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Integrated Sustainability Assessment of Divergent Mediterranean Farming Systems: Cyprus as a Case Study

Andreas Stylianou [1,2,*], Despina Sdrali [2] and Constantinos D. Apostolopoulos [2]

[1] Rural Development Department, Agricultural Research Institute, P.O. Box 22016, 1516 Nicosia, Cyprus
[2] Department of Home Economics and Ecology, Harokopio University, El. Venizelou 70, Kallithea, 17676 Athens, Greece; dsdrali@hua.gr (D.S.); c.d.apostolopoulos@gmail.com (C.D.A.)
* Correspondence: a.stylianou@ari.gov.cy; Tel.: +357-22-403116

Received: 19 June 2020; Accepted: 27 July 2020; Published: 29 July 2020

Abstract: A variety of indicator-based methods have been developed for the sustainability assessment of farming systems (FSs). However, many of them lack holisticity, focus on a specific agricultural sector/product, and do not provide aggregated results to better support decision-making process. The goal of this study was, for the first time, to assess, in a holistic manner, the sustainability performance of different FSs in southeastern Cyprus. The methodological framework involved three major steps. First, the sustainability context was set, and a list of 41 environmental, social, and economic indicators was created. The indicators were then calculated using data from 324 farms. Second, six FSs were identified using multivariate analysis. Finally, the sustainability of FSs was assessed by combining numerical (construction of four composite sustainability indices) and visual (presentation of indicator scores and values with graphs and tables) integration approaches. While the indices provided the "big picture", visual integration revealed the areas where policy interventions are needed. The analysis showed that sustainable agricultural practices are already used by some farmers in the area. The results could be used for benchmarking purposes and to aid decision-making process in Cyprus but might also be useful for other Mediterranean regions with similar agro-ecological conditions.

Keywords: integrated sustainability assessment; farming systems; indicators; visual integration; numerical integration; Mediterranean; Cyprus

1. Introduction

In the agricultural sector, sustainability assessment is a key step in building sustainable farming systems (FSs), viz. that are environmentally friendly, economically viable for farmers and socially acceptable [1,2]. It follows that such assessments, methodological approaches, frameworks or tools, should consider all three dimensions of sustainability to allow an integrated (or holistic) assessment of FSs [3–8].

The most common approach to assess agricultural sustainability relates to the use of indicators [7,9,10]. Consequently, a large number of indicator-based sustainability assessment tools already exist and are applied in practice [2,3]. In such tools, indicators are used individually, as part of a set, or in the form of a composite index [6,11]. Generally, a balanced set of indicators is preferred, even when heterogeneous, since individual indicators are of limited use to sufficiently represent all essential sustainability aspects of a complex system [3,7].

Van Passel and Meul [2] identified two approaches that are used to integrate a balanced set of sustainability indicators. In the first approach, called visual integration, indicators are kept separate and are presented together within a single table or diagram, such as radar graph [3,12,13]. In the second approach, called numerical integration, indicator values are aggregated to yield a global composite index [6,14–16]. Both approaches present advantages and drawbacks (for details see Reference [2]) and should be combined to maintain a high level of detail and communicability. In the same vein, various authors recommend the joint use of aggregated and individual indicators [9,17], and the decomposition of composite indices to provide transparency at the indicator level [18].

The literature review on indicator-based sustainability assessments permits us to draw certain conclusions:

1. Most of the assessments focus on the environmental pillar and give little or no attention to social and economic pillars [1,5,7,10,19]. Such assessments are not holistic and cannot be used for integrated sustainability evaluation of FSs [3,6].
2. Few attempts have been made by researchers to develop composite sustainability indices (CSIs) using multiple indicators at the farm and farming system levels [9,16].
3. The majority of farm level sustainability assessment tools use a visual integration approach and/or lists of individual indicators to present the results [2,9]. Only few of them combine visual and numerical integration approaches in order to maintain high level of transparency, detail and communicability. In fact, aggregation of indicator results (including normalization and weighting) to better aiding the decision-making process, is generally avoided in farm level sustainability assessment tools [9].
4. Some approaches compare the sustainability of farms within a system or sector [3,11], whereas others compare the sustainability of quite similar FSs within a region [13,20]. As a matter of fact, sustainability frameworks are usually focused on a specific agricultural (sub)sector (e.g. dairy) or product; thus, the comparison of heterogeneous situations is not possible [7] and the dynamics of the wider agricultural sector are not considered [11]. In this perspective, studies using multiple indicators to compare the sustainability of different FSs or sectors would be very interesting [11,21]. An example of such a study is that of de Olde et al. [22].
5. Finally, multifunctionality in agriculture (e.g. biodiversity conservation, contribution to employment) and interaction between indicators (viz. trade-offs and/or synergies) are often overlooked in sustainability assessments [7,19,20].

The main objective of this study was to assess and compare in a holistic manner the sustainability performance of different FSs that exist in southeastern Cyprus. Despite the fact that agricultural sustainability is of major concern in Cyprus [23], to the authors' knowledge, however, no attempt has been made to date to empirically assess the sustainability of FSs in this biodiversity hotspot area [24]. Beyond this empirical investigation, this paper explores the suitability of the proposed methodological framework for assessing and comparing the sustainability performance of divergent FSs, while an attempt is made to address the aforementioned "limitations" identified in the literature. Specifically, to address the first limitation, a comprehensive set of 41 indicators representing all three sustainability dimensions (environmental, social, economic) is selected, thus allowing a holistic or integrated sustainability assessment of FSs. The second and third limitations are addressed by aggregating the 41 individual indicators to develop four CSIs at the farm and farming system levels (numerical integration), while the individual indicator values/scores are also presented with tables and graphs (visual integration). To cope with the fourth limitation, we assess and compare the sustainability performance of six significantly divergent FSs with multiple farm enterprises. In this way, the heterogeneity and the dynamics of the wider agricultural sector are taken into account. Finally, to deal with the fifth shortcoming, indicators that reflect multifunctionality in agriculture, such as contribution to employment, are included in the assessment, while the interaction between indicators is addressed using correlation analysis.

2. Materials and Methods

2.1. Case Studies

Cyprus is an island country and a member of the European Union located in the northeastern corner of the Mediterranean Sea (35° N, 33° E) with a total area of 9251 km^2 (Figure 1). The Republic of Cyprus comprises five main districts, namely Nicosia, Limassol, Larnaca, Pafos, and Famagusta.

This study focuses on two key agricultural districts located in the southeastern part of Cyprus, namely Larnaca and Famagusta (Figure 1) with a population of about 144,900 and 47,000, correspondingly [25]. These districts were chosen as case studies since they can be considered as a microcosm of the wider Cypriot agricultural sector [23]. Specifically, around 41% and 100% (the highest proportions among the five districts) of the population of Larnaca and Famagusta, respectively, are rural residents [25], showing, in part, their purely rural character. Furthermore, in the case studies there are 8197 farms (21% of the total in Cyprus) with 41,685 ha of Utilized Agricultural Area (UAA), accounting for the biggest share (>35%) in the total UAA compared to the other districts. Likewise, about half of the livestock farms in Cyprus are found in the two districts and key crops of Cyprus are grown there. For example, 76%, 38%, and 47% of the total area of potatoes, fresh vegetables (open field and/or under cover, e.g. tomatoes, cucumbers, melons), and cereals/fodder crops (e.g. wheat, barley, oats, vetches), correspondingly, are found in Larnaca and Famagusta [26].

Additionally, the two districts are interesting examples of environmental degradation as they are characterized as Nitrate Vulnerable Zones according to the Directive 91/676/EEC [27]. Groundwater over-pumping—motivated by insufficient water supply—due to a large number of private boreholes used for irrigation and subsequent salinization of coastal aquifers and agricultural lands, as well as land degradation, soil, and water pollution from the irrational use of agrochemicals, as a result of intensive farming and monocultures, are also major concerns for the areas' agriculture [23,28]. Last but not least, most of the villages/communities of the two districts have strong linkages with the tertiary sector, mostly tourism. This is of vital importance for the local producers, mainly small-scale farmers, as they have many opportunities to supplement their income with off/non-farm income and/or sell their products directly to local enterprises (e.g. hotels and restaurants) and tourists. Thus, it is obvious that focusing on the agricultural sector of these two districts is not only interesting, but also challenging, in terms of environmental, social, and economic sustainability [23].

