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Sustainability analysis of dairy cattle farms and their susceptibility to climatic hazards in the semi-arid area of Setif (Algeria)

Abdenour Bir[1*], Mohamed Benidir[2], Sarah Ikhlef[3]

[1]*Department of Agronomy, Faculty of Nature and Life Sciences, Ferhat ABBAS University of Setif, 19000 Sétif, Algeria*
[2]*Algeria's National Institute for Agricultural Research (INRAA), 19000 Sétif, Alegria*
[3]*Higher National School of Agronomy, El Harrach, 16200 Alger, Algeria*
[*]*Corresponding author:* biranour@yahoo.fr

Abstract

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In this study, the method of farm sustainability indicators (IDEA) was used to assess the sustainability of dairy cattle farms and their susceptibility to climatic hazards in three agro-bioclimatic stages of the semi-arid region of Setif (Algeria). Overall, the results show a high level of agro-ecological sustainability (56.24 points out of 100), acceptable for economic sustainability (54.36 points out of 100) and average for socio-territorial sustainability (52.31 points out of 100). The best sustainability performances were recorded at the farms of the North agro-bioclimatic stage, with 60.42 points out of 100 for the agro-ecological scale, 54.60 points out of 100 for the socio-territorial scale, 60.31 points on 100 for the economic scale and 51.21 points on 100 for agricultural sustainability. However, Southern agro-bio-climatic farms recorded the lowest scores of 49.82, 48.38, 46.71 and 41.97 points out of 100 respectively for the agro-ecological scale, socio-territorial scale, economic scale and agricultural sustainability.

Keywords: sustainability; indicators; dairy cattle; semi-arid zone; climatic hazards

Introduction

In the semi-arid region of the high plains of Setif, located in eastern Algeria, agriculture is mainly based on cereal production and livestock, while complexly combining other crops (Pluvinage, 1995 ; Benniou et al., 2001 ; Abbas et al., 2002). The concentration of dairy cattle farming in these high plains as a result of the agricultural policies implemented by the government since the independence of the country, aims to increase milk production, often to the detriment of the environment and the society. Thus, European dairy cattle breeds have rapidly integrated into the production systems of this semi-arid, larger and more agricultural area than the rugged coastal regions with a relatively lower land potential (Yakhlef et al., 2008). The emergence of this new agropastoral system in an area traditionally reserved for small ruminants naturally leads to questions about its sustainability. This is what this work tries to answer by setting two main objectives: i) to evaluate the sustainability of the dairy cattle farms of the 3 agro-bioclimatic stages and ii) to estimate their sensitivity to climatic hazards.

Materials and Methods

Methodology

In order to analyze the sustainability of dairy cattle farms and their sensitivity to climatic hazards in the semi-arid zone of Setif, our choice is focused on the method of farm sustainability indicators (IDEA) (Vilain, 2008) which was transposed to the local context.

It is a scoring method that establishes an overall performance of the farm from 42 indicators. The main hypothesis of this tool is based on the idea that it is possible to quantify the various characteristics of agricultural systems by assigning them an encrypted score, then to aggregate the information obtained to obtain a score or an overall performance.

The higher the score, the more the exploitation is considered sustainable for the scale considered. Aggregation is done on three scales: agro-ecological (18 indicators), socio-territorial (18 indicators) and economic (6 indicators). The number of sustainability points or units assigned to each indicator is between 0 and a ceiling value that is specific to each indicator. This method was chosen for its multidisciplinary, its robustness, its ease of implementation and for its adaptability to a survey in limited time.

Two major types of modifications guided the adaptation of this sustainability assessment matrix to the local context. The first relates to the clarifications or modifications made (acceptance, modification or rejection of the variables and the weighting of each variable or indicator) before the calculation of the indicators. The second type relates to the maximum limits that have been set so as not to exceed the capped total for each sustainability component.

