those impacts. At the agricultural phase, Fotia et al. (2021), Gkisakis et al. (2020) and Maesano et al. (2021) calculated emissions from farming inputs (including processes and activities used to extract, generate, and transport those inputs to the farm) and farming activities. Typical farming inputs assessed for this indicator included seeds, agrochemicals (fertilizer, pesticides), energy (fuels, gasoline, diesel, and lubricants) and agricultural equipment. Activities on the farm that formed part of the calculation were related to energy consumption (electricity), soil management, pest control, irrigation, harvesting, pruning and other post-harvest storage and transportation processes.

Fernández-Lobato et al. (2020, 2022), and Restuccia et al. (2022) calculated emissions during the industrial phase from inputs (olives, water, fuel, energy, and equipment) and the energy consumed by processing activities such as washing, crushing, gramoling and extraction. Salomone and Ioppolo (2011) included the emissions from processing waste and Manzini et al. (2014) assessed the global warming potential of international distribution (transportation by containers) of olive oil originating in Italy. Navarro et al. (2018) made a distinction between the global warming potential of different packaging solutions (glass, tin, and PET) in olive oil production and examined the emission of GHGs at the consumption level for the use of non-refillable containers.

Land Use

Land use indicators (Figure 9c) were frequently used in farm level and to a lesser extent industrial phase LCAs in Spain, Italy, Greece and Tunisia. The indicator essentially provides information on the amount of land used over a given period (agricultural land occupation) and how (land use transformation). A third application of the indicator was the quantification of soil organic matter loss due to both land use occupation and transformation, reported as kg C deficit (Abdallah et al., 2022; Fernández-Lobato et al. 2020, 2021, 2022; Guarino et al., 2019; Romero-Gámez et al., 2017; Russo et al., 2016;).

3.2 Results of Case Study in Southern Spain

3.2.1 Distribution of Sustainability Criteria

A total of 77 sustainability criteria were identified by farmers across both study sites. In the Alpujarra region, 37 were presented by the participants. The criteria were distributed across each sustainability dimension with a predominant focus (59%) on the social aspect of the farming system. Environmental and economic criteria followed at 19% and 3% respectively. Similar results were obtained in Puebla, with the larger percentage of the 40 criteria presented focusing on social wellbeing (38%). The environmental dimension followed closely at 30% and economic at only 12%.

Of the 77 criteria identified, 54 were common across both regions (Appendix 2). As with inter region criteria, a majority of the shared criteria were largely focused on social wellbeing (41%) and less on environmental (20%) and economic issues (9%). Figure 10 summarizes the distribution of these criteria across all three dimensions (Figure 10).

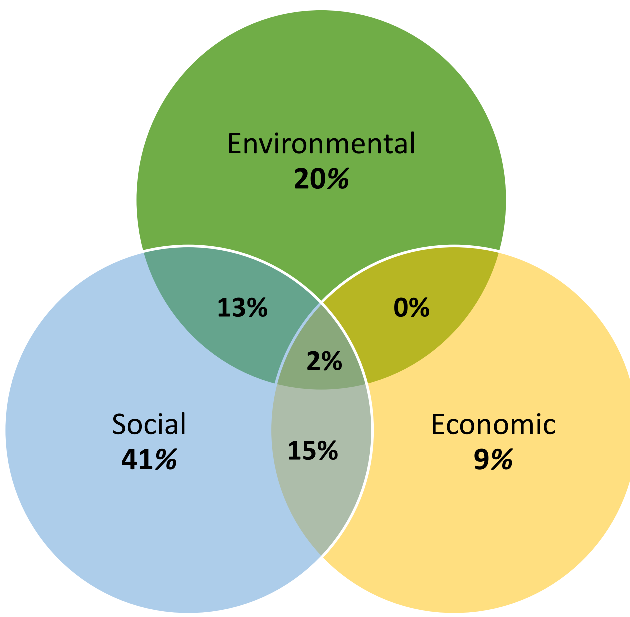


Figure 10 Distribution of sustainability criteria in Alpujarra and Puebla regions of Spain

3.2.2 Contextualized Indicator Set (Reconciliation of Literature Review and Case Study)

An evaluation of the results from the literature review and case study revealed common sustainability themes and trends in the Mediterranean region as it relates to olive production. Reconciling the results of both desk and field investigations, a specific set of highly inclusive and contextualized criteria and relevant indicators emerged (Table 5). This could serve as a comprehensive assessment guide or framework that adequality addresses sustainability issues at the agricultural phase of the value chain.

