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Are Tunisian organic olive growing farms sustainable? An adapted IDEA approach analysis

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Abstract

Sustainability and multifunctionality of agriculture have become widely shared goals for both scientific community and decision makers. Nowadays, it is important to assess not only the economic sustainability of farms, but also their environmental and socio-territorial sustainability. Numerous sustainability measurement tools have been developed by researchers and some institutions to assess these three dimensions. With the purpose to improve farms' sustainability, this paper aims providing oriented strategies to go toward more conscientious farmers' practices in the Tunisian organic olive sector. To reach this goal, two methodological steps were followed: (i) a sustainability measurement process to quantify farms' sustainability by a methodological adaptation of the IDEA approach; (ii) on the basis of the obtained scores of the three sustainability scales, farms' segmentation was carried out by the use of cluster analysis. In that sense, a questionnaire directed to a sample of organic olive growing farmers was carried out in the regions of Sfax and Mahdia, Tunisia. Results show a variability of sustainability levels within and between groups of farms. Cluster analysis results confirmed the existence of two main farms' groups. The first group is more agro-environmentally and socio-territorially sustainable than the second one. Weaknesses in the sustainability performances have been identified and improvement strategies have been formulated and oriented to each group. Results also indicate that in some cases there is no antagonism between environmental, socio-territorial and economic sustainability, so it is possible to improve simultaneously the three dimensions of sustainability.

Additional key words: cluster analysis; multifunctionality; sustainability; Tunisia.

Resumen

Son sostenibles las explotaciones olivareras orgánicas tunecinas? Un análisis "IDEA" adaptado

Hoy en día es importante evaluar no solamente la sostenibilidad económica de las explotaciones agrarias, sino también la ambiental y socio-territorial. Con el propósito de mejorar la sostenibilidad de las explotaciones agrarias, este estudio tiene como principal objetivo proporcionar estrategias orientadas a impulsar el uso de prácticas más concienciadas por parte de los agricultores del sector del olivar ecológico de Túnez. Para alcanzar este objetivo, se han desarrollado dos etapas metodológicas: (1) implementando un proceso de medición cuyo objetivo es cuantificar la sostenibilidad de las explotaciones, mediante una adaptación metodológica del enfoque IDEA; (2) sobre la base de la puntuación obtenida de las tres escalas de sostenibilidad, y mediante el uso de un análisis de conglomerados, se ha llevado a cabo una segmentación de las explotaciones. Se elaboró un cuestionario dirigido a una muestra de agricultores del olivar ecológico en las regiones de Sfax y Mahdia (Túnez). Los resultados muestran una gran variabilidad de los niveles de sostenibilidad dentro y entre grupos de explotaciones. Los resultados del análisis de conglomerados confirmó la existencia de dos principales grupos de explotaciones. El primer grupo es agro-ecológica y socio-territorialmente más sostenible que el segundo grupo. Se han detectado debilidades en los indicadores de sostenibilidad y diseñado estrategias orientadas hacia cada uno de los dos grupos. Los resultados indican también que en algunos casos no hay antagonismo entre la sostenibilidad ambiental, socio-territorial y económica y por lo tanto es posible mejorar simultáneamente las tres dimensiones de sostenibilidad.

Palabras clave adicionales: análisis de conglomerados; multifuncionalidad; sostenibilidad; Túnez.

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Introduction

Sustainability and multifunctionality are concepts which date back to the beginning of the last century. They emerged as a consequence of a set of environmental concerns involving both current and future generations. To advance these issues, several studies and reports emerged, the most important of which being: "The Limits to Growth" in 1972, "Brundtland Report" in 1984 and the "Green Book" of the European Commission in 1985 (Parra-López *et al.*, 2007). But, it is only since the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 that the sustainability and multifunctionality of agriculture have become widely shared goals not only in the scientific community but also in the modern design of agricultural and environmental policies. Based on an economic and a normative perspective, multifunctionality refers to the multiple functions that society assigns to and demands from agriculture. These functions preserved in time lead to the concept of sustainability. Thus, sustainability is a multi-dimensional and multi-criteria concept that entails an amalgamation of economic, social, and environmental criteria (Elfkih *et al.*, 2009). To evaluate and to measure sustainability, the international community, at the World Summit on Sustainable Development held in Johannesburg in 2002, has encouraged further work on indicators. This leads to a *simplification of* the complexity, a qualitative and a quantitative description of the studied systems, in order to *communicate* operational information necessary for decision-makers (Desbois, 2007).

Many sustainability measurement methods based on indicators in order to evaluate the impact of agricultural practices (Galan *et al.*, 2007) are implemented, the most sound of which are: the IDEA, abbreviation of the French appellation "Indicateurs de Durabilité des Exploitations Agricoles" Farm Sustainability Indicators; IDERICA; Indigo, abbreviation of the French reference "Indicateurs de Diagnostic Global à la parcelle"; the Dialect method; the Arbre method; etc. (Peschard *et al.*, 2004). These methods present three major differences: the nature of used indicators (quantitative or qualitative), the scale of their applications (farms or plots) and the sustainability studied dimensions (Peschard *et al.*, 2004). The choice of the adequate method and indicators are crucial to reach satisfactory results and this depends on which objectives investigators or decision makers are interested in. Details about the differences between sustainability measurement methods are reported by Peschard *et al.* (2004) and Bockstaller *et al.* (2008).

