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Article

Assessing Sustainability Performance at the Farm Level: Examples from Greek Agricultural Systems

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Abstract: In recent years, farmers and policymakers have faced ample challenges and have struggled to support the sustainability of the agricultural sector. Sustainable agriculture encompasses multiple concepts, and its performance produces extensive debate about data requirements, appropriate indicators, evaluation methods, and tools. Under the European Union (EU) financed project FLINT (Farm Level Indicators for New Topics in policy evaluation), detailed data have been collected at the farm level to provide broader coverage of sustainability indicators on a wide range of relevant topics to facilitate the assessment of sustainability performance. The approach has been applied in a pilot network of representative farms at the EU level, considering the heterogeneity of the EU farming sector to provide data infrastructure with up to date information for sustainability indicators. This study aims to assess sustainability performance at the farm level in Greece. Representative and dominant agricultural systems, such as permanent crops, olive trees, arable crops, and livestock (sheep) farms, comprise the Greek sample. It uses the analytical hierarchy process (AHP) methodology and attempts to gain insights into the sustainability performance of agricultural systems. The outcome of the sustainability assessment reveals knowledge and develops support for strategic farm choices in order to support both farmers and policymakers towards more sustainable development plans. The results indicate that three typical Mediterranean farming systems, like permanent crops, olive trees, and extensive livestock systems (sheep farms), are more sustainable in contrast to intensive and arable crop farms.

Keywords: sustainability assessment; farm level; AHP methodology; Greece

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1. Introduction

Today, there is growing interest in assessing the sustainability of agriculture. Sustainability has become a high priority, both in scientific research and in policy agendas [1]. Despite the existence of many studies examining particular dimensions, the need for an integrated assessment of sustainability at the farm level has been widely recognized in scholarly research [2-9]. This realization is a result of the sustainability concerns of citizens, as well as frequent policy changes, which create new information needs for all sustainability dimensions at the farm scale [10,11]. In the concurrent consideration of the multifaceted nature of sustainability at the farm level, diverse methods for the measurement of indicators and the aggregation of scores have been used [12,13]. The most frequently used methods include tools, frameworks, and indices based on indicators. These are followed by multi-criteria methods, including the analytical hierarchy process (AHP) [14-18,9].

However, the above task is hampered by the complexity of the concept of sustainability and the heterogeneity of agricultural systems [19], as well as the limited availability of data, which could possibly allow the calculation of meaningful and relevant indicators [20]. Besides the lack of data at the farm level, recent research has pointed out the need to broaden the scope and complement well-established monitoring tools, such as farm accountancy data networks (FADN) [10,20] . Also, any

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effort for the assessment of sustainability involves various controversial issues, including the process of computing composite indicators, which encompass much information from multiple indices [6,9,11].

The sustainability assessment of Greek agriculture is crucial and could provide vital information for an appropriate strategy that will support its improvement. Greek agriculture features a high degree of sectorial and spatial heterogeneity, as well as a prevailing small-scale structure. The country presents the highest proportion (53%) of high nature value farmland in its utilized agricultural area (UAA), and various farming systems of crucial importance are extensive. For example, the average density in olive orchards is 139 trees per hectare (ha), which is much lower than the threshold of intensive systems (more than 180 trees per ha) [21,22]. Similarly, the extensive production system is predominant in sheep rearing, with 78% of the Greek sheep flocks being reared in low-input production systems [23]. On the other hand, Greek agriculture presents some noteworthy distinctive features compared to the majority of EU countries, such as the highest share of permanent crops (tree cultivations and vineyards) in the total UAA among EU countries [24], as well as large numbers for sheep and goat rearing mainly for the production of dairy products rather than meat.

As part of the broader Mediterranean region, Greek agriculture is facing a series of challenges with clear sustainability implications, such as fragile social structures, the intensive exploitation of natural resources, increasing risks of droughts and biodiversity loss, decrease in crop yields, and rising demand for water [25,26]. At the same time, the long-term viability of farms is in jeopardy, all the more so because most of them are small and are less powerful actors in a rapidly consolidating agri-food system. All these challenges undoubtedly imply a necessity for a multidimensional sustainability assessment at the level of farms. It has to be noted that, with few exceptions [27-29], the literature on this critical issue is scant in regard to Greek agriculture.

This study aims to conduct a comparative assessment of the sustainability performance of various agricultural sectors by using an AHP method to aggregate sets of economic, social, and environmental sustainability indicators. To this end, we use data from different sources, including farm-level data from FADN, complemented with additional data from the EU FLINT project (Farm Level Indicators for New Topics in policy evaluation), along with expert opinions and stakeholder views. This synthetic approach is applied across the professional farms of four typical farming systems in Greece, i.e., arable crops, olive trees, permanent crops, and livestock. All these sectors account for nearly half of the total output of Greek agriculture [30], while they are vital for many rural areas of the country. Besides, these systems are characteristic not only for Greece but also for many other Mediterranean countries.

The paper is organized as follows. The next section describes the applied methodology and the data used in the study. The empirical application is then illustrated, followed by the discussion of the results. The paper concludes by reporting the main findings.

2. Materials and Methods

2.1. Analytical Hierarchy Process

The analytical hierarchy process (AHP) method was employed here to assess the sustainability of performance at the farm level. The AHP method can be useful in addressing sustainability issues since it can accommodate conflicting, multi-dimensional, and incommensurable sets of objectives [31] and is considered by many as the most reliable multiple criteria decision analysis (MCDA) method [18]. The AHP methodology has been used widely, either alone or in combination with other MCDA methods (such as PROMETHEE, ELECTRE, and TOPSIS) for the sustainability assessment of various aspects of the agricultural sector (e.g., agricultural production models, cultivation techniques, farm types, public policies, and conceptual issues such as development models, etc.) and various regions.

More specifically, the AHP has been implemented in the comparative sustainability analysis of agricultural production models (organic, integrated, and conventional) for the cultivation of the olive trees in the Mediterranean [32,33]. The sustainability levels of alternative cultivation techniques also have been estimated, such as the tillage practices of maize in Poland [34] and irrigation management

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alternatives in Portugal [31]. Important agricultural regions in China and Romania have been assessed from the sustainable agricultural point of view [35, 36]. Furthermore, the dimension of farm-type sustainability has been investigated in the cases of the irrigated agriculture of the Duero Basin in Spain [37] and dairy farming and its possible geographic variability in Portugal [38]. Also, the prioritization of public policies has been analyzed through AHP to support farmer livelihoods in sugarcane growing regions in Brazil under the three pillars of sustainability [39]. Appropriate conceptual models, such as sustainable agricultural development and ethics models in Iran, have been determined via the AHP methodology [40, 41].

In the case of Greece, the AHP has been implemented to evaluate the most sustainable farm management practice for the cultivation of *Pistacia vera* L. on the island of Aegina [28], but also to identify the optimum locations for adoption, and the formation of precision farming clusters as a sustainable solution in the region of Central Macedonia, Greece [18]. Alternative multi-criteria methods have also been applied for sustainability analysis of the agricultural sector in Greece. Dantsis et al. [27] applied multiple attribute value theory to evaluate the sustainability of farms in two geographical regions [42], and Papathanasiou et al. [43] applied TOPSIS and VIKOR methods to classify the rural areas of Central Macedonia in Northern Greece using a set of social sustainability indicators. Although MCDA methods have been used for sustainability analysis in Greek rural areas, the current study presents a comprehensive sustainability analysis, taking into account the three major types of farming (arable farming, tree farming, and livestock farming).

2.2. Description of the main methodological issues and AHP

The AHP method was developed by Saaty [44] and is considered an efficient method for dealing with multiple criteria for decision-making problems, aiming to find the optimal choice among alternatives, based on the objective set, taking into account a set of criteria. The steps for applying the AHP method are described below.

A. Development of the AHP model

The first step corresponds to the structure of the decision within a hierarchical model. The decision problem is structured at different levels of the hierarchy, which are usually three or four, in particular, level 1 of the hierarchy corresponds to the objective, level 2 to the criteria, level 3 to the sub-criteria, and level 4 to the alternatives. As can be seen, in our research, we include four levels of the hierarchy (see also Figure 2).

