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Abstract

Demand for animal products is expected to increase due to human population growth, resulting in a need for increased production. At the same time, climate change poses a major threat to the viability and sustainability of livestock production systems. This study aimed to evaluate and compare the sustainability of dairy cattle farms belonging to three farming systems (rainfed, irrigated, and mixed) at the northeast zone of Tunisia using the IDEA method (version 3). Collected data of 102 farms were subjected to an analysis of variance using the GLM procedure of SAS software (version 9.4). Results showed that the socio-territorial scale was the limiting factor for all systems and that the irrigated system had the lowest scores of agro-ecological and socio-territorial scales, compared to the other ones, but it recorded the highest score for the economic scale. The best agro-ecological and socio-territorial scores characterized the mixed system. However, it had the lowest score on the economic scale. Finally, the rain-fed system was exhibited medium performances of the three scales. It was concluded a difference between the three farm systems, but there was no disassociation between the three sustainability dimensions; thus, improvements should proceed across all scales simultaneously.

Keywords: *Assessment, Cattle, Comparison, Dairy, Farming systems, IDEA, Sustainability.*

1. Introduction

In Tunisia, the livestock sector plays an important role in the national economy. Small farmers account for 80% of all farms and occupy 43% of the total agricultural products. This small-scale family farming had an important function in terms of food security, biodiversity, and resource conservation. It also contributes to the preservation of the income and the employment of the rural population, the land use planning, and the conservation of rural areas and local knowledge (Bessaoud *et al.*, 2017). However, small farms face many constraints and run the risk of disappearing under the effect of several factors, such as the significant fragmentation of land, the old age of farmers, and the disinterest of young people. This situation calls into question the sustainability of these small farms. The concept of sustainability dates

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to the beginning of the last century. The concept of sustainable development was defined in 1992 at the Rio summit as 'a development that meets the needs of the present without compromising the ability of future generations to meet their needs' (Del'Homme and Pradel, 2005). The application of this concept in the agricultural sector considers the economic, social, and environmental components by defining a comprehensive framework. Applied on farms, the assessment of sustainability requires the establishment of methods. Indeed, many methods based on indicators to evaluate the impact of agricultural practices and the sustainability of farms are implemented (Galan *et al.*, 2007).

The IDEA method (version 3) 'Indicateurs de Durabilité des Exploitations Agricoles or Farm Sustainability Indicators' (Zahm *et al.*, 2008), assesses farm sustainability in its three dimensions (agro-ecological, socio-territorial and economic). It is one of the four most used methods in the European Union (Schader *et al.*, 2014; De Olde *et al.*, 2016). It is conceived as a self-assessment grid for farmers, provides operational content for the notion of agricultural sustainability (Vilain *et al.*, 2008). In the Maghreb region, the IDEA method was used in various agronomic fields. For example, in Tunisia, M'Hamdi *et al.* (2009) and M'Hamdi *et al.* (2017) assessed bovine farms' sustainability. Laajimi and Ben Nasr (2009) used it to compare the sustainability of two farming systems: organic and conventional olive growing farms. Also, Elfkih *et al.* (2012) implemented it in the case of the Tunisian organic olive system. Also, Bouzaida and Doukali (2019) evaluated the sustainability of irrigation water for the farming system in southern Tunisia and Abdelhafidh *et al.* (2020) evaluated the sustainability of irrigated farms in the south-eastern. In this research, this tool was chosen due to the possibilities of quantifying sustainability indicators and objective analysis of the strengths and weaknesses of the production systems. The objective was to compare the sustainability of small bovine dairy farms from three breeding systems in the northeast of Tunisia, considering the three dimensions, agro-environmental, the socio-territorial, and economic one, through an adapted IDEA approach.

2. Materials and methods

2.1. *Study area and selected farms*

This study was carried out for 15 months, ranging from January 2018 to March 2019, in the northeast region of Tunisia. The governorate of Bizerte benefits from a humid climate allowing an average rainfall of over 600 mm and an average temperature of 19.9 °C. It has a very fertile soil that favors forages cropping and a cattle herd that represents 11% of the national herd. The region contributes up to 10% of the national milk production that makes it a major dairy area. However, the district has small farms where bovine production is the predominant activity. The survey was performed in 10 different areas from the Governorate (Aousja, Laazib, Bouhnache, Mrezigue, Teskreya, Bach Hamba, Utique, Bejou, Ras Jbal, and Garia). Over 90% of the selected farms maintained herds not exceeding 8 present cows. Based on water factors, these farms are associated with three farming systems: rain-fed, irrigated, and mixed systems. The choice of the study area was explained by the diversity of crops and the abundance of dairy cattle breeding. The study involved 102 dairy cattle farms selected considering the accessibility, responsiveness, and cooperative spirit to recover the maximum amount of information.

The sample size was selected based on the following equation reported by Cochran (1977) under a 95% confidence interval and precision of 10%.

$$n = N/(1 + (e^2)$$

Where: n is the sample size, N is the population size, and e is the level of precision.

2.2. *Data collection and survey conduct*

A survey including 122 questions inspired by the IDEA grid was developed to collect information to assess sustainability. It covered general information about the farm, livestock management ways, biodiversity aspects, land management and agricultural practices, farmer's relationship with his entourage and quality of life, and economical aspects. Some modifications guided the adaptation of the IDEA tools

Table 1 - Adaptations made to IDEA indicators.

