Evaluation by an Expert Panel of Agroecological Practices in Olive Groves from an Environmental, Economic and Technical Feasibility Perspective

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Abstract

The transition towards sustainable agricultural practices is imperative to address the environmental challenges posed by conventional farming systems. Agroecology, a holistic approach that integrates ecological principles into agricultural practices, offers a promising pathway for achieving sustainable olive cultivation. This study delves into the viability of agroecological practices in olive groves, encompassing their social, economic, and environmental benefits. Drawing upon scientific evidence and insights from previous research, we evaluate the sustainability of diverse agroecological practices in olive cultivation. To achieve our objective of developing a comprehensive strategy for promoting more sustainable olive oil production, we employed the Delphi method, engaging a panel of 26 experts to assess the viability of 12 agroecological practices based on various criteria, including biodiversity enhancement, soil management, climate change mitigation, water management, and cultural ecosystem services. Our findings highlight the exceptional performance of several agroecological practices, particularly living covers, pruning residue covers, minimal soil disturbance, and the implementation of multifunctional margins and buffer strips. These practices consistently received high scores across all five evaluation criteria, demonstrating their remarkable potential to contribute to a sustainable olive cultivation system.

Keywords

Agroecology, Olive groves, Sustainability, Delphi method, Spain

1. Introduction

The traditional production system has been criticized for its environmental impact, including soil erosion, agrochemical pollution, and biodiversity loss. In this sense, agroecology emerges as a medium and long-term alternative for sustainable olive grove management. Additionally, Agroecology promotes a holistic approach that integrates ecological, social, and economic principles to design more resilient, productive, and progressively fair agricultural systems.

Francis et al. [1] argued that a comprehensive approach necessitates the integration of both natural and social sciences, underpinned by systems thinking and ecological principles. This perspective underscores the importance of considering all stakeholders involved in food production and distribution, from input suppliers to consumers. Moreover, the authors highlighted the need to trace the complete flow of energy and materials throughout the food system, including the potential for nutrient recycling. This holistic framework provides a foundation for addressing the complexities of sustainable food production and consumption.

Research over the last fifteen years has shown that various agroecological practices are often effective in improving soil, reducing the use of synthetic inputs, increasing biodiversity, and enhancing ecosystem services in olive groves.

The adoption of agroecological practices in olive groves can contribute to improving environmental, economic, and social sustainability. This involves assessing the economic impact of adopting the practice

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on the profitability of farms and the technical difficulty of its adoption by farmers.

The objective of this article is to analyze the sustainability of various agroecological practices in olive groves, considering both their impact on farm profitability and their technical feasibility, with the aim of developing a comprehensive strategy to promote more sustainable olive oil production.

1.1. Background

Olive groves face various challenges in the current context, such as agricultural intensification, climate change, and biodiversity loss. Agroecology aims to address these challenges and build a more sustainable and resilient production system. Table 1 shows some agroecological practices oriented towards olive groves.

These agroecological practices in olive groves offer various benefits. An example of the latter is the incorporation of elements such as trees, hedges, and wildflowers into olive groves, which create habitats for a wide variety of plant and animal species. The adoption of these practices can generate a positive impact on the environment, creating a more sustainable and resilient olive grove in the context of climate change and the environmental challenges of this century.

These benefits are transformed into economic and social impacts for farmers and rural communities. Hrameche et al. [2] and Martín-García [3] mention that the main economic benefits for farmers include:

- Promotion of crop diversification and the production of other products, such as honey, nuts, or vegetables, generating new sources of income for farmers.
- Less dependence on inputs, such as chemical fertilizers and pesticides, reduces production costs and increases the profitability of olive groves.
- Olive oil produced under agroecological practices can access higher-value markets, such as organic or fair-trade markets, obtaining better prices.
- Agroecological systems are more resilient to price fluctuations and extreme weather events, providing greater economic stability for farmers.