B. Determining Local priorities (weights) for the sub-criteria and criteria

A pairwise comparison matrix is filled, referred to as A (Saaty's hierarchy matrix). It contains the performance of each criterion (or sub-criterion) against each other, taking into consideration expert judgment [45].

Saaty [44] proposed a scale from 1 to 9 in order to determine the preference intensity among criteria or sub-criteria (see Table 1). The subsequent rules must be followed when constructing the comparison matrix:

-If $a_{ij} = a$, then $a_{ji} = 1/a$;

-If criterion or sub-criterion i has equal importance to criterion or sub-criterion j, respectively, then $a_{ij} = a_{ji} = 1$, so $a_{ii} = 1$ for all i [45].

Table 1. Evaluation scale for pairwise comparisons.

Verbal evaluation	Value
The two factors are of equal importance	1
i element is slightly more important than j	3
i element is clearly important than j	5
i is much more important than j	7
i is extremely more important comparing with j	9
Intermediate values	2, 4, 6, 8

Source: Georgiou et al., 2015

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After constructing the pairwise comparison matrix A, its consistency should be checked by following the four steps below:

1. Calculation of A*W^T, where W concerns the criteria or sub-criteria weights.

In more detail, the evaluation of the weights $W_1 \ldots W_n$ of the criteria or sub-criteria is made as follows:

1i. Each element of column i of the comparison matrix A is divided with the sum of the column. This results in a normalized table whose sum equals 1.

1ii. We calculate the average of values of row i in the normalized table.

2. Calculation of the largest eigenvector (λmax):

$$\frac{1}{n}\sum_{i=1}^{n}\frac{i^{th}\, entry\ in\ AW}{i^{th}\, entry\ in\ W} \quad (1)$$

where n corresponds to the dimension of the pairwise comparison matrix [45].

3. Estimation of the consistency index (CI):

$$CI = \frac{(\lambda max)-n}{n-1} \quad (2)$$

The lower levels of the consistency index (CI) are associated with lower levels of inconsistency, which is desirable.

4. The consistency index (CI) estimated in the previous step is compared with the random index (RI), which is the average CI of 500 randomly filled matrices [46]. The indicator derived from this comparison is the consistency ratio (CR):

$$CR = \frac{CI}{RI} \quad (3)$$

The acceptable level of the CR may not exceed 10%, however, some authors suggest that the acceptable level of the CR may expand to 20% [34, 47] .

In order to prioritize the economic sub-criteria, AHP pairwise comparison questionnaires were distributed to experts at the Agricultural University of Athens, the Agricultural Economics Research Institute, and the Technical University of Crete. Among the completed questionnaires, those who achieved a CR <= 10% or those who marginally exceeded this threshold were taken into account in our analysis. We then calculated the average of their weights for each sub-criterion to derive the final local priorities of the economic sub-criteria. In the case of the hierarchy process of social and environmental sub-criteria, the averages of experts' responses to the European Union project FLINT were used. Within the FLINT project, the hierarchy process was implemented via a scale from 2 to –2 (where 2 = ++; 1 = +; 0 = +/-; -1 = -; -2 = --) and then incorporated by the authors into the pairwise comparison matrix. After completing the comparison matrices, the consistency test was carried out, where the CR received values of less than 4% in both categories of the sub-criteria. At this point, it should be noted that the weights of the criteria (level 2) were not determined by experts but preferred to apply a variety of distributions (scenarios), with emphasis on a different criterion each time. The baseline scenario corresponds to the distribution of 0.33/0.33/0.33 among the three criteria considered, namely, the environmental, social, and economic criteria. In the case of the preferred scenario, the distribution is broken down to 0.5/0.25/0.25. For example, in the case of the environmental preference scenario, the weight for environmental criterion equals 0.5, while, for each of the other two criteria, they equal 0.25.

C. Determining local priorities for the alternatives

For each sub-criterion, the performances of the alternatives were compared via pairwise comparisons using a scale of 1 to 9 as before (step B). Additionally, consistency tests were performed in the process of evaluating the performance of the alternatives for each sub-criterion, where the CR was limited to values below 5%. Then, the weight of each sub-criterion was multiplied by the corresponding performance of each alternative and then summed up to estimate the local priorities of alternatives for each criterion (or performance for each criterion, namely environmental, social and economic performance). The performances of alternatives for each criterion or sub-criterion sum to 1.

D. Determining overall priorities for the alternatives and sensitivity analysis

In order to determine the overall priorities (or performances) of the alternatives, we synthesized the performance of each alternative for each criterion and the weight of the corresponding criterion, which was determined in the form of the scenarios mentioned above. More specifically, the performances of alternatives for each criterion were multiplied by the corresponding criteria weights and summed up to calculate the overall performances of the alternatives.

2.3. Data collection and sample description

Data were collected in the framework of the European research project FLINT, whose primary objective was to provide indicators for assessing agriculture sustainability at the farm level to support policy evaluation [10]. A wide range of indicators have been organized to cover several sustainability themes and merged with the FADN database, where economic indicators are dominant [6]. The Greek case study collected data from the most prevailing farming types in the country, like permanent crops, olive tree farms, arable crops farms, and livestock (sheep) farms. The optimal farm selection plan was based on two determinant factors, namely, the farm holding had to be part of the FADN, following the design of the selection plan on FADN structure covering the farming type and farm economic size classes, and willingness of the farmer to cooperate. In Greece, a sample of 124 agricultural holdings was selected, following the goal to have at least 25 observations per principal type of farming. The data were collected with educated data collectors via face-to-face interviews in the spring of 2016, referred on the calendar year of 2015.

The Greek survey took place in different geographical areas according to the locations of the farming types. Arable crops farms are located in the regional unit of Serres, cultivating mainly irrigated crops such as maize, cotton, and alfalfa (Figure 1 and Map 1). These farms have the highest percentage of irrigated land (76.5%) compared to other types of the surveyed farms, and the vast majority of them are in lowland areas (87%) (Table 2). The olive tree farms are located in the regional units of Laconia and Messinia (Map 1). Almost all of the cultivated land is occupied by olives, mainly non-irrigated (Figure 1). The irrigation rate corresponds to 42.5%, and the majority of farms are in lowland areas (46%) (Table 2). The permanent crops farms of the survey are mainly located in the regional units of Laconia and Messinia (Map 1). The distribution of crops consists mostly of trees such as olives and oranges (Figure 1). The percentage of irrigated land is 42.2%, and the majority of farms are in lowland areas (53%) (Table 2). Finally, regarding the livestock farms of the survey, they are located in the regional units of Ioannina and Laconia (Map 1). The average number of sheep corresponds to 259 animals, and the mainland uses corresponds to pastures and the cultivation of animal feeds such as alfalfa (Figure 1). The percentage of irrigated land is 8.9% of total land, which is by far the smallest compared to the other studied farm types, and the majority of farms are in mountainous areas (50%) (Table 2).

All farms were family farms, with full agricultural training, and the average age of managers was 51.7 years. It is worth mentioning that female managers were present in permanent crops and olive farms, in contrast to the other farm types (Table 2). Regarding the economic size of farms, as determined by FADN standard output (SO), the majority of permanent crop farms (58%), arable crops farms (47%), and livestock farms (58%) are considered large (SO > €25,000). The majority of olive tree farms (48%) are considered medium (SO €8000-25,000), while presenting the largest percentage of small farms (17%) compared to other farm types (SO < €8000). In addition, there are no very large farms in the case of olive tree farms (SO > €50,000), whereas small farms are not observed in the case of livestock farms (SO < €8000).

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Table 2. Descriptive statistics of the Greek sample.