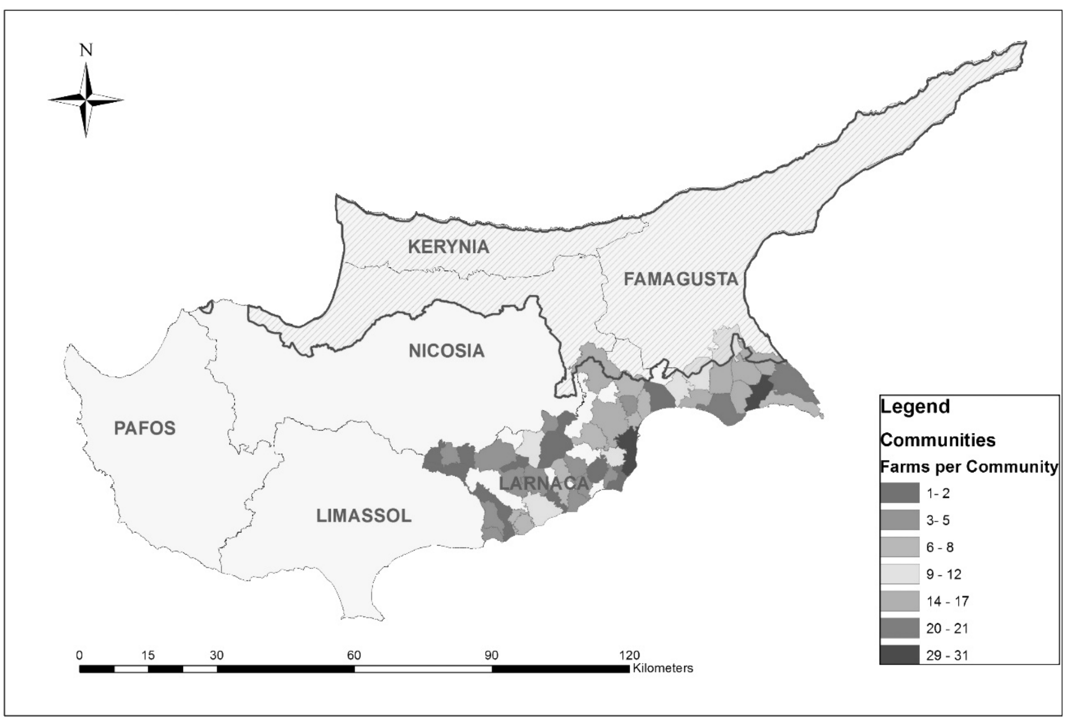

Figure 1. Study area and geographic distribution of the sampled farms (n = 324) in the two districts, Larnaca and Famagusta (only the area under the control of the Republic of Cyprus); the bold line indicates the area occupied by Turkey.

2.2. Methodological Framework

The methodology employed in this study encompasses three main steps (Figure 2).

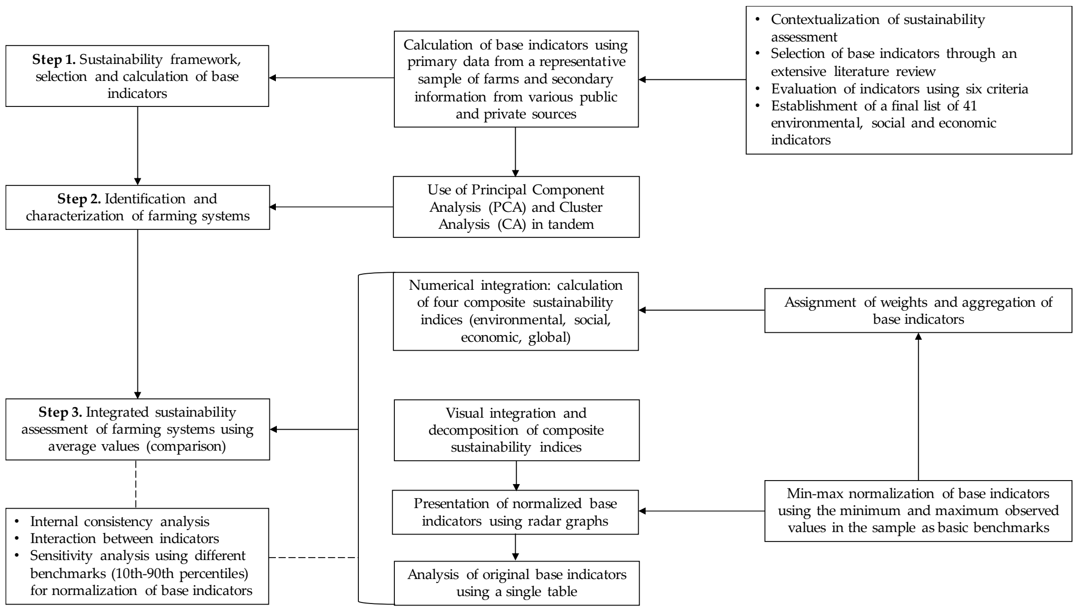

Figure 2. Three-step methodology employed in the study.

2.2.1. Sustainability Framework, Selection, and Calculation of Base Indicators

The first methodological step involved the contextualization of the sustainability assessment, as well as the selection and calculation of base indicators.

2.2.1.1. Contextualization of Sustainability Assessment

Contextualization consists of defining the objective of the analysis and the conceptual framework of sustainability assessment, specifying the system under consideration, along with spatial and temporal scales of analysis, as well as identifying the type of end-users of the assessment [1,7,17,19].

The goal of this analysis was to assess and compare the sustainability performance of different FSs based on environmental, social, and economic indicators; that is an integrated or multidimensional approach [3,9]. The spatial scale was the farm level, including off/non-farm activities and on-farm processing. At this level, improvements in terms of sustainability are possible [1]. In fact, we used farm level data to assess sustainability on FS (or agricultural (sub) sector) level [2]. The temporal scale was annual, even though the influence of certain parameters was taken into consideration for the calculation of indicators presenting high inter-annual variability [29] (see Section 2.2.1.3.). The intended end-users of the assessment are policymakers and researchers, although it can also be used to support farmers and their organizations.

An FS is defined as "a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate" [30]. In a nutshell, within a broader farm typology, an FS is referred to a group of "similarly structured" farms [16,31].

The sustainability concept adopted in this study is based on the traditional triple perspective of environmental friendliness, economic viability and social justice [14], and is consistent with the wider vision of the Ministry of Agriculture, Rural Development, and Environment (MARDE) of Cyprus for a sustainable agricultural sector [32]. Accordingly, a sustainable FS should be able to maintain and improve biodiversity and natural ecosystems; create profit in order to provide prosperity to the farmer and the farming community; and improve the quality of life of farmers and distribute benefits and costs fairly [1,5,14,33,34].

2.2.1.2. Selection of Base Indicators

The selection process of a minimal, consistent and sufficient set of base indicators comprised two steps. First, through an extensive literature review [1,3,6,11–14,16,20,21,29,33–42], an initial list of indicators was created according to their relevance to this study. The indicators were classified only by sustainability pillar as this is considered to be more straightforward than further dividing pillars into themes and/or attributes [21].

Second, for establishing a comprehensive final set of indicators, the indicators found in the literature were evaluated using the following criteria: relevance, analytical soundness, practicability, end-user value, parsimony and sufficiency [1,7]. Parsimony and sufficiency refer to the indicators as a set [1,6,14,15]. Although it was difficult for the indicators to meet all the above criteria, it was important that they were met as far as possible.

Therefore, we excluded the indicators not suitable to compare different FSs, such as livestock density and animal profitability, and those constituted by direct measurements, such as actual greenhouse gas (GHG) emissions, since such indicators do not meet the practicability criterion; that is, they cannot be calculated from easily obtainable data, i.e. directly from farmers or from existing databases, and their calculation is relatively costly and time consuming [1,7,15]. Moreover, to respect the parsimony criterion and, at the same time, avoid problems of double counting in the aggregation process (Section 2.2.3.1), the correlations between indicators referring to the same pillar were examined [1]. This was done after the calculation of indicators (Section 2.2.1.3.). Thus, in the case of a pair of indicators with a correlation coefficient higher than ± 0.80, one of the pair was deleted, based on the criteria of practicability and end-user value.

Finally, 41 base indicators were selected and classified according to the three pillars (Table 1). Thresholds or reference values are minimum and maximum sustainability levels defined to evaluate indicator value [14] and vary according to the nature of the indicators.

Table 1. List of base indicators used in the sustainability assessment: pillars, indicator name, definition, thresholds, and effect on sustainability (positive (or negative) effect: there is a positive (or negative) correlation between the indicator and sustainability).

Pillar	Indicator Name	Definition/Unit	Thresholds [a]	Effect
Environmental	Intensification	Cost of external inputs [b] per ha of UAA (k€ ha^{-1})	(1) min-max (2) 10th-90th	Negative
	Irrigation Water Consumption	Absolute volume of irrigation water required per ha of UAA (m^3 ha^{-1})	(1) min-max (2) 10th-90th	Negative
	Crop diversity	Number of crops per farm (no. crops $farm^{-1}$)	(1) min-max (2) 10th-90th	Positive
	Nitrogen-fixing crops	Share of nitrogen-fixing crops [c] in UAA (%)	(1) min-max (2) 10th-90th	Positive
	Mean area per plot	Average plot size (ha $plot^{-1}$)	(1) min-max (2) 10th-90th	Negative
	Specialization rate	Share of the main crop in UAA (%)	(1) min-max (2) 10th-90th	Negative
	Environment sensitization	The farmer acknowledges the negative impacts of agriculture on the environment and implements good agricultural practices [d] (binary)	Yes/No	Positive
	Agri-environmental measures	Farm enrolment in agri-environmental measures [e] (part of or the total UAA) (binary)	Yes/No	Positive
	Organic farming	Farm enrolment in organic farming systems (part of or the total UAA) (binary)	Yes/No	Positive
Social	Contribution to employment	Human labor required per ha of UAA (AWU ha^{-1})	(1) min-max (2) 10th-90th	Positive

