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Ecological and Economic Indicators for the Evaluation of Almond (*Prunus dulcis* L.) Orchard Renewal in Sicily

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Abstract: Globally, almond production is experiencing a growing trend thanks to a strong interest in the health, gastronomic, and industrial properties that are linked to the fruits and their derivatives. After a constant and marked decline in the second half of the last century, the Mediterranean Basin is thoroughly reassessing this crop, which provides significant results with a modern orchard management. The opportunity determined by the transition from traditional to modern systems have increased the interest in evaluating the different environmental impacts of the two cultivation models that still coexist today. In this work, through the application of the Life Cycle Assessment (LCA) and an economic assessment approach with an in-depth analysis related to the cultivation cycle and the use of resources, the role played by each factor involved in production was determined. Overall, the Greenhouses Gases (GHG) emissions in modern farms are higher (Global Warming Potential (GWP) 0.224 kg CO_2 eq.) than those in traditional farms (GWP 0.182 kg CO_2 eq.). Regarding the economic assessment, it appears relevant that the modern almond model in the full production phase guarantees significantly higher margins (+84%).The perception of the importance attributed to evaluating economic and environmental aspects by different stakeholders shows relevant differences in the approach coming from growers, dealers, and governmental institutions allows the investigators to positively underline the current innovation in almond orchard systems considering the balance between fruit production and the conservation of environmental resources.

Keywords: almond; innovation; Life Cycle Assessment (LCA); economic assessment; sustainability

1. Introduction

The cultivation of nuts has secured a significant place in strategies linked to a healthy and balanced diet as a result of its renewed importance in human nutrition and its ultimately strengthened importance in cultivation around the world [1,2]. The content of bioactive substances capable of fighting against cardiovascular diseases [3] has certainly played a significant role in this re-evaluation, especially in developed countries where inadequate nutrition has determined the need to change the lifestyles of the population, starting with school-age children [4].

In other parts of the world, on the other hand, dried fruit has historically assumed an important role in the daily diet because of its ease of acquisition or cultivation and the possibility of storing it for a long period of time without substantial qualitative alterations [5].

Almonds (*Prunus dulcis* L. (Mill.) D.A.Webb) are widely produced and consumed worldwide [6]. The almond seeds, which represent the edible part of the product, are protected by a very fine external tegument and, as a whole, are rich in protein, unsaturated fats, vitamins, fiber, and minerals as well as many nutraceutical substances that have attracted the attention of many researchers in the agronomic, pharmacological, and biomedical fields who have supported the direct relationship with human health [7].

According to Food and Agriculture Organization (FAO) statistical data [8], the global production of almonds in their shells is estimated to be just over 3,200,000 t in an area of over 2,000,000 hectares. The United States, with a production of over 1,000,000 t of shelled almonds, has now consolidated its leadership (78%) of the world's almond production, which was followed by Australia (8%), Spain (6%), Turkey (3%), and Italy (2%) (Table 1).

This breakdown is considered to be the effect of rapid and significant development, which has involved California since the second half of the 1960s and Australia since the end of the second millennium [7,9]. It is also linked to the specific characteristics of the varieties grown. Table 1 reveals that the main difference between the varietal models of almond trees between California and Australia and the Mediterranean leads to substantially different results in terms of production due to the cultivation of soft-shell almond cultivars in the former with a high shelling yield. The most widespread varieties such as Nonpareil, Carmen, Mission, Texas, and Ne Plus Ultra produce 'California-type' fruits with a lower lipid content, and they are widely used, especially among snacks and for direct consumption [10]. These are also the same cultivars typically used in genetic improvement programs [11]. On the other hand, the 'Mediterranean-type' almond refers to the more traditional genotypes cultivated in Europe, North Africa, and parts of Turkey. The lipid and starch content contribute to the close links of this product to food processing, especially in very traditional pastries, and to the more industrial sector of cosmetics and pharmacology [12,13]. In addition to this, the recent renewed interest in almond cultivation has given even more value and importance to its limited but continuous scientific research, ranging from genetic improvement linked to cultivars and rootstocks [14–16] to cultivation techniques [17–19] and the reuse of product processing waste [20,21].

Table 1. Production, area harvested, export, and consumption of almonds around the world (FAOSTAT, 2017).