Variables	Permanent Crop Farms	Olive Tree Farms	Arable Crop Farms	Livestock Farms
Holder's average age (years)	52.6	50.8	50.2	53.6
Total size or total utilized agricultural area (UAA) ha	248.8	225.3	330.8	537.9
Average size (UAA) ha	7.8	9.8	22	22.4
Irrigated land (% of UAA)	42.1%	42.5%	76.5%	8.9%
Average number of sheep	-	-	-	259
Altitude <300 m as a percentage of farms	53%	46%	86.7%	8%
Altitude 300-600 m as a percentage of farms	19%	29%	6.7%	42%
Altitude >600 m as a percentage of farms	28%	25%	6.7%	50%
Gender of farm manager (% female)	37%	42%	16%	16%
Degree of agricultural education of farm manager				
Only practical agricultural experience	24%	32%	44%	53%
Basic agricultural training	-	-	4%	17%
Full agricultural training	76%	68%	52%	30%

Source: Authors, based on farm accountancy data networks (FADN) and farm-level indicators for new topics in policy evaluation (FLINT) data.

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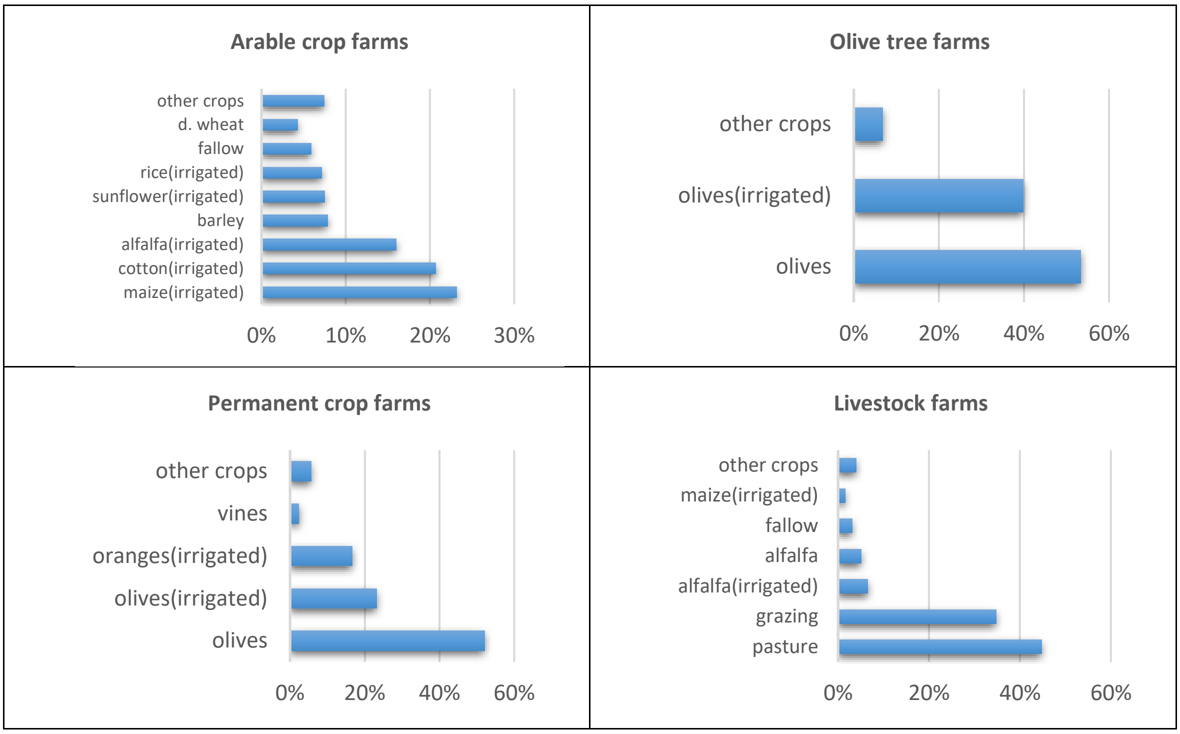
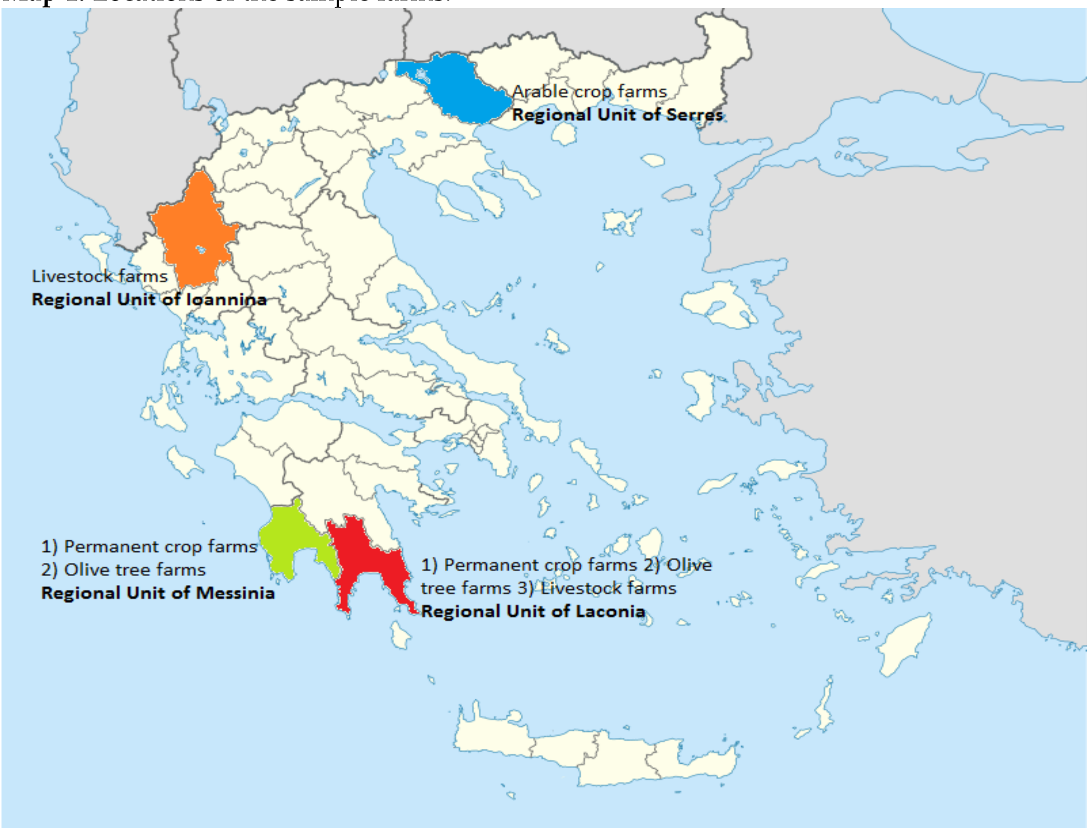
Figure 1. Crop allocation per farming system.



Map 1. Locations of the sample farms.



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2.4. Description of Sustainability Indicators at the farm level

A set of indicators has been selected to comprehensively and reliably represent the farming systems, encountering the complexity and the multifunctional character of Greek agriculture. Within the FLINT project, an extensive literature review identified a selection of core variables and themes of sustainability [6]. The themes cover the three sustainability dimensions known as "triple P", i.e., planet (environmental), people (social), and profit (economic) (Table 3), following the definition of the United Nations, i.e., that sustainable development pertains equally to ecological, social, and economic issues. The indicators of sustainability at the farm level were chosen from the wide list of 33 topics developed by the FLINT project consortium, taking into account policy needs [48] and consultation from stakeholders and FLINT partners [49, 50]. The mean value of each indicator for each farm type corresponds to a sub-criterion, which is used as input by the AHP model (see also Figure 2).

Table 3. Set of sustainability indicators at the farm level.