Table 5 Reconciliation of case study criteria with indicators in literature at the farming system level

SAFA Themes	Case Study Criteria	Literature Review Indicators
Environmental Dimension		
Biodiversity	Adequate crop diversity Coexistence with nature Integration of crops and livestock Preservation and collection of wild species Protection of beneficial organisms Protection of autochthonous seed Protection of biodiversity Protection of local varieties	Biodiversity structures Index of biological diversity Species richness Olive grove genetic diversity (olive varieties) Habitat/ landscape (ecosystem) diversity Biodiversity loss Buffers, natural and security areas
Water	Good water protection management	Water consumption
Land	Adequate soil protection	Soil protection Soil erosion
	Organic fertilization practices	Soil fertility Nitrogen balance
Land/Air/Water	Reduction of agrochemicals Responsible use of phytosanitary products Caring for crop necessities Improved recycling practices	Eutrophication Acidification Human toxicity Pesticide use Pesticide risk
	Closing nutrient cycles	Nitrogen balance

SAFA Themes	Case Study Criteria	Literature Review Indicators
Energy and Minerals	Increased use of renewable energy	Energy consumption Abiotic depletion (minerals and metals) Fossil resource scarcity Energy intensity /efficiency/ratio
Animal Wellbeing*	Animal wellbeing	No indicator identified
Social Dimension		
Decent Livelihood	Sufficient labor availability	Employment creation
	Maintenance of a decent quality of life Reconciliation of family life in the countryside Fair division of domestic tasks Increase healthy diets Maintenance of self sufficiency Belonging and identity Companionship and protection (through domestic animals)	Percentage of working time devoted to farming* Quality of life* Social diversification index* Satisfaction with quality of life*
	Environmental education for children Generation of knowledge Knowledge transmission	Level of training and education
Participation*	Organization in cooperative Networks of trust Care and cooperation in rural areas Mutual support practices	Membership of agricultural cooperatives* Responsible communication*
Holistic Management*	Insurance of generational succession Effort and dedication	Intergenerational succession to farming*
Labor Rights	Respectful treatment of migrant workers Compliance with labor rights	Fair employees' treatment* Respect for human rights throughout the supply chain* Labor type

SAFA Themes	Case Study Criteria	Literature Review Indicators
Human Safety and Health	Adequate mechanization	Worker safety and health
Equity*	Recognition of female farmers Improved gender equity	Gender equality* Worker equity and rights* Worker equity of treatment *
Cultural Diversity*	Conservation of knowledge about natural medicine Preservation of traditional agricultural practices Production of artisanal products	Agronomic traditions* Compatibility with local socio-cultural values* Heritage* Index of protection of olive heritage*
Rule of Law	Availability of public celebrations Social recognition for farmwork Availability of public services Adaptation to change rural areas Positive change agricultural policy Rural liberty and autonomy	Services, multi-activities* Community involvement Social justice in rural areas* Social implication*
Fair Trading Practices*	Close producer consumer relations Fair prices	Relationships with all the involved stakeholders, with particular reference to the choice of suppliers and distributors* Short food supply chain* Supplier absence of corruption*
Economic Dimension		
Product Quality and Information	Increased traceability of agricultural products	Product quality, safety, and compliance Traceability Certification and labelling*
Holistic Management*	Good accounting practices	Financial performance*
Investment	Adequate profitability	Profitability

*Themes and indicators that were not presented in Table 4 having occurred in less than 5% of papers.

4. Discussion

4.1 Environmental Sustainability

The environmental dimension was assessed in 88% of studies included in the review. The number of studies and prevalence of indicators associated with biodiversity, climate change, land use, water and energy are indicative of the prevailing environmental issues and concerns in the region. The results further indicated a heavy concentration of studies on the agricultural and industrial phase of the value chain. These results were not surprising as it had long been globally established in the scientific community that agriculture exerts negative pressures on the environment through land and water overuse, biodiversity loss, erosion among others (Ben Abdallah et al.,2018). In 2016, around 31% of global emissions were attributed to agri-food systems (FAO, n.d.). Agriculture also accounts for more than 70% of global water withdrawals (FAO, 2020). Extensive and intensive olive production mirrors that reality. As previously indicated, olive cultivation and extraction processes consume large amounts of energy and water (Vicario-Modroño et al., 2022). Further, agricultural management practices, especially those associated with highly intensive systems, generate considerable amounts of waste and emissions to land, air and water (Avraamides & Fatta, 2020; Jellali, et al., 2021).

During the action research phase of the study, 25% of criteria were attributed to the environmental dimension. Despite being of a lesser focus to farmers, the environmental criteria aligned well to the themes and associated indicators identified in literature such as biodiversity, land and water. Biodiversity appeared to be a central sustainability theme for farmers with a keen focus on the preservation of cultural heritage through the collection and protection of native seeds, olive varieties and wild species. Farmers expressed a desire to coexist with nature, integrate crops with livestock and protect biodiversity. Biodiversity was also a common theme in environmentally based studies, occurring in over 30% of sustainability assessments. To test fulfillment of this criteria, sufficient biodiversity-based indicators were isolated in literature. While the case study was conducted in Spain, the preservation of local varieties is a matter of law in countries such as Italy (Lombardo et al., 2022). Generally, agricultural biodiversity is protected by the European Directive 2008/62/EC applicable in 27 member states including the olive producing Mediterranean countries: Greece, Spain, France, Italy and Cyprus. Land-based criteria involved adequate soil protection and organic fertilization practices. Regarding the former criteria, corresponding indicators were soil protection and soil erosion. Soil fertility and nitrogen balance were the indicators applicable to organic fertilization. Farmers also recognized the importance of water resource protection management, that is, the fair allocation of water resources and conservation. This was a prevalent theme and indicator in literature primarily accounted for by the water consumption indicator, occurring in around 25% of studies. Farmers were keen on environmental protection through the reduction of agrochemicals and responsible use of phytosanitary products to minimize emissions to air and land and water pollution. Indicators (eutrophication, human toxicity, acidification, pesticide use and pesticide risk) for the assessment of these criteria were prevalent in literature. Overall, farmers addressed the major issues associated with environmental sustainability identified not just in Spain but the wider Mediterranean.