The IDEA method has been one of the most successful methods used to assess farms sustainability in its three dimensions. It was implemented in various agronomic domains. Del'Homme & Pradel (2005) assessed farmers' sustainability awareness in the field of viticulture. Srour (2006) implemented it in the case of small ruminants breeding farmers in Lebanon. Fortun-Lamothe & Auvergne (2008) implemented it to compare two production systems of goose and duck liver. Laajimi & Ben Nasr (2009) have used it to compare the sustainability of two farming systems: organic and conventional olive growing farms in Tunisia. However, in this paper the IDEA method is presented in a rather different way. Any methodological aspects will be outlined with the purpose of adapting the IDEA method to the case study of organic olive growing farms in Tunisia. In fact, there is not just one farm sustainability model and, therefore, the indicators must be adapted to local farming before using the IDEA method (Zahm *et al.*, 2008).

In particular, this paper aims i) to measure the sustainability of organic olive growing farms in Tunisia taking into consideration the three dimensions: agro-environmental, socio-territorial and economic through an adapted IDEA approach and; ii) to examine the outlined results in order to study the influence of farmers' behavior and practices and farm location on agricultural sustainability. This ultimately aims at advancing oriented strategies to go toward more sustainable practices.

Material and methods

Sample selection and study area

A survey to a sample of 27 organic olive growing farms has been carried out. The sampled farms are located in the regions of Sfax and Mahdia, two coastal regions situated respectively in the south-center and the center of Tunisia. These two regions are at less than 100 km of distance, with different but not very pronounced climatic conditions.[1] Sample selection was based on the following criteria: farm location and farm

[1] Mahdia belongs to the semi-arid lower floor and Sfax to the arid upper floor. (http://library.wur.nl/isric/index2.html?url = http://library.wur.nl/WebQuery/isric/17536).

size. Sfax region accounts for 25 large organic olive growing farms. Using a stratified probabilistic sampling, 12 farms have been selected from Sfax, which represents around 50% of total population. Concerning Mahdia region, the total number of organic growing farms is about 300 grouped into 10 groups of 30 farms each (CTAB, 2008). Belonging to agricultural regional experts, these farms' groups have the same organizational structure. For this reason, only one group was considered. To minimize the possible effects of climatic conditions and to minimize execution costs, we opted to study the nearest farms' group, in terms of distance, to Sfax region. From the selected group 15 organic growing farms have been sampled, representing 50% of the group total population.

The Tunisian organic olive growing sector has a strategic importance for the Tunisian economy. This sector represents the main organic activity in Tunisia. Sfax and Mahdia are the most important Tunisian organic olive growing regions in surface, in production and in farmers' number. This sector is characterized by the coexistence of private and public farms. But, only private farms will be considered because of the complexity that can entail the study of the two kinds of farms at the same time. The two studied regions present depth structural differences. Sfax region includes 64,000 ha (55% of total organic olive growing area). Olive growing farm sizes are mostly medium to large with an average plot size around 100 ha. Mahdia region regroups 30,000 ha of organic olive growing farms. Farm sizes are mostly small with surfaces generally lower than 20 ha. Farmers in the region of Mahdia are organized into groups that have established marketing contracts with an organic olive oil mill from the same district (CTAB, 2008).

IDEA method: an adaptation to Tunisian organic olive growing farms

To fulfill the outlined objectives, the IDEA method was considered to be the most appropriate for this research. It is easily applied at the farm scale and provides quantitative information concerning the three sustainability scales (Vilain, 2008; Zahm *et al.*, 2008). Moreover, the estimation of indicators is easy and is facilitated by a survey directed to farmers. The information obtained through the questionnaire permits easy calculation of different scores corresponding to each indicator. For example, to calculate diversity, we asked farmers about the number of varieties existing in their orchards and depending on the total number a note was attributed based on the IDEA Standards.

The IDEA method was implemented in 1996, representing an operational framework to measure farms sustainability (Zahm *et al.*, 2005). It was initially designed to be applied to French case studies. It is based on 42 indicators organized into 10 components covering the three scales of sustainability: the agro-environmental, the socio-territorial, and the economic one. The method adopts a rating system that assigns a determined upper limit for each component and an upper limit of 100 points to each scale.

The calculation method is based on two principles. The first one is the *compensation between criteria* in the same component. Indeed, the score value of each component is the cumulative number of basic sustainability units. This score is limited to a ceiled value. Therefore, within the same scale, the full sustainability value is the cumulative of components scores and has an upper limit of 100 points. Thus, favorable practices will offset practices with a harmful effect on another component. This has a real meaning within the same scale. For example, in the diversity component (Table 1) low animal diversity can indeed be partially compensated for by a greater diversity of annual and permanent crops. The second principle is the *rule of key constraints*: the lowest value of the three scales is used as the final numerical sustainability. Viaux (2003) and Zahm *et al.* (2006) stated that using an all-inclusive single score based on a combination of the three scales would have no real meaning, as it would allow compensation across the three scales. This second principle has been questioned by many authors stating that the key constraints can penalize the overall sustainability by the lowest score and an aggregation of the three scales seems to be more appropriate to express the overall sustainability (Mitchell *et al.*, 1995; Cornelissen *et al.*, 2001; Bockstaller & Girardin, 2003). These authors claim that the response to this question can be instrumental in developing methods under the multi-criteria framework (goal programming or analytic hierarchy process methods). In this way, many multi-criteria investigations based on indicators can be useful to investigate this issue where the cases more related to the olive growing farms are the investigations of Alonso & Guzman (2006) and Parra-López *et al.* (2005, 2007, 2008).