Nature and origin of data

The data analyzed are those collected from 128 dairy cattle breeders in the Sétif region of eastern Algeria, which extends between 36° and 36°30’ of latitude and between 5° and 5°30› of longitude on an area of 6 549 km². It is characterized by a semi-arid continental climate. The farms surveyed are spread over three agro-bioclimatic stages: 48 farms in the mountainous area in the north with a rainfall more than 450 mm/year, 46 farms in the central high plains zone with a rainfall of between 250 and 450 mm/year and 34 farms in the zone of southern depressions whose rainfall is less than 250 mm/year. The raw data collected are those related to the 56 variables of the IDEA method (42 variables reflecting the scores of the 42 indicators, 14 variables reflecting the different components and scales of sustainability as well as agricultural sustainability).

Statistical analysis

The raw data collected on the basis of a questionnaire inspired by the IDEA method was analyzed to allow the calculation of sustainability indicators. The information obtained was entered into an Excel table to form the basic file on which the statistical analyzes were performed using the Excel (2007) and SPSS 18 software (means, standard deviations, variance and linear regression).

Table 1. Scores of indicators, components and agro-ecological scale

Agro-bioclimatic stages	**Northern Zone**	**Central zone**	**Southern zone**	**Mean**	**Maximum value**
A1 – Diversity of annual crops	5.19 [a]	5.07[a]	5.03[a]	5.10	10
A2 – Diversity of perennial crops	5.27 [a]	3.04 [ab]	1.53 [b]	3.48	10
A3 – Animal diversity	5.83 [a]	6.02 [a]	6.59 [a]	6.10	9
A4 – Enhancement of genetic resources	2.42 [a]	2.39 [a]	2.12 [a]	2.33	4
Domestic diversity component	18.71 [a]	16.52[ab]	15.26 [b]	17.01	33
A5 – Cropping pattern	4.38 [a]	4.57 [a]	4.03 [a]	4.35	7
A6 – Plot size	3.79 [b]	3.57 [b]	4.82 [a]	3.98	5
A7 – Organic matter management	2.15 [ab]	1.70 [b]	2.71 [a]	2.13	4
A8 – Ecological Buffer area	4.77 [a]	4.09 [a]	2.62 [b]	3.95	7
A9 – Contribution to environmental issues	1.52 [a]	1.41 [a]	1.24 [a]	1.41	2
A10 – Enhancement of space	1.48 [a]	1.76 [a]	1.00 [a]	1.45	4
A11 – Forage area management	2.71 [a]	2.76 [a]	2.82 [a]	2.67	4
Space organization component	20.79 [a]	19.85[a]	19.24 [a]	20.04	33
A12 – Nitrogen balance	3.63 [a]	3.80 [a]	1.76 [b]	3.20	6
A13 – Effluents processing	1.58 [a]	1.33 [a]	1.50 [a]	1.47	4
A14 – Pesticides	4.27 [a]	4.24 [a]	4.32 [a]	2.27	5
A15 – Veterinairy treatments	1.40 [a]	1.59 [a]	1.32 [a]	1.45	3
A16 – Soil resource protection	2.75 [a]	2.15 [b]	1.35 [c]	2.16	5
A17 – Water resources management	4.60 [a]	4.41 [ab]	3.97 [b]	4.37	6
A18 – Energy dependence	2.69[a]	2.74[a]	1.09 [b]	2.28	5
Farming practices componenet	20.92 [a]	20.26[a]	15.32 [b]	19.19	34
Agro-ecological scale	**60.42[a]**	**56.63 [a]**	**49.82 [b]**	**56.24**	**100**

Results and Discussion

Agro-ecological sustainability

Agro-ecological sustainability presented the best performance for the farms surveyed; it averages 56.24 points out of 100, or 56.24% of the theoretical maximum (Table 1). This value is lower than that obtained, on one hand, by Yakhlef et al. (2005), Yakhlef et al. (2008) for the same region with respectively 70 and 67.61%, and on the other hand that obtained by M'Hamdi et al. (2009) for Tunisia, 60.02%. It is also lower than that reported by Ghozlane et al. (2006) for the wilaya of Tizi Ouzou, i.e. 65.5%. However, it is much higher than that reported for the plain of Mitidja by Bekhouche (2004, 2011) (respectively 45.2 and 51.6%) and Ikhlef et al. (2015, 2017) (respectively 45.97 and 45.71%).