Sustainability Dimension	Indicator	Unit	Source
Environmental	Greenhouse gas (GHG) emissions at farm	tCO_2 eq/ha	FLINT e_14_1
	Percentage of farm UAA with nitrate risk	%	FLINT e_10_4
	Water consumption per kg of product	Lt/kg	FLINT e_16_1
	Farm gate N-balance	Kg/ha	FLINT e_5_1
	Pesticide risk score	Kg/ha	FLINT e_4_1
Social	Advisory contacts per year per holding	n	FLINT s_1_1
	Degree of agricultural training of the manager	Category	FLINT s_2_1
	Total labor in annual working units	n	FLINT s_5_1
	Satisfaction with quality of life	n	FLINT s_6_4
	Social diversification index	Count	FLINT s_7_2
Economic	Total output/total input	Euro	FADN SE132
	Total subsidies/family farm income	Euro	FADN SE605/SE420
	(Family farm income/family work unit)/reference income	Euro	FADN SE430
	Farm net value added (FNVA)	Euro	FADN SE415

Source: Authors, based on FLINT and FADN data sources.

2.4.1. Environmental Indicators

GHG emissions at farm level: The GHG emission per farm (tons of carbon dioxide equivalent, i.e., tCO_2 eq.) is a primary policy target and is estimated using the tier 1 and tier 2 procedures of the Intergovernmental Panel on Climate Change—IPCC [48]. The best value for this indicator is a low one, which means a more environmentally sustainable farm. It provides useful information about the applied production practices and broadly about the agricultural systems. Moreover, it supports the long-term evaluation of GHG production and is enhanced with the relevant information for the right Common Agricultural Policy (CAP) actions for climate change mitigation. It also helps to adjust the applied strategy for Greek farming systems and practices that contribute positively to reducing GHG emissions.

Percentage of farm UAA with nitrate risk: The level of nitrate risk is crucial for economic, environmental, and health issues [48, 51]. Farmers have to apply for the careful matching of crop requirements of fertilizers and nutrients in order to adjust optimal cost-effective and environmentally beneficial management for the farm [52]. A low value of this indicator indicates a more environmentally sustainable level for the given farm.

Water consumption per kg of product: Water is an essential environmental factor which contributes to sustainable economic growth. Water, as a limited recourse in the Mediterranean area, is therefore a central theme to include in the sustainability assessment in regard to water consumption by agriculture. An effective strategy towards water efficiency can make a substantial contribution to assess the level of sustainability. Hence, the level of water consumption through irrigation was estimated. The water footprint indicator evaluates the volume of water consumed by the unit of the product obtained. The lower the value of this indicator, the more environmentally sustainable the farm is considered to be [53].

Farm gate N-balance: The information about the level of nitrogen use is crucial at the farm level. It helps farmers to identify opportunities to save on fertilizer costs, reduce greenhouse gas emissions, and improve agronomic efficiency and environmental sustainability. It supports optimal fertilizer management, with no adverse impact on either the profitability of production or the environment. A suggested indicator in the FLINT was the farm gate N-balance [48]. The farm gate approach focuses on imports and exports, over which the farmers may apply direct control. Values that tend to approach zero are considered ideal. In the case of negative values, they are converted to absolute values so that they are directly comparable to positive values. Consequently, the lower the absolute value of this indicator, the more environmentally sustainable the farm is considered to be.

Pesticide risk score: The pesticide risk score, or pesticide usage, has many impacts for farmers, consumers, and the sustainability of agricultural sectors. Pesticides can have a significant impact on water quality and can affect water quality for human consumption, livestock consumption, and aquatic habitats and wildlife [54]. It refers to the amounts and types of different types of pesticides used on farms. This information is used to calculate a farm-level pesticide risk score [48]. A low value for this indicator is preferable, which indicates that the farm is environmentally sustainable.

2.4.2 Social Indicators

Advisory contacts per year per holding: The total number of contacts with advisory services per year was used to operationalize the type and the range of themes on which farmers seek advice. Advisory services contribute to the dissemination of innovative agricultural practices to increase productivity and improve environmental performance [55]. It is expected that those farms accessing advisory services are better informed and produce better knowledge, and, therefore, may be more innovative. The higher the value of this indicator, the more socially sustainable the farm is considered to be.

Degree of agricultural training of the manager: Education is a variable that represents the qualifications of human resources. The higher the value of this indicator, the more socially sustainable the farm is considered to be.

Total labor in annual working units: The total labor input, expressed in annual work units or full-time person equivalents, is an indicator that counts the potential of an agricultural sector to retain or even augment the number of jobs in an area, usually a remote, mountainous, or less favored rural area. Thus, it is an indicator of significant importance, especially during the crisis period which the Greek economy has been experiencing within the last ten years. The higher the value of this indicator, the more socially sustainable the farm is considered to be.

Satisfaction with quality of life: This indicator tries to measure the quality of jobs in the agricultural sector, which is one of the crucial dimensions in social sustainability. This helps to determine causalities among quality of life perceptions and economic, social, and environmental conditions [56]. The indicator is measured on a scale from zero to ten. A higher value indicates a more socially sustainable farm.

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Social diversification index: The social diversification index refers to the expansion of the range of activities both inside and outside the farm. It refers to the total number of activities. It is a clear indication of a significant livelihood strategy of a farm, denoting the range of diversification activities, both at the farm and the farm household level [48]. The higher the value of this indicator, the more socially sustainable the farm is considered to be.

2.4.3 Economic Indicators

The evaluation of economic sustainability focuses on the viability, productivity, and dependence of the relative farming systems. Short-term and long-term viability refer to the level of profitability, the level of support from subsidies (which determine autonomy), and the long term sustainability. Four indicators have been used to describe the economic pillar. More specifically, the total output/total input, total subsidies/farm family income, farm family income per family labor unit compared to the reference income, and farm net value added.

Total output/total input: The total output per total input indicator refers to the total output of crops and crop products, livestock, and livestock products, and of the other output, divided by the total input costs linked to the agricultural activity of the holder and those which are related to the output of the accounting year. This indicator is a measure of productivity at the farm level. The higher the value of this indicator, the more economically viable the farm is considered to be.

Total subsidies/farm family income: Total subsidies (excluding on investment) are compared with the farm family income (FFI) to determine to what extent FFI depends on subsidies, and, consequently, how sensitive it could be in the case of policy changes. FFI consists of two components, namely, FFI from the market and subsidies. Therefore, if the FFI from the market is less than zero (i.e., when cash expenses and depreciation exceed farm output), the index total subsidies/FFI will be higher than 100%. The lower the value of this indicator, the more economically viable the farm is considered to be.

Farm family income/family work unit compared to the reference income: Family farm income is expressed by the per family work unit and compared to the reference income, i.e., the mean income of a worker in the non-agricultural sectors of the economy. This indicator reflects a socio-economic approach to farm economic viability, as it encompasses two different dimensions, firstly, the reproduction of a farm's productive system, since with a net farm income greater than zero, the farm revenue covers both all cash expenses and the depreciation. Secondly, the support of the standard of living of the farm household. It is possible to assess to what extent the needs of the household members are fulfilled by comparing the FFI/FWU with the poverty line and the reference income. Thus, we consider a farm as economically viable if it attains a FFI/FWU value greater than 80% of the reference income. The higher the value of this indicator, the more economically viable the farm is.

Farm Net Value Added (FNVA): The farm net value added indicator is the remuneration to the fixed factors of production (work, land, and capital), whether they be external or family factors. The higher the value of this indicator, the more economically viable the farm is.