Country	Production (Kernel) t	Area Harvested Ha	Kernel Yield t/ha	Export %	Consumption pro Capita kg/Year
United States of America	1,060,318	441,000	2.4	69	2.05
Australia	103,700	37,000	2.8	5	2.13
Spain	78,060	657,000	0.1	10	2.39
Turkey	21,055	42,000	0.5	<1	1.43
Italy	18,667	58,000	0.3	<1	1.56
Others	89,550	2,071,000	0.4	9	1.10

Moreover, while in the United States, the significant growth of the plants has been consolidated in Californian valleys that appear rich in water resources, which, through flooding irrigation models, made it possible to obtain considerable quantitative results [22]. In addition, its uniform and flat orography has enabled the development of strong mechanization of harvesting through models that are entirely managed by machines and led to a considerable reduction in operating costs. In Europe, on the other hand, for many years, almond farming has remained linked to ancient models poorly specialized with low planting densities and very little use of machinery [23]. In both Spain and Italy, which are two countries with the greatest interest in the species, planting is still obsolete and not competitive. This is mainly due to planting in areas without natural resources, especially water, likely as a result of an overestimated tolerance of the species to aridity [24]. As a matter of fact, regardless of the different varietal typology, European almond farming has never been able to withstand global economic competition and has increasingly restricted its production to marginal rural conditions [23].

The most recent contribution of research and the evolution of international markets and consumption on the domestic market [6] have led to a new interest in the Italian almond sector, especially in southern Italy and, in particular, in Sicily. For 10 years now, there has been constant growth of commercial interest in the product from Italy [12], and there are many instances of new investments even from large companies. These new plantings are managed with the consideration that the almond grove in a specialized system and with appropriate cultivation techniques is able to offer significant productive and qualitative output with great relevance in modern fruit growing [12].

More recently, therefore, Sicily has begun a phase of applying two different but coexisting models of almond farming. The traditional model, which is not very competitive and often linked to a more historical and landscape function, and the modern model in which, while respecting a varietal choice linked to the tradition of Mediterranean typicality, specialized cultivation techniques derived from modern fruit-growing have also been adopted [12,23]. Medium-high-density systems with surface or underground irrigation systems with total or partial mechanization of the harvest as well as the use of mechanical facilitators are the technical aspects that are the basis of the relaunch of almond cultivation. To this is added modern techniques of processing, storage, and post-harvest management that allow marketing in Italy and abroad to generate significant interest. It is clear that the great interest in issues related to the agroecological transition of European agriculture [18] and the indispensable choices, which must be made today to restore sustainability in agriculture, are aspects that are currently requiring farmers to make wise choices supported by adequate scientific and technical knowledge, particularly in light of the Agenda 2030 objectives and the Sustainability Development Goals [25].

As a consequence, in this paper, it appears significant to carry out a series of experimental tests aimed at analyzing the environmental and economic sustainability derived from the recent development process of the almond sector in Sicily. This evaluation was carried out through interviews with growers in order to better understand the new innovative model and to directly share the obtained results with local stakeholders. This work, therefore, applies the Life Cycle Assessment (LCA) methodology [26–28] and profitability analysis for the field systems linked to the traditional and modern almond growing models.

2. Materials and Methods

The development of innovation in the Sicilian almond sector necessarily requires that all stakeholders, from the grower to the dealers, are involved in the processes related to proper strategic planning. In order to achieve this goal, an attempt was made to identify appropriate tools that would allow an evaluation of performance. These tools are based on the application of LCA and the analysis of return on investment indicators, which have a common purpose but are applied independently.

The study was conducted in two different phases. The first phase involved a quantitative analysis using the LCA approach in order to assess the efficiency of the agricultural system in terms of environmental sustainability. For this assessment, an approach "from farm-gate to farm-gate" [26] was chosen by considering the full production phase of the planting, as it is the most representative phase in terms of the practices, inputs, and environmental impacts, according to the specific methodology [27,28].

A total of 15 modern farms and 15 traditional ones have been evaluated by selecting from the Regional Association of Almond Growers (AProMaS). The interviews with the producers allowed the quantification of the resources used in the cultivation through consultation of the field-book of each company. The average data for an area of about 10 ha were obtained for the two approaches including traditional planting (8.8 ha) and modern planting (11.1 ha).

In the second phase, through semi-structured interviews, a qualitative and quantitative analysis was carried out. The questionnaire includes questions about all inputs such as fertilizers, pesticides, water, fuel, natural gas, and electricity used during the time considered in the study. Other general data on the holding, the total area, the area actually cultivated, the planting density, the cultivars adopted, the types of crop and harvest management, and the number of employees were also recorded.

