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Agroecological Sustainability of Tomato-Producing Vegetable Farms in Northern Benin

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Abstract: ***Tomato production on vegetable farms is gaining considerable importance in Northern-Benin. However, its sustainability remains a challenge. Based on a random sample of 202 vegetable farms and using the multi-criteria approach and Multiple-Correspondence-Analysis (MCA), the study identifies two categories of tomato producers, those oriented towards organic farming (group 1) and the others using chemical fertilisers and pesticides (group 2). While overall, none of these farms were very sustainable due to their low agroecological score (35.4%), the component "Agricultural practices" appears as the one that contributes the most (44.37%) to the achievement of this total score, followed by "Ecological diversity" (40.48%) and "Spatial organization" (15.01%). Specifically, the group 1 achieved the highest score (43.01%) compared to the group 2 (38.35%). Thus, agroecological sustainability of tomato-producing vegetable farms in northern-Benin remains a challenge and a big concern that requires prompt actions to help producers in adopting and implementing sustainable production practices.***

Keywords: Agroecologial, sustainability, MCA, Tomato-Benin

1. Introduction

The question of sustainability is a major development policy issue today, as internationally demonstrated by Goal 12 of the SDGs. It puts emphasis on sustainable consumption and production methods in order to ensure efficient use of resources thereby reducing the effects of economic activities on the environment by 2030. At the regional level, in sub-Saharan Africa, the adoption of the African Regional Strategy for Nutrition (SRAN) and the development at the national level in Benin of policy documents PSRSA and PSDSA [1]in the agricultural sector is in line with these objectives. Such policy statements are particularly important for countries like Benin whose economy relies mainly on agriculture. This is more so due to the fragile environmental conditions and the paucity of the agricultural production systems in the country. Far from being stable and sustainable, although contributing to around 34.3% of the GDP [2], agriculture in Benin remains, extensive and rain-fed, with low productivity. It is, therefore, subject to numerous exogenous shocks including climatic hazards, fluctuations in the terms-of-tradeand the fluctuating market conditions, especially in Nigeria, its neighbouring country [3]. In recent years, the share of loss of productivity of the main crops that is attributable to continuous soil degradation and climatic disturbances [4]has been obviously increasing [5],[6]. The phenomenon is becoming all the most alarming as land pressure resulting from population growth has led to a reduction in fallow periods. In addition, the abusive use of chemical fertilizers has speedup the process of soil degradation and as a matter of fact, the continuous decline in the productivity of the main crops [7].

In Northern Benin, especially in the cotton growing areas, farming practices based essentially on the excessive use of fertilizers and every types of pesticides already acknowledged as a major cause of deterioration of the environment and of the living hood of rural populations [8] is a major concern of the sustainability of the agricultural systems of this region. Indeed, those practices may cause over-mineralization of the soils and negative side-effects of the use of these phytosanitary products [9]. Confronted with the instability of their seasonal agricultural production and their low income, most producers diversify their activities by engaging in vegetable production, specially tomato production in the surrounding shallows, given that tomato remains the most consumed vegetable product and therefore the most demanded throughout the year in Benin [10], [11]. The development of vegetable farming translates nowadays into a multitude of tomato-producing farms based on the intensification or not of the production which is extended even to the urban outskirts. Considering the increasing importance of such activities, a certain number of studies have been devoted to the analysis of this vegetable farming, among which the tomato production. However, most of those studies [12],[13] dealt only with the importance of vegetable farms for the livelihood of households or with the economic performance of those farms. In contrast, very few of them dealt with the sustainability of the vegetable farms. One such study in Benin [14] addressed the sustainability of vegetable production in general in southern Benin, but did not specifically target the production of tomato, which remains the most common fruit vegetable consumed in Benin. Therefore, the sustainability of these tomato farms remains unexplored in northern Benin despite the growing importance of vegetable production in this region.

To fill this gap, the current study aims at contributing to a better understanding of the practices and problems related to the sustainable management of these tomato farms in Northern-Benin, by providing a usable database for all researchers and policy makers concerned with sustainable development issues in Benin.