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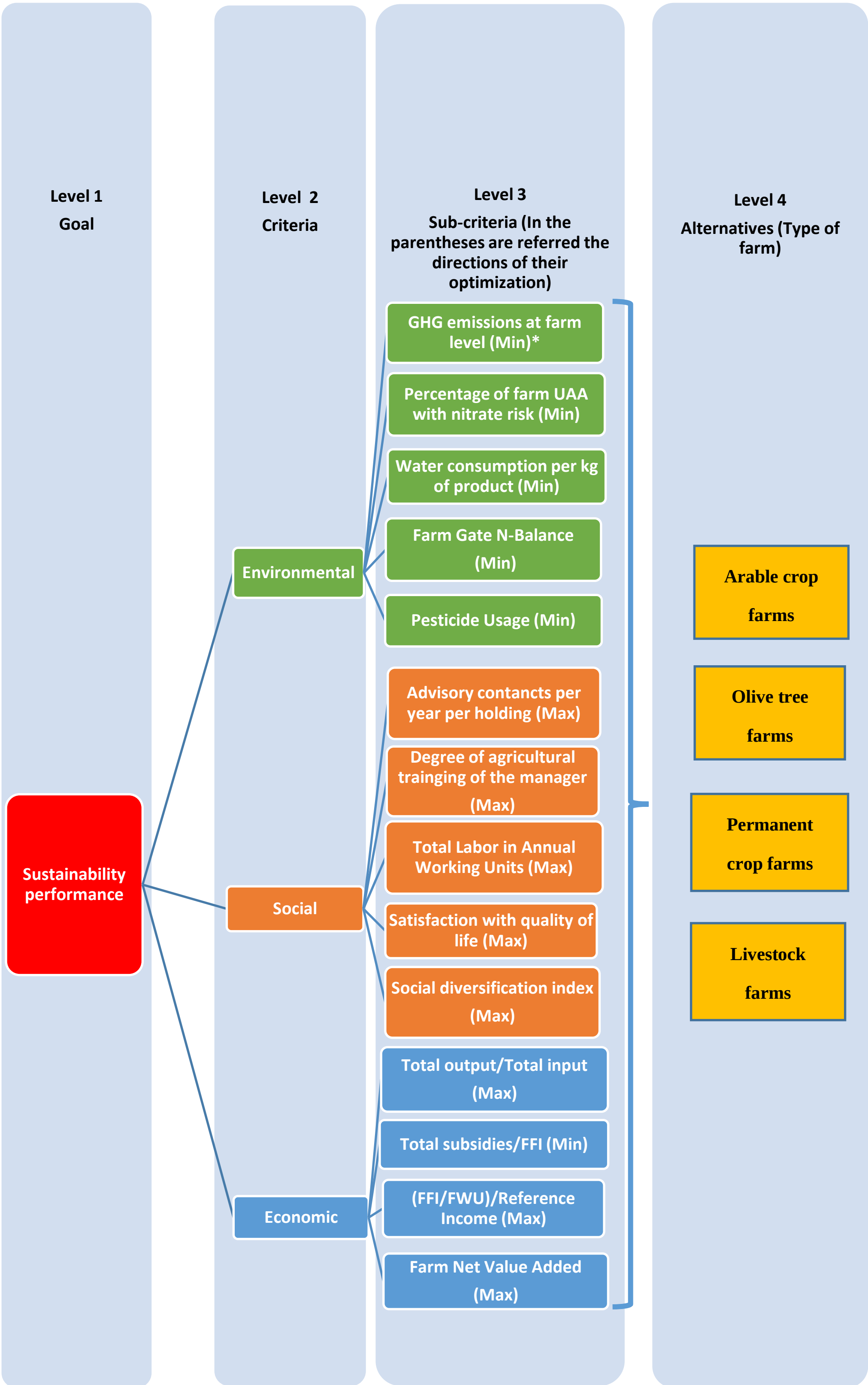
Figure 2. Analytical hierarchy process (AHP) model for the assessment of the sustainability performance.



(*) Values that tend to approach zero are considered more ideal than others that are far from zero. In the case of negative values, they are converted to absolute values so that they are directly comparable to positive values.

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3. Results

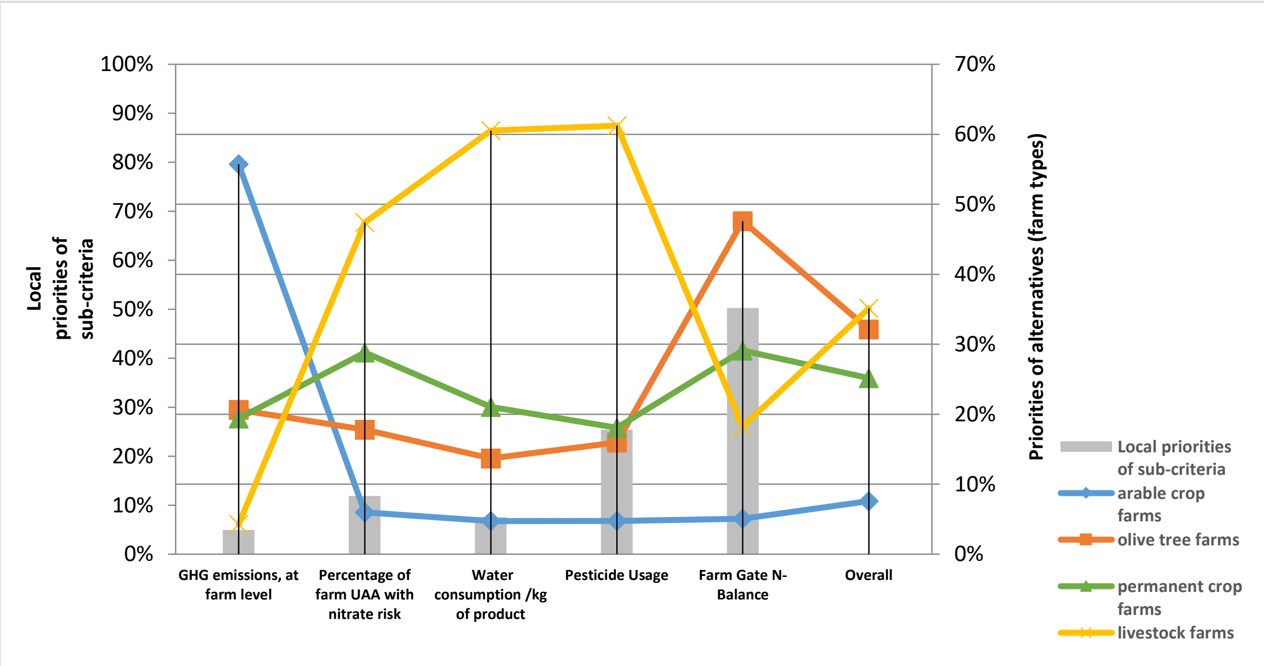
3.1. Environmental Performance

As for the local priority rankings of the environmental sub-criteria, according to experts, the farm gate N-balance has the highest weight at 50%, followed by pesticide usage at 25%, percentage of farm UAA with nitrate risk at 12%, water consumption per kg of product at 8%, and GHG emissions at 5% (see also Figure 3 and Table A1 in the appendix). The overall environmental performance shows that livestock farms rank first, with marginal differences from olive tree farms (see also Figure 3 and Table A2 in the appendix). Then, permanent crop farms followed, while the arable crop farms have a significant difference from all other examined farm systems. It is also worth noting that livestock farms outperform all other farming systems in three out of the five sub-criteria.

Table 4. Environmental sub-criteria (mean values per farm type).

	GHG Emissions at the Farm Level	Percentage of Farm UAA with Nitrate Risk	Water Consumption per kg of Product	Pesticide Usage	Farm Gate N-Balance
Arable crop farms	0.24	61%	710.86	8.32E-04	139.69
Olive tree farms	1.22	42%	126.16	2.88E-04	44.11
Permanent crop farms	1.44	35%	120.79	2.64E-04	72.59
Livestock farms	80.43	17%	7.03	2.75E-05	81.93

Figure 3. Performance of farms per environmental sub-criterion and overall.