4.2 Social Sustainability

Social sustainability was assessed in only 26% of articles, providing minimal information about the social wellbeing and view of actors within the value chain. Only five indicators were prevalent in at least 5-10% of the studies: employment creation, level of training and education, worker safety and health, type of labor and community involvement. These indicators were relevant at the agricultural and processing phases. It is worthwhile to note that indicators associated with social sustainability were variable in literature and somewhat challenging to decode and standardized compared to environmental and economic indicators.

Nonetheless, the five highlighted indicators provide an outlook to the most significant social sustainability issues in the region. Tzouramani et al. (2020), through stakeholder consultation, describes and confirms the importance of training, employment creation, job quality and community involvement in the sustainability of Greek agricultural systems. Triviño-Tarradas et al. (2020) using the INSPIA model in Southern Spain highlighted the importance of training for farmers and links higher levels of training to better application of management and technical skills.

While socio-cultural themes and indicators were rarely represented in literature compared to other dimensions, they formed the majority (71%) of sustainability criteria posited by farmers. Areas (themes) of similarity between literature and the case study were decent livelihood, labor rights, and rule of law. The decent livelihood theme was noticeably more developed by the farmers, dedicating several criteria to the maintenance of a good quality of life where there is balance between personal and family life with production, diet, belonging and self-sufficiency. These areas need further indicator development. Themes and indicators that were not prevalent in literature, but which stood out in the case study were those associated with participation, cultural diversity, and equity. Generally, there was good correlation between sustainability criteria in the case study and indicators in literature.

4.3 Economic Sustainability

The economic dimension was assessed in 52% of studies, mostly in conjunction with other dimensions. The economic and environmental pillars were assessed together in 18% of studies while 24% of studies simultaneously assessed the three dimensions. Only 9% of studies solely addressed the economic sustainability of the value chain. Several economic indicators emerged with net present value, net income and product quality, safety and compliance occurring in 10-15% of studies. Arulnathan et al. (2023) also found net present value to be one of the most common indicators used to assess economic sustainability in LCC literature. De Luca et al. (2017) describes the indicator as a means to determine the viability of olive growing system, that is "investment feasibility and represents the sum of discounted future cashflows incurred during the whole life cycle." Indicators associated with product quality, safety and compliance are critical as higher product quality that complies with regulations and public or private certification schemes such as organic certifications and protected designations of origin (PDO) fetch higher prices and lessen loss and liability to the producers.

In the case study, farmers raised three economic sustainability criteria: increased traceability of agricultural products, good accounting practices and adequate profitability. Adequate profitability was expressed as having increased revenues while minimizing costs. The aim is a positive net income. The exploration of cost cutting measures and revenue generation were areas that could be developed as a transformative pathway to a more sustainable position. A recommendation in this regard is diversification of the agri-food system. Farmers could improve revenue through the production and sale of other fresh produce and livestock (integrated in olive cultivation) and value-added products. As it relates to cost cutting, organic management systems present an opportunity.

4.4 Downstream Value Chain Segments

About 7% of studies assessed sustainability at the distribution and consumption phases of the value chain – considerably less than the 91% at the agricultural phase. In addition, the social and economic dimensions were largely unexplored. However, some focus was given to the environmental sustainability of these segments, placing further emphasis on the importance of environmental integrity in olive production. At the distribution phase, seven indicators emerged in at least 5% of the studies: climate change, ozone layer depletion, photochemical oxidation, terrestrial ecotoxicity, eutrophication, human toxicity, acidification. These indicators were midpoint indicators derived from the environmental footprint of packaging materials. The climate change indicator was the only indicator applied at all phases of the value chain, highlighting the extent to which food and agriculture activities - from farm to fork - contribute to GHG emissions.

As photovoice action research was conducted with just farmers, an extension of this activity is required with processors, distributors, and consumers to develop a more robust portfolio of sustainability criteria and corresponding indicators for the sector and for the revision of SAFA guidelines.