Indicators	*Adaptation*
A2-Diversity of perennial crops A5-Crop rotation A6-Size of plots A7-Organic matter management A8-Ecological regulation zone A11-Fodder area management A12-Fertilization A13-Liquid effluents management A18-Energy dependence	- Reformulation of determination modalities - Score changed - Thresholds values adjusted
B1-Quality approach B3- Management of non-organic waste B4-Accessibility of space B9-Employment contribution B10-Collective work B12-Contribution to the world food balance B15-Labor intensity	
C1-Economic viability C2-Economic specialization rate C5-Economic transferability	- Item linked to income potential added

to the local context. These changes concerned nineteen of the calculated indicators by restructuring the definitions and the determination modalities. It relates to the clarifications or modifications made (acceptance, modification, or rejection of the variables and the weighting of variables or indicators) before the calculation of the indicators (Table 1). Then, the collected data was translated via calculation to scores corresponding to different indicators, components, and scales.

2.3. *The Sustainability Assessment Model: IDEA*

We decided to use version 3 as although the theoretical framework of IDEA version 4 (Zahm *et al.*, 2019) was innovative in its approach to sustainability properties and its operational calculation tools; version 4 was not fully available during our research. The IDEA method (version 3) was structured around 17 objectives grouped to form three sustainability scales: agro-ecological, socio-territorial, and economic scale (Vilain *et al.*, 2008; Zahm *et al.*, 2008). Indeed, the objectives of the agro-ecological scale refer to the agronomic principles of integrated agriculture. They must allow good economic efficiency at the lowest possible ecological cost. Those of the socio-territorial sustainability scale refers more to ethics and human development that are essential characteristics of sustainable agricultural systems. Finally, the objectives of the economic sustainability scale specify essential notions related to the entrepreneurial function of the farm (Zahm *et al.*, 2008). Each of these three scales is subdivided into three or four components (making 10 components), which in turn were made up of 42 indicators. A single objective can contribute to the improvement of several components of sustainability. Indicators are intended to translate these objectives into measurable criteria. For this reason, a matrix was constructed with 42 indicators that provide information on the 17 objectives (Vilain *et al.*, 2008). The IDEA method allowed a diagnosis of farm sustainability based on a direct farm survey. Indeed, Zahm *et al.* (2008) state that there is not just one farm sustainability model and, therefore, the indicators must be adapted to local farming before using the IDEA method.

2.4. *Calculation and statistical analyses*

The obtained information was entered into an Excel table to form the basic file, on which the calculation of the indicators and scores were performed. A linear general model including fixed effects was used to investigate the effect of all factors included in the model on the sustainability of farms. Parameters were analysed using PROC GLM using SAS 9.4 (SAS Institute Inc., Cary, NC, USA, 2012). The following model was used:

$$Y_{ijklm} = \mu + P_i + Year_j + FS_k + R_l + e_{ijklm}$$

Where: Y_{ijklm} = observation sustainability; μ = mean; P_i = fixed effect of the period (i = 1–4); $Year_j$ = fixed effect of the year (j = 1, 2); FS_k = fixed effect of farming systems (k = 1, 2, 3;); R_l = fixed effect of the region (l = 1–10); and e_{ijklm} = random error.

Results were expressed as means. Results with an associated probability less than or equal to 0.05 were considered significant.

The factor levels were compared two by two using the SNK test.

3. Results and discussion

3.1. *Characterization of the main systems in the study area*

Based on water factors, we identified three farming systems that are described in Table 2. Thus, 30% belong to the rain-fed system, 33%

Table 2 - Farming Systems characteristics.

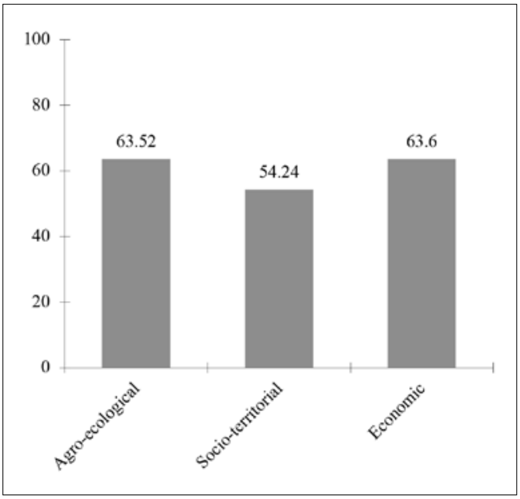
	Rain-fed System		*Mixed System*		*Irrigated System*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Farm surface area (ha)	13.5	13.9	8.09	7.7	4.02	5.01
Used agricultural area (ha)	12.9	13.4	8.01	7.7	3.56	4.09
Irrigated area (%)	-	-	33.6	16.2	100	0
Cereal area (%)	17	24.1	7.05	16.6	-	-
Hay and green forage area (%)	81	24.5	74.2	22.3	68.4	29
Vegetable cropping area (%)	-	-	15.9	17.7	28.4	28.3
Cattle, LU	13.9	9.9	9.6	6.1	11.02	6.5
Sheep, LU	26.1	37.2	10.2	18.3	8.1	13.2
Goat, LU	2.5	5.13	0.3	1.03	0.6	1.37
Present cow (head)	6.7	4.3	5.4	3.03	6.4	3.2
Holstein, LU	7.2	7.3	5.4	4.13	7.07	4.2
Swiss, LU	1.7	2.8	1.85	2.4	1.1	1.6
Tarentaise, LU	0.42	1.65	0.1	0.42	-	-
MPPC (l/year)	3084	938	3360	1036	4146	864
MPLC (l/year)	4105	1068	4324	987	5005	866
Concentrate, %DM	37.5	11.8	41.8	8.9	47.2	10.8
Dry Forage, %DM	45.9	15.7	37.3	13.4	28.9	11.4
Green Forage, %DM	16.1	10.1	20.7	8.9	23.9	6.9
Silage, %DM	0.4	2.01	0.2	1.33	-	-
Frequency of farms' distribution, %	30		37		33	

adopt irrigation and 37% were in the mixed system where they alternate between rainwater and irrigation according to their needs.