3.2. Social Performance

In the case of the social sub-criteria, the ranking formed by the responses of the experts was as follows. The total labor in annual working units has a weight of 44%, advisory contacts per year per holding has a weight of 29%, satisfaction with quality of life has a weight of 13%, degree of agricultural training of the manager has a weight of 8%, and, finally, the social diversification index has a weight

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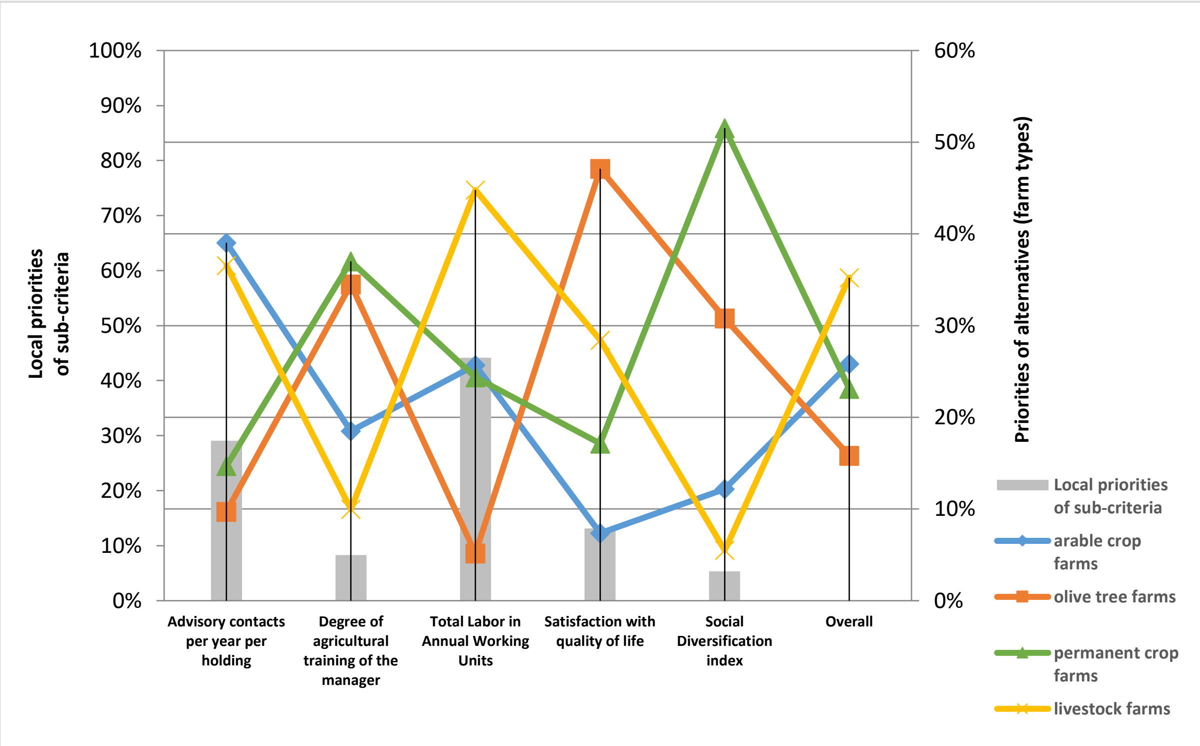
of 5% (see also Figure 4 and Table A1 in the appendix). The highest overall social performance was observed for livestock farms followed by arable crop farms, permanent crop farms, and, finally, by olive tree farms (see also Figure 4 and Table A2 in the appendix).

Table 5. Social sub-criteria (mean values per farm type).

	Advisory Contacts	Degree of Agricultural Training of the Manager	Total Labor in Annual Working Units	Satisfaction with Quality of Life	Social Diversification Index
Arable crop farms	37.6	2.07	1.29	5.33	1.27
Olive tree farms	12.7	2.39	0.96	7.43	1.30
Permanent crop farms	15.8	2.44	1.27	6.06	2.00
Livestock farms	33.5	1.75	1.80	6.29	0.92

Figure 4. Performance of farms per social sub-criterion and overall.



3.3. Economic Performance

According to experts, the economic sub-criteria ranking was as follows: (FFI/FWU)/reference income has a weight of 50%, total output/total input has a weight of 22%, FNVA has a weight of 21%, and total subsidies/FFI has a weight of 6% (see also Figure 5 and Table A1 in the appendix). In terms of prioritization of alternatives or overall economic performance, permanent crop farms are the first (see also Figure 5 and Table A2 in the appendix). They differ significantly from all other types of farms, followed by olive tree farms, livestock farms, and, finally, arable crop farms. It is also worth noting that permanent crop farms outperform the other crops in all economic sub-criteria, which explains their high-performance range over other farming systems. Specifically, permanent crops score a lower dependency on subsidies, which indicates that family farm income depends on market income and not on external sources like subsidies. The productivity scores were higher compared to all other analyzed sectors, meaning that permanent crops have a high value of output and lower costs. Moreover, farm family income had the highest score, reflecting a primary indicator of farm

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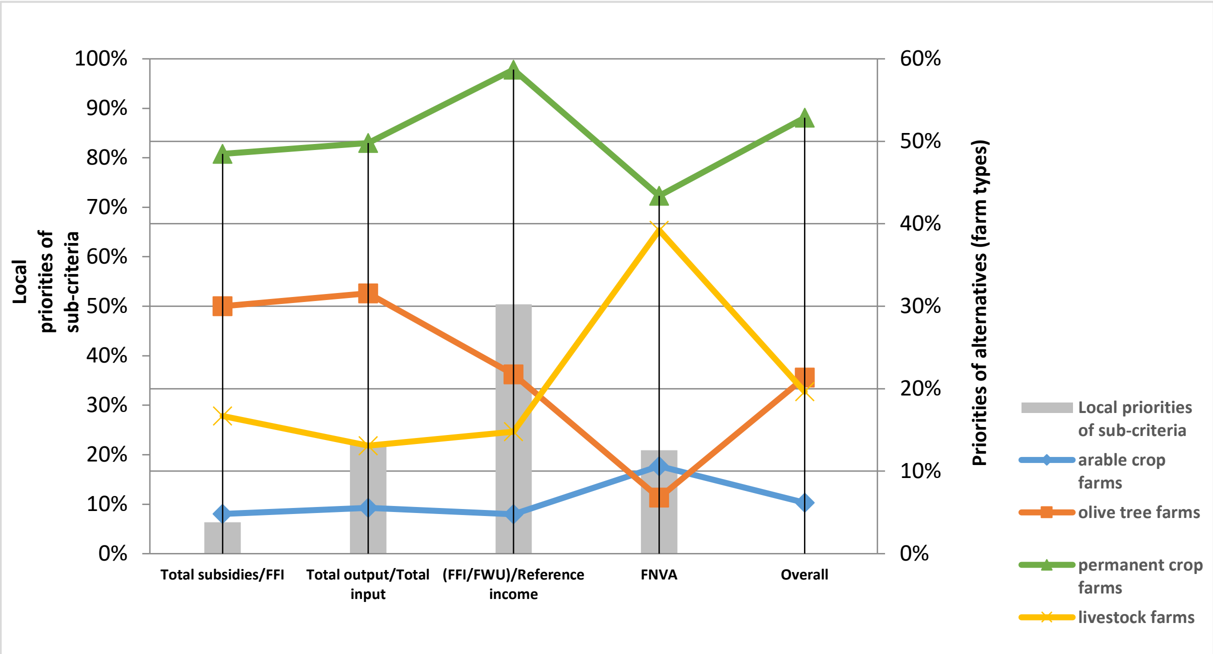
economic viability in combination with the revenues to cover all cash expenses, and the depreciation contributes to the support of farm household standard of living. Finally, the farm net value added, which represents the remuneration of the fixed factors of production, scored higher than all other sectors.

Table 6. Economic sub-criteria (mean values per farm type).

	Total Subsidies/Farm Family Income	Total Output/ Total Input	(Family Farm Income/Family Work Unit)/Reference income	Farm Net Value Added (€)
Arable crop farms	345%	78%	54%	17,850
Olive tree farms	32%	202%	158%	16,875
Permanent crop farms	25%	258%	202%	26,457
Livestock farms	112%	152%	140%	25,567

Figure 5. Performance of farms per economic sub-criterion and overall.