2. Materials and Methods

2.1. Concept of farm sustainability

According to [15], sustainable agriculture must not degrade man or the land. Similarly, for [16], sustainable agriculture is an agriculture that is able of evolving indefinitely towards a greater utility for Man. This implies a better efficiency of the use of resources and a balance with the environment that are beneficial both for humans and for most other species. [17] define sustainable agriculture as environmentally sound, economically viable, socially just and human. In the same perspective, [18] define sustainable agriculture as the capacity of production systems to last in the future.

It emerges from all these definitions that sustainability can be considered as a coherent combination of ecological, social, economic and time-transmitted aspects [19]. It is on this basis that in most sustainability assessment methods, three dimensions are taken into account. These are the agroecological, socio-economic and socio-territorial dimensions. In this article, however, only the agroecological sustainability dimension also known as environmental dimension has been addressed.

2.2. Assessment approach of farms sustainability

The multi-criteria method remains the main analytical approach in the evaluation of sustainability. It is a global approach that can be used at different spatial scales (plot, company / farm, industry, region, country), according to the targeted objectives; thus, it can be applied to the designing of new systems (*ex ante*) or for *ex post* evaluation of an existing agricultural system [20].

In the evaluation of agricultural systems, this approach is based on a very wide number of tools among which the best known are: "IDEA", "DIALECTE", "ARBRE", "DIAGE", "INDIGO", and "EDEN" [21],[22], [20]. While some of these tools are applied to the analysis of specific aspects of sustainability, others such as IDEA are used to assess the whole dimensions of sustainability of the agricultural sector at the level of agroecology, agro-spatial and agroeconomic. Although most of the main tools can be applied at the farm level, IDEA appeared as the most relevant tool for this study. However, due to the specificity of vegetable farms which are better taken into account by IDPM (Indicators of Sustainability of Vegetable Production) which is only a variant of IDEA [23], it is the IDPM that was used as a sustainability assessment tool for this study.

As an ecosystem and quantitative method of approach, the IDPM makes it possible to quantitatively assess practices at the level of a plot or vegetable farm that are likely to go in the direction of sustainable development [19]. It is based on 40 indicators and the assessment is made on three sustainability scales of the same weight, varying from 0 to 10. They include the agro-ecological sustainability scale (environmental impact of farm activities on the territory and the natural environments), the socio-territorial sustainability scale (integration of the farm into its territory), and the economic sustainability scale (economic operation of the farm). However, only the agroecological sustainability scale which, according to [24] analyses the propensity of the technical system to combine efficient development of environmental resources, ecological cost and techno-economic viability is relevant for this study.

2.3. Classification of tomato-producing vegetable farms

The typology of vegetable farms was based on a number of variables chosen on the basis of a literature review and on personal observations made in the study area. Thus, as suggested by some authors [25],[26], variables related to soil fertility management and conservation practices, fertilization techniques and the type of materials used for production were chosen to characterize the farms. Then a Multiple Correspondence Analysis (MCA) was made using the R Analysis Software.

2.4. Calculation of the scores of sustainability

Agroecological sustainability scores, the also called environmental sustainability scores were calculated based on the fifteen (15) indicators defined according to the IDPM and that are listed in table 1. These indicators are grouped into three components: Ecological Diversity, Spatial Organization and Agricultural Practices. Depending on their importance, as defined by the IDPM, each indicator was weighted from 0 to 12 and each component from 0 to 45. On this basis, scores were awarded to each of the indicators and to each of the 202 producers. Agroecological sustainability scores were obtained by summing-up the scores of the different indicators assigned to tomato producers.

Table 1: Components and indicators of agroecological sustainability

Components	Indicators	Assigned scores (in points)
Ecological Diversity (30)	Diversity of local crops	0-8
	Diversity of exotic crops	0-8
	Associated plant diversity	0-2
	Development and conservation of the genetic heritage	0-5
	Preservation of biodiversity	0-7
Spatial organization (25)	Cropping	0-10
	Plot size	0-10
	Crop rotation	0-5
Agricultural practices (45)	Water Management	0-3
	Energy dependence	0-3
	Chemical packaging management	0-8
	Organic matter management	0-4
	Fertilization	0-12
	Plant protection	0-12
	Soil protection	0-3
Total agroecological sustainability (100)		100

Source: Adapted from IDPM

2.5. Study area, sampling and database

The study area is the northeast of Benin divided into three agricultural development poles which cover several municipalities in two Departments. In each of these agricultural development poles, a municipality and at least three districts were selected on the basis of the importance of tomato production (see fig. 1). At the level of each selected district, villages with the largest tomato producers were chosen. From the list of tomato producers established by the extension service, a random sample of 202 tomato producers was drawn.