	Hired labor	Permanent and seasonal hired labor costs/total labor costs (%)	(1) min-max (2) 10th-90th	Positive
	Age	Farmer's age (years)	(1) min-max (2) 10th-90th	Negative
	Education	Farmer's education level (years of schooling)	(1) min-max (2) 10th-90th	Positive
	Agricultural training	The farmer has followed agricultural education courses (binary)	Yes/No	Positive
	Type of employment	Full-time or part-time farmer (binary)	Full-time = 1 Part-time = 0	Positive
	Prospects of succession	Intergenerational continuity of farming activity (scale)	0–3 [f]	Positive
	Farm continuity	Farmer's willingness to continue farming in the next years (0 = no; 1 = maybe; 2 = yes) (scale)	0–2	Positive
	Household size	Number of household members (no. of members)	(1) min-max (2) 10th-90th	Positive
	Farm expansion	Size of the farm (in ha and/or LU) the last 5 years (0 = decreased; 1 = stable; 2 = increased) (scale)	0–2	Positive
	Participation in POs	Participation in agricultural Producer Organizations/unions/cooperatives (binary)	Yes/No	Positive
	Farming activity satisfaction	Perceived satisfaction level from farming (scale; farmer self-assessment)	0–4	Positive
	Leisure time satisfaction	Perceived satisfaction level from leisure time (scale; farmer self-assessment)	0–4	Positive
	Quality of life satisfaction	Perceived quality of life satisfaction (scale; farmer self-assessment)	0–4	Positive
	Agricultural advisory services	The farmer receives advice by public and/or private experts (scale)	0–3 [g]	Positive
	Salary level	Return to labor (wages + net profit [h]) per AWU/legal minimum wage in other economic sectors (ratio)	(1) min-max (2) 10th-90th	Positive
	Disposable income	The total annual income (earned either at the farm or outside) that the household members have at their disposal (k€/household member)	(1) min-max (2) 10th-90th	Positive
Economic	Land productivity	Farm income [i] per ha of UAA (k€ ha^{-1})	(1) min-max (2) 10th-90th	Positive
	Labor productivity	Farm income per AWU (k€ AWU^{-1})	(1) min-max (2) 10th-90th	Positive
	Capital productivity	Farm income per unit of farm capital (non-land) (€ $€^{-1}$)	(1) min-max (2) 10th-90th	Positive
	Level of farm modernization	Depreciation of land improvements, buildings, machinery and equipment per AWU (k€ AWU^{-1})	(1) min-max (2) 10th-90th	Positive
	Land fragmentation	Number of plots per farm (no. plots $farm^{-1}$)	(1) min-max (2) 10th-90th	Negative
	Economic efficiency	Gross income [j] excluding subsidies/total production costs, viz. benefit-cost relation (ratio)	(1) min-max (2) 10th-90th	Positive

Capital efficiency	Rate of return to total capital [(land rent + interests + net profit)/(farm capital + land capital)] (%)	(1) min-max (2) 10th-90th	Positive
Profitability	Net profit/gross income (%)	(1) min-max (2) 10th-90th	Positive
Owned area	Share of area owned by the farmer in UAA (%)	(1) min-max (2) 10th-90th	Positive
Dependency on external inputs	Cost of external inputs/total production costs (%)	(1) min-max (2) 10th-90th	Negative
Subsidies dependency	Total subsidies [k]/gross income (%)	(1) min-max (2) 10th-90th	Negative
Financial records	Use of a farm financial record-keeping system (0 = no; 1 = informal; 2 = formal) (scale)	0–2	Positive
Off/non-farm income	Off/non-farm income/total household income (%)	(1) min-max (2) 10th-90th	Positive
Short Food Supply Chains	Utilization of Short Food Supply Chains, viz. direct sales and/or farmers' markets and/or local supermarkets/greengroceries (binary)	Yes/No	Positive
On-farm processing	The farmer is also a processor, viz. transforms part of or the whole production on-farm (binary)	Yes/No	Positive

UAA: Utilized Agricultural Area; AWU: Annual Work Unit (2080 h year^{-1}); LU: Livestock Unit (according to Eurostat [43]; POs: Producer Organizations; k€: thousand euros; for binary indicators: yes = 1, no = 0. [a] Min–max = minimum and maximum observed values used as the basic benchmarks to normalize indicators; 10th–90th = 10th and 90th percentiles used as minimum and maximum benchmark values for sensitivity analysis. [b] Pesticides, fertilizers, seeds, diesel, lubricants, off-farm feedstuff, electricity, irrigation water. [c] Include beans, peas, cowpeas, broad beans, vetches, lucerne/alfalfa, chickling vetch. [d] Include but not limited to: rational use of pesticides and fertilizers, efficient use of irrigation water, soil protection from erosion, maintenance of soil organic matter and soil structure, protection of farmed animals. [e] Subsidized by the national Rural Development Program, e.g. crop rotation, integrated crop management, mechanical weed control, preserving endangered animal species. [f] Children working on the farm (1 = yes; 0 = no children in the household or on the farm) + children willing to take the activity (0 = no or no children in the household, 1 = maybe/not sure, 2 = yes). [g] Public advisors/extension service, public advisors/Agricultural Research Institute researchers, private advisors/input suppliers/consultants. [h] Net profit = gross income − total production costs (variable + fixed). [i] The remuneration of all factors of production (land, labor, capital) + net profit. [j] All incomes from agricultural activities including subsidies. [k] All subsidies received by the farmer, including direct payments and payments for agri-environmental measures and less favored areas.

2.2.1.3. Calculation of Base Indicators

For the calculation of base indicators, the dataset of our recent work was used [23], which includes information on a representative sample of 324 farms in the study area (Figure 1). In brief, primary information was obtained via a farm survey using a specially designed questionnaire, which was completed through 90-min face-to-face interviews with farm managers. Although the obtained information was referring to the 2012 production year, for data presenting high inter-annual variability (e.g. input/output prices and production volume) a three-year average was provided by farmers to mitigate a year specific effect in (economic) indicators.

Secondary information was obtained from various sources (e.g. Cyprus Statistical Service, Cyprus Agricultural Payment Organization, MARDE, Producer Organizations) to complete and cross-check primary information, and was related to input/output prices, subsidies, labor, irrigation water consumption, depreciation, interest rates and land value. The calculation of irrigation water consumption was primarily based on Christou et al. [44]. For more details on the data collection process see Stylianou, Sdrali and Apostolopoulos [23].

The values of the variables and indicators were then calculated at the farm level and were stored in SPSS (version 25.0) for further analysis.

2.2.2. Identification and Characterization of Farming Systems

The objective of the second methodological step (Figure 2) was to capture agricultural heterogeneity within the study area. Dealing with FSs heterogeneity is a fundamental step prior to their sustainability assessment. The overall process for the identification and characterization of FSs that exist in the study area, as well as the necessity of this step, are also thoroughly described in our recent work [23]. In short, using multivariate statistical analysis, we identified and characterized six significantly different FSs (FS1–FS6), which are shown in Table 2. A brief description of the identified FSs, along with the variables used for FS characterization are also given in the Supplementary Material (Tables S1 and S2).

Table 2. Identified farming systems and their distribution across the study districts.

Label of Farming Systems (n = Number of Farms)	Acronym	Share in the Total Sample (% of Farms)	Distribution of Farming Systems Across the Study Districts (% of Farms)	
			Larnaca	**Famagusta**
Medium-sized irrigated farms with open field vegetables/potatoes, profitable with or without subsidies (n = 60)	FS1	18.5	36.7	63.3
Small to medium-sized irrigated farms with greenhouse/open field vegetables and permanent crops, labor-intensive (n = 46)	FS2	14.2	65.2	34.8
Large farms with market-oriented rainfed cereals and fodder crops [a], high dependency on subsidies and high off/non-farm income (n = 35)	FS3	10.8	85.7	14.3
Small irrigated farms with open field vegetables, potatoes and permanent crops, off-farm based (n = 70)	FS4	21.6	41.4	58.6
Specialized medium-sized sheep/goats farms with high off/non-farm income (n = 103)	FS5	31.8	77.7	22.3
Large specialized, capital-intensive dairy cattle farms, with young and educated farm managers (n = 10)	FS6	3.1	80.0	20.0

Farm size (small, medium, large) is based on Utilized Agricultural Area and/or herd size. [a] Cereals and fodder crops production is destined for the market and not for on-farm consumption, viz. not for livestock feeding. Source: Reference [23].

2.2.3. Integrated Sustainability Assessment of Farming Systems

The last methodological step was concerned with assessing the sustainability of the six identified FSs through the combination of numerical and visual integration tools [2], along with the original indicator values. Moreover, preliminary sensitivity and internal consistency analyses were conducted to verify the robustness of the proposed method [20].

2.2.3.1. Numerical Integration

Numerical integration involved the construction of four CSIs for each farm, namely environmental (EnCSI), social (SCSI), economic (EcCSI), and global (GCSI). The construction of CSIs was based on a methodology proposed by Organisation for Economic Co-operation and Development (OECD) [18] and included nine stages:

1. Formulation of the theoretical framework.
2. Selection and calculation of base indicators.
3. Imputation of missing data.
4. Correlation analysis between indicators of the same pillar.
5. Normalization of indicators.
6. Assignment of weights and aggregation.
7. Decomposition of CSIs.
8. Internal consistency and sensitivity analysis.
9. Presentation of the results.

Stages 1, 2, and 4 were already discussed in Section 2.2.1. Regarding Stage 3, no further comments are required since we included only fully-completed questionnaires.

Normalization of base indicators (Stage 5) is crucial before their aggregation, since they have been calculated using different measurement units [8]. In this study, among the various normalization methods reported in the literature (for a review see Reference [18]), we opted to employ the min-max normalization technique so that the value of each normalized indicator would lie within a dimensionless range between 0 (least sustainable) and 1 (most sustainable) [14]. To this end, depending on the correlation between the indicator and sustainability (Table 1), the following equations were used:

For indicators with a positive impact on sustainability:

$$I_k = \frac{X_k - \min(X_k)}{\max(X_k) - \min(X_k)}. \quad (1)$$

For indicators with a negative impact on sustainability:

$$I_k = \frac{\max(X_k) - X_k}{\max(X_k) - \min(X_k)}, \quad (2)$$

where I_k is the normalized value of indicator k, X_k is the original value of indicator k, and $\min(X_k)$ and $\max(X_k)$ are the minimum and maximum observed values of X_k in the sample.