3.4. Overall Sustainability Performance and Sensitivity analysis

Aggregating the results of the previous sections, we may observe that livestock farms outperform all other farms in two criteria, namely, the environmental and social criteria (see also Figure 6 and Table A2 in the appendix). On the other hand, arable crop farms occupy the last position in the environmental and economic criteria. It is also worth noting the clear superiority of the permanent crop farms in the economic criterion, a situation which is not observed in the other two criteria. In the process of evaluating the overall sustainability performance of each alternative (farm type), in addition to the basic distribution of equal weights (0.33/0.33/0.33) among criteria, we have studied three alternative policy scenarios from the policy maker's perspective. For each preference scenario, the weight distribution among criteria was adjusted accordingly (0.50/0.25/0.25). As can be seen, permanent crop farms rank first in the baseline scenario of equal weights, followed by livestock farms with a slight difference (see also Figure 7 and Table A2 in the appendix). Olive tree farms are in third place with a distinct difference, while arable crop farms rank last with a big difference. When it comes to the environment, permanent crop farms and livestock almost equalize, followed by olive tree farms, with a decreased difference compared to the baseline scenario, while, for arable crop farms, the distance becomes wider. In the case of social preference scenario, permanent crop farms and livestock almost equalize, followed by olive tree farms with an increased difference compared to baseline scenario, while arable crop farms rank last but decrease the gap significantly. Finally, in the case of economic preference scenario, the sustainability performance of permanent crop farms improves significantly; as a result, they rank first with a significant difference over livestock farms, which reveal a lower performance than other scenarios. Olive tree farms are in third place, with a distinct difference, revealing lower sustainability performance compared to baseline scenario, while arable crop farms rank last.

Figure 6. Performance of farms per criterion.

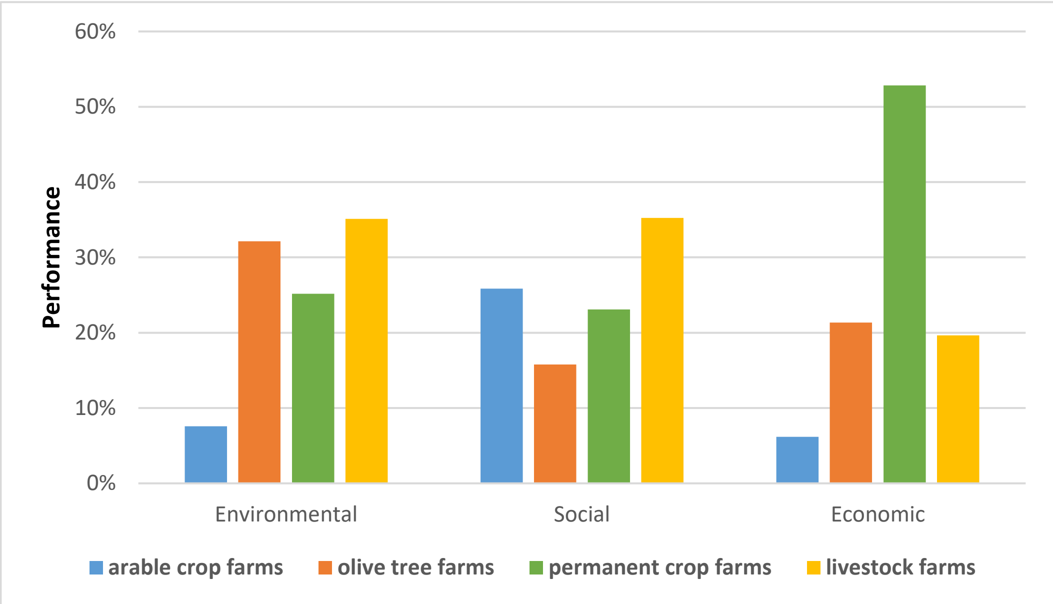
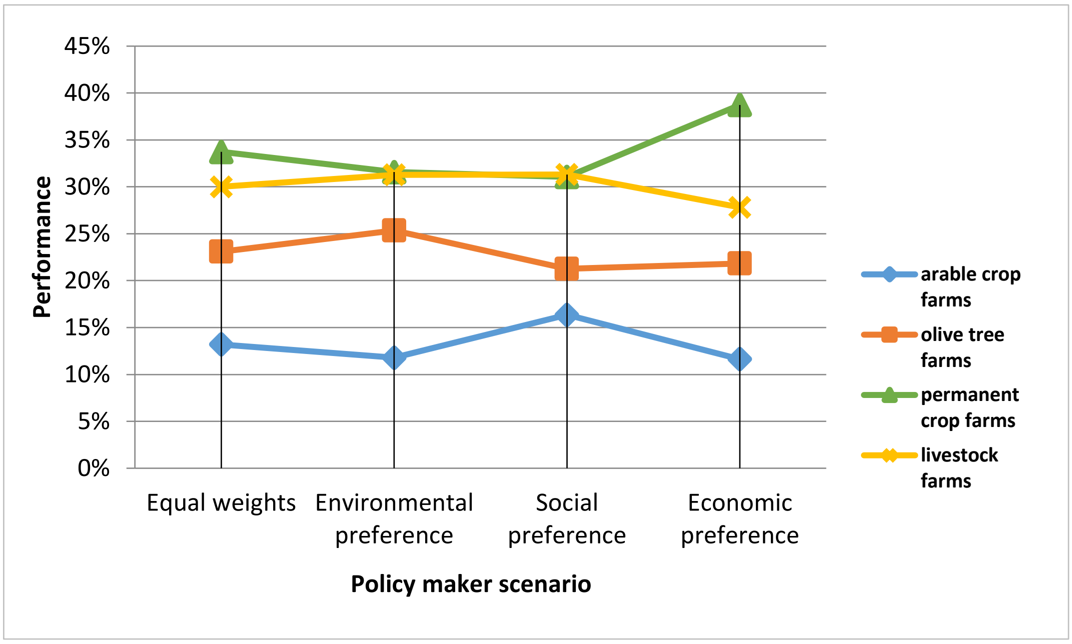


Figure 7. Overall sustainability performance per policymaker scenario.



4. Discussion

This study contributes to filling a gap in the integrated assessment of farm-level sustainability for some critical Greek farming systems. It is worth mentioning that two of the examined systems concern permanent crops, for which only a few sustainability assessment methods have been applied so far [57]. A series of methodological and empirical issues emerge from the preceding analysis.

Sustainability assessment is not an easy task, especially when it is conducted across all pillars and through composite indicators. Composite indicators are easy to interpret, while they convey and summarize valuable information in complex, multi-dimensional issues. On the other hand, their interpretation could be ambiguous, where they can send misleading policy messages [58]. Two further problems are the subjectivity in the process of assigning weights to individual indicators, which, along with their aggregation, is the essential stage in the process of constructing composite indicators [59]. This ambiguity is mitigated by the fact that the opinions of experts reflect, at least to some degree, the "preferences" of the society on the debated and multi-faceted issue of sustainability. Therefore, future research could broaden the pool of experts (whose opinions are used to assign weights to separate indicators) with other stakeholders from the agri-food system, such as policymakers, farmers, cooperative members, etc. Additionally, future research should include small farms, which make up the backbone of Greek agriculture.

The proposed methodology has enabled us to identify both intra- and inter-agricultural system heterogeneity in regards to the sustainability performance of different farms across the sub-criteria in each of the three dimensions (pillars). In the social dimension, this variation is more pronounced. Nevertheless, the picture is much clearer when the overall sustainability assessment is conducted. Interestingly, it seems that three "typical" Mediterranean farming systems, as practiced by professional farms in Greece (permanent crops, olive trees, and sheep), are more sustainable than arable crops. Also, the relative ranking of the examined farming systems seems to be consistent across four different policy priorities. This finding implies that even under diverse prioritization concerning the three pillars of sustainability, permanent crops, olive trees, and sheep will be expected to outperform arable crops.

Taking into account the appeal for broadening the datasets of the established monitoring tools [20], we have shown that the enrichment of FADN data with a series of farm-level information from the FLINT project, concerning environmental and social aspects of farm functioning, provides a meaningful set of indicators that enable a thorough sustainability assessment.

Assessing sustainability at the farm level is a powerful tool that can be used for a variety of purposes, such as the improvement of the governance of the agricultural sector [59] and the facilitation of the marketing of food products [60]. It can also support farmers to carry out detailed diagnoses to find the strengths and weaknesses of farms, thus contributing to the construction of a viable farm development plan. Also, the findings of this study can prove useful in identifying the actions needed to ensure the long-term sustainability of the examined systems, as well as in the formation of strategies for sustainable development in both sectoral and spatial terms.