This result can be explained by the relatively high scores of the 3 components of this scale: 60.7% for the organization of space component, 56.4% for the farming practices component and 51.5% for the diversity of productions component (Fig. 1). The fairly good ratings of these three components result from fairly high average scores attributed to a number of indicators – annual crop diversity (A1), animal diversity (A3), crop patterns (A5), plot size (A6), ecological buffer areas (A8), forage management (A11), pesticides (A14) and irrigation (A17) (Table 1).

Animal diversity, which has a very high value (6.10 out of 9 points, i.e. 67.80% of the maximum theoretical score), is related to the presence of widely diversified animal species and breeds (cattle, sheep and goats)) within most farms. These farms are also characterized by a good crop patterns (4.35 points/7) and a very good plot size (3.98 points/5, 80.46% of farmers have no spatial unit of the same crop that exceeds 15 ha). These performances result from the good diversity of annual crops (5.10 points/10).

The generalization of forage crops and the valorization of stubble and straw contribute significantly to the improvement of the score obtained by the forage area management indicator (2.76 points/4). The presence of non-mechanized area (environments considered very favorable for the regeneration of wild fauna and flora), fallow land, untreated crops and orchards and the presence of water points are at the origin of the good scores obtained for the indicator ecological buffer area (3.95 points/7). In addition, the use of pesticides is not important in the semi-arid region of Setif; it is limited to small areas often reserved for vegetable crops with a polluting pressure not exceeding the value of 2 (pp < 2). In the farms surveyed, irrigation is relatively low and most often restricted to vegetable crops, fodder crops and young plantations.

Table 2. Scores of indicators, components and socio-territorial scale

Agro-bioclimatic stages	Northern zone	Central zone	Southern zone	Mean	Maximum value
B1 – Quality approach	5.38 [a]	4.20 [ab]	3.03 [b]	4.33	10
B2 – Enhancement of buildings and landscape heritage	4.46 [a]	3.74 [a]	3.94 [a]	4.06	8
B3 – Processing of non-organic waste	2.29 [ab]	2.54 [a]	1.94 [b]	2.29	5
B4 – Accessibility of space	3.08 [a]	3.22 [a]	2.76 [a]	3.05	5
B5 – Social involvement	3.60 [a]	3.61 [a]	3.71 [a]	3.63	5
Quality of products components	18.81 [a]	17.30 [ab]	15.38 [b]	17.36	33
B6 – Short trade	4.00 [a]	3.89 [a]	4.09 [a]	3.98	5
B7 – Autonomy	3.88 [a]	4.28 [a]	3.82 [a]	4.01	10
B8 – Services, multiactivities	2.21 [a]	2.48 [a]	2.06 [a]	2.27	4
B9 – Contribution to employment	5.00 [ab]	4.52 [b]	5.15 [a]	4.87	6
B10 – Collective work	1.46 [a]	1.93 [a]	1.56 [a]	1.66	4
B11 – Probable sustainability	3.52 [a]	3.41 [a]	3.21 [a]	3.40	4
Employment and services component	20.06[a]	20.52[a]	19.88[a]	20.18	33
B12 – Contribution to world food balance	1.98 [a]	1.87 [a]	0.68 [b]	1.59	7
B13 – Animal welfare	2.79 [a]	2.54 [a]	2.47 [a]	2.62	4
B14 – F Training	2.31 [a]	1.35 [b]	1.09 [b]	1.64	5
B15 – Labor intensity	2.02 [a]	2.50 [a]	2.79 [a]	2.40	6
B16 – Quality of life	3.21 [a]	3.20 [a]	2.76 [a]	3.09	5
B17 – Isolotaion	1.60 [a]	1.80 [a]	1.62 [a]	1.68	3
B18 – Reception, hygiene, and safety	1.73 [a]	1.65 [a]	1.71 [a]	1.70	4
Ethics and human development	15.65 [a]	14.91 [ab]	13.12 [b]	14.71	34
Socio-territorial scale	**54.60 [a]**	**52.83 [a]**	**48.38 [b]**	**52.31**	**100**