4.5 Transformative Pathways to Sustainability

The study was successful in identifying key areas of focus both in literature and case study. Of paramount importance is mitigating the impacts of intensification and highly mechanized and conventional styled agriculture on environmental integrity. The literature review highlighted sustainability assessments that were predominantly comparative of organic, integrated, and conventional farming systems. Undoubtedly, intensified organic systems present a more sustainable alternative to conventional intensive systems, if the right managerial competencies are applied (Egea & Perez, 2016; Elfkih et al, 2022; Jellali et al., 2021). Organic systems provide an opportunity to reduce inputs associated with negative externalities such as agrochemicals and their impact on the environment as well as reduced depletion of natural resources. Romero-Gamez et al. (2017) in a comparative study in Andalusia, Spain points out the reduced impact of organic practices on the environment but highlighted the need for improved productivity. The authors found that an integrated (mix of organic and conventional) system is best from both an economic and environmental perspective.

The benefits of organic systems also extend into the social and economic dimensions. Iofrida et al. (2020) found that organic systems in Italy were more economically feasible on the basis that they attract higher public subsidies and market prices for olive oil. This competitive advantage of organic products offsets higher production costs. The study also found that workers benefitted from better working conditions associated with reduced exposure to synthetic agrochemicals. In the case study, the reduction of agrochemicals was a criterion highlighted by farmers showing an inclination towards more organic practices. Sousa et al. (2020b) indicated a correlation with age and level of education with successful operation of organic farms in southern Spain. Younger, more educated farmers were inclined towards operating organic systems with a greater sense of environmental stewardship. It leads to the notion that capacity building interventions (training) would encourage a more rapid conversion from conventional to organic systems in the region.

Another transformative pathway less explored in literature was that of circular economy. Only two studies comparatively assessed the sustainability of linear and circular production systems. Linear systems follow a make, use and dispose approach whereas a circular economy is characterized by reuse and recycling of waste as raw material inputs streams. Essentially, materials have a longer residence time in the system, reducing waste and the need for raw material extraction - overall, reducing the negative environmental footprints of the production system. In the case of olive production, waste streams from pruning and harvesting may be used as fertilizer and pomace and pits as sources of biofuel production and fertilizer. Falcone at al. (2020) indicated in the evaluation of olive production at the agricultural and processing phase that "the implementation of circular strategies represents one of the possible trajectories to guide the ecological transition, and the proposed methodological framework can support the decisions of both producers and public decision-makers towards more sustainable and efficient production patterns." A similar argument was shared by Ncube et al. (2022) with the application of a circular approach to the olive sector with a view to improving environmental sustainability. Adopting a circular economy approach can also have a positive impact on economic sustainability by reducing costs associated with inputs such as fertilizer and soil amendments. The isolation of comparative papers in literature presents an opportunity for meta-analysis to be conducted so that the superiority of organic and circular systems could be supported with quantitative data.

5.0 Conclusion

Sustainability assessments of the olive value chain in the region were predominantly focused on environmental integrity at the agricultural phase. Studies highlighted both the reliance of intensive olive cultivation on the extraction of natural resources such as water, energy, and biodiversity – limiting factors to crop yields as well as the negative externalities imposed on the same environment (and the cascading socio-economic effects). This supports the nested hierarchy view of sustainability where the environmental pillar forms the base necessary for the very existence of social and economic dimensions. The literature review and case study confirmed the multidimensional and complex nature of sustainability and proved the long-established notion that any definition of sustainability or perception of its 'achievement' must be supported by the views and desires of stakeholders within the systems in question. The pathways for transformation of olive value chains to more sustainable configurations seem to lie within organic and circular economy approaches and management practices to improve environmental stewardship – the foundation of production. Successful transition will require the partnership of Swiss consumers who should opt to purchase olive products with verified organic and sustainability certifications; exerting positive transformative forces on the value chain segments outside its borders.

The findings of this study must be viewed within the frame of several limitations associated with the methodology. Sustainability, as previously indicated, is a complex and multidimensional subject and while due care was taken to select keywords and search codes, apply sound screening techniques and develop suitable selection criteria, it is possible that a few studies germane to the scope of the research may not have been included. This is primarily due to the myriad of wording and presentation of sustainability and sustainability concepts in literature which may have evaded the limits of the review. Secondly, the sheer number of indicators extracted from literature and the high variability necessitated standardization to the extent possible. Thus, the originality of some indicators may have been adjusted, though due care was taken to preserve its original meaning and description. This was mostly applicable to social indicators. As it relates to the case study, subjectivity remains an issue as with all qualitative research that are dependent on the opinions of individuals especially on such a complex matter. Despite these limitations, the results remain valid and provide useful information for further transformation of the olive value chain to a more sustainable position.