Consequently, the lowest-performing and best-performing farms in the sample were used as thresholds for the majority of indicators (Table 1). This choice of thresholds was made because: (a) this results in a dynamic and motivating tool for farmers, setting ambitious goals [2,41]; (b) the literature concerning thresholds criteria in Cyprus is insufficient; and (c) the determination of normative reference values (instead of relative reference values) is very difficult and sometimes pointless, since agricultural sustainability is a relative concept that varies over time and space [6,38].

Assignment of weights and aggregation (Stage 6) is probably the most important stage in the process of constructing CSIs. As regards the assignment of weights, when no explicit evidence to prefer an indicator over another is available, as in our study, equal weighting seems to be the norm [8,15]. As such, we considered all indicators within a pillar as equally important. Likewise, the three pillars were assigned an equal weight; this equality is imposed by the very same sustainability concept [3].

The two most widely used aggregation methods in the literature are the linear and the geometric; for a comparison, see, e.g. reference [8,15,45]. In general, the linear aggregation method is more straightforward for communication and engagement as users can clearly trace scores from the bottom level to the top [45]. Additionally, the use of linear aggregation with equal weights allows a quick overview of the sustainability performance of FSs [22]. This study employed a linear approach at two levels of aggregation: from the base indicators to the three pillars and from the pillars to the global index. Consequently, for each farm, the 41 indicators were first aggregated into three CSIs (i.e. EnCSI, SCSI, EcCSI) using the respective equation for linear aggregation as described in Gómez-Limón and Sanchez-Fernandez [14]. Subsequently, the three CSIs were aggregated with the same linear method into a global index (GCSI). To assess and compare the sustainability performance of FSs, the average values of CSIs were used.

Stages 7 and 8 are discussed next, while the results are presented using tables and radar graphs (Stage 9).

2.2.3.2. Visual Integration and Decomposition of CSIs (Stage 7)

The CSIs are appealing for communication, but they may potentially send over-simplistic (or even misleading) messages as they only provide aggregate information [8,21,45]. A possible solution to this is the decomposition of CSIs into their individual indicators (both original and normalized), in an attempt to reveal the main drivers for an overall good or bad performance. Various methods are available for presenting such decompositions [18]. Likewise, an analysis of individual indicators is indispensable to describe FSs in detail [21].

By the same token, transparency is desirable and essential in constructing credible CSIs [8,45]. This study provides complete transparency at indicator level by (a) placing all individual indicators together (by pillar and system) into a single table, using the original indicator values; and (b) putting together all (normalized) indicators of each pillar using radar graphs (visual integration). As a result, a detailed comparison of FSs in terms of the base indicators was allowed.

2.2.3.3. Internal Consistency and Sensitivity Analysis (Stage 8)

The internal consistency of the GCSI was examined by performing simple correlation analysis (Spearman's rho) between the GCSI and its components (i.e. EnCSI, SCSI, EcCSI) [20,46]. Through this analysis it was also possible to identify any trade-offs (or synergies) that may exist between the CSIs [46].

The choice of thresholds is a delicate step in sustainability assessments as they may have an important impact on the CSIs scores or even on the ranking of FSs [15].

As mentioned, we have chosen to use the lowest-performing and best-performing farms as basic benchmarks for the CSIs development. A possible disadvantage of this choice is the risk of using extreme values as thresholds that could distort the results [11,18]. Therefore, to make a preliminary assessment of the sensitivity of our methodology to this aspect, we recalculated the CSIs scores and the ranking of systems using as benchmarks (min(X_k) and max(X_k) the 10th and 90th percentiles (viz. the 10% lowest-performing and 10% best-performing farms) of the sample [2,15] (see Table 1).

In this case, it is noted that, when the value of the base indicator was above the upper threshold (90th percentile) or below the lower threshold (10th percentile), the indicator value was then reset so that it was equal to the upper or lower threshold value, respectively. In this way, we did not allow "over-performance" or "under-performance" and the range of the normalized indicators was always between 0 and 1. For this, the min-max normalization technique was again employed based on Equations (1) and (2).

3. Results and Discussion

3.1. Composite Sustainability Indices—Numerical Integration

The average scores of the four CSIs for each system and their respective ranking are reported in Table 3a.

Despite average values of GCSI ranging from 0.387 (FS5) to 0.474 (FS2), there were good results in single farms: out of 324 farms, 85 scored above 0.474. If the threshold was set at 0.55, 12 farms were identified; of these, four belonged to FS1, three to FS2, three to FS3, one to FS4, and one to FS5. These results indicate that, in the study area, according to this methodology, relatively sustainable agricultural practices are feasible and are already used by some farmers.

At the pillar level, a quite different trend was observed. For instance, in terms of EcCSI, FS4 (small farms) was the most sustainable and FS3 the least sustainable. Furthermore, the values of EcCSI were comparatively low for all the systems studied.

Due to the aggregation method employed (additive), it is obvious that compensation effects (trade-offs) took place among pillars. For instance, FS6 scored the highest on SCSI, but low on EnCSI and EcCSI. This provided an intermediate to high GCSI value for FS6, which was not too different from the score of the most sustainable FS2. In this sense, the use of linear aggregation renders the GCSI a weak sustainability tool. This, however, is not necessarily a disadvantage, but it is a methodological feature that needs to be considered by stakeholders during the decision-making process [4].

Table 3. Mean ± SD of the four composite sustainability indices (CSIs) by farming system and ranking of the systems based on CSIs values. The two tables were compiled using different thresholds ((min($\boldsymbol{X_k}$) and max($\boldsymbol{X_k}$)) to rescale base indicators. Min($\boldsymbol{X_k}$) and max($\boldsymbol{X_k}$) were equal in case (a) to the minimum and maximum observed values in the whole sample, and in case (b) to the 10th and 90th percentiles of the distribution of indicators observed. The bold type identifies the farming systems that ranked differently in (b) compared to (a).

Composite Sustainability Indices/System Ranking	**Farming Systems (FSs)**					
	FS1 (n = 60)	**FS2 (n = 46)**	**FS3 (n = 35)**	**FS4 (n = 70)**	**FS5 (n = 103)**	**FS6 (n = 10)**
(a)						
EnCSI	0.533 ± 0.077 $_{a}$	0.522 ± 0.114 $_{a}$	0.525 ± 0.127 $_{a}$	0.508 ± 0.088 $_{a}$	0.425 ± 0.100 $_{b}$	0.495 ± 0.064 $_{ab}$
Ranking	1	3	2	4	6	5
SCSI	0.453 ± 0.085 $_{ac}$	0.473 ± 0.086 $_{c}$	0.405 ± 0.094 $_{ab}$	0.396 ± 0.087 $_{b}$	0.346 ± 0.092 $_{d}$	0.527 ± 0.071 $_{c}$
Ranking	3	2	4	5	6	1
EcCSI	0.429 ± 0.076 $_{a}$	0.426 ± 0.079 $_{ab}$	0.358 ± 0.060 $_{c}$	0.431 ± 0.063 $_{a}$	0.388 ± 0.078 $_{bc}$	0.374 ± 0.049 $_{abc}$
Ranking	2	3	6	1	4	5
GCSI	0.472 ± 0.051 $_{a}$	0.474 ± 0.053 $_{a}$	0.430 ± 0.070 $_{b}$	0.445 ± 0.046 $_{ab}$	0.387 ± 0.057 $_{c}$	0.465 ± 0.044 $_{ab}$
Ranking	2	1	5	4	6	3
(b)						
EnCSI	0.478 ± 0.109 $_{a}$	0.496 ± 0.139 $_{a}$	0.529 ± 0.142 $_{a}$	0.478 ± 0.114 $_{a}$	0.388 ± 0.136 $_{b}$	0.465 ± 0.088 $_{ab}$
Ranking	**4**	**2**	**1**	**3**	6	5
SCSI	0.525 ± 0.101$_{b}$	0.546 ± 0.099 $_{b}$	0.457 ± 0.112 $_{a}$	0.431 ± 0.098 $_{a}$	0.374 ± 0.106 $_{c}$	0.598 ± 0.075 $_{b}$
Ranking	3	2	4	5	6	1
EcCSI	0.522 ± 0.115 $_{a}$	0.500 ± 0.117 $_{ab}$	0.344 ± 0.086 $_{d}$	0.461 ± 0.083 $_{bc}$	0.373 ± 0.102 $_{d}$	0.398 ± 0.075 $_{cd}$
Ranking	**1**	**2**	6	**3**	**5**	**4**
GCSI	0.508 ± 0.070 $_{a}$	0.514 ± 0.065 $_{a}$	0.443 ± 0.087 $_{b}$	0.457 ± 0.057 $_{b}$	0.378 ± 0.077 $_{c}$	0.487 ± 0.051 $_{ab}$
Ranking	2	1	5	4	6	3

n: number of farms; for the abbreviations of farming systems, see Table 2. GCSI: Global Composite Sustainability Index; EnCSI: Environmental Composite Sustainability Index; SCSI: Social Composite Sustainability Index; EcCSI: Economic Composite Sustainability Index. Different subscript lowercase letters within rows indicate significant differences between means at $p < 0.05$ according to Tukey HSD test or Games-Howell test (when the equality of variances assumption was violated). Ranking: 1 = system obtained the highest index value; 6 = system obtained the lowest index value.

3.2. Visual Integration and Decomposition of CSIs

Table 4 offers the original values of the 41 base indicators and Figure 3a–c illustrates their normalized values per pillar.

Table 4. Absolute original values (mean ± SD for continuous variables; frequencies (%) for binary variables) of base indicators by sustainability pillar and farming system.