The data were collected in 2019 and represent the average value for three years (2017–2019). Regarding the interpretation of the results, three groups of stakeholders in the target area were identified: farmers, traders, and policymakers. In total, 20 people were invited to discuss during three seminars, 10 farmers from the AProMaS list, four dealers considered the most representatives from growers, and six representatives from the governmental districts. The flowchart of the conceptual model used is shown in Figure 1.

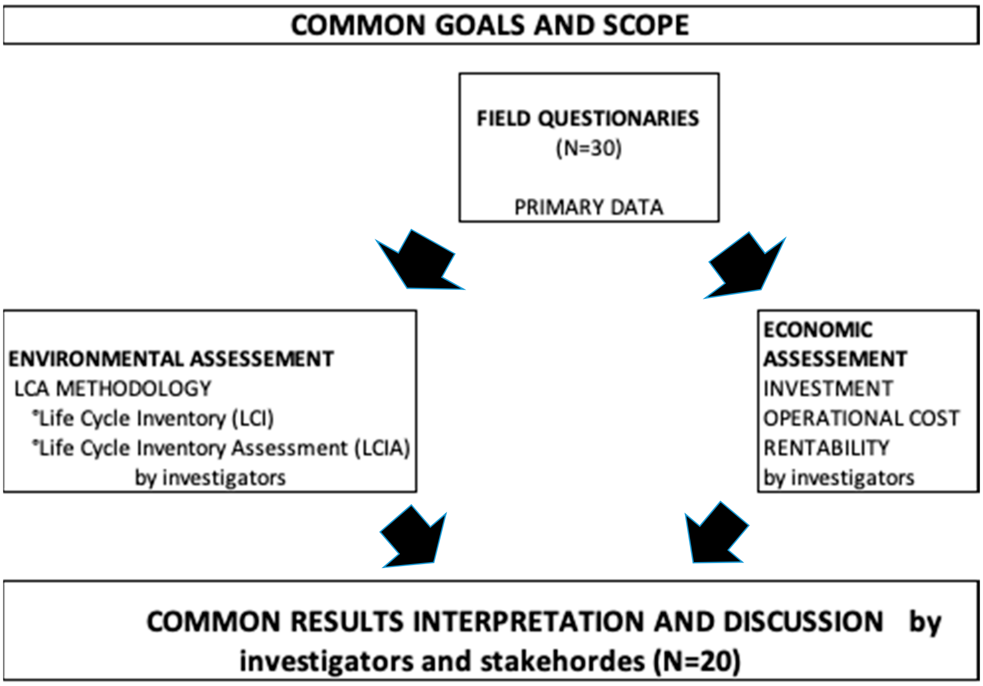

Figure 1. Methodological flowchart.

2.1. Geographical Context and Planting Typologies

As already reported, Sicily represents the first Italian region for the production of almonds with about 15,000 ha distributed in the two provinces of Syracuse and Caltanissetta, covering more than 65% of Italian production [12]. These two Sicilian provinces are particularly suitable for the cultivation of almonds. The medium clayey soils in hilly areas with a dry and warm climate allow the almond tree to grow and bear fruit with excellent results in both qualitative and quantitative terms.

The most traditional planting systems are characterized by an old approach. While not very productive, it entails sowing *P. amygdalus* Batsch var. *amara* seeds and then grafting the seedlings in the field with very wide distances between them and low density per hectare (at least 6 × 6 m or more, with a density of about 270–300 trees ha^{-1}) without irrigation systems and with very rough cultivation techniques for pruning and fertilization. In modern plantings, previously grafted trees are planted at a higher density (>370 trees ha^{-1}), managed with specialized cultivation techniques, and fertigated. These plants are managed according to modern fruit-growing criteria. The most widely used rootstock is GF 677, which, when compared with others, has superior physiological efficiency [29]. The main adopted cultivars are the self-fertile Tuono, Genco, and Supernova, the self-unfertile Ferragnés and Filippo Ceo, and, in one case only, the Spanish Vairo. The traditional plantings, instead, are linked to cultivars belonging to the Sicilian germplasm, which is of ancient origin and of high quality but has a low profile in terms of yield. Pizzuta d'Avola, Fascionello, Romana, Vinci a tutti, and Cavalera are the most widespread and represent part of a large almond local biodiversity that is preserved today for ecological reasons and genetic improvement. The two methods of cultivation result in a different rapidity of the first fruiting and varying yield as well as a large difference in terms of the shelling rate (Table 2).