Table 1
Agroecological practices in olive groves

Dimensions	Practices	Description
Soil management	Minimal or no tillage	Minimizes soil erosion, improves its structure and biological activity, and sequesters carbon [4].
	Plant cover	Conserves soil moisture controls weeds and erosion, and provides organic matter [5].
	Organic amendments	Compost, manure or other organic materials improve soil fertility and structure.
Water management	Efficient irrigation	Techniques such as drip irrigation or remote sensing optimize the use of water, a scarce resource in many olive grove regions [6].
	Rainwater harvesting	Harnessing rainwater for irrigation reduces dependence on external sources and pressure on aquifers [6].
	Mulching	Covering the soil with organic materials such as straw or bark helps conserve moisture and reduce evaporation [7].
Plague and illness management	Biologic control	Use natural enemies, such as parasitoids.
	Integrated pest management	Combines biological, cultural, and chemical methods selectively to minimize environmental impact [8].
	Promotion of biodiversity	Planting trees, wildflowers, and other elements in the olive grove attracts natural enemies and creates a more balanced ecosystem [9]
Biodiversity	Intercropping	Combining the olive tree with other crops, such as legumes or cereals, diversify production and benefits the soil.
	Habitat conservation	Preserving natural areas within the olive grove provide shelter and food for various organisms [10].
	Pollinator management	Encourage the presence of bees and other pollinators for the reproduction of some olive tree varieties [11].

Galt et al. [12] and Bezner Kerr et al. [13] mention several social benefits for rural communities, highlighting:

- Agroecology requires more labor, especially for tasks such as manual weed control and harvesting, generating employment opportunities in rural areas.
- Agroecological practices contribute to a healthier and safer environment, which improves the quality of life for people living in olive-growing communities.
- Agroecology promotes collaboration among farmers, community organizations, and knowledge sharing, strengthening the social fabric in rural areas.
- Olive groves represent an important cultural heritage in many regions, and agroecological practices contribute to their conservation.

2. Materials and Methods

This research employs a quantitative methodological approach based on the evaluation of different practices by a panel of experts using interval and ordinal scales. The research has a descriptive focus, as its purpose is to describe agroecological practices in terms of sustainability, profitability, and technical difficulty. The success of the Delphi method is linked to the quality and experience of the selected experts. The following describes how the experts were chosen for this research.

A Knowledge Resource Nomination Worksheet (KRNW) was developed to identify and select experts. This tool aimed to categorize experts based on a detailed description of their experience and contribution to the analysis. Experts were sought whose areas of specialization converged with the disciplines of agronomy, agricultural, economics, and rural sociology [14].

This categorization allows the selection of a diverse and qualified group of experts to participate in the study. To establish contact with the selected experts, a multi-channel communication strategy was implemented. This strategy included face-to-face meetings, phone calls, and institutional emails. The communications focused on informing the experts about the research objectives, the Delphi methodology, and the importance of their participation in the study [14]. In this way, 26 experts confirmed their availability and willingness to collaborate with the proposed research.

A structured questionnaire was employed for data collection to evaluate the environmental and socioeconomic benefits of various agricultural practices in olive groves. This questionnaire investigates a variety of key sustainability indicators.

The first part of the questionnaire assessed the impact of each practice on biodiversity conservation and enhancement, soil structure and quality improvement, climate change mitigation, water pollution minimization, and cultural ecosystem services provision. By gathering data on these diverse aspects, a comprehensive understanding of the practices' potential contributions to a sustainable olive grove management system can be achieved. Each expert was asked to allocate 100 points across each column, representing each criterion, thus quantifying the contribution of each practice to each criterion.

The second part of the questionnaire evaluates the impact of practice adoption on the profitability of farms using a three-point ordinal scale, ranging from minimal to high. Following the evaluation of the impact on profitability, the technical feasibility and challenges associated with implementing the practices are analyzed using the same ordinal scale. A pilot test was conducted with a small group of experts to validate the questionnaire, ensuring the clarity and validity of the instrument.