Data collection was made using an individual questionnaire, semi-structured interviews and the triangulation technique. The primary data collected was related to the socio-economic characteristics of producers, the characteristics of their farm, their cropping system, the marketing system, etc. Secondary data incorporated general information related to tomato production and were collected from different sources of documentation. Data analysis was done using SPSS software and R software.

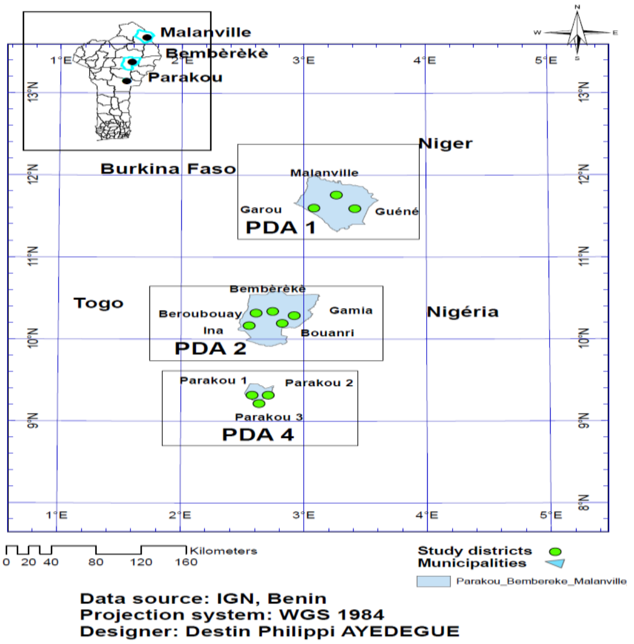

Figure 1: Study area

3. Results

3.1 Socio-economic characteristics of tomato producers

Analysis of the socioeconomic characteristics of the selected vegetable producers revealed that most of them were female (51%) with an average age of 49 years (± 16.23). The dominant marital status remained marriage (78%) followed by widowhood (17%), celibacy (4%), and divorce (1%). The analysis also showed that the majority of vegetable producers surveyed (60% of them) did not attend school. Among the educated ones, 19% had a primary education level, 15% with a secondary level and 4% with a university level. With regard to literacy, only 2% of vegetable producers surveyed can read and write in their local language. The household size is 6 people (± 3.56), including on average 5 agricultural workers. Although each producer has an average land size of 1,411 m² (± 1,871), the area allocated to growing tomatoes averaged only 331.98 m² (± 561), representing around 24% of the total land size (see Tab. 2). The productivity of their tomato averaged 4 kg / m² (± 2), which is equivalent to 40,000 Kg per hectare and an average annual income of 567 FCFA (± 88) per m², or 5,670,000 FCFA per Ha.

Table 2: Socio-economic characteristics of the selected producers

Variables	Modalities	Frequencies
Gender	Male	49%
	Female	51%
Marital Status	Celibacy	4%
	Divorced	1%
	Married	78%
	Widow	17%
Level of education	No level	60%
	Primary	19%
	Secondary	15%
	University level	4%
	Literacy	2%
Quantitative variables		
Variables	Means and standard deviation	
Age	49 years (±16.23)	
Household size	6 persons(±3.56)	
Farm size	1,411.20 m² (±1870.80)	
Cultivated area of tomato	331.98 m² (±560.85)	
Tomato yield	4 kg/ m² (±2.69)	
Income from tomato production	567 FCFA (±88)	

Source: Survey data, September 2019

3.2 Typology of tomato-producing vegetable farms

As described in section 2.3., the MCA led to the identification of two (2) main groups of tomato producers split into two factorial axes.