Indicator (Unit)	Farming Systems (FSs)						
	FS1 (n = 60)	FS2 (n = 46)	FS3 (n = 35)	FS4 (n = 70)	FS5 (n = 103)	FS6 (n = 10)	All (n = 324)
Environmental pillar							
Intensification (k€ ha^{-1})	6.02 ± 3.93	8.88 ± 9.19	0.49 ± 0.19	4.13 ± 3.25	7.38 ± 19.10	4.12 ± 2.05	5.79 ± 11.75
Irrigation Water Consumption (m^{3} ha^{-1})	2828.9 ± 1420.5	3895.3 ± 1969.0	181.7 ± 268.8	3231.5 ± 1814.9	344.1 ± 652.3	294.0 ± 432.1	1913.2 ± 2010.6
Crop diversity (no. crops farm^{-1})	4.1 ± 2.8	6.9 ± 2.9	3.5 ± 1.8	4.1 ± 2.1	2.5 ± 1.5	3.5 ± 1.5	3.9 ± 2.6
Nitrogen-fixing crops (%)	4.0 ± 6.8	6.2 ± 8.7	3.4 ± 14.8	4.4 ± 9.4	6.1 ± 11.9	0.1 ± 0.2	4.9 ± 10.4
Mean area per plot (ha plot^{-1})	1.0 ± 0.9	0.8 ± 0.7	1.1 ± 1.7	1.0 ± 1.5	1.6 ± 1.6	0.9 ± 0.4	1.2 ± 1.4
Specialization rate (%)	67.5 ± 24.1	48.9 ± 20.6	72.6 ± 19.8	60.0 ± 24.0	71.3 ± 26.5	57.8 ± 14.0	64.7 ± 24.9
Environment sensitization (% of farms)[a]	93.3	78.3	77.1	91.4	35.9	80.0	70.4
Agri-environmental measures (% of farms) [a]	66.7	37.0	34.3	37.1	10.7	10.0	33.0
Organic farming (% of farms)[a]	0.0	6.5	14.3	4.3	2.9	0.0	4.3
Social pillar							
Contribution to employment (AWU ha^{-1})	0.3 ± 0.3	1.0 ± 0.8	0.0 ± 0.0	0.3 ± 0.3	0.3 ± 0.6	0.1 ± 0.0	0.4 ± 0.6
Hired labor (%)	43.1 ± 19.9	54.2 ± 21.7	8.7 ± 17.8	21.3 ± 23.1	14.2 ± 21.4	48.5 ± 23.6	27.2 ± 26.6
Age (years)	52.1 ± 10.5	52.7 ± 10.5	55.0 ± 13.3	64.1 ± 7.6	56.6 ± 10.3	43.2 ± 11.5	56.3 ± 11.3
Education (years)	8.9 ± 2.8	9.0 ± 3.5	9.7 ± 3.2	7.6 ± 3.0	7.5 ± 3.1	12.5 ± 3.2	8.4 ± 3.3
Agricultural training (% of farms) [a]	56.7	52.2	45.7	55.7	37.9	100.0	50.0
Type of employment (% of farms) [b]	83.3	87.0	45.1	60.0	70.9	90.0	71.0
Prospects of succession (scale)	1.0 ± 1.0	1.2 ± 1.1	0.9 ± 1.1	1.3 ± 1.1	1.3 ± 1.2	0.9 ± 1.0	1.2 ± 1.1
Farm continuity (scale)	1.7 ± 0.6	1.9 ± 0.4	1.9 ± 0.4	1.7 ± 0.6	1.7 ± 0.6	1.8 ± 0.6	1.8 ± 0.6
Household size (no. of members)	3.6 ± 1.4	3.9 ± 1.7	3.6 ± 1.3	2.9 ± 1.2	4.1 ± 1.8	4.3 ± 1.6	3.7 ± 1.6
Farm expansion (scale)	1.2 ± 0.6	1.3 ± 0.6	0.9 ± 0.6	0.9 ± 0.5	0.8 ± 0.8	1.1 ± 0.9	1.0 ± 0.7
Participation in POs (% of farms) [a]	61.7	54.4	68.6	58.6	14.6	70.0	46.0
Farming activity satisfaction (scale)	1.4 ± 1.0	1.6 ± 1.0	1.4 ± 1.0	1.3 ± 1.0	1.0 ± 1.0	2.3 ± 1.2	1.3 ± 1.0
Leisure time satisfaction (scale)	0.9 ± 1.0	1.0 ± 1.0	1.8 ± 1.0	1.5 ± 0.9	0.7 ± 0.8	1.1 ± 1.3	1.1 ± 1.0

Quality of life satisfaction (scale)	2.0 ± 1.1	2.0 ± 1.0	2.3 ± 1.1	2.3 ± 1.0	1.7 ± 1.1	2.2 ± 1.0	2.0 ± 1.1
Agricultural advisory services (scale)	1.6 ± 0.7	1.7 ± 0.8	1.2 ± 0.9	1.3 ± 0.8	1.4 ± 0.8	1.5 ± 0.7	1.4 ± 0.8
Salary level (ratio)	1.70 ± 0.78	0.94 ± 0.20	1.40 ± 0.78	0.99 ± 0.29	0.75 ± 0.25	1.60 ± 0.79	1.10 ± 0.61
Disposable income (k€/household member)	8.06 ± 4.05	7.80 ± 4.01	9.72 ± 9.56	7.68 ± 4.37	7.18 ± 7.95	6.91 ± 2.08	7.81 ± 6.29
Economic pillar							
Land productivity (k€ ha^{-1})	6.32 ± 6.23	11.83 ± 9.64	0.57 ± 0.22	4.37 ± 3.33	3.15 ± 5.04	1.35 ± 0.36	4.90 ± 6.41
Labor productivity (k€ AWU^{-1})	24.30 ± 9.51	12.87 ± 2.65	36.23 ± 17.02	14.47 ± 4.49	12.70 ± 3.69	32.85 ± 11.46	18.42 ± 11.21
Capital productivity (€ $€^{-1}$)	0.59 ± 0.36	0.56 ± 0.30	0.52 ± 0.32	0.52 ± 0.30	0.24 ± 0.09	0.18 ± 0.07	0.44 ± 0.30
Level of farm modernization (k€ AWU^{-1})	2.00 ± 1.97	1.45 ± 1.45	4.71 ± 5.85	0.99 ± 1.28	1.63 ± 1.81	6.72 ± 4.18	2.02 ± 2.88
Land fragmentation (no. plots $farm^{-1}$)	19.9 ± 23.2	17.4 ± 32.4	109.8 ± 102.7	7.0 ± 5.4	17.0 ± 23.1	155.7 ± 118.5	29.8 ± 57.6
Economic efficiency (ratio)	1.11 ± 0.16	1.01 ± 0.12	0.68 ± 0.13	0.94 ± 0.11	0.88 ± 0.11	0.98 ± 0.06	0.93 ± 0.17
Capital efficiency (%)	4.7 ± 4.6	3.6 ± 3.0	1.0 ± 0.5	1.7 ± 1.2	1.4 ± 1.2	2.1 ± 0.5	2.4 ± 2.8
Profitability (%)	13.1 ± 10.8	5.5 ± 8.1	5.8 ± 18.0	1.9 ± 7.6	−0.4 ± 6.5	6.2 ± 6.1	4.3 ± 10.7
Owned area (%)	37.1 ± 30.4	47.8 ± 38.3	24.3 ± 32.0	65.6 ± 33.6	16.6 ± 27.8	10.9 ± 12.9	36.1 ± 36.5
Dependency on external inputs (%)	57.8 ± 10.4	40.9 ± 10.2	45.7 ± 10.0	45.1 ± 13.3	55.5 ± 12.0	70.5 ± 8.1	51.0 ± 13.5
Subsidies dependency (%)	5.3 ± 2.9	5.5 ± 5.9	36.8 ± 9.9	8.9 ± 6.9	12.3 ± 8.7	8.5 ± 4.3	11.8 ± 11.6
Financial records (scale)	1.7 ± 0.7	1.5 ± 0.8	1.3 ± 0.8	1.1 ± 0.9	1.2 ± 0.8	2.0 ± 0.0	1.4 ± 0.8
Off/non-farm income (%)	28.6 ± 28.1	23.6 ± 26.9	44.4 ± 33.2	56.8 ± 24.0	45.2 ± 31.5	8.3 ± 14.3	40.3 ± 31.1
Short Food Supply Chains (% of farms) [a]	25.0	21.7	25.7	40.0	39.8	10.0	32.1
On-farm processing (% of farms) [a]	6.7	6.5	5.7	7.1	46.6	50.0	20.7

n: number of farms; k€: thousand euros; POs: Producer Organizations. For indicators definition, see Table 1; for the abbreviations of farming systems, see Table 2. [a] The figures within respective rows indicate the percentage of farms with positive (yes) response. [b] The figures within respective row indicate the percentage of full-time farmers.