The quantitative data will be grouped in an Excel spreadsheet to apply descriptive statistical techniques and evaluate the degree of association between the data. Before analysis, the database was cleaned to remove erroneous values. Data processing was carried out using the RStudio [15] and JASP [16] software packages. These same programs were used to generate graphs and tables that illustrate the findings and facilitate the understanding of the object of study.

Descriptive statistics were used to analyze the data, including measures of central tendency and dispersion. The results of these analyses will allow for the identification of patterns in the data, the evaluation of the relationship between variables, and a comprehensive understanding of the research topic.

The consensus value is calculated using the interquartile range: the number of experts who rated within this range is evaluated and then divided by the total number of experts. Equation 1 expresses the calculation of the interquartile range.

$$ICR = \frac{3(n+1)}{4} - \frac{n+1}{4} \tag{1}$$

Equation 2 expresses the consensus calculation

$$\frac{Number\,of\,Experts\,within\,the\,ICR}{Total\,Number\,of\,Experts} \tag{2}$$

The weighting is obtained from the average of the importance of each criterion multiplied by the assessment of each practice in each criterion. Equation 3 shows the calculation of a normalized weighting.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{\sum_{i=1}^{n} w_i} = \frac{x_1 w_1 + x_2 w_2 + x_3 w_3 + \ldots + x_n w_n}{w_1 + w_2 + w_3 + \ldots + w_n} \tag{3}$$

x_i is the average of the experts' evaluations in each practice.
w_i is the average of the weight assigned by the experts to the criteria.

3. Results

Table 2 presents a summary of the experts' evaluations of the benefits of various agroecological practices in olive cultivation systems. The table highlights practices that received scores on all five criteria, indicating the potential to contribute to a variety of positive farm outcomes.

Table 2
Scores for agroecological practices

Agroecological practices	Rating	Ranking
Cover crops	24,21	1
Crop residues	12,42	2
Minimal mechanical alteration of the soil	8,75	4
Agricultural operations following contour lines	4,63	9
Fertilize according to soil deficiencies and crop needs	6,61	7
Organic fertilizer	8,55	5
Integrated Pest Management strategy (IPM)	5,49	8
Precision agriculture technologies	4,28	10
Multifunctional Margins (MFM) and Buffer zones	10,22	3
Retention structures to reduce the impact of erosion and runoff	7,13	6
Prevention of contamination by phytosanitary products	3,99	11
Optimized waste management	3,53	12

The classification shows the importance of the use of cover crops, covers from pruning remains, multifunctional margins and buffer strips, and minimal soil alteration, which ensures positions within the top four positions, respectively. In fifth place in the ranking is the use of organic fertilizer, a practice that received favorable evaluations for its contributions to the evaluated criteria.

The use of cover crops receives the highest assessment for its capacity to increase the diversity of flora and fauna as confirmed by Bretzel et al. [17], since this practice implemented in agroecosystems generates ecological niches that increase the availability of food for wildlife. Likewise, it helps to increase soil organic matter [18], improves its structure, and reduces erosion [19].

Additionally, it prevents leaching of nutrients and filtering contaminants from runoff water, minimizing water pollution. Durán Zuazo & Rodríguez Pleguezuelo [20] confirm that this type of practice prevents erosion caused by rain and wind, keeping the top layer of soil in place and reducing the loss of nutrients and organic matter. Similarly, Ma et al. [21] mention that vegetation acts as a natural barrier, reducing the speed of water flow and allowing sediments and contaminants to settle on the ground before reaching water bodies.

The use of covers with pruning rest has a positive impact on soil fertility, water retention capacity, the yield of successive crops, efficiency in water use and weed suppression [18] and on soil carbon storage, contributing to climate change mitigation efforts [22].

The implementation of functional margins was valued positively for its contribution to the creation of habitats for a wide range of species, the regulation of microclimate, and the pollination of crops. Brittain et al. [23] through the "Operation Pollinator" program demonstrated how margins are beneficial for biodiversity in agricultural landscapes. Also, it benefits the preservation of traditional landscapes, providing habitat for wildlife [24] and supporting cultural practices such as bird watching and nature walks [25].