Table 2. Main traits of the two planting systems.

Planting Typology	Duration of Planting (Years)	Year of First Yield	Planting Density (Tree ha^{-1})	Cultivar Type	Presence of Irrigation Systems	Average Yield (In Shell) (t ha^{-1})	Cumulative Yield (t ha^{-1})
Modern	25	5th	>370	National	yes	4.8 (5th–24th year)	101.1
Traditional	40	6th	270–300	Regional	no	2.3 (6th–39th year)	80.5

2.2. Life Cycle Impact Assessment (LCIA)

According to the methodology described by Goossens et al. [30], the environmental footprint of products and international life cycle data (ILCD) have been realized through 16 categories of analysis. The LCA methodology was applied following the guidelines of the International Organization for Standardization (ISO)'s 14,040 standard [31]. The LCA methodology is a tool that is currently successfully applied in agricultural and agri-food systems [32,33].

In the case of Sicilian almond growing, we deepened the selection phase of the impact categories [34,35] and applied our analysis to global warming potential (GWP), according to Intergovernmental Panel on Climate Change (IPCC) (GWP 100a kg CO_2 eq.) and to non-renewable energy (primary mega joule (MJ)), as already done in previous works [33]. In this way, it was possible to carry out an impact assessment of production in direct relation to the climate crisis, which is certainly a relevant issue for the parties involved. The category of non-renewable energy sources, therefore, allowed an assessment of impacts in relation to emissions and also consumption, which cannot be neglected in the agricultural sector.

The data acquired during the Life Cycle Inventory were analyzed through SimaPro 7.3 (Consultants B.V., Amersfoort, NL) and subsequent updates [36], which has a systematic and transparent monitoring capability compliant with the ISO 14,040 standard [31]. A 2% cut-off was applied, and all data recorded below this percentage were grouped into the "other" category. The databases used for the inventory are in Ecoinvent 2.2 and LCA food DK.

With this methodology, the LCA analysis was carried out in order to evaluate the environmental impact of the production of 1 kg of almonds in shells in traditional plantings compared to 1 kg of almonds in shells obtained in modern ones. The data used to perform the field LCA analysis were acquired through questionnaires administered to 30 growers who were equally distributed between the two scenarios.

All the cultivation management processes were considered including the associated ones such as the transport of the materials used and the waste generated in each phase (Figure 2).

The length of the cultivation period is 25 years for modern almond plantings and 40 years for the traditional ones. The impacts from all field operations (e.g., fertilization, planting, and plant removal) occurring over the 25-year-old or 40-year-old orchard lifespan were added together and then divided by the number of respective years of production. The same procedure was employed for all of the outputs. Productivity was evaluated as an average (in tons) between the period that the planting entered production and the stage of full production.