A direct application of this method, without any adaptation measures, to another context or another

Table 1. Agro-environmental, socio-territorial and economic components and indicators in the original and the adapted IDEA method

Components	Indicators	Original IDEA (original score)	Adapted IDEA (new score)	Maximum value of each component
Agro-environmental				
Diversity	A1- Diversity of annual and temporary crops	14	14	33
	A2- Diversity of perennial crops	14	14	
	A3- Animal diversity	14	14	
	A4- Enhancement and conservation of genetic heritage	6	6	
Organization of space	A5- Cropping patterns	8	removed	
	A6- Size and location of plots	6	18	33
	A7- Organic matter management	5	18	
	A8- Ecological buffer zones	12	removed	
	A9- Contribution to the environmental value of the area	4	removed	
	A10- Load of animals	5	10	
	A11- Fodder area management	3	removed	
Farming practices	A12- Fertilization	8	20	34
	A13- Effluent processing	3	removed	
	A14- Pesticides	13	combined with A12	
	A15- Veterinary treatment	3	3	
	A16- Soil resource protection	5	8	
	A17- Water management	4	4	
	A18- Energy dependence	10	10	
Total of the agro-environmental scale				100
Socio-territorial				
Quality of the products and land	B1- Quality implementation	10	15	33
	B2- Enhancement of buildings and landscape heritage	8	removed	
	B3- Processing of non-organic waste	5	6	
	B4- Accessibility of space	5	5	
	B5- Social involvement	6	11	
Employment and services	B6- Short trade	7	12	33
	B7- Autonomy and evaluation of local resources	10	removed	
	B8- Services, multi-activities	5	8	
	B9- Contribution to employment	6	removed	
	B10- Collective work	5	8	
	B11- Probable farm sustainability	3	5	
Ethics and human development	B12- Contribution to world food balance	10	removed	34
	B13- Animal wellbeing	3	4	
	B14- Training	6	8	
	B15- Labor intensity	7	9	
	B16- Quality of life	6	6	
	B17- Isolation	3	3	
	B18- Reception, hygiene and safety	4	6	
Total of socio-territorial scale				100
Economic				
Viability	C1- Economic viability	20	20	30
	C2- Economic specialization rate	10	10	
Independence	C3- Financial autonomy	15	15	25
	C4- Sensitivity to subsidies and allowances	10	10	
Transferability	C5- Economic transferability	20	20	20
Efficiency	C6- Productive process efficiency	25	25	25
Total of economic scale				100

geopolitical area may lead to biased results. In addition the lack of data to assess any indicators makes its integral application difficult. In this sense, Zahm *et al.* (2008) state: "It would be unrealistic to believe that a single method could cover all different types of production (from the Mediterranean to boreal climates). The indicators will have to be adapted to local contexts while continuing to comply with the key principles regarding their scientific construction".

For these reasons, an adaptation of the IDEA method to the present case study has been undertaken. A total of 32 indicators were selected and adapted to the case study, leading consequently to a new scoring system. The new scoring system is established based on the principle of compensation between criteria within the same component (Zahm *et al.*, 2008), and on the importance of the criteria to the olive growing farms. In this adaptation and new scoring, no major negative effects are expected, mainly for two reasons: i) the IDEA method offers a very large number of possible technical combinations resulting in the same degree of sustainability; indeed the elimination or the substitution of any indicators can be compensated by the retained indicators of the same component; ii) the calculation of the components scores is obtained through the cumulative number of basic sustainability units of indicators that is usually higher than its ceiling value; this offers more flexibility in adapting scoring punctuation.

Table 1 shows the selected and adapted indicators and the new scores. Modifications affected 11 indicators. Nine indicators were removed and two indicators combined. The reasons for these modifications are exposed as follows:

— A5. Cropping patterns: assess the influence of annual crops rotation on productivity and soil conservation. This indicator is not considered in the present study because the studied farms contain perennial crops.

— A8. Ecological buffer zone: by means of a graphic map, this indicator can indicate the presence or not of hedges, ponds, old stonewalls, forest edges, and wetlands, which are essential to the equilibrium of agricultural ecosystems. The indicator was removed due to a lack of information.

— A9. Contributions to the environmental value of the area: it identifies the areas affected through compliance with a territorialized compliance handbook. In the case of the organic olive growing sector in Tunisia, a compliance handbook is available but it is not territorialized. For this reason this indicator was not considered.

— A11. Fodder area management: this indicator takes into account the presence of fodder crops area, grazed area and corn ensilage. In the studied farms these practices do not exist because of its non adaptation to climate conditions. Thus, the indicator was removed.

— A13. Effluent processing; this indicator highlights the degree of effluent treatments. The lack of information concerning this indicator makes its measurement difficult.

— B2. Enhancement of buildings and landscape heritage: this indicator highlights the maintenance of old buildings, small rural heritage, architectural quality and surrounding identity as territorial heritage. The complexity of self-estimation of this indicator makes it difficult to assess.

— B7. Autonomy and evaluation of local resources: this indicator takes into account food autonomy, autonomy in organic amendments and fertilizers, development of local renewable energy resources, the recovery of rainwater, and self-seed. Due to the lack of precise data concerning these issues, it was not taken into consideration.

— B9. Contribution to the employment: this indicator is difficult to estimate because of the non registration of employees (by the employer) in the employment office. For this reason, the estimation of the contribution to the employment becomes a very complicated task.

— B12. Contributions to world food balance: this indicator quantifies the independence of operation from foreign productions (imports). Not knowing the origins of the products used in each farm may lead to inaccurate information. To avoid this problem this indicator was not considered.