The high performance of permanent crops, olive trees, and sheep, in terms of the economic, social, and environmental dimensions of sustainability, has very significant implications. As far as permanent crops are concerned, two issues should be highlighted. First, the need for opening new export markets for oranges, especially in Northern European countries, in specific time slots, where other Mediterranean countries (e.g., Spain and Italy) do not export their produce. Second, addressing severe plant infestation from the citrus tristeza virus (CTV), which poses a serious threat to orange cultivation in the study areas. Ensuring the sustainability of this system requires various actions: (a) One action is the adoption and planting of new citrus varieties, i.e., a reorganization of the system through new investments, which is hindered by the unfavorable economic environment of austerity macroeconomic policies that has been applied to the Greek economy since 2010. (b) Another action is the provision of critical elements in the whole organizational and supporting infrastructure, such as certified nurseries, and the effective collaboration of farmers with researchers (in both research institutions and universities). (c) Finally, the creation of a learning environment among farmers is ideal, which will favor the dissemination of the existing practices of some farms that successfully

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integrate scientific with traditional knowledge. This learning environment can strengthen the adaptive capacity of farms [61, 62], and contribute to the resilience of the system after each successive shock [63].

On the other hand, our findings on the sustainability performance of professional olive tree farms can be used as an underpinning for the formation of a strategy for its products, especially olive oil. One of the focal points in this strategy could be the valuation of positive externalities provided by this system. As has been documented by an ample number of studies, extensive olive tree systems, while lagging behind intensive systems in terms of yields, economic outcomes, and profit, in many cases, they provide landscape and habitat diversity, along with multiple benefits for the local communities [64,65]. A supporting argument is a fact that intensified olive farming is a major cause of one of the major environmental problems affecting the EU today, i.e., widespread soil erosion and desertification in all southern EU countries [66].

Moreover, the high sustainability performance of professional sheep farms confirms previous findings in the literature [67,68]. Sheep milk is mainly transformed into typical dairy products that have a regional or local connotation of origin and quality, especially "feta" cheese, which is the flagship of all Greek products with a designated geographical indication. However, although feta is highly appreciated in foreign markets and regarded as a central element of the Mediterranean diet, stock-breeders and processors struggle to capture a greater share of the value created in the international value chain, owing to a lack of a coherent strategy to promote and secure the specific attributes of this product. Hence, serious initiatives need to be taken, as scholarly research indicates that in the cases of products with geographic indications "reactions to counterfeits and imitations are more difficult to put in place due to collective action constraints and to limited financial resources to be devoted to the discovery of such situations" [69].

We should not forget that the dual entity farm firm/farm household is a system which is part of a broader hierarchy of agriculture-related systems. Therefore, a systemic approach is needed, whereby sustainability is seen as an emergent property, related to particular levels within the hierarchy. As Webster [70] rightly points out, "its operational definition at the farm level thus may not apply at other levels in the hierarchy".

Furthermore, Prosperi et al. [71] have claimed that the high sustainability performance of agri-food systems implies an enhanced ability to withstand shocks and stressors of various kinds, i.e., it renders these systems less vulnerable. Consequently, the findings of this study assume significant importance in view of all challenges facing Greek (and more generally the Mediterranean) agriculture, especially climate change, economic crises, and other stressors.

In the previous paragraphs of this section, we have provided some policy suggestions, implied by the results of our study. In the same vein, this study could support the role of specific agricultural sectors and farmers through compensating them according to their significant contribution to more sustainable farming practices. Given the multidimensional nature of any sustainability assessment, some room should be given for flexibility in the use of sustainability performance indicators. In that sense, the proposed varied prioritization of the three pillars can aid policymakers to have a clear picture of the expected sustainability performance of each farming system. Besides, this analysis, under the holistic view of farms, will support policy advice and improve the applied institutional framework under the new CAP and the focus on the sustainable way of thinking.

5. Conclusions

The objective of this paper was to conduct a comparative assessment of the sustainability performance of four typical farming systems in Greece using an AHP method to aggregate sets of economic, social, and environmental sustainability indicators. The preceding analysis has yielded some interesting results, from both a methodological and an empirical point of view.

Despite the large amount of data needed, the concurrent consideration of all pillars of sustainability through AHP at the farm level, based on an enriched database of FADN, can provide a meaningful set of indicators that enable a thorough sustainability assessment. By applying the

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proposed methodology, we have identified significant intra- and inter-agricultural system heterogeneity in regard to the sustainability performance of different farms, as well as a clear ranking of the relative performance of the examined systems. At least two of the studied farming systems were found to be both extensive and sustainable in economic, social, and environmental terms. In addition, three "typical" Mediterranean farming systems, as practiced by professional farms in Greece (permanent crops, olive trees, and sheep), were observed to be more sustainable than arable crops.

Far from being "neutral" or "objective", composite indicators for each of the pillars of the sustainability facilitate the relative ranking of the examined systems. Moreover, the proposed methodology enables the inclusion of sustainability assessment into policy formation, by assigning the three pillars of sustainability different weights. We have seen that the relative ranking holds under some possible varied priorities of policymakers. Future research efforts could focus on developing approaches to assess the sustainability performance to provide insights for recommendations and improvement for the long-term sustainability of farms.

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Appendix A

Table A1. Local priorities of the sub-criteria according to expert judgement.

Criterion	Sub-Criterion	Local Priorities (Weights)	Ranking
Environmental	GHG emissions at the farm level	0.049	5th
	Percentage of farm UAA with nitrate risk	0.119	3rd
	Water consumption per kg of product	0.076	4th
	Farm gate N-balance	0.502	1st
	Pesticide usage	0.254	2nd
Social	Advisory contacts per year per holding	0.291	2nd
	Degree of agricultural training of the manager	0.083	4th
	Total labor in annual working units	0.441	1st
	Satisfaction with quality of life	0.131	3rd
	Social Diversification Index	0.054	5th
Economic	Total output/total input	0.219	2nd
	Total subsidies/FFI	0.065	4th
	(FFI/FWU)/reference income	0.498	1st
	Farm net value added	0.218	3rd

Table A2. Performance of farms (priorities of alternatives) per sub-criterion, criterion, and the overall sustainability performance per policymaker scenario.

Criterion/Sub-criterion, Scenario	Arable crop Farms	Olive Tree Farms	Permanent Crop Farms	Livestock Farms
Environmental	0.076	0.321	0.252	0.351
GHG emissions at the farm level	0.557	0.206	0.194	0.043
Percentage of farm UAA with nitrate risk	0.060	0.178	0.288	0.474
Water consumption per kg of product	0.047	0.137	0.210	0.606
Farm gate N-balance	0.051	0.476	0.291	0.182
Pesticide usage	0.048	0.159	0.181	0.612
Social	0.258	0.158	0.231	0.352
Advisory contacts per year per holding	0.391	0.097	0.147	0.366
Degree of agricultural training of the manager	0.185	0.345	0.370	0.100
Total labor in annual working units	0.257	0.052	0.244	0.448
Satisfaction with quality of life	0.074	0.471	0.171	0.284
Social diversification index	0.122	0.308	0.515	0.055
Economic	0.062	0.213	0.529	0.196
Total output/total input	0.055	0.316	0.370	0.131
Total subsidies/FFI	0.048	0.300	0.485	0.167
(FFI/FWU)/reference income	0.048	0.217	0.587	0.148
Farm net value added	0.106	0.068	0.434	0.392
Overall sustainability performance **Equal weights scenario (rank)**	0.132 (4th)	0.231 (3rd)	0.337 (1st)	0.300 (2nd)
Overall sustainability performance **Environmental preference scenario (rank)**	0.118 (4th)	0.253 (3rd)	0.316 (1st)	0.313 (2nd)
Overall sustainability performance **Social preference scenario (rank)**	0.164 (4th)	0.213 (3rd)	0.311 (2nd)	0.313 (1st)
Overall sustainability performance **Economic preference scenario (rank)**	0.114 (4th)	0.226 (3rd)	0.385 (1st)	0.274 (2nd)

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