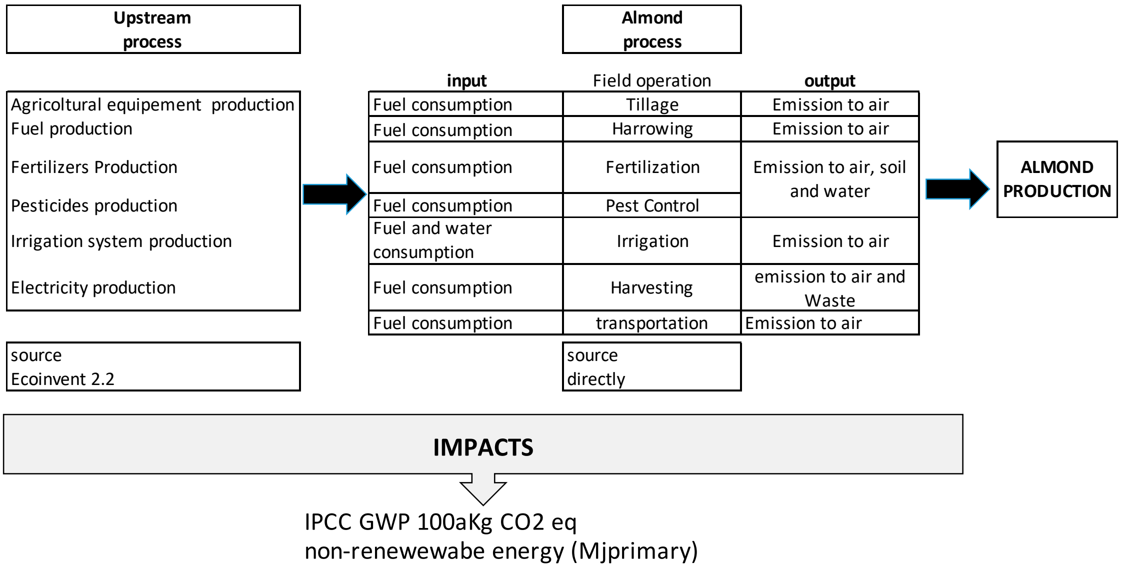

Figure 2. System boundaries flowchart.

2.3. Economic Assessment

An economic analysis based on data obtained from both field questionnaires and discussions with stakeholders was also performed to compare the rentability of the two growing/planting systems. Data were converted into economic information, inputting the prices presented in Tables 3 and 4. The economic estimates were obtained from interviews with 30 farmers and several agricultural stakeholders including an extended service and market operators.

Table 3. Cost of inputs from field questionnaire and farm's field-book (average 2017–2019).

Production Factors	Cost	Unit
Extraction pump	514.00	€
Hoses	0.52	€/m
Fertilizers	283.08	€/ha
Manure	15.00	€/T
Plant protection products	12.41	€/ha
Grafted tree	4.50	€/tree

For the cost analysis of the cultivation operations, the hourly wages of farm managers, specialized wage earners, and agricultural machinery [37] were taken into consideration, according to the rates shown in Table 3, which were obtained from the official national reports for the rental of agricultural machinery and from the regional and provincial employment contracts of agricultural and horticultural operators provided by institutional stakeholders (agricultural patronage).

Table 4. Hourly cost calculations of field operations (average 2017–2019).

Field Operations	Hourly Cost (€)
Tractor driver	23.68
Specialized employees	11.84
Non-specialized employee	9.46
Manure spreader *	61.00
Operating machine *	34.00
Plowing burglary *	108.00

* The cost is related only to the use of the vehicle without a driver.

The analysis of the production costs included both the investment for the realization of the almond orchard (year 1) and the operational costs related to all the years of the cultivation lifespan assumed for the two scenarios (Table 2). The economic results were calculated as the difference between the total output and the operational costs. The total output was the revenue from sales of almonds where the yields considered were those declared by producers (field questionnaire) and prices were fixed at 1.90 €/kg for the ones harvested in modern plantings and 2.40 €/kg for the ones collected in traditional plantings.

In order to compare the rentability (economic benefits) of the two farming practices, a Conventional Life Cycle Costing (LCC) approach in which cash flows generated during the life of the planting are actualized to their Net Present Value (NPV), was used [38–41].

The NPVs of the two alternative planting typologies were estimated by taking into account the total output and operational costs generated during the entire plantation lifetime. Cash flows generated in the first periods of the investment are valued more. Therefore, a discount factor is used. *NPV* is calculated as the cumulated yearly present value (FAO, 1991) with the following formula.

$$NPV = -IC + \sum_{1}^{n} CF_n (1+r)^{-n}$$

where IC represents the investment costs, CF_n is the annual cash flow generated, is obtained by subtracting total output operational costs, and r is the discount rate. Different baseline discount rates, as advised by the European Commission [42], were set (ranging from 1% to 5%), according to recent studies in which tree crop plantation investments were analyzed [42–47].

3. Results

3.1. LCIA Field Production System

Overall, the GHG emissions in modern farms are higher (GWP 0.224 kg CO_2 eq.) than those in traditional farms (GWP 0.182 kg CO_2 eq.), which is in agreement with results from Martin-Gorriza et al. [38] (Table 5).

Table 5. Environmental impact categories in two different planting typologies.

Impact Category	Unit	Modern	Traditional
Global warming	kg CO_2 eq.	0.22	0.18
Non-renewable energy	MJ primary	6.53	2.95
IPCC GWP 100a	kg CO_2 eq.	0.23	0.18

In the modern orchards (Figure 3), with respect to the traditional ones (Figure 4), the main impact items are irrigation water (45.78%), mechanical processing (weeding and elimination of pruning residues) (28.37%), plowing (10.75%), and harvesting (including small-scale harvesting in the field) (5.67%). All the other elements considered have much less impact, and, together, they account for 9.41% of the total value, which is 0.22, expressed in kg CO_2 eq.