— A14. Pesticides and A12. Fertilization, are combined. The purpose is the measurement of sustainability in the organic olive growing sector where farmers are not allowed to use chemical products. But these two indictors were combined in order to determine if farmers have surfaces of conventional crops near their organic farms. The use of chemical products in this case can affect the sustainability of farms conducted on organic system.

Cluster analysis

To better appreciate the difference in sustainability between farms, we opted in a second step to segment the sampled farms on the basis of the three sustainability scales. Cluster analysis has been undertaken in that order. A two step classification was used. In the first step, a hierarchical conglomeration analysis was applied using the method of Ward agglomeration and the measurement of Euclidean squared distance (SPSS 14.0). The observations of the agglomeration coefficients and the dendrogram helped us to decide the most suitable number of segments to consider (Ketchen & Shook, 1996). In a second step, based on this information and on the centers of clusters previously obtained, a non-hierarchical cluster analysis (k-means method) was applied.

Internal clusters' validation is examined by the use of Anova tables whereas external cluster validation is undertaken by the use of external variables.

Results and discussion

Overall sustainability

The overall sustainability obtained scores revealed high variability. These scores vary from 21 to 63 points. In the case of the majority of farms located in the region of Sfax, overall sustainability is limited by the economic scale. This is in accordance with results obtained by Laajimi & Ben Nasr (2009) in the same region whereas in the majority of farms located in the region of Mahdia, overall sustainability is mainly limited by socio-territorial scale. No cases of overall sustainability limited by the agro-environmental scale are registered. This indicates the importance of the agro-environmental scale in the organic olive growing studied farms. It seems to be important to highlight that sustainability scales are inversely considered in the olive growing conventional system (rain-fed and irrigated farms) (Laajimi & Ben Nasr, 2009; Bakir, 2011). In these systems, overall sustainability is limited by agro-environmental and socio-territorial scales, whereas the economic scale presents the highest scores.

The sustainability scores variability reflects mainly a difference in the farmer's practices and behaviors. These practices and behaviors may be related to a set of external factors, such as socio-territorial and climatic conditions, and other criteria related to farmer's training and educational level. For these reasons, the interpretation of farms practices, the correlation with external factors and the proposition of any recommendations will be undertaken in the next sections.

Mean sustainability scores calculated for farms belonging to Sfax and Mahdia regions are respectively 47.9 and 39.8, indicating that farms located in Sfax are more sustainable than those located in Mahdia (Table 2). Sustainability scores for farms located in Sfax vary from 34 to 63, while sustainability scores for farms located in Mahdia vary from 21 to 52. Sustainability variation among each group of farms is almost the same with a coefficient of variation around 0.20.

Agro-environmental sustainability scale

The agro-environmental scale consists of three components (diversity, organization of space and farming practices). This scale analyses the propensity of the technical system to make efficient the use of the environment at the lowest possible ecological cost (Zahm *et al.*, 2006).

Results show a variation in scores in the agro-environmental scale and within components of this scale between farms (Fig. 1). The comparison between the agro-environmental scale score averages of the two regions shows the existence of significant differences (Table 2). In general, farms belonging to Sfax region show higher agro-environmental scores (mean = 86.8) than those from Mahdia region (mean = 74.6). In the former group, scores vary from 66 to 100 points, whereas in the latter group they vary from 42 to 100. Higher variation among farms is observed in Mahdia region. In the case of some farms, the scores have exceeded 100 points (Fig. 1); these scores were ceiled to 100 points as stated by the IDEA method.

In relation to the diversity component; registered weaknesses are mainly related to: i) diversity of annual and temporary crops indicator, which registered the lowest values in the case of Sfax region; this is explained by the climatic restrictions that characterize this region and limit the introduction of water demanding crops. ii) Breeding diversity indicator, which registered the lowest values in the case of Mahdia region; this is explained by the small size of farms and the limited experience of these farmers in such activity. Concerning conservation of genetic heritage, all farmers use local variety (Chemlali Sfax in the region of Sfax and Chemlali Sahel in the region of Mahdia) and differences registered for this indicator arise essen-

Table 2. Anova table for the three sustainability scales

Scale score		Sum of squares	d.f.	Mean square	F	Sig.
Sustainability	Between groups	439.202	1	439.202	6.049	0.021**
	Within groups	1,815.317	25	72.613		
	Total	2,254.519	26			
Agro-ecological	Between groups	984.150	1	984.150	4.671	0.040**
	Within groups	5,267.850	25	210.714		
	Total	6,252.000	26			
Socio-territorial	Between groups	3,640.007	1	3,640.007	47.688	0.000***
	Within groups	1,908.233	25	76.329		
	Total	5,548.241	26			
Economic	Between groups	14.669	1	14.669	0.200	0.659
	Within groups	1,837.183	25	73.487		
	Total	1,851.852	26			

***, **: statistically significant at respectively 1% and 5% levels.

tially from animal diversity and annual and temporary crops diversity.

About the organization of space component; the following observations can be done: First, in the case of the olive organic growing sector, the size and location of plots indicator was positively considered. So, as far as the size is bigger and plots are in different locations, the negative effect of the alternating character of Tunisian olive tree production can be mitigated. Second, the organic matter management indicator is highly considered by the great majority of farmers. Even farmers who did not practice animal breeding try to buy compost substance regularly. Third, the load of animal indicator expressed by livestock unit/area designated for cattle feed, is very low. In fact, farmers practice only intensive breeding. The improvement of this indicator is required but difficult to fulfill because of the non-compatibility of extensive breeding with arboriculture. However, some surfaces can be devoted only for cattle feed especially in big farms.