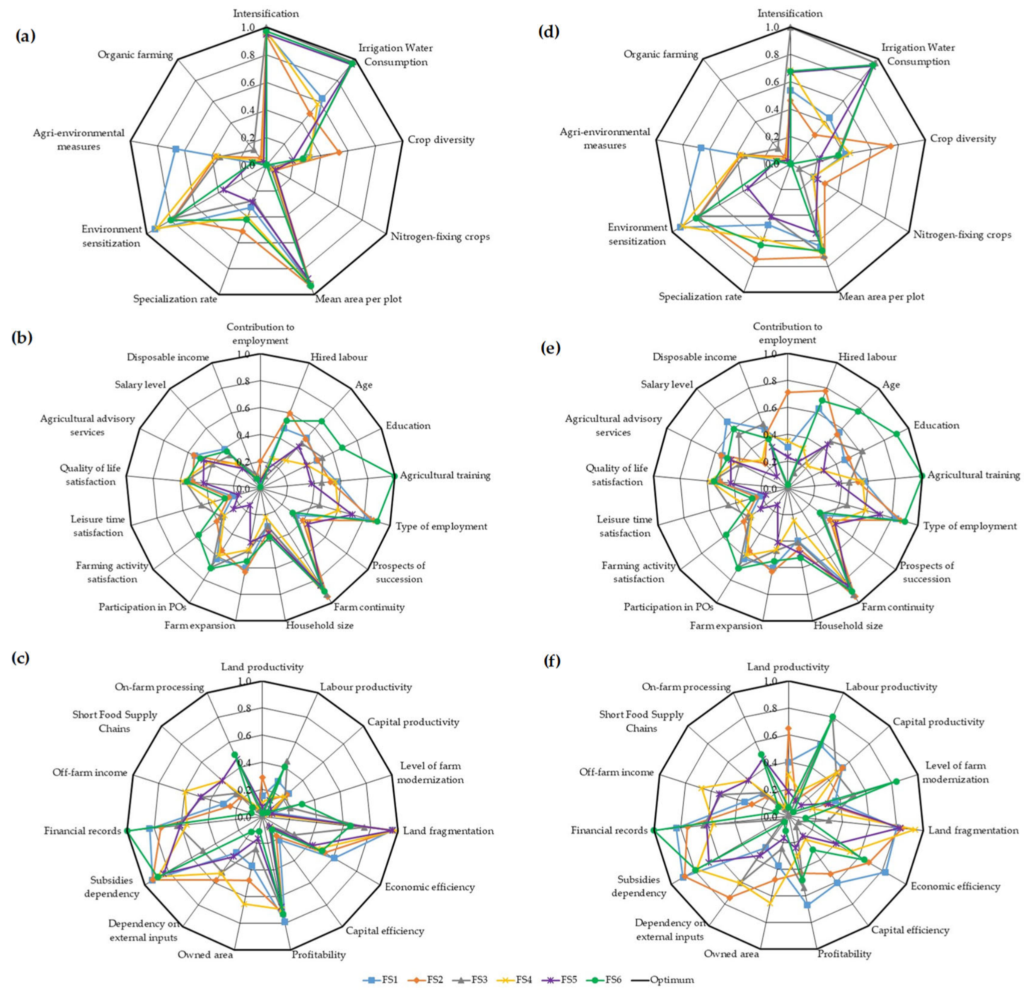

Figure 3. Visual integration of individual sustainability indicators; in (**a**–**c**),(**d**–**f**) indicators were normalized using as thresholds the worst and best performing farms of the whole sample, and 10th-90th percentiles, respectively; (**a**,**d**): indicators of the environmental pillar; (**b**,**e**): indicators of the social pillar; (**c**,**f**): indicators of the economic pillar; POs: Producer Organizations; for the abbreviations of farming systems, see Table 2.

3.2.1. Environmental Indicators

FS1, which scored the highest on EnCSI (Table 3a), exhibited the largest proportions of environmentally sensitized farmers and farms enrolled in agri-environmental measures (Table 4; Figure 3a). Indeed, the majority of FS1 farmers were certified with quality assurance certificates, which are based upon integrated farming or integrated crop management principles, and received agri-environmental subsidies. This may be attributed to the dynamic and export-oriented potato production, chiefly in Famagusta district [23,47]. Therefore, FS1 could be fairly characterized as an integrated system. According to Pretty [48], integrated farming leads the way to sustainable intensification. As a matter of fact, Vlahos, Karanikolas, and Koutsouris [27] and Reganold et al. [49] found that integrated FSs are more sustainable than conventional ones, while Gómez-Limón and Sanchez-Fernandez [14] showed that farm sustainability increases when agri-environmental subsidies increase.

Despite the score for EnCSI being similar in FS2 and FS3 (Table 3a), striking differences were observed in individual indicators. Due to the nature of the crops grown (rainfed field crops), FS3 obtained the lowest intensification and irrigation water consumption values. However, FS2 scored best on, e.g. crop diversity and nitrogen-fixing crops. Interestingly, FS3 had the largest proportion of farms enrolled in organic schemes, although it showed the highest specialization rate.

The score of EnCSI for FS4 and FS6 was quite similar (Table 3a) and this is also true for the score of some individual indicators (e.g. intensification and specialization rate). Yet, FS4 exhibited sufficiently higher values for irrigation water consumption, nitrogen-fixing crops and enrolment in agri-environmental schemes. Notably, the low value of EnCSI for FS5 was due to the bad performance on most environmental indicators. As shown in the Supplementary Material (Table S1), FS5 also had a high livestock density (4.4 Livestock Units ha^{-1}), which means that a high amount of manure was available per ha of UAA, implying a high potential of GHG emissions and a high risk of nutrient leaching [12]. However, this situation can be substantially improved by adopting efficient management practices related to the collection, storage and use of manure as organic fertilizer [23].

FS1, FS2, and FS4 include vegetables, potatoes and citrus which require large amounts of water. Albeit previous studies [16] have found a positive relation between irrigation and farm economic sustainability—similarly, in our study, the correlation between irrigation water consumption and EcCSI was also positive ($r_s = 0.36$, $p < 0.01$)—in a country, like Cyprus, with a serious water shortage problem, the efficient use of irrigation water and the shift, where possible, to less water-intensive crops should be considered by stakeholders. Nonetheless, prior to any action, other important issues, such as water productivity of crops, the suitability of land for "new" crops and various marketing issues should also be taken into consideration [28].

3.2.2. Social Indicators

The score of SCSI for FS6 was the highest among systems (Table 3a) due to good performance on most social indicators (Table 4; Figure 3b), while the opposite was true for FS5. Nevertheless, FS5 showed the highest prospects of succession.

FS2 had intermediate to high social performances and thus exhibited the second highest SCSI (Table 3a). Due to high labor input and small UAA, this system had the highest contribution to employment, while it also showed the largest proportion of hired labor. Paradoxically, although the salary level of FS2 was low, satisfaction from farming was comparatively high. FS1 ranked third for SCSI as a result of the intermediate performance on most social indicators. In contrast to FS2, it exhibited the highest salary level; however, satisfaction from farming was intermediate.

Despite the score for the SCSI being quite similar in FS3 and FS4 (Table 3a), large differences were observed in some individual indicators. Due to low labor input and large UAA, FS3 had the lowest contribution to employment. Likewise, it showed the smallest proportion of hired labor. FS4 scored better on agricultural training and prospects of succession. Interestingly, both FS3 and FS4 exhibited relatively large proportions of part-time farmers and comparatively high satisfaction for leisure time and quality of life. Actually, interviews with farmers revealed that part-time farmers had more free time to enjoy their everyday life.

Contribution to employment reflects multifunctionality in agriculture [1]. The FSs that offer opportunities to absorb labor (e.g. FS2) can boost rural economies and prevent urbanization [48]. However, contribution to employment as defined in this study, is disadvantageous for systems with large UAA (FS3, FS6) (see Supplementary Material; Table S1). Therefore, interpretation should be performed with care, taking into account the impact of the chosen functional unit (per ha of UAA) on indicator results, as well as other complementary indicators (e.g. hired labor) and the system's structure [1,22]. Additionally, in some situations (e.g. poor labor productivity of the system; e.g. FS5), employing labor, despite its contribution to social sustainability, may have a negative effect on global sustainability [14].

Previous studies have shown that farmer's age has a negative effect on farm sustainability, while education level has a positive effect [14,20]. This is substantiated by our results, as the farmers of FS4 and FS5, which had the lowest values of SCSI, were, on average, the most elderly and least educated. Likewise, the correlation between SCSI and age was negative ($r_s = -0.31$, $p < 0.01$) but positive with education ($r_s = 0.32$, $p < 0.01$).

Considering that the sustainability of FSs is also based on their ability to carry on from one generation to the next [40] and that the lack of a successor often leads to farmland abandonment [50], the indicator of prospects of succession was included in the social pillar as a proxy for intergenerational continuity in agriculture [35]. Worryingly, prospects of succession were low for all the systems studied, indicating that the intergenerational transfer of the farms may not be ensured. In contrast, the score for farm continuity was high across the systems (Figure 3b), thus ensuring farming continuation in the short to medium term.

Producer Organizations (POs) is a form of social capital with important benefits for their members/farmers, such as increased negotiating power and lower input costs [23,51]. As revealed by other studies [14], farmers that are members of cooperatives are more likely to be sustainable. In this study, the least sustainable system (FS5) also had the lowest level of organization; only 14.6% of the farmers were members of POs. This result confirms the absence of organization in the Cypriot sheep/goats sector [23].

The high quality of life of the farmer is one of the main objectives of rural development policies [39]. In essence, the way the farmers perceive and rate their quality of life is crucial to determining continuity in farming [21]. Here, quality of life was represented by three indicators; satisfaction from: farming, leisure time, and quality of life. The values of these indicators were generally medium to low across systems, as a result of the harsh working conditions and relatively low incomes, as supported by the farmers themselves. Indeed, the correlation between these indicators and salary level was positive (r_s = 0.18–0.26, $p < 0.01$).

The indicator of agricultural advisory services was used as a proxy for capacity building and access to knowledge, but it could also be considered a proxy for the professionalism of the farm [50]. It is expected that those farmers using advisory services are better informed, have more knowledge, and may be more innovative [39]. In this research, it was found that the systems with the largest proportions of part-time farmers (FS3, FS4) had the lowest average scores for advisory services, which is consistent with the findings of Ripoll–Bosch, Díez–Unquera, Ruiz, Villalba, Molina, Joy, Olaizola, and Bernués [21].