First factorial axis: The first factorial axis puts together producers using organic fertilizers including cow dung, compost, poultry droppings and who use natural insecticides, biopesticides and plant extracts as a pest control and management measure. The variables of the model that provide information on this first group of tomato producers are: PRONATU, CREDI and FIVOL

Second factorial axis: The second factorial axis brings together the category of producers who, unlike their counterparts in the first group, use synthetic chemical fertilizers including chemical herbicides, and chemical insecticides in the fight against pests and for the maintenance of their farms. The variables NPK, UREE, HERB illustrating this second group are found in graph 2 of the model.

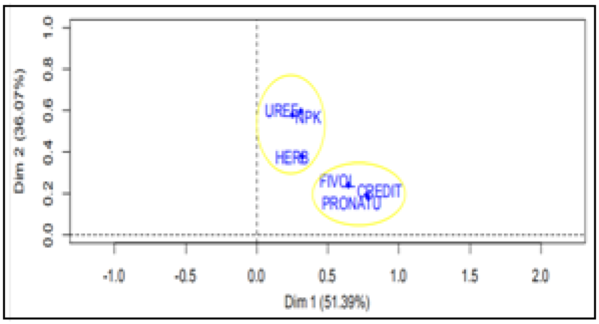

Figure 2: Variable Graph
Source: Survey data, September 2019

3.3 Dimensions from the multiple correspondence analysis

The results from the categorization led to six dimensions capable of explaining the model as a whole (see table 3). However, the first two dimensions were selected for further analysis since they offer the highest variances.

Table 3: Contribution of each dimension to the explanation of the model

	Eigen values					
	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5	Dim.6
Variance	0.514	0.361	0.073	0.031	0.019	0.002
% of var.	51.389	36.075	7.342	3.057	1.941	0.196
Cumulative % of var.	51.389	87.464	94.806	97.863	99.804	100.000

Source: Survey data, September 2019

Indeed, the eigenvalues of the variances of the first two dimensions of the categorization are the closest to 1, and their sum being equal to 0.875 is equivalent to almost all of the total inertia whose value is 1. One can deduce that the first dimension alone explains 51.39% of the global information of the model and the second dimension 36.07% of this information. Cumulatively, dimensions 1 and 2 explain the model at 87%, thus suggesting that, taken together, these two dimensions explain most of the information related to vegetable producers in the study area. These two dimensions can then be considered as the most representative of the model and therefore serve as a basis for interpreting the rest of the analysis.

3.4 Linkage and significance of variables

The MCA analysis made it possible, through the results of the Fisher test, to establish not only the degree of linkage of the variables, but also the significance of their belonging to the different dimensions. Compared to the first dimension, the results of the Fisher test (R^2 and *p*-value probabilities) recorded in Table 4 provide information on the global link between each variable and the dimension. It appears from this table that it is the variables PRONATU (use of natural products and poultry droppings) and CREDIT (use of credit) that are significantly linked to the first dimension because their R^2 is close to 1 and their p-value very close to 0.

Table 4: Link of variables of the dimension 1

Variables	R²	p.value
PRONATU	0.7854462	9.043965e-69
CREDIT	0.7776363	3.245384e-67
FIVOL	0.6431079	1.256759e-46
HERB	0.3187517	2.114539e-18
NPK	0.3092195	8.611495e-18
UREE	0.2491740	3.983874e-14

Source: Survey data, September 2019

With regard to the second dimension, the values of R^2 and of the probabilities resulting from the Fisher test (see. Table 5) make it possible to confirm that the variables NPK (use of NPK), UREE (use of Urea) and HERB (use of Herbicide) are significantly related to dimension 2 given the values of their R^2 and p-value around 1 and 0 respectively

Table 5: Link of variables of the dimension 2

Variables	R²	p.value
NPK	0.5968482	2.560757e-41
UREE	0.5781244	2.436446e-39
HERB	0.3767506	2.664125e-22
FIVOL	0.2416761	1.092027e-13
CREDIT	0.1924532	6.559834e-11
PRONATU	0.1786464	3.702689e-10

Source: Survey data, September 2019

3.5 Evaluation of the agroecological sustainability of tomato-producing vegetable farms

3.5.1 Agroecological sustainability of all selected vegetable farms

Analysis of the agroecological sustainability of all the selected farms reveals that these farms collect a total of 35.4 points out of the 100 points recommended, or a total of 35.4%. This total score is distributed between the three components of agroecological sustainability previously defined. Thus, “agroecological diversity” recorded 40.48%, “spatial organization” 15.14% and the component “agricultural practices” 44.37% of the total score (see. table 6).