The component agricultural practices have registered many weaknesses that concern mainly: the veterinary treatment indicator presenting very low values in the case of all farmers and the soil protection indicator presenting the lowest values in the great majority of Mahdia farms. These two issues must be better

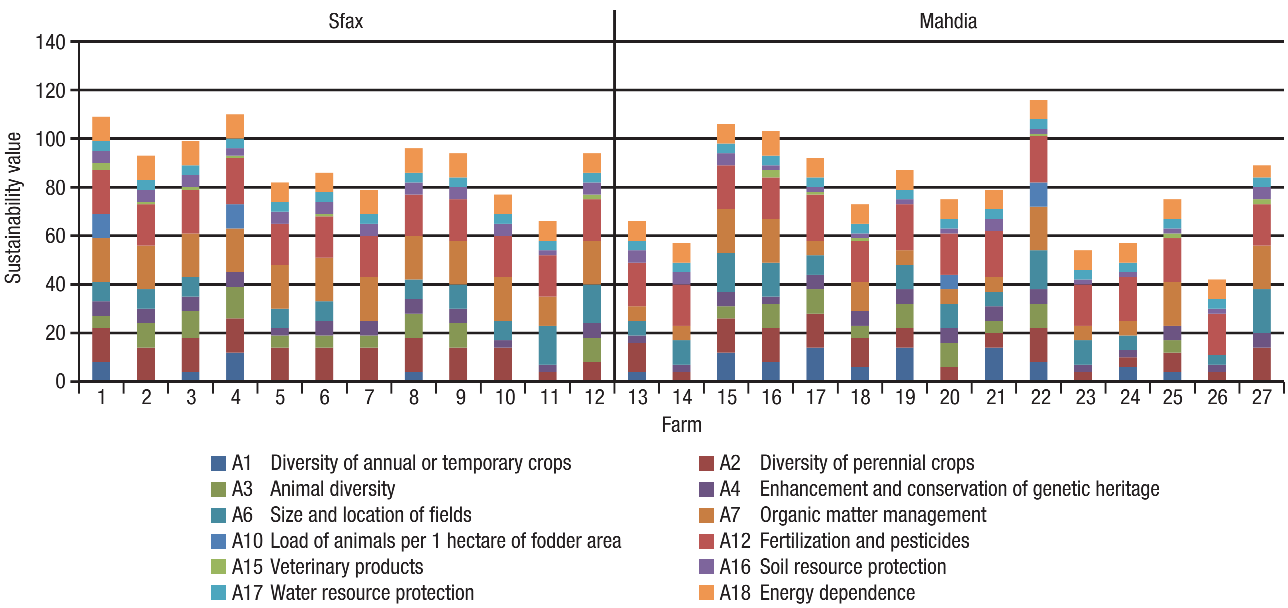

Figure 1. Indicators' results of the agro-environmental scale.

considered by the concerned farmers. So, i) in the case of veterinary treatment, controls must be more frequent to ensure the good health of cattle, and ii) in relation with soil resource protection, more attention must be given to best tillage practices such as non-inversion tillage, and the implementation of anti-erosive mechanisms.

Socio-territorial sustainability scale

The socio-territorial scale consists of three components (quality of the products and land, employment and services, and ethics and human development). This scale, characterizes the integration of the farm within its landscape and in society (Zahm *et al.*, 2006).

Results show best socio-territorial sustainability in Sfax region and worst results in Mahdia region (Fig. 2). Results in Table 2 show a significant difference between averages of socio-territorial scores in the two regions (average score for Mahdia region is 42.1 and average score for Sfax region is 65.5). Socio-territorial scores for farms located in Mahdia vary from 21 to 55 points. These scores vary in the case of Sfax farms from 57 to 79. For the Mahdia group, the socio-territorial scale is the constraining sustainability factor for 73% of farms.

In relation to the component "quality of the products and land", some weaknesses are registered, particularly the proceeding of non-organic wastes indicator and the social involvement indicator, especially in the region of Mahdia. Indeed, the lowest scores of proceeding of non-organic wastes indicator are due to the burning of non-organic wastes (causing toxic gases emissions) practiced by many farmers. For the social involvement indicator, low scores are a consequence of the limited involvement of farmers in social activities such as training courses, participation in social events, and accessibility to information.

The employment and services component has registered also many weaknesses that are mainly related to: i) short trade indicator where the lowest scores are registered in Mahdia region; so, instead of establishing a sale-contract, farmers might try to be organized into a cooperative to commercialize their products directly and to control the production chain; ii) the indicator of services and multi-activities refers mainly to the agro-tourism and the involvement into scientific research; this indicator has registered low results, so only seven farmers from Sfax have high scores; and finally iii) the collective work indicator