The first system relies on rainfall. The average size of these farms is about 13.5 ha, reserved for hay and green forages about 81%, and cereals about 17%. This system integrated bovine and sheep with the respective livestock units of about 13.9 and 26.1 and counted about 7 present cows. The average dairy cow's diet throughout the year was composed of 38% of concentrate, 46% of dry forage, and about 16% of green fodder, based on DM. The mixed system is represented by the medium average size of farms, which was about 8 ha. Indeed, in this case, about 34% of the total area was irrigated, while 66% is dry farmed. Farmers of this system cultivate in the largest proportion of their land hay and green forages (74%), but also cereal and vegetable cropping (about 7 and 16% respectively). The mixed system gathers the medium headcount of sheep (10 LU) and the lowest for bovine (9.6 LU) flock compared to the other systems and counted about 5.4 present cows. Diet composition was based on 41% of concentrate, 37% of dry forage, and 21% of green forage with about 0.2% of silage, based on DM. The last system has 100% irrigated area and included 33% of farms; mostly small (4 ha on average). Farmers cultivated hay and green forage in 68% of the area and vegetable cropping in 28%. The flock is composed of 11 LU bovine with 6.4 present cows and 8.1 LU sheep, which was among the smallest of the rain-fed and mixed systems (26.1 and 10.2 LU respectively). Dairy cows were fed over the year by 47% of concentrate, 29% of dry forage, and 24% of green forage based on DM.

This analysis revealed that Bizerte had diversified farming systems. The mixed system was the most adapted for the study area due to climatic, economic, social, and environmental factors. Indeed, it was the dominant system with the highest and the most diversified livestock integration with fodder and cereal crops. Therefore, the mixed system reminds us of the integrated (or semi-integrated) system that was practised mainly in small and medium-sized farms in the North. It was a farming system integrated into an agricultural area, the forage production of which ensures exclusively or partially the feeding of the livestock. This could explain the rent of agricultural land by 42% of farmers and their eventual migration from other systems to the mixed one. These changes have primarily entailed a transition from a predominantly extensive system to more complex farming systems that integrate livestock with forage production.

Figure 1 - Global sustainability score of the studied sample

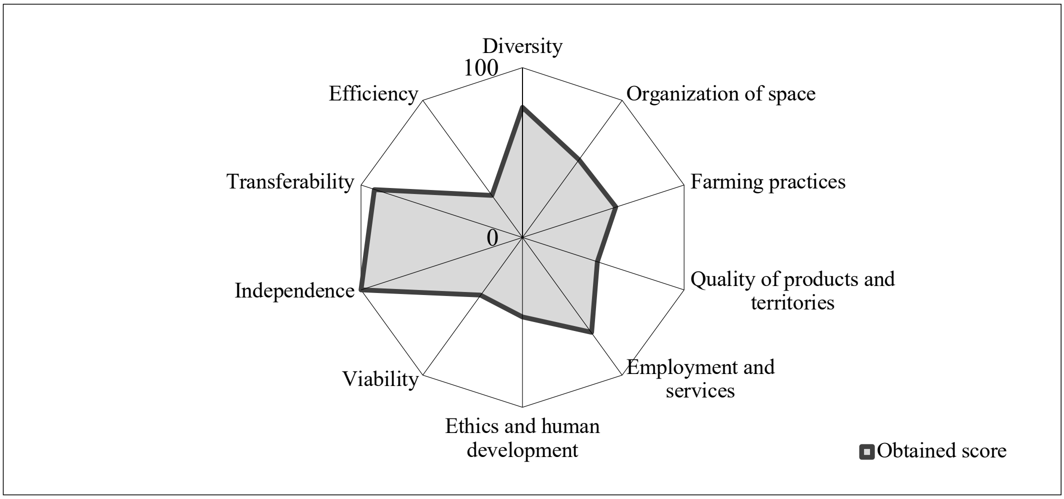


3.2. *Overall Sustainability of the Studied Farms*

Figure 1 illustrates the results of the sustainability scores obtained from the investigated farms. Global sustainability score, which corresponds to the lowest value, was the socio-territorial one with a value of 54.24 ± 5.63.

However, the agro-ecological and economic scales present similar scores of 63/100. According to the graphical representation of these sustainability components (Figure 2), we noticed that the components 'quality of products and territories, ethics' and 'human development', 'viability' and 'efficiency' had the lowest values of 46, 47, 42 and 31 out of 100, respectively. The components; diversity, employment, and services, independence, and transferability recorded the highest scores, respectively 77; 69; 100 and 92 out of 100.

Figure 2 - Graphical representation of the components of the studied sample.

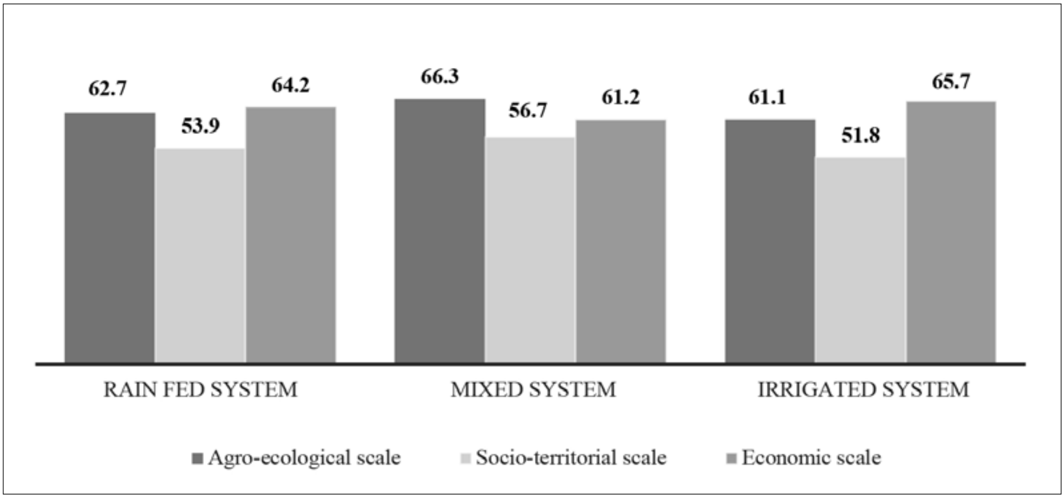


3.3. *IDEA Global Sustainability Scores Relative to the Different Systems*

The results of the sustainability scores obtained from the three farming systems were presented in Figure 3.