Table 6: Agroecological sustainability scores for all farms

Components	Indicators	Mean	Std dev.	Min	Max
Ecological Diversity (30)	Diversity of local cultures	5.76	2.184	2	8
	Diversity of exotic cultures	1.56	1.611	0	**6**
	Associated plant diversity	1.18	0.986	0	**2**
	Development and conservation of the genetic heritage	3.96	1.101	1	**5**
	Preservation of biodiversity	1.87	3.202	-3	**7**
	Total	**14.33**			
Spatial organization (25)	Cropping	0.60	2.177	0	**10**
	Plot size	3.13	2.899	1	**10**
	Crop rotation	1.63	1.279	0	**4**
	Total	**5.36**			
Agricultural practices (45)	Water Management	.36	1.453	-1	**3**
	Energy dependence	1.78	1.474	0	**3**
	Chemical packaging management	2.49	2.910	-2	**8**
	Organic materialmanagement	1.38	2.210	-2	**4**
	Fertilization	2.60	5.540	-6	**12**
	Plant protection	9.82	1.750	7	**12**
	Soil protection	-2.72	1.621	-5	**-1**
	Total	**15.71**			
Total agroecological sustainability (100)		**35.40**			

Source: Survey data, September 2019

3.5.2 Agroecological sustainability according to the different categories of tomato producers

Referring to the two categories of tomato producing farms previously defined, the results show that producers in category 1 (producers using biopesticides and organic fertilizers) achieved an agroecological sustainability score of 43.01 points out of 100.

Between the three dimensions of agroecological sustainability, the distribution of this score gives the “ecological diversity” component 43.18%, the “spatial organization” dimension 19.30% and the “agricultural practices” dimension 37.53%.

As for the farms in category 2 (producers using pesticides, chemical fertilizers), they achieved a total score of 38.35 points out of 100 which distributed among the three dimensions with 41.04% for ecological diversity, 20.91% for spatial organization and 38.04% for agricultural practices (see table 7).

Table 7: Agroecological sustainability according to the two main categories of tomato producers

	Indicators	Category 1				category 2			
		Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum
Ecological Diversity (30)	Diversity of local crops	6.92	2.143	2	8	6.62	2.059	2	8
	Diversity of exotic crops	1.84	1.629	0	6	1.86	1.538	0	5
	Associated plant diversity	1.97	1.001	0	2	1.45	0.902	0	2
	Development and conservation of the genetic heritage	5.87	1.073	1	5	4.19	1.146	1	5
	Preservation of biodiversity	1.97	3.399	-3	7	1.62	2.661	-2	7
	Total	**18.57**				**15.74**			
Spatial organization (25)	Cropping	0.68	2.423	0	10	0.4	1.388	0	7
	Plot size	6.01	1.838	1	10	5.93	3.162	1	10
	Crop rotation	1.61	1.258	0	4	1.69	1.34	0	4
	Total	**8.3**				**8.02**			
Agricultural practices (45)	Water Management	0.51	1.578	-1	3	-0.02	1	-1	3
	Energy dependence	1.62	1.496	0	3	2.17	1.353	0	3
	Chemical packaging management	2.96	2.996	-2	8	1.31	2.319	-2	8
	Organic materialmanagement	1.39	2.284	-2	4	1.34	2.031	-2	4
	Fertilization	2.61	5.751	-6	12	2.57	5.023	-6	12
	Plant protection	9.58	1.695	7	12	10.41	1.758	8	12
	Soil protection	-2.53	1.655	-5	-1	-3.19	1.444	-5	-1
	Total	**16.14**				**14.59**			
Total agroecological sustainability		**43.01**				**38.35**			