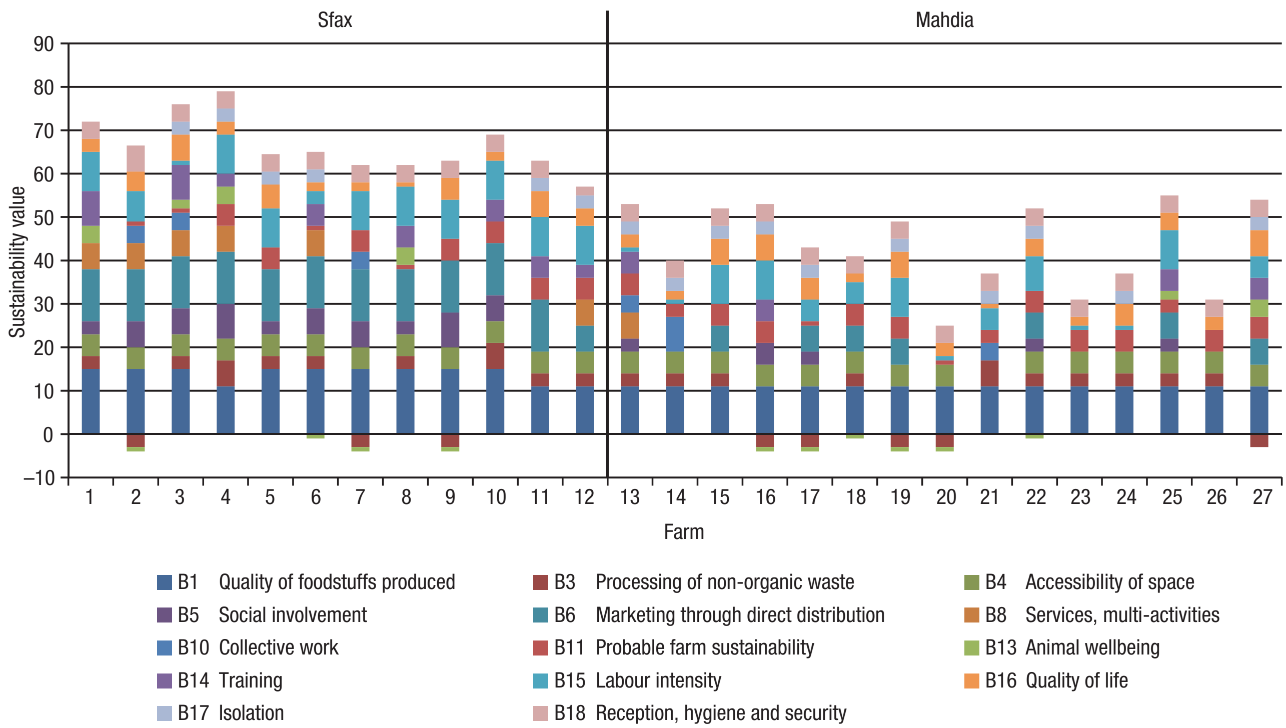

Figure 2. Indicators' results of the socio-territorial scale.

that has registered low scores essentially in the case of Mahdia farms. So, an improvement concerning these aspects is required.

The component of ethics and human development has registered some weaknesses that affect mainly animal wellbeing and training indicators. Getting better animal welfare is possible especially with the increasing of grazing area. Concerning training, many farmers, essentially those from Mahdia region, must participate more in training courses and collaborate more with scientific research services.

Economic sustainability scale

The economic sustainability scale consists of four components (viability, independence, transferability, and efficiency). This scale analyses "the economic sustainability" based not only on economic profitability but also on the relation of farmers with their economic environment and the sustainability of their activity (Zahm *et al.*, 2006).

Despite the structural differences between the studied farms, economic scores' means comparison between farms of the two regions indicates no significant differences between the two groups (Table 2). The average score is 48.8 for Sfax farms (minimum = 34, maximum = 69) and 47.3 for Mahdia farms (minimum = 37, maximum = 65). These results are explained by the compensation between indicators in this scale but essentially by the importance devoted to other criteria than economic profitability to express economic sustainability (Fig. 3).

In relation to the first component; indicators are economic viability and economic specialization rate:

— The first indicator is measured by the calculation of the importance of farmers' income compared with the SMIG (The guaranteed inter-professional minimum wage). Results show serious economic problems in the case of some farmers which present levels of incomes lower than the SMIG. Special attention should be dedicated to these farmers. On the other hand, the great majority of farmers present incomes higher than the SMIG and in many cases they have reached the maximum scores.

— The second indicator is based on the assumption that diversification in economic activity is economically more sustainable than specialization. So, higher scores are assigned to farms who present more diversification. In the case of olive growing farms; despite the importance of specialization in improving technical performances; this assumption is valid because of the irregularity of productions characterizing this activity. Results show low scores in relation to this indicator in the case of the great majority of farmers. Similar results were registered in the case of rain-fed conventional