In the non-renewable energy (MJ primary) impact category of the total 6.53 MJ consumed, irrigation water has a higher value when compared with the other components. The water resource accounts for 67.16% of total consumption, which is followed by mechanical processing including the management of pruning residues (15.72%), plowing (5.81%), harvesting and trimming (3.14%), and, lastly, polyethylene irrigation pipes (2.56%). In the case of traditional almond orchards, the main impact is represented by mechanical processing at 43.72%, which is followed by plowing at 27.61%, harvesting at 14.57%, and fertilization at 5.87%.

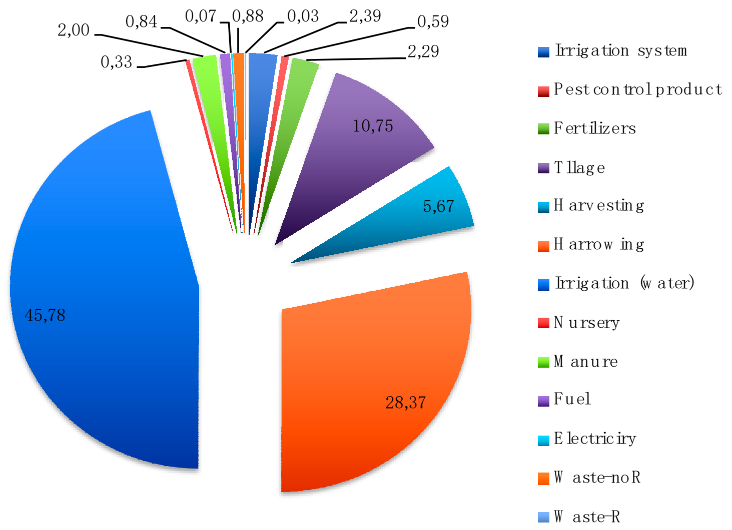

Figure 3. Items of environmental impact and relative weight (%) in the management of a modern almond orchard.

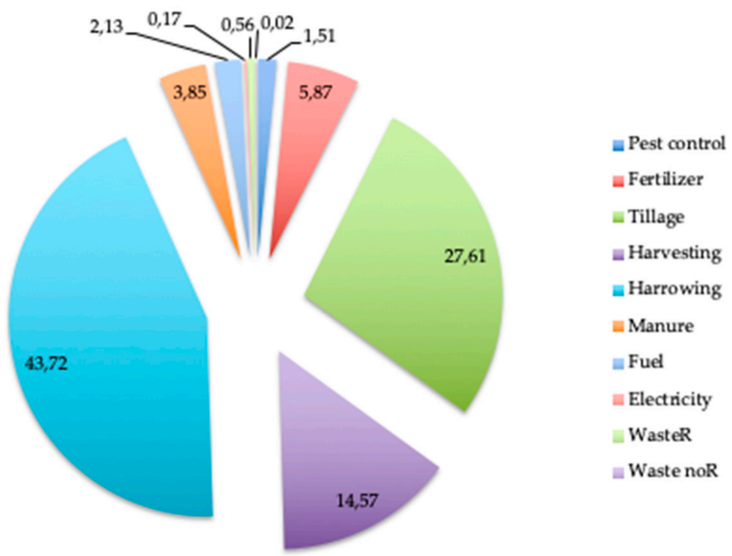

Figure 4. Items of environmental impact and relative weight (%) in the management of a traditional almond orchard.

3.2. Economic Results

The Conventional LCC implementation allowed the calculation of investments (start-up, operational costs, and rentability) of each almond production system for its whole life cycle.

The investments per hectare are reduced when compared with other fruit species. In particular, they account for about €5,800.00 for the modern plantings and about €1,600.00 for the traditional ones. The operational costs and total output associated with the field operations analyzed in the flowchart (Figure 2) were calculated. Table 6 shows total output, operational costs, and the difference between these two items, reported as the gross margin, which is related to the different growing phases of the two types of plantings.

Table 6. Total outputs, operational costs, and gross margins.