Results showed that the final durability score, which was the limiting factor, corresponds to the socio-territorial scale among the three systems. The lowest score was attributed to the irrigated system (51.8) comparatively to the rain-fed and the mixed systems (53.9 and 56.7 points). The agro-ecological scale was ranging between 61 and 66 points and the highest score was recorded by the mixed system (66.3 points). The economic score ranged between 61 and 65 points with a high value recorded by the irrigated system (65.7). Our results agreed with those of Benidir *et al.* (2013) and Araba and Boughalmi (2016) who found that the socio-territorial scale is the limiting factor in sheep farming (36 and 35 points); Yakhlef *et al.* (2008), M'Hamdi *et al.* (2009) and Bir *et al.* (2019) recorded the same results in dairy cattle (23, 53 and 52 points). However, Srour *et al.* (2009) noted that the agro-ecological was the lowest (39).

Figure 3 - Global sustainability score of farming systems.



The mean variation on the socio-territorial scale was homogeneous (a deviation of 6 points). This could be explained by the fact that families in the different systems are part of the same farming community, share the same territory, and have access to the same infrastructure and services. The results achieved for the agro-ecological scale were slightly variable among the systems (a deviation of 5 points), reflecting a certain homogeneity of agricultural practices. These farms were mainly distinguished by the diversity of annual or temporary crops, water resource management, and energy dependence. The economic scale also obtained homogeneous results (a deviation of 5 points), reflecting the strong economic independence of all the farmers within the three systems. However, there were many differences between systems that reflected their characteristics.

3.4. *Agro-ecological scale*

Results of the agro-ecological scale were presented in Table 3 and Figure 4. Farms belonging to the rain-fed and irrigated systems presented the lowest performances (61.1 and 62.7). The highest score was recorded for the mixed system (66.3 points). These variations were not statistically significant. Our results were following those of Yakhlef *et al.* (2008) and M'Hamdi *et al.* (2009) who found 67.6 and 60 points. However, Bir *et al.* (2019) reported a lower agro-ecological score of about 56. These results were attributed to the variable scores of components and indicators used to calculate this scale within each system.

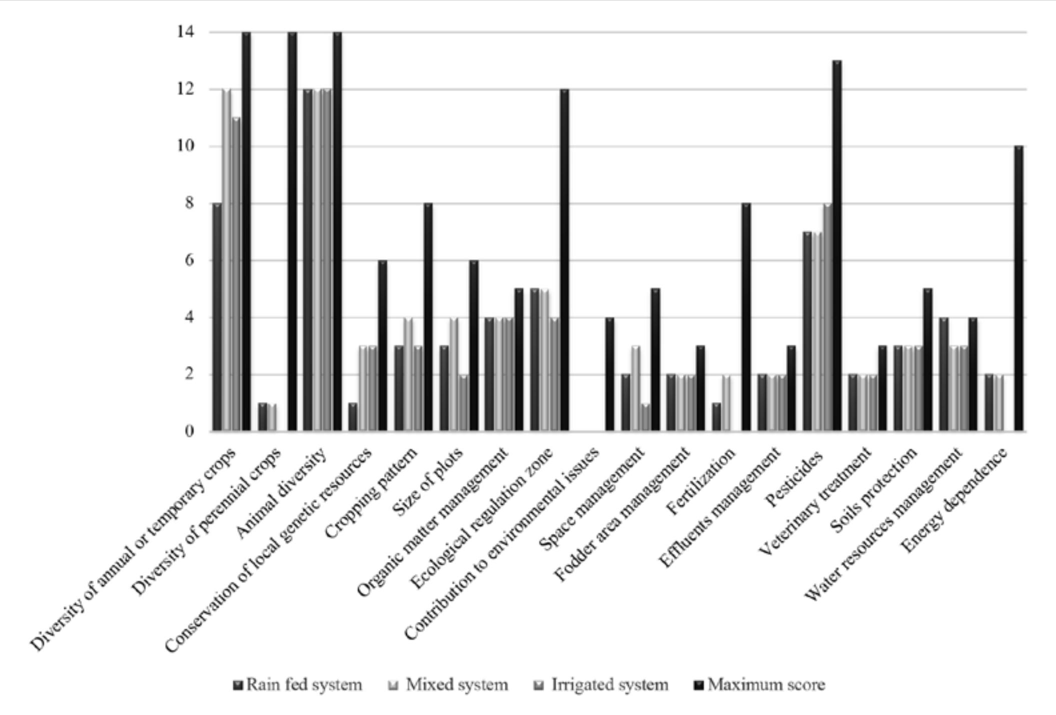
In the diversity component, the values were between 70 and 80% of the maximum theoretical score. These high scores were enhanced by

Table 3 - Scores of indicators and components of agro-ecological scale.