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7. Appendices

Appendix 1: List of studies included in review (n=74)

No.	Reference (Authors, Year)	Title	Country	Sustainability Dimension
1	**Aguilera et al. (2014)**	Greenhouse gas emissions from conventional and organic cropping systems in Spain. II. Fruit tree orchards	Spain	EI
2	**Avraamides & Fatta (2007)**	Resource consumption and emissions from olive oil production: a life cycle inventory case study in Cyprus	Cyprus	EI
3	**Beltran-Esteve et al. (2013)**	A metafrontier directional distance function approach to assessing eco-efficiency	Spain	EI, ER
4	**Ben Abdallah et al. (2018)**	A sustainability comparative assessment of Tunisian organic and conventional olive growing systems based on the AHP methodology	Tunisia	EI, SW, ER
5	**Ben Abdallah et al. (2020)**	Evaluation of the environmental sustainability in the olive growing systems in Tunisia	Tunisia	EI
6	**Ben Abdallah et al. (2022)**	Sustainability assessment of traditional, intensive and highly-intensive olive growing systems in Tunisia by integrating Life Cycle and Multicriteria Decision Analyses	Tunisia	EI, SW, ER
7	**Bernardi et al. (2020)**	Harvesting system sustainability in Mediterranean olive cultivation: Other principal cultivar	Italy	EI, ER
8	**Bernardi et al. (2018)**	Harvesting system sustainability in Mediterranean olive cultivation	Italy	EI, ER
9	**Cappelletti et al. (2010)**	Life Cycle Assessment (LCA) of Spanish-style green table olives	Italy	EI
10	**Cardone et al. (2021)**	Assessment of the economic sustainability of an organic olive oil farm in the Puglia region (Italy) under the voluntary regional quality scheme	Italy	ER
11	**De Luca et al. (2017)**	Evaluation of sustainable innovations in olive growing systems: a Life Cycle Sustainability Assessment case study in southern Italy	Italy	EI, SW, ER
12	**Egea & Perez (2016)**	Sustainability and multifunctionality of protected designations of origin of olive oil in Spain	Spain	EI, SW, ER

No.	Reference (Authors, Year)	Title	Country	Sustainability Dimension
13	**Elfkih et al. (2012)**	Are Tunisian organic olive growing farms sustainable? An adapted IDEA approach analysis	Tunisia	EI, SW, ER
14	**Elfkih et al. (2022)**	Organic olive growing farms' sustainability assessment: the Tunisian case	Tunisia	EI, SW, ER
15	**Expósito & Berbel (2017)**	Sustainability implications of deficit Irrigation in a mature water economy: A case study in southern Spain	Spain	EI
16	**Falcone et al. (2022)**	Life cycle and circularity metrics to measure the sustainability of closed-loop agri-food pathways	Italy	EI, ER
17	**Fernández-Lobato et al. (2020)**	Life cycle assessment of the Spanish virgin olive oil production: A case study for Andalusian region	Spain	EI
18	**Fernández-Lobato et al. (2021)**	Life cycle assessment, C footprint and carbon balance of virgin olive oils production from traditional and intensive olive groves in southern Spain	Spain	EI
19	**Fernández-Lobato et al. (2022)**	Life cycle assessment of the most representative virgin olive oil production systems in Tunisia	Tunisia	EI
20	**Fotia et al. (2021)**	LCA-based environmental performance of olive cultivation in northwestern Greece: From rainfed to irrigated through conventional and smart crop management practices	Greece	EI
21	**Giourga et al. (2008)**	Assessing the sustainability factors of traditional olive groves on Lesvos Island, Greece (Sustainability and traditional cultivation)	Greece	EI, SW, ER
22	**Gkisakis et al. (2020)**	Developing a decision support tool for evaluating the environmental performance of olive production in terms of energy use and greenhouse gas emissions	Greece	EI
23	**Gomez-Limon et al. (2012)**	Eco-efficiency assessment of olive farms in Andalusia	Spain	EI, SW, ER
24	**Gómez-Limon et al. (2020)**	Building a composite indicator to measure environmental sustainability using alternative weighting methods	Spain	EI

No.	Reference (Authors, Year)	Title	Country	Sustainability Dimension
25	**Guarino et al. (2019)**	Life Cycle Assessment of olive oil: a case study in Southern Italy	Italy	EI
26	**Guzman et al. (2011)**	The land cost of agrarian sustainability. An assessment	Spain	EI, ER
27	**Iofrida et al. (2020)**	The socio-economic impacts of organic and conventional olive growing in Italy	Italy	SW, ER
28	**Iraldo et al. (2013)**	An application of Life Cycle Assessment (LCA) as a green marketing tool for agricultural products: the case of extra-virgin olive oil in Val di Cornia, Italy	Italy	EI
29	**Jellali et al. (2021)**	Sustainable configuration of the Tunisian olive oil supply chain using a fuzzy TOPSIS-based approach	Tunisia	EI, SW, ER
30	**Lehmann et al. (2020)**	Environmental impact assessments of integrated food and non-food production systems in Italy and Denmark	Italy	EI
31	**Lombardo et al. (2022)**	Development of a sustainability technical guide for the Italian olive oil supply chain	Italy	EI, SW, ER
32	**Lopez-Bellido et al. (2016)**	Assessment of carbon sequestration and the carbon footprint in olive groves in southern Spain	Spain	EI
33	**Lopez-Pintor et al. (2018)**	Assessment of agri-environmental externalities in Spanish socio-ecological landscapes of olive groves	Spain	EI
34	**Maesano et al. (2021)**	Economic and environmental sustainability of olive production: A case study	Italy	EI, ER
35	**Maffia et al. (2020)**	Environmental impact assessment of organic vs. integrated olive-oil systems in Mediterranean context	Italy	EI
36	**Maffia et al. (2022)**	The olive-oil chain of Salerno Province (Southern Italy): A Life Cycle Sustainability Framework	Italy	EI, SW, ER
37	**Manzini et al. (2014)**	Sustainability and quality in the food supply chain. A case study of shipment of edible oils	Italy	EI
38	**Menozzi (2014)**	Extra-virgin olive oil production sustainability in northern Italy: a preliminary study	Italy	SW