Agro-ecological sustainability is however penalized by the very low scores attributed to perennial crop diversity indicators (A2), space enhancement (A10), effluents processing (A13), soil resource protection (A16) and energy dependence (A18). The difficult climatic conditions are at the origin of the relatively low scores obtained by the perennial crop diversity indicator, especially in the central and southern regions, whereas the low score obtained by the soil resource protection indicator is linked to the absence of no-till technique, bare soil surfaces in the form of fallow land and the scarcity of anti-erosion devices favoring water and wind erosion. The low stock rate score (1.44 points/4) expresses the high feed dependence of farms, which is reflected in the massive importation of livestock feeds and in the deterioration of natural environment due to overgrazing.

Socio-territorial sustainability

Socio-territorial sustainability is the weak point of these farms with only 52.31 out of 100 points, or 52.31% of the theoretical maximum (Table 2). However, this score is far larger than that reported by Yakhlef et al. (2008) for the same region (22.76%). It is also more important than the scores calculated by Ghozlane et al. (2006) for the Tizi-Ouzou wetland (36.06%) and Bekhouche (2004, 2011) and Ikhlef et al. (2017) for Mitidja with 29.43 and 34.88 and 38.3% respectively. It remains on the other hand similar to that reported by M'Hamdi et al. (2009) for Tunisia (52.5%).

Socio-territorial sustainability is penalized by the low scores obtained by the human development (43.5%) and product and territory quality (52%) components. The employment and services component, on the other hand, has a very acceptable level (61.1%) (Fig. 1). All the aspects related to the quality of the products, to the different services rendered to the territory and the ethics are not taken into account by the breeders who privilege more the profitability aspect of the farm than the citizenship. Added to this, there is the absence of training programs adapted to the educational levels of breeders, a low involvement of breeders in the associative structures, a working time by worker (breeder) important and a strong feeling of isolation.

This explains the need for an improvement that must be made at the level of the several indicators with very low scores including quality approach indicators (4.33 points/10), autonomy (4.01 points/10), collective work (1.66 points/4), contribution to the balanced diet (2.26 points/7), training (1.64 points/5), work intensity (2.4 points/6), health and safety (1.7 points/4). The indicator of the probable sustainability of the exploitation (B11) reaches a very important score (84.9%), i.e. 3.40 out of 4 (Table 2). This high value refers to the attachment character of the local populations to agricultural activity (Djenane, 1997).

Economic sustainability

The economic sustainability reaches an average value of about 54.36% of the theoretical maximum (54.36 points out of 100) (Table 3). This is comparable to those reported by Yakhlef et al. (2008) for the same region, 49, but also by Bekhouche (2011) for Mitidja and M'hamedi et al. (2009) for Tunisia with 55 and 57.5% respectively. However, it is far more important than the 44.4% score reported by Ikhlef et al. (2017) for the peri-urban area of the city of Algiers (Mitidja).

In contrast to agro-ecological and socio-territorial scales, the economic scale is characterized by amplitude of scores on its various indicators that is relatively greater (Fig. 1). These farms have the advantage of having a moderate level of specialization (6.52 points/10) which allows farmers to make adjustments to economic constraints (especially market fluctuations) or in case of climatic hazards (Table 3). The very acceptable economic independence of these farms (84.6% or 21.14 out of 25 points) is the result of a considerable financial autonomy because

Table 3. Scores of indicators, components and economic scale and agricultural sustainability