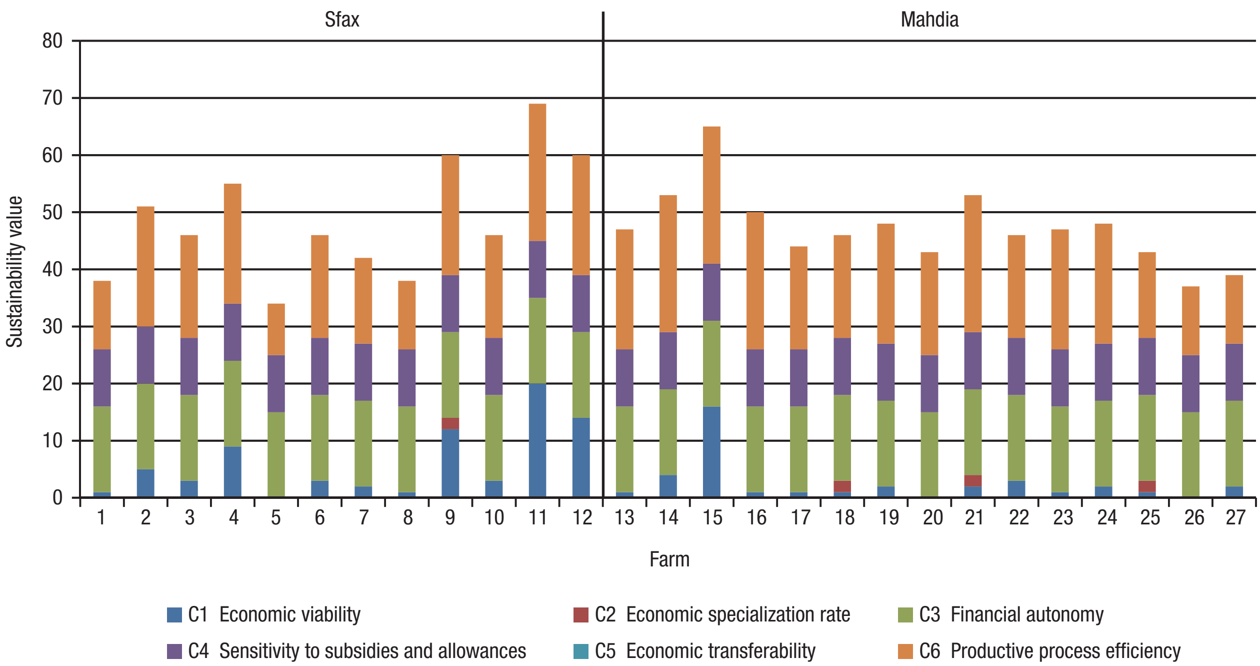

Figure 3. Indicators' results of the economic scale.

olive growing system in Sfax (Laajimi & Ben Nasr, 2009) but inverse results were registered in intensive olive growing system in Sfax (Belhaj, 2012) and in Karouan in the center of Tunisia (Bakir, 2011), These results, can lead us to attest that this indicator is mainly related to water supply. Subsequently, it may be improved only with associated activities that are not demanding in water such as associated perennial crops compatible perfectly with olive tree.

The independence component provides information on financial autonomy and sensitivity to subsidies and allowances. For these two indicators, farmers have the highest scores. In fact, they are in majority financially autonomous (they do not have large loans) and subsidies are too low to be significant in farmers' income.

The economic transferability component concerns the continuity of a company and its dependency on its associates. This indicator is calculated using the following equation:

$$\text{Transferability} = \\ = \text{Operating Capital / MWU of Non-Paid Employee}$$

being MWU a man-work unit.

Consequently, the capital must be distributed for more than one associate to ensure the company continuity. Scores corresponding to this indicator are minimal. This is due to the fact that in all studied cases the farm owner is usually one person. So, if the farmer leaves the agricultural activity or has economic difficulties, there is no other associate who can bear the situation.

The efficiency component measures the efficiency of input use. It is calculated using the following equation:

$$\text{Efficiency} = (\text{Outputs} - \text{Inputs}) / \text{Outputs}$$

Results show high scores registered in the great majority of farms. This reflects the independence of the studied farms and the good management of its own resources. These results go in accordance with those of Laajimi & Ben Nasr (2009), and Belhaj (2012). In fact, this efficiency of the production process is a logical result because of the traditional character of the olive tree culture in Tunisia and especially in the zones of Sfax and in the Sahel (central coastal zone of Tunisia).

Sustainability scales' correlations

Generally, it is stated that there is a form of opposition between agro-environmental sustainability and economic sustainability (Zahm *et al.*, 2007). Coefficients of correlation matrix between sustainability farm scales for each region (Table 3) indicate a statistically significant non-correlation between agro-environmental and economic sustainability in the case of Sfax farms (although the coefficient sign is negative). Some farms (4, 10, and 12) present high scores for both indicators. The same result was obtained in the case of Mahdia farms, with no statistically significant correlation between the two scales (although in this case the coefficient sign is positive). Farm 15 in Mahdia region presents the highest sustainability agro-environmental and economic scores (100; 65). These results indicate that it is possible to improve at the same time farms' agro-environmental and economic sustainability. The two factors are not always inversely proportional.

In the case of the two regions, a possible positive correlation could be detected between agro-environmental and socio-territorial scales, although the correlation coefficients are lower than 0.6. Weak negative or positive correlations are detected between socio-territorial and economic scales respectively for farms located in Sfax or in Mahdia regions. Farm 5 located in Sfax region, presents high sustainability levels for agro-environmental, socio-territorial and economic scales with respectively 95, 79 and 55 points. These

Table 3. Correlation matrix between sustainability farms scales for each region

	Sfax			Mahdia		
	Agro-ecological	Socio-territorial	Economic	Agro-ecological	Socio-territorial	Economic
Agro-ecological	1			1		
Socio-territorial	0.346	1		0.547**	1	
Economic	–0.280	–0.175	1	0.403	0.250	1

** statistically significant at 5% level.

results indicate that it is possible for farmers to move simultaneously toward more sustainability in its three dimensions.

Cluster analysis results

The results obtained in the previous sections indicate that many differences as well as some similarities exist when comparing farms from Sfax and Mahdia regions. In this section, we undertook farms segmentation on the basis of the three sustainability scales making abstraction of their region of origin.

The observation of the agglomeration coefficients and the dendrogram shows that the best alternative is to segment the sample into 2 groups. Based on this information and the centers of the clusters previously obtained, a non-hierarchical cluster analysis (k-means method) was applied. The first group is composed of 15 farms representing nearly the 56% of the sample. The second group is composed of the remaining 12 farms. Groups' characterization on the basis of scales sustainability shows that there is a statistically significant difference attached to the agro-environmental and socio-territorial scales. Indeed, the first group of farms is characterized by the highest score of sustainability. This group is composed of farms more agro-environmentally and socio-territorially sustainable. The second group of farms presents lower scores of sustainability related to these two scales. Regarding the economic sustainability scale, results show no significant difference between the two groups of farms. Average sustainability scores are 47.7 and 48.2 corresponding respectively to the first and the second groups. This indicates that the economic aspect is equally considered by the two groups of farms.