No.	Reference (Authors, Year)	Title	Country	Sustainability Dimension
39	**Mohamad et al. (2014)**	Optimization of organic and conventional olive agricultural practices from a Life Cycle Assessment and Life Cycle Costing perspectives	Italy	EI, ER
40	**Navarro et al. (2018)**	Tackling the relevance of packaging in Life Cycle Assessment of virgin olive oil and the environmental consequences of regulation	Spain	EI
41	**Ncube et al. (2022)**	Circular economy paths in the olive oil industry: a Life Cycle Assessment look into environmental performance and benefits	Italy	EI
42	**Neira et al. (2013)**	Energy analysis of organic farming in Andalusia (Spain)	Spain	EI, ER
43	**Oplanic et al. (2022)**	Achieving economic sustainability by eco-labelling: Case study of Croatian olive oil and foreign consumers	Croatia	ER
44	**Parra-López et al. (2007)**	A systemic comparative assessment of the multifunctional performance of alternative olive systems in Spain within an AHP-extended framework	Spain	EI, SW, ER
45	**Pattara et al. (2016)**	Carbon footprint of extra virgin olive oil: a comparative and driver analysis of different production processes in centre Italy	Italy	EI
46	**Pellegrini et al. (2017)**	Economic sustainability of the olive oil high and super-high density cropping systems in Italy	Italy	ER
47	**Polenzani et al. (2020)**	Sustainability perception of local extra virgin olive oil and consumers' attitude: A new Italian perspective	Italy	EI, SW, ER
48	**Proietti et al. (2014)**	Carbon footprint of an olive tree grove	Italy	EI
49	**Proietti et al. (2015)**	Assessment of carbon balance in intensive and extensive tree cultivation systems for oak, olive, poplar, and walnut plantation	Italy	EI
50	**Restuccia et al. (2022)**	Sustainability assessment of different extra virgin olive oil extraction methods through a Life Cycle Thinking Approach: Challenges and opportunities in the Elaio-technical sector	Italy	EI

No.	Reference (Authors, Year)	Title	Country	Sustainability Dimension
51	**Rinaldi et al. (2014)**	Assessment of carbon footprint and energy performance of the extra virgin olive oil chain in Umbria, Italy	Italy	EI
52	**Romero-Gamez et al. (2017)**	Optimization of olive growing practices in Spain from a life cycle assessment perspective	Spain	EI
53	**Rossi et al. (2019)**	Long-term water footprint assessment in a rainfed olive tree grove in the Umbria region, Italy	Italy	EI
54	**Russo et al. (2014)**	Environmental sustainability of different soil management techniques in a high-density olive orchard	Italy	EI
55	**Russo et al. (2016)**	Comparison of European olive production systems	Greece, Spain, Italy	EI
56	**Salomone & Ioppolo (2012)**	Environmental impacts of olive oil production: a Life Cycle Assessment case study in the province of Messina (Sicily)	Italy	EI
57	**Sanchez-Escobar et al. (2018)**	Measurement of sustainable intensification by the integrated analysis of energy and economic flows: Case study of the olive-oil agricultural system of Estepa, Spain	Spain	EI, ER
58	**Sgroi et al. (2015)**	Cost-benefit analysis: A comparison between conventional and organic olive growing in the Mediterranean area	Italy	ER
59	**Skaf et al. (2018)**	Food security and sustainable agriculture in Lebanon: An environmental accounting framework	Lebanon	EI
60	**Sousa et al. (2019)**	Application of a dynamic model using agronomic and economic data to evaluate the sustainability of the olive grove landscape of Estepa (Andalusia, Spain)	Spain	EI, ER
61	**Sousa et al. (2019)**	Ecological and economic sustainability in olive groves with different irrigation management and levels of erosion: A case study	Spain	EI, ER
62	**Sousa et al. (2019)**	Estimation of soil loss tolerance in olive groves as an indicator of sustainability: The case of the Estepa region (Andalusia, Spain)	Spain	EI