Agro-bioclimatic stages	Northern zone	Central zone	Southern zone	Mean	Maximum value
C1 – Economic Viability	11.17 [a]	7.48 [b]	5.06 [b]	8.22	20
C2 – Economic specialization rate	6.42 [a]	6.48 [a]	6.71 [a]	6.52	10
Economic Viability component	17.58 [a]	13.96 [b]	11.76 [b]	14.73	30
C3 – Financial autonomy	14.00 [a]	14.09 [a]	13.24 [a]	13.83	15
C4 – Sensitivity to aid and quotas	7.21 [a]	7.54 [a]	7.18 [a]	7.32	10
Independence component	21.21 [a]	21.63 [a]	20.41 [a]	21.14	25
C5 – Economic transferability	11.35 [a]	11.24 [a]	9.32 [a]	10.77	20
C6 – Efficiency of production process	10.19 [a]	6.98 [b]	5.21 [b]	7.71	25
Economic scale	**60.31 [a]**	**53.80 [b]**	**46.71 [c]**	**54.36**	**100**
Agricultural sustainability	**51.21 [a]**	**46.22 [b]**	**41.97 [c]**	**46.96**	**100**

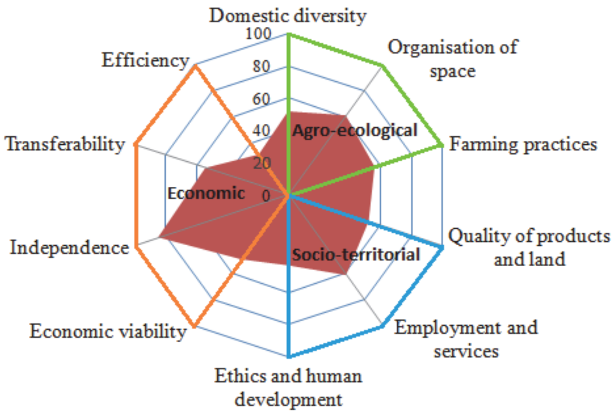

Fig. 1. Graphical representation of the components of dairy farm sustainability

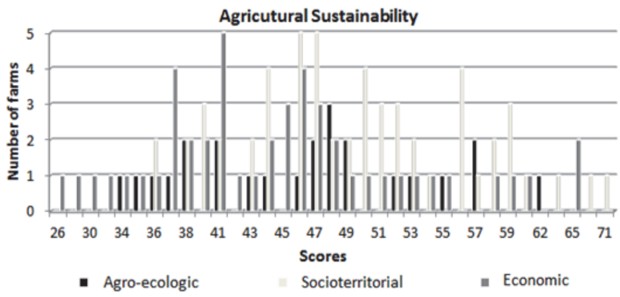

Fig. 2. Histogram of agricultural sustainability

75.78% of farmers have a financial dependence of less than 10% of the GOS (Gross Operating Surplus) but also the weakness of the direct aids which are concluded by the premium of collected milk, wheat and heifers. However, the importance of capital has a negative impact on the transferability of these farms, especially those of large public or private types, while the importance of inputs and the rise in the prices of concentrates, fertilizers, phytosanitary products and energy results in a low efficiency of the productive process, which automatically affects economic viability.

Agricultural sustainability

In the IDEA method, with regard to the question of the aggregation of global scores between the 3 scales, some authors like Girardin et al. (2004), Zahm et al. (2004) and Del'homme and Pradel (2005) attribute to the final numerical value of sustainability the lowest value of the three scales, thus applying the rule of limiting factors that is required in ecosystem dynamics. Indeed, assigning a single overall sustainability score has no real meaning as it would allow offsets between the three scales.

Based on this principle, agricultural sustainability ratings range from 26 to 71 points with an average value of 46.96 points/100 (Table 1). This result is clearly superior to that reported by Ikhlef et al. (2017) for the peri-urban area of the city of Algiers (Mitidja), i.e. 31.7. The distribution of results (Fig. 2) shows the existence of 24 farms whose sustainability is limited by the agro-ecological scale, 48 farms whose sustainability is limited by the economic scale and finally 57 farms whose sustainability is limited by the socio-territorial scale.