Salary level indicator, defined in this study as the ratio between return to labor per annual work unit and legal minimum wage in other economic sectors (i.e. opportunity cost of labor), should exceed unity. This is the case for FS1, FS3 and FS6, whereas FS2 and FS4 scored marginally lower than unity. The salary level for FS5 was only 0.75 (Table 4), pointing out that the average farmer/laborer could not meet the basic needs for subsistence without off/non-farm income. This might be closely related to the socioeconomic characteristics of FS5 farmers, such as high age and low education level. Actually, salary level was negatively associated with age (r_s = −0.12, $p < 0.05$) and positively with education (r_s = 0.15, $p < 0.01$).

3.2.3. Economic Indicators

The score of EcCSI for FS1, FS2, and FS4 was rather similar (Table 3a), albeit significant differences were found in individual indicators (Table 4; Figure 3c). FS4 scored best on EcCSI because of good performance on specific economic indicators, e.g. owned area and off/non-farm income. Yet, it was the least modernized. The integrated FS1 (second rank for EcCSI) scored the highest on efficiency, profitability, capital productivity and dependency on subsidies, while FS2 showed the highest land productivity and the lowest dependency on external inputs.

The score of EcCSI for FS5 was close to that of FS6 (Table 3a), but FS5 performed better on, e.g. land productivity, dependency on external inputs, off/non-farm income, and utilization of Short Food Supply Chains (SFSC). The farmers of FS5 and FS6 were mostly land tenants, while, due to (primarily) halloumi cheese making, both systems performed good on on-farm processing indicator.

The least economically sustainable FS3 was the most dependent on subsidies; however, it exhibited the highest labor productivity, the second highest level of farm modernization and relatively high off/non-farm income.

Similar to contribution to employment, the indicator of land productivity is disadvantageous for systems with large UAA (FS3, FS6), but advantageous for systems with relatively small UAA and high outputs (e.g. FS2) (see Supplementary Material; Tables S1 and S2). Thus, when comparing different systems, interpretation should be done with caution, considering the influence of system's structure on indicator outputs [1,21]. In essence, horticulture farms (e.g. FS1, FS2) have smaller UAA [50] and higher land productivity than extensive cereal farms (e.g. FS3).

As shown in Table 4 and illustrated in Figure 3c, the systems that scored relatively high on labor productivity (FS1, FS3, FS6) also had a high level of farm modernization. Evidently, there is a synergy between these indicators. Indeed, at the farm level, the correlation was positive ($r_s = 0.36$, $p < 0.01$), indicating that the more modernized a farm is, the more productive is in terms of labor [39]. However, a negative correlation (trade-off) was found between farm modernization and capital productivity ($r_s = -0.42$, $p < 0.01$).

Subsidies dependency is an important aspect of system's autonomy and economic independence [35,40]. The high and disproportionate dependence on (Common Agricultural Policy-CAP) subsidies (e.g. FS3) could hinder or slow down innovation [29] and make farms highly vulnerable to any policy reforms that target the reduction of subsidies. This, of course, might put the sustainability of farms at risk [35]. On the contrary, the systems with low dependency on subsidies, such as FS1 and FS2, might adapt more readily to such reforms.

In this study, economic and capital efficiency were negatively associated with subsidies dependency ($r_s = -0.77$ and $r_s = -0.54$, $p < 0.01$, respectively). Indeed, FS3 was the most dependent on CAP subsidies and the least efficient, whilst the opposite was true for FS1 and FS2. Van Passel, Nevens, Mathijs, and Van Huylenbroeck [11] also found a negative correlation between dependency on subsidies and sustainable efficiency of farms, while Gómez-Limón and Sanchez-Fernandez [14] revealed no correlation between CAP subsidies and farm sustainability. These results question the role of CAP subsidies and their effectiveness in enhancing the sustainability of the agricultural sector. In any case, we agree with other authors [11,14] that policymakers should re-examine the current criteria by which subsidies are provided and allocated to farms.

Another important aspect of system's autonomy is the dependency on external inputs (e.g. fertilizers, pesticides, feedstuff). In essence, sustainable FSs should seek to minimize the dependency on external inputs [34,36], which makes them highly sensitive to market volatility and shocks [35]. This is the case particularly for FS6, which exhibited the highest dependency on external inputs, mainly purchased feedstuff (representing ca. 48% of total costs). In this aspect, FS6 farms mirror those identified by other studies [52]. The sensitivity of FS6 households to market volatility is reinforced by their strong reliance on agriculture income—nearly 92% of household income was derived from agriculture (Table 4)—and is substantiated by the negative correlation found between dependency on external inputs and EcCSI ($r_s = -0.31$, $p < 0.01$).

FS1, FS2, and FS4, which scored best on EcCSI, also had the largest proportions of owned area. Accordingly, the correlation between EcCSI and owned area was strong ($r_s = 0.53$, $p < 0.01$). This is consistent with the findings of Gómez-Limón and Sanchez-Fernandez [14]. According to these authors, the farmers that own their land are more likely and more willing to make long-term investments on their farm. At the same time, land ownership may enhance prospects of succession, even though in our study the correlation between owned area and prospects of succession was weak and negative ($r_s = -0.09$, $p = 0.09$). Conversely, land tenancy might increase risk and the financial stress of the farm [53].

Off/non-farm income reflects system's adaptability to an ever-changing environment (e.g. climate and input/output prices volatility). It is a source of income diversification and an alternative livelihood strategy (especially for small-scale farmers) that may keep farming activity alive [16,21,35]. Likewise, it is supported that farm households with off/non-farm income may be more resilient to the fluctuations of farm income [42]. The system of small farms in this study (FS4), which scored the highest on EcCSI, also had the highest proportion of off/non-farm income. In addition, off/non-farm income had a positive effect on the EcCSI of the farm ($r_s = 0.28$, $p < 0.01$). Nonetheless, bearing in mind the specific socioeconomic features of FS4 households, such as elderly and low-educated farmers, as well as low profitability (Table 4), their relatively substantial amount of off/non-farm income may imply a future exit from farming.

It follows that, apart from the traditional economic indicators, such as labor productivity and profitability [1], sustainability assessments need to consider income and product diversification activities to comprehend the dynamics of farms and FSs. For the sake of example, FS4 and FS5 had low labor productivity and profitability. However, to be flexible and adaptable to external changes and disturbances, as well as to disperse the risk of crop/livestock failure and income loss, these farmers were diversified through off/non-farm activities, utilization of SFSC and on-farm processing (only FS5). It is noteworthy that small farms are relatively more involved in SFSC. Moreover, although more labor-intensive for farms, the utilization of SFSC potentially supports sustainable development by, e.g. reducing transport costs and GHG emissions, assuring fairer prices for both producers and consumers, and strengthening the relationship between them [54]. Interestingly, SFSC indicator was positively related to EnCSI ($r_s = 0.14$, $p < 0.05$), EcCSI ($r_s = 0.58$, $p < 0.01$) and GCSI ($r_s = 0.20$, $p < 0.01$). To minimize, however, the negative impact on the environment, SFSC should, at the same time, be local and use environmentally friendly production methods [54].

3.3. Internal Consistency and Sensitivity Analysis

The internal consistency analysis revealed strong correlations between the GCSI and pillar scores, both for the overall sample and for each system (Table 5). The correlations were higher with the EnCSI (r_s = 0.50–0.77) and the SCSI (r_s = 0.55–0.85) than with the EcCSI (r_s = 0.25–0.67). Nevertheless, all correlations were positive, showing performance in the same direction, which is desirable when constructing composite indices [20,46].

Table 5. Correlation (Spearman's rho) between the four composite sustainability indices by farming system and for the overall sample.

Farming System	EnCSI vs. SCSI	EnCSI vs. EcCSI	SCSI vs. EcCSI	GCSI vs. EnCSI	GCSI vs. SCSI	GCSI vs. EcCSI
FS1 (n = 60)	0.35 **	0.00	0.07	0.60 **	0.79 **	0.49 **
FS2 (n = 46)	0.10	−0.22	−0.15	0.61 **	0.61 **	0.25
FS3 (n = 35)	0.25	0.30	0.19	0.75 **	0.70 **	0.58 **
FS4 (n = 70)	0.16	−0.12	−0.15	0.65 **	0.67 **	0.28 *
FS5 (n = 103)	0.14	0.22 *	−0.19	0.75 **	0.55 **	0.44 **
FS6 (n = 10)	0.09	0.08	0.62	0.50	0.85 **	0.67 *
Overall (n = 324)	0.33 **	0.12 *	0.00	0.77 **	0.72 **	0.43 **

Note: The indices in this table were calculated using as thresholds the minimum and maximum observed values in the sample. n: number of farms; for the abbreviations of farming systems, see Table 2. GCSI: Global Composite Sustainability Index; EnCSI: Environmental Composite Sustainability Index; SCSI: Social Composite Sustainability Index; EcCSI: Economic Composite Sustainability Index. ** Significance level $p < 0.01$; * Significance level $p < 0.05$.

For the overall sample, the EnCSI was positively associated with the SCSI ($r_s = 0.33$) and the EcCSI ($r_s = 0.12$), indicating that socioeconomic development and environmental protection are not necessarily mutually exclusive [11,16]. Surprisingly though, the SCSI and EcCSI were not correlated. This contradicts the theory that economic sustainability is often linked with the social pillar [1].

At the systems' scale, the correlations among the pillars themselves were varied, but they were in general low and non-significant (Table 5). These results indicate that the three pillars represent different aspects of sustainability, which is desirable from an index development perspective [46]. However, the negative associations between the EnCSI and EcCSI (FS2, FS4), as well as between the SCSI and EcCSI (FS2, FS4, FS5), point to the existence of trade-offs between them. In this case, good performance on all pillars might not be possible simultaneously. Hence, it may be argued that one should focus on the three pillars and try to identify synergies and trade-offs between them, instead of aggregating them into a single index. Notwithstanding the foregoing, the results suggest the internal consistency of the GCSI.