No.	Reference (Authors, Year)	Title	Country	Sustainability Dimension
63	**Sousa et al. (2020)**	A multifunctional assessment of integrated and ecological farming in olive agroecosystems in southwestern Spain using the Analytic Hierarchy Process	Spain	EI, SW, ER
64	**Sousa et al. (2020)**	Evaluation of the objectives and concerns of farmers to apply different agricultural managements in olive Groves: The case of Estepa region (southern, Spain)	Spain	EI, SW, ER
65	**Sousa et al. (2021)**	Impacts of erosion on the sustainability of organic olive groves: A case study (Estepa region, southwestern Spain)	Spain	ER
66	**Spada et al. (2022)**	Economic sustainability assessment of Mediterranean crops: A comparative Life Cycle Costing (LCC) analysis	Italy	ER
67	**Stillitano et al. (2016)**	Economic profitability assessment of Mediterranean olive growing systems	Italy	ER
68	**Taxidis et al. (2015)**	Comparing organic and conventional olive groves relative to energy use and greenhouse gas emissions associated with the cultivation of two varieties	Greece	EI
69	**Triviño-Tarradas et al.**	Evaluation of agricultural sustainability on a mixed vineyard and olive-grove farm in southern Spain through the INSPIA Model	Spain	EI, SW, ER
70	**Tsarouhas et al. (2015)**	Life Cycle Assessment of olive oil production in Greece	Greece	EI
71	**Tziolas et al. (2022)**	Economic and environmental assessment of olive agroforestry practices in northern Greece	Greece	EI, ER
72	**Tzouramani et al. (2020)**	Assessing sustainability performance at the farm level: Examples from Greek agricultural systems	Greece	EI, SW, ER
73	**van Evert et al. (2017)**	Can precision agriculture increase the profitability and sustainability of the production of potatoes and olives?	Greece	EI, ER
74	**Vicario-Modroño et al. (2022)**	Sustainability evaluation of olive oil mills in Andalusia (Spain): A study based on composite indicators	Spain	EI, SW, ER

Key: EI – Environmental SW – Social ER – Economic

Note: Published date and acceptance date may result in 1-year differences for some references.

Appendix 2: Sustainability criteria in the Alpujarra and Puebla regions of Southern Spain

No.	Sustainability Criteria	Environmental	Economic	Social	Goal Statement
1	Adaptation to change rural areas			+	Farmers are resilient enough to adapt to changing environmental and policy conditions in rural areas.
2	Adequate crop diversity	+			Farmers invest sufficiently in crop diversity to increase resilience against shocks and disturbances and to promote biodiversity.
3	Adequate mechanization		+		Farmers have access to adequate machinery that facilitates their work and reduces the strain of physical labor.
4	Adequate profitability		+		Farmers are able to maintain or increase their revenue while limiting expenses.
5	Adequate soil protection	+			Farmers are applying soil protection measures like soil cover, reduced tillage, erosion protection, Windbreaks, and/or application of effective Microorganisms.
6	Animal wellbeing	+		+	Farmers working with animal commit to disease prevention and appropriate veterinary care, shelter, management and nutrition, a stimulating and safe environment, humane handling and humane slaughter or killing.
7	Availability of public celebrations			+	Rural communities can commit sufficient resources and effort to maintain traditional festivities, celebrations and social events to allow community members to reconnect and exchange.

No.	Sustainability Criteria	Environmental	Economic	Social	Goal Statement
8	Availability of public services			+	Farmers can count on basic public services like health care, waste removal and transportation in their rural communities.
9	Belonging and identity			+	Farmers develop a positive sense of who they are and feel that they are valued and respected as part of a community.
10	Care and cooperation in rural areas			+	Care work is fairly distributed in rural communities and cooperation between community members facilitates the overcoming of structural challenges.
11	Caring for crop necessities	+			Farmers are able to observe and identify the needs of their crops to act in a caring and preventive manner for their agricultural ecosystems.
12	Close producer consumer relations		+	+	Farmers foster close relationships with consumers to transmit knowledge about the production circumstances and reduce their dependencies from intermediaries and globalized markets.
13	Closing nutrient cycles	+			Farmers aim to close nutrient cycles in production through systemic understanding of their input and output management.
14	Coexistence with nature	+		+	Farmers structure their production system in a way that allows for coexistence with natural elements and biodiversity.
15	Companionship and protection (through domestic animals)			+	Farmers (especially in remote areas) can maintain a feeling of companionship and protection (provided by domestic animals that accompany them).

No.	Sustainability Criteria	Environmental	Economic	Social	Goal Statement
16	Compliance with labor rights		+	+	Farmers provide opportunities for full and productive employment and decent work while eradicating forced labor, human trafficking and child labor and promoting labor rights and safe and secure working environments.
17	Conservation of knowledge about natural medicine	+		+	Knowledge about natural and traditional medicine is conserved and transmitted in rural communities.
18	Effort and dedication			+	Farmers invest effort and dedication into their work to achieve satisfactory production goals.
19	Environmental education for children			+	Children receive education about their environment and learn about natural process in school and beyond.
20	Fair division of domestic tasks			+	Household chores and domestic tasks are fairly distributed between all family members.
21	Fair prices		+	+	Farmers receive fair prices for their products that cover the costs of production and allow for profit while respecting their customers, community, and environment.
22	Generation of knowledge			+	Farmers actively engage in knowledge creation through individual field experiments and sharing of practical experiences.
23	Good accounting practices		+		Farmers are skilled enough in accounting to manage their income, spending and paperwork relating to subsidy requirements.