Effect of agro-bioclimatic stages on sustainability performance

The comparison of the performances of the three sustainability scales and the agricultural sustainability of the three agro-bioclimatic stages of the study area reveals significant differences ($P < 0.05\%$) (Tables 1, 2 and 3). The best performances are in the assets of the farms of the North agro-bioclimatic stage with relatively higher scores (60.4% for the agro-ecological scale, 54.6% for the socio-territorial scale and 60.3% for the economic scale). The farms of the southern agro-bioclimatic stage record the lowest scores with respectively 49.8, 48.4 and 46.7% for the agro-ecological, socio-territorial and economic scales and those of the Center region are intermediate with respectively 56.6% for the agro-ecological scale, 52.8% for the socio-territorial scale and 53.8% for the economic scale. These results are confirmed by linear regression analysis. In fact, reading Table 4 shows that the regression slopes reflect negative relationships between the sustainability performance of the three scales and agricultural sustainability and the fact that the farms belong to the Central and South agro-bioclimatic stages.

Table 4. Effects of the bioclimatic stage on the scales of sustainability and agricultural sustainability (slopes of the regressions ± standard deviation)

Effect	Agro-ecological sustainability	Socio-territorial sustainability	Economic sustainability	Agricultural sustainability
Northern region	0	0	0	0
Central region	-2,69±1,74	-1,33±1,67	-6,16±2,48	-4,50±1,51
Southern region	-6,13±2,05	-4,52±1,96	-11,5±2,92	-7,08±1,78

The high scores (60.4 points out of 100) of the farms in the North region for the agro-ecological scale are explained, on the one hand, by the more favorable climatic conditions that favor a higher plant diversity (arboriculture and natural grasslands) which also contribute to the protection of the soil and animal resource, and on the other hand to less irrigation, a low use of pesticides and fertilizers, to more space for ecological buffer areas and to a less dependable energy (use of firewood).

The socio-territorial sustainability of farms in the Southern region, which is at a level below the theoretical average (50 points out of 100), is linked to the low scores obtained by the indicators of product and territory quality and ethics and human development components (less collective work, high concentration of imported concentrates, lack of training and social involvement, average quality of life and isolation).

The importance of inputs which results in a low efficiency of the productive process, the weakness of the capital and the agricultural surfaces which acts negatively on the transferability of the exploitations, the productions and the random yields and not important especially for the cereal and forage crops which are often affected by episodes of drought explain for their part the low score (46.71 points out of 100) recorded by farms in the South region for the scale of economic sustainability.

Conclusion

The analysis of the sustainability of dairy farms in the semi-arid zone of Setif shows a great diversity of results whatever the type of farm, region or specificity of production. In fact, the results relating to the evaluation of sustainability make it possible to highlight a satisfactory level for agro-ecological sustainability, a means for economic sustainability and a weak one for the socio-territorial dimension, which is the weak point for the majority of farmers.

In-depth analysis shows the important role of the diversity of productions in acquiring better performances for the agro-ecological sustainability scale. Farmers' practices are acceptable but the organization of the space is poorly controlled especially for large farms. The weak performances obtained for the socio-territorial scale are due to the weakness of the quality component of the products and the territory and ethics and human development. Finally, the average performances obtained by the economic scale are induced by the viability and the economic independence and the transmissibility whereas the efficiency of the productive process knows a declension due to the importance of the financial burdens.

As for the sensitivity of farms' sustainability to climatic hazards, the comparison of the performances of the three sustainability scales and the agricultural sustainability of the farms of the three agro-bioclimatic stages of the study area reveals significant differences. The best performances are obtained by the farms of the North agro-bioclimatic stage with scores relatively higher than those of the farms in the central region and especially in the southern region.

Thus, the challenge of the farms studied for the coming years lies both in maintaining their economic competitiveness and in meeting the expectations of society in terms of the environment and product quality.

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