To ensure the validity of the obtained groups, we carried out external validation by means of external variables not used in the process of farms' segmentation. Farm localization was found to be statistically significant. In that order, 92% of farms located in Sfax belong to the first group and 73% of farms located in Mahdia belong to the second group. These results confirm those obtained in previous sections showing that the organic olive growing farms located in Sfax are agro-environmentally and socio-territorially more sustainable than those located in Mahdia. Concerning farmers' educational level, we can observe that farmers in the first group have a higher level of education with 80% of them reaching university level (66% are engineers). The majority of farmers belonging to the second group have an educational level not exceeding secondary school (66%). It is probable that educational level has a positive effect on sustainability achievement.

The comparison of sustainability components for the two identified organic olive growing groups is mapped in Fig. 4. The obtained results have very interesting policy implications. First, they were useful to delimitate the targeted groups which must be subsequently intervened with. Therefore, the area of intervention is limited and the efforts of decision makers can be better canalized. In this studied case the second group is the targeted group which needs more sustainability improvements. Second, the weaknesses registered in each scale and detailed in previous sections can lead decision makers to design an oriented strategic plan. Thus, based on the registered weaknesses, three strategic programs can be proposed:

i) A strategic program of training oriented to farmers to promote good agronomic and environmental practices. Such program can contribute to sensitize farmers to any practices that can improve fertilization and soil conservation, vegetable biodiversity and soil nitrogen balance, limit toxic gases emissions and improve animal wellbeing, etc.

ii) A strategic program oriented to good economic management focused on two issues: first on farms' management introducing practices that can contribute to more stability of economic farmers' incomes and

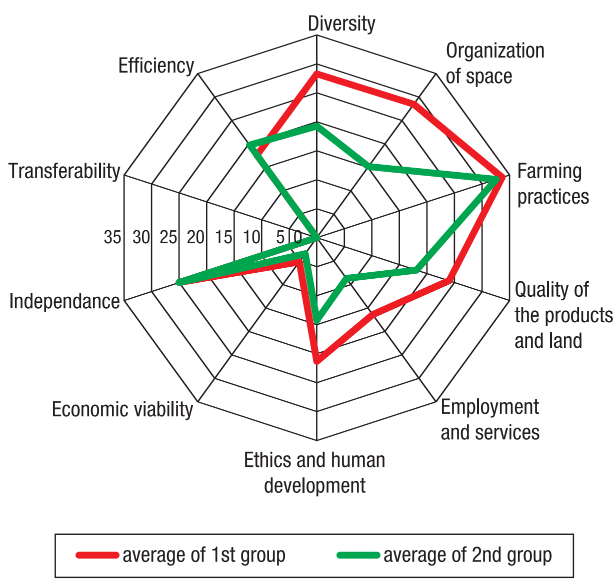

Figure 4. Sustainability components for the two farms groups.

second on sensitizing farmers to the existing mechanisms to be organised on cooperatives and on direct commercialization;

iii) A strategic social program based on a participative approach and aims at a higher social implication by: integrating farmers' associations, offering training practices and participation in research programs, etc.

This study claims that a sound measurement of sustainability is one of the most important issues in agricultural sustainability evaluation. In order to make such measurement possible, an adapted IDEA method was implemented which seems to be a fruitful method to assess sustainability at farm level. In fact, this method ensured the simplification of the complexity of information, the quantitative description of qualitative criteria and the communication of useful operational information to decision makers. Despite all its advantages, this method has its limitations, especially sustainability aggregation, which need deeper analyses in future researches.

Results derived from the measurement of the three scales of sustainability show different sustainability levels. These differences reflect variability in farmer's practices which can be improved. This implies the improvement of any practices as far as possible through oriented recommendations to targeted groups. In this way, the results confirmed the existence of two main farms' targeted groups. The first group is mainly composed of farms located in Sfax (92%), whereas the second group is composed essentially of farms from Mahdia region (73%). The first farms' group is more agro-environmentally and socio-territorially sustainable than the second farms' group. Weaknesses in sustainability are more accentuated in the second group which needs deeper adjustments in farmers' practices. Therefore, in the second group formed mainly by farmers located in the region of Mahdia, sustainability could be improved.

Moreover, the results demonstrated that in some case the three scales have reached simultaneously the highest scores. This represents a practical case where a compromise within the different dimensions of sustainability was attained. The examples of some successful farms (in Sfax and Mahdia regions) should be carefully analyzed with a view to being subsequently presented as models to follow.

Based on the outlined results, decision makers may design their strategies taking into account registered weaknesses as well as successful cases. In fact, it is possible to reach higher economic sustainability without damaging environment and social values. In this way, oriented strategies and correction measurements may be designed through incentive policies. These measurements and strategies must be adapted in accordance with farms' specificities. In this way, a strategic program can be implemented covering essentially three issues: good agronomic and environmental practices, good economic management mechanisms and a social program based on a participative approach that aims at a higher social implication of farmers.

Two possible extensions of the actual study are examined which remain for future research. The first one is of a practical character and aims to apply the same methodology to farms conducted in other olive production systems such as the conventional mode (rain-fed or irrigated). This may lead us to generalize the obtained results in order to design a sustainability measurement tool that can be implemented to farms in the olive sector which is a strategic sector in Tunisia and in the whole Mediterranean region. The second possible extension has a theoretical character and aims to study the question of overall sustainability aggregation through a Multi-criteria approach, such as Goal Programming and Analytic Hierarchy Process.

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