Minimal soil mechanical alteration was positioned as one of the best practices for preserving soil structure, promoting beneficial soil microorganisms, and improving overall soil quality [26].

3.1. Evaluation of Economic Impact and Technical Difficulty

The second section of the questionnaire delves into evaluating the economic impact of adopting specific practices on farm profitability. The findings reveal that the use of pruning residue covers, minimal soil disturbance, performing agricultural operations following contour lines, balanced fertilization, implementing IPM strategies, and optimizing waste management have a null or minimal impact on profitability. These practices are considered economically viable and do not alter the overall profitability of farms (see Figure 1).

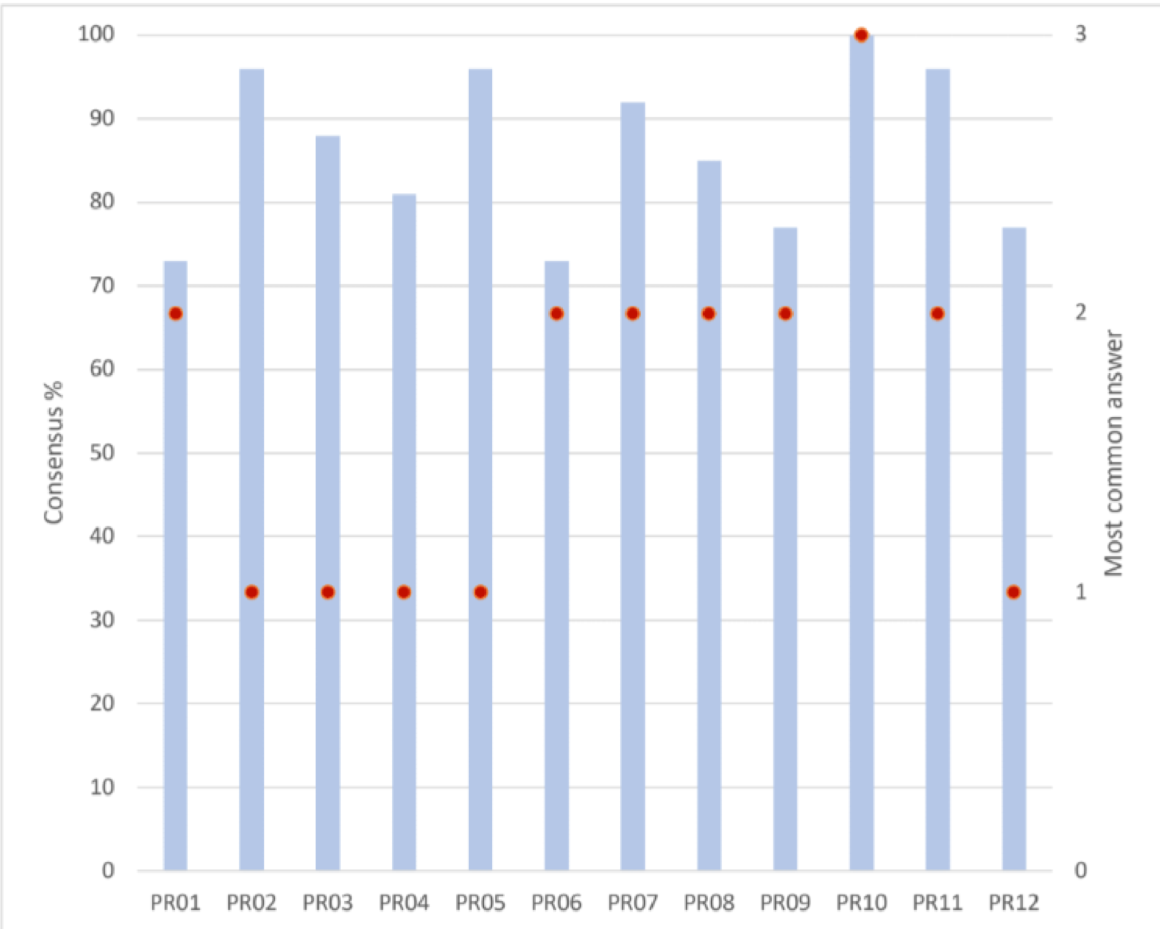

Figure 1: Impact on profitability

The use of organic fertilizers and pesticide contamination prevention practices were evaluated as agroecological practices with an economic impact ranging from null or minimal to reduced. These practices offer economic benefits while minimizing environmental harm. The implementation of cover crops, multifunctional margins, and buffer strips was assessed, and it was determined that the economic impact can range from reduced to moderate or high. These practices offer potential economic gains but may require initial investments and careful management.

The employment of precision agriculture technologies and the construction of erosion control structures were perceived as practices with a moderate or high impact on profitability. These practices may involve significant upfront costs but can lead to long-term economic benefits through improved efficiency, resource optimization, and reduced environmental damage.

The findings reveal that half of the experts consider the use of cover crops to be of low difficulty, while the use of pruning residue covers is perceived as of minimal difficulty. Similarly, minimal soil disturbance is perceived as of minimal difficulty by 54% of the experts and of low difficulty by 42%, while the implementation of agricultural operations following contour lines is considered of minimal difficulty.

Regarding balanced fertilization and the implementation of multifunctional margins, these practices were evaluated as of low difficulty, while optimized waste management was perceived as of minimal difficulty. Additionally, the use of precision agriculture technologies and the construction of containment structures are considered by experts to be of moderate or high difficulty.

The use of organic fertilization and pesticide contamination prevention received difficulty ratings ranging from minimal to low, while Integrated Pest Management (IPM) was evaluated as having a difficulty ranging from low to moderate or high (see Figure 2).