Agro-ecological scale					
	Rain-Fed	*Mixed*	*Irrigated*	*p*	*SEM*
A1-Diversity of annual or temporary crops	9 b	11.8 a	11.4 a	<0.01	0.3
A2-Diversity of perennial crops	0.6	0.9	0.3	NS	0.15
A3-Animal diversity	12	11.2	11.8	NS	0.31
A4-Conservation of local genetic resources	1.5 b	2.5 a	3.2 a	<0.01	0.22
Diversity	*23*	*26*	*26.5*	*NS*	*0.63*
A5-Cropping pattern	3.1	3.6	2.6	NS	0.26
A6-Size of plots	2.9 ab	3.8 a	2.3 b	<0.01	0.22
A7-Organic matter management	4.1	4.6	4.4	NS	0.13
A8-Ecological regulation zone	4.1 b	5.3 a	4.1 b	<.0001	0.18
A9- Contribution to environmental issues	0	0	0	NS	0
A10-Space management	2.4 a	2.6 a	1.3 b	<0.05	0.21
A11-Fodder area management	1.7	1.7	1.8	NS	0.07
Organization of space	*17.6 b*	*21.4 a*	*16.4 b*	*<0.01*	*0.58*
A12-Fertilization	1.7 a	1.2 ab	0.3 b	<0.05	0.22
A13-Effluents management	2.1	1.8	1.9	NS	0.09
A14-Pesticides	7.7	6.2	7.5	NS	0.28
A15-Veterinary treatment	2.2	2.3	2.4	NS	0.09
A16-Soils protection	2.5	2.6	2.7	NS	0.18
A17-Water resources management	4 a	3.2 b	3 b	<0.01	0.17
A18-Energy dependence	1.9 a	1.6 a	0.1 b	<0.01	0.21
Farming practices	*22.2 a*	*18.9 b*	*18.2 b*	*<0.01*	*0.52*
Total score	62.7	66.3	61.1	NS	1.09

a, b, c: Different letters on the same line indicate significant differences. SEM: Standar error of the mean, P: probability.

Figure 4 - Indicators of agro-ecological scale.



the diversity of animal diversity (12, 11.2, and 11.8 points) which reflects the existence of several species with different breeds in the same herd, and by a high plant diversity of annual or temporary crops with different cultivated varieties. However, farms of the irrigated and mixed systems presented statistically (p <0.01) higher average score of the 'Diversity of yearly or temporary crops' indicators (11.6 equivalents to 83% of the maximum score) than the rain-fed farms, 64%. This was explained by the variation of cultivation across systems. Indeed, rain-fed system farmers were concerned about cereals (17% of the UAA) and forage crops (81%). Mixed system farmers represented the highest diversity of cereals and vegetable crops, besides forages (an average of 7, 16, and 74%). While farms in the irrigated system produced forages in 68% of the UAA and 28% of the vegetable crops. Concerning the 'conservation of local genetic resources', the comparison of these systems indicated the existence of significant differences (p <0.01). Farms belonging to irrigate and mixed systems obtained more elevated scores (53 and 42%) than the rain-fed (25%). This was related, also, to the cultivation of vegetables with varieties specific to the region. Nevertheless, there is a lack of perennial crops at the three systems level (mean= 4%) which affects the total score of the component. This result was considerably lower than that of M'Hamdi *et al.* (2017) in the same region (20%). This may be due to the limited size of the farmland of these smallholders, who prefer to foster annual crops.

There was a high and significant difference (p <0.01) between the systems regarding the 'organization of space'. The mixed system recorded a higher score (21.4 points) of about 21% comparatively to the two other systems which are not distinct statistically (a mean score of 17 points). This is due to some variations in the group of indicators used to measure this component. Farms of mixed systems had the highest (p <0.01) score of plots size (63%), 82.5% of farmers have no spatial unit of the same crop that exceeds 30% of UAA, followed by farms of the rain-fed and mixed systems (48 and 38%). Bir *et al.* (2019) observe similar results. The space management score was the greatest ($p < 0.05$) for the rain-fed and mixed systems (2.5 points) compared to the irrigated system (1.3 points). This indicator expressed by livestock units/areas designated for cattle feed is explained by the values obtained in the order of 1.07, 1.19, and 3.09 LU/ha respectively. Indeed, the irrigated system had the smallest land area (3.56 ha) with a relatively high cattle load (11.02 LU). Contrarily, the farms of rain-fed and mixed systems counted an average of 13.9 LU in 12.9 had and 9.6 LU in 8.01 ha respectively. The improvement of this indicator must reduce the massive importation of animal feed. Our results are higher than the results of Yakhlef *et al.* (2008) and M'Hamdi *et al.* (2017). A highly significant difference ($P < 0.0001$) was observed between the systems concerning the 'ecological regulation zone'. The highest score of the mixed system (5.3 points) could be attributed to the ecological zones that should surround the farms such as lakes, rivers and dams or also to the absence of mechanization on certain farms. However, there is no difference between systems in 'organic matter management' that recorded the highest score for all systems (an average of 87% of the theoretical maximum), explaining that all farmers use their produced manure to fertilize their lands. Second, the majority of farmers consider the fodder area management's indicator. They ensure efficient forage management by alternating between pasture and mowing. Zero penalizes all three systems or low scores attributed to 'contributions to environmental issues' and 'cropping pattern' indicators. The inexistence of specifications engaging farmers to respect and protect the natural heritage explained the null score registered by all the farms. Whereas the low score achieved by the 'cropping pattern' indicator (average of 39%) is linked to the large surface area allotted by the majority of farmers in the main harvest with the total surface area.