	First Harvest		Full Production		Last Year of Production	
Modern planting typology	Yield t ha^{-1}	2.0	Yield t ha^{-1}	4.8	Yield t ha^{-1}	3.0
	Operational costs € ha^{-1}	329,209	Operational costs € ha^{-1}	5113.00	Operational costs € ha^{-1}	5113.00
	Total output € ha^{-1}	3800.00	Total output € ha^{-1}	9120.00	Total output € ha^{-1}	5700.00
	Gross margin € ha^{-1}	507.91	Gross margin € ha^{-1}	4297.00	Gross margin € ha^{-1}	877.00
Traditional planting typology	Yield t ha^{-1}	0.8	Yield t ha^{-1}	2.3	Yield t ha^{-1}	1.5
	Operational costs € ha^{-1}	1876.02	Operational costs € ha^{-1}	3207.72	Operational costs € ha^{-1}	3207.72
	Total output € ha^{-1}	2470.00	Total output € ha^{-1}	5520.00	Total output € ha^{-1}	3600.00
	Gross margin € ha^{-1}	593.98	Gross margin € ha^{-1}	2336.28	Gross margin € ha^{-1}	446.28

The analysis of the achievable annual margins shows that, on the one hand, the initial and final production phases of both planting systems guarantee that the growers generate comparable annual gross margins, and, on the other hand, the modern production process in the full production phase guarantees significantly higher margins (+84%). The estimated cash flows were then discounted (five different scenarios of the discount rate were analyzed) in order to determine the rentability per hectare of the single planting system (Table 7). For both plantings, the net present value (NPV) always has positive values, which verifies the profitability of both scenarios in line with what has been found in the literature regarding almond orchard profitability in the Mediterranean area [18].

Table 7. Net present value per hectare invested.

Planting Typologies	0.01	0.02	Discount Rate 0.03	0.04	0.05
Modern	68,596.84	59,407.11	51,596.38	44,928.91	39,213.04
Traditional	62,929.73	51,134.66	41,957.60	34,743.37	29,014.06

4. Discussion

Sustainability assessment is a complex field, and its use among agricultural producers is limited. Moreover, current sustainability assessment tools are not always considered by downstream actors in the agricultural system and local governance, and, often, the interpretation of the results and their application does not lead to the identification of concrete solutions [48]. For this reason, after developing the analysis of the environmental and economic impact of the two planting systems (traditional almond orchards and modern ones), it was decided to avoid the subjectivity of the interpretation of the results by the investigators and to adopt, instead, a participatory approach to their interpretation and discussion.

The three groups of stakeholders (10 farmers, 4 dealers, and 6 policymakers) were held for two main reasons. First, in order to try to overcome the risks of misunderstandings due to the use of technical terms from different sectors, second, to reduce the influence of the researcher on the final interpretation that could result from the formulation and grouping of options presented in questionnaires. Specifically, in multidisciplinary scenarios, such as those in this paper, all stakeholders involved represent a wide range of perspectives, and the areas of expertise and discussion may be the only way in which certain groups can be made aware of the interests and knowledge of others [49].

With regard to the farmers' group, the economic assessment was considered the most interesting category. In particular, profitability achieved the highest assessment, which is followed equally by operational cost and investment. The aspect that most influenced farmers was the higher profitability, together with a reduced need for investments, both at first planting and in subsequent stages. In fact, it is not necessary, beyond the irrigation system, to proceed with the renewal or integration of the fleet. Moreover, the high profitability highlighted in the assessment is closely related to reduced increases in operating costs. The environmental aspect is the one that obtained the least interest from growers, and, when relevant, the discussion focused on the impact of irrigation. In fact, even though this operation accounts for almost 50% of the total impact of the modern almond orchards in the Sicilian territory with the agronomic techniques adopted, this value is always much lower than that calculated for almond trees in California and Australia [50,51]. In addition, comparing the irrigation needs of the almond trees with other fruit crops in the area, the amount used in almond orchards is significantly lower. More generally, the environmental weights (greenhouse gas emissions) highlighted in this study are much lower than those highlighted in the peach production sector in Sicily [52]. Despite the possibility of directing the positive results of LCA toward consumers [53], the group of traders was not interested in this type of assessment. This group of stakeholders showed particular interest in the yield obtained from modern almond orchards due to the better quality of the final product, especially in terms of kernel homogeneity. Furthermore, they stressed that the results of the economic assessment were important for undertaking new development strategies in terms of further development of Sicilian almond cultivation. Lastly, they showed great interest in the results related to rentability, which affects the possibility of experiencing a significant increase in marketed volumes (increase in yield) and values (increase in shelling rate). The third group of stakeholders involved (policymakers) was particularly interested in the results of the environmental assessment. This is due to their interest in the valorization of territorial products and landscapes, which are closely linked to the food and wine tourism policies of Sicily [54,55]. Moreover, they underlined that, taking into consideration the economic assessment as well, this study allows farmers to realize crop differentiation in advantageous conditions to strengthen the nut sector (Table 8).