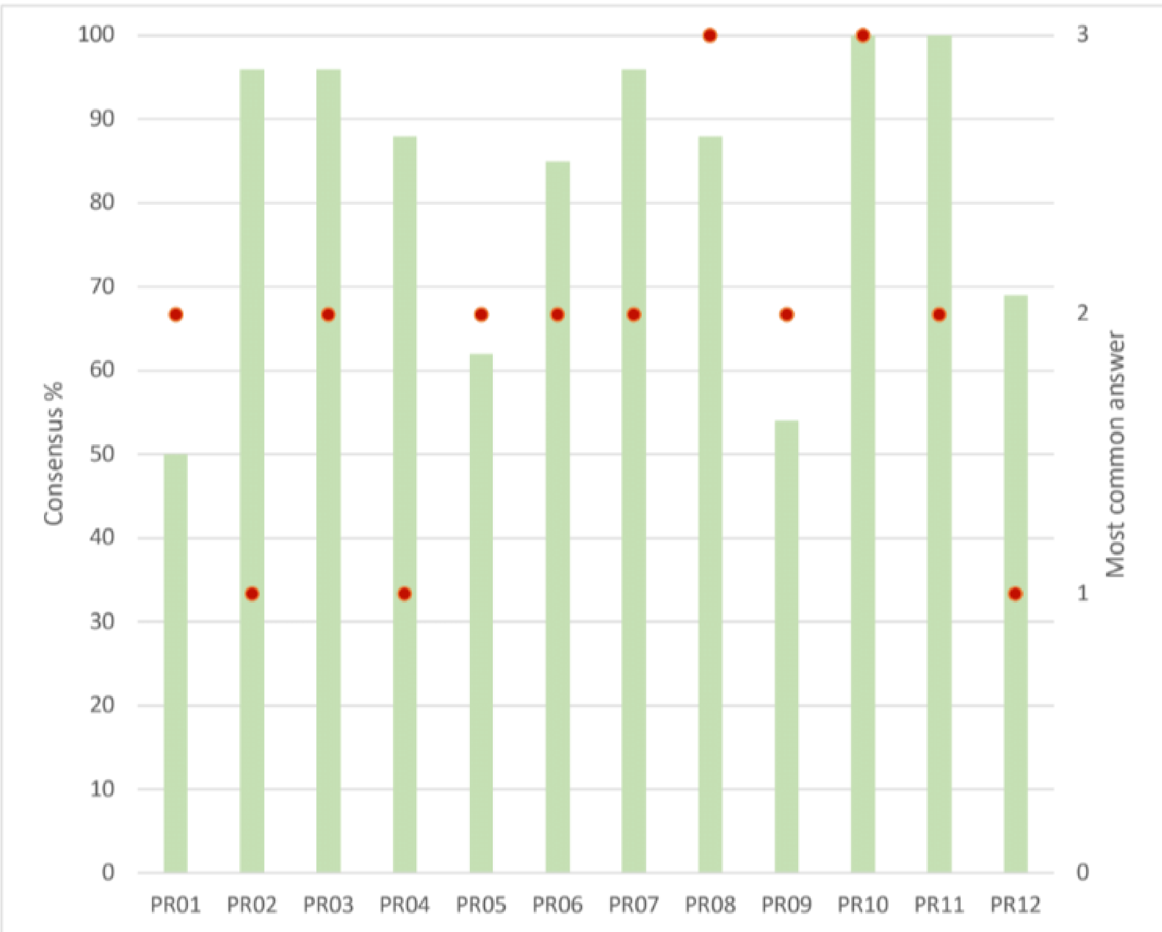

Figure 2: Technical difficulty of adoption.

4. Conclusions

The presented research emphasizes the remarkable efficacy of certain agroecological practices in enhancing sustainability and improving the technical feasibility of olive cultivation. These practices, including the utilization of cover crops, pruning residue covers, minimal soil disturbance, and the implementation of multifunctional margins and buffer strips, have garnered high scores in various evaluation criteria.

Cover crops emerged as the most favorable agroecological practice across all five evaluation criteria, demonstrating their comprehensive benefits for olive cultivation systems. This finding aligns with the positive perceptions of over two-thirds of the experts, who indicated that the economic impact of this practice on olive farms is either null or minimal. Additionally, experts rated the technical difficulty of implementing cover crops as minimal or low, suggesting their practical viability and ease of adoption.

Covered with pruning remains secured the second position among the most favorable agroecological practices, achieving a prominent standing in the overall ranking. This practice received high scores for its benefits in preventing soil erosion and mitigating climate change. Moreover, experts rated the economic impact of vegetation covers favorably, indicating a minimal or null reduction in profitability and a minimal or low technical difficulty of adoption.