No.	Sustainability Criteria	Environmental	Economic	Social	Goal Statement
24	Good water protection management	+		+	Water as a resource is shared in a fair manor within the community and irrigation practices are applied in the most responsible way possible to reduce water loss.
25	Improved gender equity			+	Farmers promote gender equity through commitment to institutional and cultural change.
26	Improved recycling practices	+		+	Infrastructure for recycling is available in rural communities and farmers commit to recycling as far as possible.
27	Increase healthy diets			+	Farmers contribute to an increase in healthy diets and nutrition in their communities.
28	Increased traceability of agricultural products		+		Farmers are committing to traceability requirements for their products to increase transparency of production.
29	Increased use of renewable energy	+	+	+	Farmers commit to relying on renewable energy as much as possible.
30	Insurance of generational succession		+	+	Conditions in rural environments are attractive enough for younger generations to consider taking over a farm and farmers are able to develop a successional plan.
31	Integration of crops and livestock	+			Farmers try to integrate crop and livestock farming as far as possible to close nutrient cycles and reduce contamination.
32	Knowledge transmission			+	Rural communities establish an environment where knowledge can be transmitted between and throughout inhabiting generations.

No.	Sustainability Criteria	Environmental	Economic	Social	Goal Statement
33	Maintenance of a decent quality of life			+	Farmers can maintain a decent quality of life, encompassing sound personal health (physical, mental, and spiritual), relationships, education status, work environment, social status, wealth, a sense of security and safety, freedom, autonomy in decision-making, social belonging, and their physical surroundings.
34	Maintenance of self sufficiency		+	+	Farmers are able to maintain and provide for their basic subsistence needs including nutrition and working materials.
35	Mutual support practices			+	Farmers create networks of support between their peers to strengthen their communities and help each other out in times of hardship.
36	Networks of trust			+	Members of rural communities can rely on each other and build up networks of trust.
37	Organic fertilization practices	+			Organic fertilization practices are applied whenever possible to increase soil organic matter and protect soil organisms.
38	Organization in cooperative			+	Farmers organize into cooperatives to improve bargaining power, reduce costs and obtain products or services otherwise unavailable.
39	Positive change agricultural policy			+	Agricultural policies are in place that support and induce positive change for farming communities.
40	Preservation and collection of wild species	+			Knowledge about non-timber forest products and wild species from agricultural landscapes is preserved and

No.	Sustainability Criteria	Environmental	Economic	Social	Goal Statement
					their collection and use is practiced with younger generations.
41	Preservation of traditional agricultural practices	+		+	Traditional agricultural practices are preserved as a cultural heritage and applied, when possible, to transmit the knowledge to younger generations.
42	Production of artisanal products		+	+	Farmers are maintaining the production of high-quality traditional products that require direct manual contribution.
43	Protection beneficial organisms	+			Beneficial organisms are actively protected to provide ecosystem services like improved the efficiency of fertilizers or pest and disease resistance.
44	Protection of autochthonous seed	+		+	Autochthonous seeds are conserved and reproduced to maintain the genetic crop diversity of the region and reduce dependencies on agroindustry.
45	Protection of Biodiversity	+			Farmers protect, restore and promote sustainable use of terrestrial ecosystems, combat desertification, and halt or reverse land degradation to counter biodiversity loss.
46	Protection of local varieties	+			Farmers conserve and protect local crop and livestock varieties to maintain well-adapted genetic resources.
47	Recognition of female farmers			+	The work of female farmers is recognized, and they are actively included and supported in male-dominated farming communities.

No.	Sustainability Criteria	Environmental	Economic	Social	Goal Statement
48	Reconciliation of family life in the countryside			+	Farming families have enough time available to reconcile with their families.
49	Reduction agrochemicals	+			The use of agrochemicals is reduced to a minimum and alternative plant protection strategies are explored.
50	Respectful treatment of migrant workers		+	+	Migrant workers are treated respectfully and paid fairly in recognition of their hardships and the lack of availability of non-migrant farm workers.
51	Responsible use of phytosanitary products	+			Phytosanitary products are used responsibly to increase production while maintaining harm to the environment to a minimum.
52	Rural liberty and autonomy			+	Farmers are able to make their own decisions and act without interference from third parties as long as they don't do any harm.
53	Social recognition for farmwork			+	Farmers are respected by society for the basic service they provide and don't have to fear discrimination from urban populations.
54	Sufficient labor availability		+	+	A sufficient labor force is available for hire to overcome labor-intensive work periods.

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