The 'farming practices' component recorded high scores within systems. The rain-fed system registered the best performances ($p < 0.01$) compared to other systems (65% and an average of 55% respectively). Due to the high scores of 'effluent management', 'pesticides', 'veterinary treatment' and 'soil protection', these indicators (64, 55, 76, and 52%) were similar between systems. These performances were explained by the good practices applied on the farms. Indeed, all farmers manage their effluent by its spreading on the surfaces of the exploitation. It was noticed, also, that the use of pesticides was trrivial with a polluting pressure not exceeding the value of 4 ($2 < pp < 4$), and the veterinary treatment is limited. As well, the soil protection was acceptable due to the non-inversion tillage but more attention must be given to best tillage practices such as the implementation of anti-erosive mechanisms. 'Water resource management' obtained high scores that are significantly different between systems ($p < 0.01$). The amount of irrigation depends on surfaces, the crop type, and the technical resources available to farmers. Indeed, the rain-fed system obtained the highest score (100%) followed by the mixed and irrigated systems (78%) because of the rational use of irrigation and the right techniques. However, the component has registered weaknesses that concern fertilization and energy dependence. The farms of the region had an enormous use of fertilizers. The irrigated system recorded the lowest score ($p < 0.01$) followed by the mixed and rain-fed system (4, 15, and 21%). Thus, farmers used more fertilizer with vegetables than fodder crops. The energy dependence was significantly the lowest ($p < 0.01$) in the farms belonging to the irrigated system (1%). This is explained by the high use of concentrate feed and nitrogen.

3.5. *Socio-territorial scale*

The results of the socio-territorial scale were presented in Table 4 and Figure 5. Socio-territorial sustainability was the weak point of these systems with an average of 54% of the theoretical maximum. Farms belonging to the irrigated and rain-fed systems presented the lowest performances (51.8 and 53.9). The highest score was recorded for the mixed system (56.7 points). These variations are not statistically significant. Our results are following those of M'Hamdi *et al.* (2009) for dairy cattle (52.5%). However, they are much higher than those reported by Yakhlef *et al.* (2008), Ghozlane *et al.* (2006), Bekhouche-Guendouz (2011), and

Table 4 - Scores of indicators and components of socio-territorial scale.

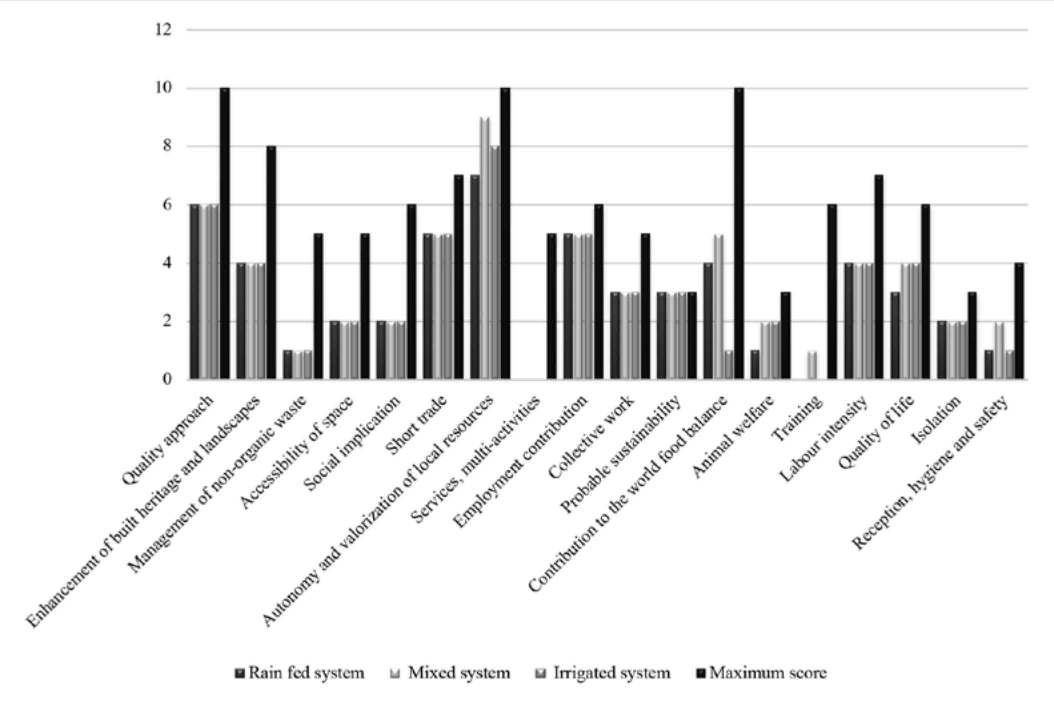
Socio-territorial scale					
	Rain-Fed	*Mixed*	*Irrigated*	*p*	*SEM*
B1- Quality approach	6	6	6	NS	0
B2- Enhancement of built heritage and landscapes	4.03	4.3	4.2	NS	0.15
B3- Management of non-organic waste	0.7	1.1	1.3	NS	0.13
B4- Accessibility of space	2.3	2.4	1.6	NS	0.13
B5- Social implication	2.1	1.8	1.9	NS	0.11
Quality of products and territories	*15.1*	*15.6*	*15.02*	*NS*	*0.30*
B6- Short trade	4.7 a	4.1 b	4.4 ab	<0.01	0.07
B7- Autonomy and valorization of local resources	7.8	8.4	7.9	NS	0.16
B8- Services, multi-activities	0	0	0.03	NS	0.01
B9- Employment contribution	4.6	5.2	4.7	NS	0.22
B10- Collective work	2.4 b	3.1 a	2.9 a	<0.05	0.09
B11- Probable sustainability	2.6	2.7	2.6	NS	0.08
Employment and services	*22.1*	*23.4*	*22.6*	*NS*	*0.36*
B12- Contribution to the world food balance	5 a	4 a	0.8 b	<0.01	0.43
B13- Animal welfare	1.4	1.8	1.6	NS	0.07
B14- Training	0.1	0.3	0.2	NS	0.09
B15- Labour intensity	4	4.3	3.9	NS	0.15
B16- Quality of life	3.4	3.6	3.6	NS	0.07
B17- Isolation	1.4 b	2 a	2.05 a	<.0001	0.05
B18- Reception, hygiene and safety	1.3	1.6	1.4	NS	0.11
Ethics and human development	*16.5 a*	*17.6 a*	*13.5 b*	*<0.01*	*0.55*
Total score	53.9	56.7	51.8	NS	0.85

a, b, c: Different letters on the same line indicate significant dufferences. SEM: Standar error of the mean, P: probability.