The preliminary sensitivity analysis showed that when using the new thresholds (10th and 90th percentiles), the average CSIs scores were in most cases higher than when using the original thresholds (Table 3b). However, the ranking of systems was not notably affected and in most cases the adoption of the new thresholds involved small shifts (indicated in bold type in Table 3b). The largest shift in ranking (three positions) was observed in EnCSI for FS1.

At the level of base indicators, the use of the new thresholds provided more clear graphs (Figure 3d–f). Albeit indicators' scores were quite different, systems' ranking remained rather unchanged.

Finally, to test the robustness of the CSIs calculated using different thresholds, Spearman's rho was employed [8]. The correlations, both for the overall sample and for each system, were strong, ranging from 0.81 to 0.96 (Table 6). This shows that (a) the ranking of the farms does not differ much when using the new thresholds and (b) the respective pairs of CSIs measure the same complex reality, viz. environmental or social or economic or global sustainability. It can therefore be concluded that the choice of CSI does not very much matter when trying to describe agricultural sustainability [14].

Table 6. Correlation (Spearman's rho) between the composite sustainability indices constructed using different thresholds to normalize base indicators, by farming system and for the overall sample.

Farming System	EnCSI [a] vs. EnCSI [b]	SCSI [a] vs. SCSI [b]	EcCSI [a] vs. EcCSI [b]	GCSI [a] vs. GCSI [b]
FS1 (n = 60)	0.89	0.95	0.90	0.91
FS2 (n = 46)	0.95	0.96	0.85	0.92
FS3 (n = 35)	0.96	0.94	0.89	0.96
FS4 (n = 70)	0.85	0.94	0.82	0.88
FS5 (n = 103)	0.94	0.96	0.90	0.95
FS6 (n = 10)	0.89	0.94	0.81	0.88
Overall (n = 324)	0.91	0.96	0.84	0.95

[a] Min-max normalization using as thresholds the lowest-performing and best-performing farms in the sample. [b] Min-max normalization using as thresholds the 10th and 90th percentiles in the sample. n: number of farms; for the abbreviations of farming systems, see Table 2. GCSI: Global Composite Sustainability Index; EnCSI: Environmental Composite Sustainability Index; SCSI: Social Composite Sustainability Index; EcCSI: Economic Composite Sustainability Index. All coefficients are significant at $p < 0.01$.

Generally, this exercise showed that the adoption of the new thresholds affected the absolute scores of CSIs and base indicators, but not the ranking of systems and farms. Similar results were obtained by Van Passel, Nevens, Mathijs, and Van Huylenbroeck [11] and Castoldi and Bechini [15], when examining the influence of different thresholds on the sustainability measures. Nevertheless, we recognize that the choice of thresholds, but also the choice of the normalization method, weighting scheme, etc. (i.e. sources of uncertainty inherent in the construction of indices), require further research. For the effect of different normalization and aggregation techniques on the results of composite indicators of agricultural sustainability, we refer to the interesting work of Talukder, W. Hipel, and W. van Loon [8].

3.4. Some Comments on the Sustainability Framework and Potential Limitations of the Study

The analysis of individual indicators revealed that similar average scores for sustainability pillars can hide large differences within individual indicators, demonstrating the strengths and weaknesses of each system. Moreover, trade-offs were observed between indicators within a pillar. For instance, as regards SCSI, the bad performance of FS6 on contribution to employment, prospects of succession and disposable income, was offset by good performance on the remaining indicators.

The process of defining the appropriate sustainability indicators (and their weights) is not an easy task [11]. As proposed by other authors [3,7,9,19,21], relevant stakeholders/end-users (e.g. farmers, agronomists, agricultural extension officers) should be involved in this process, therefore following a participatory or bottom-up approach. Due to time and financial constraints, we followed a top-down approach (expert-driven) and this may be considered a limitation. However, bottom-up approaches might be complex in practice, due to different stakeholder perceptions about sustainability [21]. In addition, bottom-up frameworks are usually very complex to manage, they often need support (financial and operational) from authorities or governmental organizations, while the overall process is very time consuming to produce results. Importantly, in bottom-up approaches, the comparison between different FSs (as is the case with our study) is rather difficult and analysis is hardly reproducible [7].

In some cases, e.g. land productivity, the thresholds used to rescale indicators, viz. worst and best performing farms, turned out to be exceptional for some sampled farms. On this basis, one could argue that benchmarking within a system (or sector) could be more reasonable or realistic. This, however, only shows the potential for improvements within a given system and entails that the agricultural structure remains constant; thereby the dynamics of the agricultural sector are not taken into account (e.g. shift from one system to another) [11]. Likewise, this approach, i.e. focusing on just a specific FS or sector, lacks the ability to compare heterogeneous situations, which is among the main advantages of the top-down frameworks [7].

It is noteworthy that, due to different structural and functional characteristics of the sampled farms, the variability of the calculated indicators between and within FSs was high. Therefore, extrapolating the results from farms to FSs (or sectors) is indeed challenging and certainly not straightforward [21]. In other words, comparing the sustainability of different FSs using multiple indicators is a daunting task. In this vein, de Olde, Oudshoorn, Bokkers, Stubsgaard, Sørensen, and DeBoer [22] assessed the sustainability performance of different organic systems in Denmark and found significant differences between them on specific indicators/subthemes. These differences were related to the structure of FSs, such as the presence or absence of livestock. However, as pointed out by these authors, a comparison of farms within a system or sector (viz. system- or sector-specific) would disable a comparison between the sustainability performance of different FSs or sectors.

In our study, the environmental pillar was the most neglected. Thus, we acknowledge that, in a further development of this framework, the list of environmental indicators should be extended, including key environmental aspects, like pesticides use and GHG emissions. In contrast, socioeconomic dimensions were well-represented here, whereas others did not take into account social and/or economic aspects [1,7,9,10,15]. In fact, important socioeconomic indicators that help understanding the dynamics of FSs, such as disposable income and off/non-farm income [21], were not considered in other studies probably due to their sensitive nature (farmers often appear reluctant to provide such information), or because these studies were conducted on the basis of existing datasets without any information on such indicators [42]. Interestingly, some studies that used bottom-up approaches to identify sustainability indicators/criteria, revealed that farmers give higher importance to socioeconomic issues than to environmental sustainability [21,55]. Nonetheless, each sustainability assessment tool, method, or framework (including ours) has its advantages and drawbacks [6,7,9]. As concluded by Arulnathan, Heidari, Doyon, Li, and Pelletier [9], scientists and tool developers are often faced with trade-offs across different methodological choices, such as the level of sustainability assessment (e.g. single indicator or multidimensional).

4. Conclusions

In this study, the sustainability of divergent FSs was assessed by combining numerical and visual integration approaches, and by analyzing the original indicator values. Although appealing for communication and appropriate for informing policymakers, the CSIs provided only the "big picture", whereas the decomposition of CSIs revealed the main drivers for an overall good or bad performance and pinpointed the areas where policy interventions are needed. Therefore, a high level of communicability and detail was maintained in this study.

However, the variability of the calculated indicators between and within FSs was high, implying that it is difficult to apply an integrated sustainability analysis to different FSs (or sectors) instead of individual farms within a sector. Nonetheless, with some modifications (e.g. inclusion/exclusion of indicators, use of different thresholds), the proposed methodology can also be used to compare the sustainability of farms within a system or sector, viz. for system- or sector-specific comparisons.

The case study results showed that the system of medium-sized irrigated farms with open field vegetables/potatoes (FS1) is representative of integrated farming, indicating that sustainable intensification and cleaner production are feasible in the study area. In contrast, the system of specialized medium-sized sheep/goats farms (FS5) is the least sustainable with several weaknesses. In our view, decision makers and public competent authorities should prioritize the survivability of FS5 farms. Nevertheless, each system has different challenges and opportunities; thus, policy interventions should be targeted and adapted to their different needs. However, in some cases, the challenges (or opportunities) are common to all systems, as is the case with the (low) prospects of succession. Here, a straightforward policy recommendation for all systems would be to strengthen existing policies of attracting and recruiting youth to agriculture in order to stimulate succession, improve the sustainability of FSs and revitalize rural areas.

The current work allows a rapid, transparent and integrated evaluation of the sustainability of FSs and the proposed top-down sustainability framework is user-friendly and reproducible. The results obtained could be used for benchmarking purposes and to support decision-making process in Cyprus but might also be useful for other Mediterranean regions with similar agro-ecological conditions.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/12/15/6105/s1, Table S1: Characterization of identified farming systems; land use/cultivation plan, livestock ownership and production orientation variables (mean ± SD), Table S2: Characterization of identified farming systems; farm and household, labor and economic variables [mean ± SD for continuous variables; frequencies (%) for categorical variables].

Author Contributions: Conceptualization, A.S. D.S. and C.D.A.; methodology, A.S. and C.D.A.; validation, A.S. and D.S.; formal analysis, A.S.; investigation, A.S.; resources, A.S.; data curation, A.S.; writing—original draft, A.S.; writing—review and editing, A.S. D.S. and C.D.A.; visualization, A.S.; supervision, C.D.A.; project administration, A.S. D.S. and C.D.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors are highly grateful to the 324 farmers interviewed during this study, to the staff of Cyprus Agricultural Research Institute (ARI), especially Mrs. Irene Charalambous for her valuable contribution during data collection and to the anonymous reviewers, whose suggestions improved this paper.

Conflicts of Interest: The authors declare no conflict of interest.

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