The implementation of multifunctional margins stood out as a beneficial practice for enhancing biodiversity and providing cultural ecosystem services, securing third place in the ranking. This practice was perceived by 40% of the experts as a practice with an economic impact ranging from moderate to high. Despite this perceived impact, 80% of the experts rated the technical difficulty of adopting multifunctional margins as minimal or low.

Minimal mechanical soil disturbance emerged as one of the five most favorable agroecological practices for preventing soil erosion and mitigating climate change. This practice aligns with the performance of pruning residue covers, as experts perceived its economic impact as minimal or null and its ease of adoption as minimal or low.

The research will be limited to the evaluation of the most common agroecological practices in olive groves in Spain. Not all existing agroecological practices can be evaluated nor can all environmental, economic, and social aspects of their adoption or implementation be analyzed in depth.

These findings contribute to the ongoing discussion regarding the suitability of agroecological practices in olive cultivation for enhancing the sustainability and technical viability of the crop. Among the proposed future research lines is the analysis of the implementation of the best practices in three olive cultivation subsystems: (a) Traditional rainfed olive groves; (b) Irrigated olive groves; and (c) Olive groves with steep slopes. Additionally, the study of factors influencing the adoption of these agroecological practices should be addressed, including the risk aversion of producers, the structural limitations of the farms, aspects related to business management, and administrative difficulties.

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