Ikhlef *et al.* (2017) in Algeria (23, 36, 35, and 38% respectively).

Socio-territorial sustainability is penalized for all systems by the weaknesses registered by the components 'quality of products and territories' (46%) and 'ethics and human development' (45%). The 'employment and services' component, on the other hand, had a high score (69%). Indeed, farmers of the region adopted irresponsible practices; particularly the proceeding of non-organic wastes (an average score of 21% for all systems) especially in the rain-fed system (14%). These low scores are due to the landfilling or the burning of non-organic wastes causing toxic gas emissions. Bir *et al.* (2019) registered better results of around 46%. Also, the farmers have limited involvement in social activities (32% of all systems combined) such as the integration in associations and social structures and participation in regional events. Effectively, such activities will allow farmers to express and defend their values, so they will guarantee social integration in the territory and dialogue with representatives of the society. This can also improve the services and multi-activity indicator (0.02% average score of all systems) by the insertion of new approaches and strategies for rural development such as agrotourism. These activities can ameliorate the social and economic life of the region. Our results are very low compared to those of Bouzaida and Doukali (2019). They

Figure 5 - Indicators of socio-territorial scale.



found that farmers of southern Tunisia were more implicated in social life (83%) and they were slightly concerned by subsidiary activities including agrotourism (40%). Moreover, there was a complete absence of training programs adapted to the farmers (an average score of 3%). Many other similar weaknesses were registered for all systems that are mainly related to 'reception, hygiene, and safety' (36%), 'accessibility of space' (40%), 'enhancement of built heritage and landscapes' (52%), 'animal welfare' (53%), 'labour intensity' (58%) and 'quality of life' (59%) indicators that should be ameliorated. These flaws observed at the socio-territorial scale recall situations previously observed in the southern Mediterranean as described by Benidir *et al.* (2013) in Algeria and M'Hamdi *et al.* (2009) in Tunisia. Some significant differences were observed between systems. Farmers assure a good valorization of the products by short trade with a considerable difference between the three systems (p <0.01). Those of the rain-fed system ensure the best sale (67% of maximum theoretical score) in short-circuits followed by those of the irrigated (63%) and mixed (58%) systems. This is could be explained by the type of sold products. These results are higher than those observed by Yakhlef *et al.* (2008) and M'Hamdi *et al.* (2009) who recorded very low scores (4 and 0% respectively). The indicator 'collective work' registered the highest (p <0.05) score for both mixed and irrigated systems (an average of 60%) compared to the rain-fed one (48%). This could be explained by the high involvement of the workforce in the vegetable crops that characterize the first two systems. The contribution to world food balance was significantly higher (P <0.01) under the rain-fed and mixed systems (45%) compared to the irrigated one (8%). This is due to the large lands of the first systems that provide relatively sufficient forages to the herd. However, farmers of the irrigated system resort to the purchase of large quantities of concentrated feed. Our results are following those of Benidir *et al.* (2013) but they were lower than those of Yakhlef *et al.* (2008) who reported 42 and 54% respectively. Also, farmers of the rain-fed system feel more isolated (47%, P <0.0001) due to the geographical dispersion of the dry land plots from the rural grouping. These scores are higher than those of Yakhlef *et al.* (2008) and Benidir *et al.* (2013) who reported respectively 38 and 39% for farmers in Algeria and M'Hamdi *et al.* (2017) who recorded 37% in Tunisia. However, M'Hamdi *et al.* (2009) and Bouzaida and Doukali (2019) found higher results for isolation indicators (92 and 100% respectively). Despite these differences and the low scores obtained by the systems, some high scores and similarities were recorded. These systems had an acceptable 'quality approach' (60%) which corresponds to the quality of products essentially milk. This is related to the control processes at the farms according to the Tunisian standards of milk acceptance. Concerning the 'employment and services' component, high scores were recorded at the level of the indicators 'autonomy and valorization of local resources', 'employment contribution' s and 'probable sustainability' (an average score of 80, 81, and 87% respectively).

3.6. *Economic Scale*

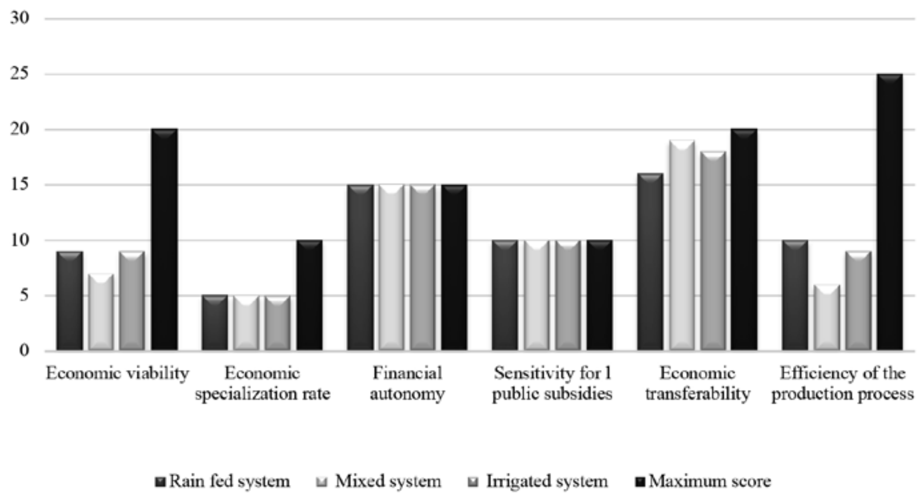
Table 5 and Figure 6 showed the results of the economic scale. Despite the structural differences between the studied farms, the comparison of economic scores between the three systems indicated no significant differences. Irrigated system performed better (65.7) than the rain-fed one (64.2), and the mixed system registered the lowest score (61.2). These results were higher than scores found by M'Hamdi *et al.* (2009) and Benidir *et al.* (2013) who mentioned total scores of 57.5 and 52.9 for dairy farms in Tunisia and Algeria respectively. This scale considers 'the economic sustainability' based not only on economic profitability but also on the connection of farmers with their economic environment and the sustainability of their activities (Zahm *et al.*, 2008).