Table 8. Relevance indicated by stakeholders of the different categories of assessment from not relevant (nr) to maximum relevance (+++).

Stakeholders Category	Assessment Category			
	LCA	Investments	Operational Costs	Rentability
Growers	+	++	++	+++
Dealers	nr	nr	nr	++
Territorial governance	+++	+	nr	+
Investigators	++	++	+	++

In the opinion of investigators, LCA, investments, and rentability should have the same relevance. As a consequence, it will be possible to assess a modern strategy for the almond Sicilian industry. The greatest environmental impact is to be attributed exclusively to irrigation, which is less relevant than in other crops. Moreover, the results of the economic assessment strengthen the modern planting model, which ensures a strong support toward a change of pace in the sector.

5. Conclusions

In this work, the discussion of the results with stakeholders successfully stimulated a shift toward consensus among a large number of different stakeholders on controversial topics such as the need to sustainably replace other fruit crops. The results, however, support the investigators' recommendations toward a substantial renewal of the sector through highly specialised technical choices. Moreover, while it is well known that the different cultivation techniques between modern and traditional plantings have no effect on the final quality of the kernels, it is nevertheless useful and interesting to envision further research involving consumers as stakeholders in the final stage of the production chain.

The interest in these in-depth studies is reinforced by the need for a renewal of the fruit orchards in the areas under study. The structural crisis faced by stone fruit crops, such as peaches and table grapes, is linked to outdated agricultural models, and it has left many agricultural areas free to use a particularly suitable area with adequate irrigation availability that is much higher than the needs of the almond tree [12]. This species, however, has always shown that, in specialized cultivation contexts, with adequate mechanization and availability of irrigated resources, it is able to offer significantly better agronomic results and to compete with most of the fruit tree crops widely distributed in the Mediterranean Basin. Due to the climate conditions, the natural inclination of the drying phase during the summer has always allowed a very simplified post-harvest management to be applied to this crop, which translates to the possibility of being commercialized for a much longer period and at lower storage costs when kept in shells [56] as well as to always meet a high degree of consumer preferences [57]. It should also be stressed that, with these specific characteristics, the transition of the plantings to complete organic management is very simple and is very much favored by the rusticity of the species and its resilience to the main fungal and insect diseases [58].

This renewed interest has, in some ways, attracted the attention of those who currently offer super-intensive systems for almond trees, as previously used for olive trees [59]. Despite the fact that there is currently a lack of sufficient scientific literature on the subject in Sicily, these systems appear to be unsuitable for the orography of the Sicilian almond tree areas and, for a social context, often sees many small-to-medium-sized plantings and small-scale growers gathered in associations or organizations only for the marketing phase. Moreover, it is evident that, to date, there is no consideration of the possibility of realizing these plantings by respecting the current significant cultivar panorama of success for Sicily, while the models developed, especially those originating from Spanish ideas, are performed by specific combinations of rootstocks and cultivars on which there is not enough information regarding the pedoclimatic adaptation in the target areas.

Considering the results of this work, the almond landscape in Sicily is destined to change with a substantial diffusion of modern but rational planting models, which offer greater assurances in terms of production and profitability, as an alternative to crops that are in crisis and certainly result in higher costs. The role played by the traditional almond orchards remains unquestionable, as it will continue to occupy a significant place in the conservation of the traditional agricultural landscape and, above all, will also contribute to the conservation of ecosystem services [60,61]. From the point-of-view of rational industrialization, it should also be considered that more recent approaches of the circular economy are being developed, which involves the reuse of all the waste from the processing of almonds, downstream of the production of the kilogram of the product in shells that we considered a focus in this study. This will make it possible to further enhance the value of by-products such as shells and tegument while maintaining a strong relationship with Mediterranean cultivars, which have a lower shelling rate than Californian ones, but have greater outcomes in terms of kernel quality and product healthiness [62].

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