The results indicated that some similarities exist when comparing farms from different systems. Indeed, the best performances were in the assets of the 'independence' and 'transferability' components (an average of 100 and 91% of maximum theoretical scores) for all farms. The 'independence' component provides information on financial autonomy and sensitivity to subsidies and aids. Therefore, these indicators were at their maximum value. This result was following those of Bouzaida and Doukali (2019) and Abdelhafidh *et al.* (2020) in Tunisia. This could be explained by the absence of recourse to credit to finance investments. Thus, it could be concluded that these farms depend on their financial potential. Baccar *et al.* (2018) affirmed that owners of small farms could use their livestock as both a savings account and productive

Table 5 - Scores of indicators and components of economic scale.

Economic scale					
	Rain-Fed	*Mixed*	*Irrigated*	*p*	*SEM*
C1- Economic viability	7.6	6.2	9.2	NS	0.69
C2- Economic specialization rate	5.4	5.1	4.5	NS	0.18
Viability	*13*	*11.2*	*13.8*	*NS*	*0.75*
C3- Financial autonomy	15	15	15	NS	0
C4- Sensitivity for l public subsidies	10	10	10	NS	0
Independence	*25*	*25*	*25*	*NS*	*0*
C5- Economic transferability	17.6	19	18.2	NS	0.39
Transferability	*17.6*	*19*	*18.2*	*NS*	*0.39*
C6- Efficiency of the production process	8.6	6	8.7	NS	0.48
Efficiency	*8.6*	*6*	*8.7*	*NS*	*0.48*
Total score	64.2	61.2	65.7	NS	1.06

Figure 6 - Indicators of economic scale.



capital. This flexibility, combined with the absence of loans, makes these farms more economically independent. The 'transferability' analyses the long-term ability to carry on from one generation to the next (Zahm *et al.*, 2008). In our study, the three systems recorded high scores ranging from 17.6 to 19 points contrary to M'Hamdi *et al.* (2009) and M'Hamdi *et al.* (2017) who reported 11.95 and 10.7 points respectively. Bir *et al.* (2019) mentioned that the importance of capital harms the transferability of the farms. However, the 'viability' and 'efficiency' components registered the lowest scores (averages of 42 and 31% respectively). The 'viability' was divided into two indicators, 'economic viability' and 'economic specialization' rates. Thereby, farmers from irrigated systems recorded the highest viability score of 46%. These farms had the highest economic viability (48%) but the lowest level of specialization (45%) comparatively to the rain-fed (38 and 54%) and mixed (31 and 51%) systems. Thus, the efficiency component followed the same variation as the viability between the systems. These highest scores of the irrigated and rain-fed systems reflect the highest level of economic viability due to the amount of income generated. Indeed, farms of the irrigated system are specialized in vegetable cropping and those of the rain-fed were specialized in cereal cropping, beside the main activities of livestock and forages. These farmers of both systems managed well their charges even with small or large farmland, which generates the best income. This resulted in the highest efficiency of the productive process, 35 and 34% respectively to the irrigated and rain-fed systems. However, the farms of the mixed system diversified production activities (cereal, vegetable, forages, and livestock) which increased the importance of inputs and the rise in the prices of concentrates, fertilizers, phytosanitary products, energy, and workforce resulting in low efficiency of the productive process (24%), which automatically affects economic viability (37%). Baccar *et al.* (2018) reported similar results of 20 and 40% to the viability and efficiency components. These results correspond to small and large farms combining rain-fed crops and livestock and farms maintaining production diversity between rain-fed crops, livestock, and vegetables. They mentioned that specialization seems overall more sustainable than diversification since specialized farms scored better. In contrast, Elfkih *et al.* (2012) reported that diversification in economic activity is economically more sustainable than specialization.

4. Conclusion

Sustainability is a key concept for ensuring resilience and attenuating the effects of major changes such as climate change, land use and socio-economic evolution. Although the three systems represented different forms of farm organization, overall, they are not very different in terms of sustainability performance. It was concluded that the limiting factor was the socio-territorial scale, along with the three systems, due to the weaknesses of the 'quality of the products' and the 'territories and ethics and human development' components. However, these systems had obviously higher levels for the other dimensions. The mixed system had the highest agro-ecological and socio-territorial sustainability, the irrigated one registered the best economic performances, and the rain-fed presented average scores for the three scales. These diversities reflected the variation in practices, management of resources, and the adaptation of farmers to their specific system. The improvements of sustainability should proceed across all three scales simultaneously. This represents a challenge for the sustainability of small dairy farms and would require government involvement, through the creation of cooperatives for example, to enhance professional links, create and encourage local exchanges, flows and collective projects in order to improve the socio-territorial sustainability of farms. Besides, policymakers should work also on the weaknesses of agro-ecological and economic scales that seemed to be associated with the organization of space, farming practices and the viability and efficiency of the exploitations. Thus, the implementation of awareness and training programs for farmers, in production ways and suitable management, adapted to the specific systems is highly recommended. Despite some limitations of the study, the sustainability assessment of different systems provides a globally representative image of small Tunisian agriculture in the northeast region of the country.

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