Source: Survey data, September 2019

4. Discussion

Our study shows that all the selected vegetable farms achieved a score of 35.4%, thus suggesting that they are very little sustainable. Compared to the results obtained by [14] on the agroecological sustainability of vegetable farms in southern Benin with an average agroecological sustainability score of 50.16%, vegetable farms in Northern Benin are less agroecologically sustainable than those in southern Benin. Although the weakness of the total score is also reflected in each of the three different components of the agroecological sustainability, the components "Ecological diversity" and "Spatial organization" were, however, those who contributed the least to this total score of agroecological sustainability achieved by all the selected farms. These results, which contrast those of [14] and [27], are however in line with the results of [24], [28] and [29] according to which the component "agricultural practices" recorded the best scores but more particularly with those of [24] showing that the contribution of the component "agricultural practices" to the sustainability is up to 75%. The weakness of the score in this study could be partly attributed to the lack of technical support from extension services to vegetable farms whom, as also asserted by [14] and [27] are not for the most part specialized in vegetable production.

In the component “agricultural practices”, the indicators “plant protection” (9.82 points out of 12), “management of packaging of chemical products” (2.49 points out of 8) and “fertilization” (2.60 points out of 12) were the most important elements while "water management" indicator was relatively lower (0.36 point out of 3) and the "soil protection" indicator with -2.72 points had a negative impact on the “Agricultural practices”. In the absence of fallows and with the desire to increase their production, most vegetable producers engage in mineral fertilization and use chemical phytosanitary products whose consequences in terms of over-mineralization, soil saturation and pollution of the environment are unavoidable, thus slowing down their development towards any farm sustainability.

As for the “spatial organization” component, which accounts for only 15% of the total agroecological sustainability score, the indicators “cropping” and “crop rotation” show relatively low values compared to the “plot size”. These scores, which remain very low compared to the reference values for each indicator, are similar to the results from the studies by [24], [29], [30] and [31]. Thus, these results show that beside the quasi-absence of rotation, the practice of monoculture is more common thus contributing to a degradation of the land and as a matter of fact to reduce the sustainability of farms.

Analysis of sustainability of the two main categories of farmers from the MCA, (namely producers using organic fertilization including the use of poultry manure and having access to credit: category 1, and that of producers using only mineral fertilization and phytosanitary products: category 2) reveals that producers of category 1 achieve a relatively higher score (43%) than producers in category 2 with only 38%. Although the two scores are relatively low, these results show that it is at the level of producers of the category 1 that the trend towards agroecological sustainability is most pronounced. It proves, therefore, that organic farming practices really constitute the basic elements of agroecological sustainability as evidenced by [24]. By analysing the different components of this agroecological sustainability, the results show that the “ecological diversity” component of category 1 is with 61.90% of the reference score for this component, so better than category 2 with only 52 %. The trend is the same for all the indicators of this component. This implies that the indicators "diversity of local crops", "diversity of exotic crops", "associated plant diversity", "development and conservation of the genetic heritage", "preservation of biodiversity" are more valued by tomato producers in category 1.

With regard to the “Spatial Organization” component, producers of category 1 are almost at the same score level (33%) as their counterparts of category 2 with 32% of the reference score. This slight difference also appears in each of the indicators of this component “Spatial organization”, thus showing that the cropping, the size of the plots and crop rotation are practiced almost in the same way and with the same intensity in each of the categories of the vegetable producers.

As for the component "Agricultural practices", the producers of category 1 with 36% of the reference score differ from their counterparts of category 2 with only 32%, in terms of organic material management, soil fertilization, and soil protection, but appear relatively ineffective in plant protection. This is probably because the effects of phytosanitary products are more immediate than organic products, and are therefore more attractive to most producers.

These different results show the unsustainable nature of most of the tomato-producing vegetable farms in the study area, thus joining those resulting from the studies of [14] and [31]. Agricultural practices that are less favourable to sustainable management of farms tend to take ascendance over those that can best contribute to preserving the immediate environment of vegetable farms. Thus, in the preventive or curative fight against phyto-parasitic attacks for example, the systematic use of chemical phytosanitary products remains the most common practice with all the consequences mentioned both in health and environmental terms by a number of authors such as [8] and [32] in their respective studies.

Facing such behavior, sustainability of tomato farms in the study area can only be improved if there is an awareness among producers of the real issue of sustainability and importance of training offered by NGOs and professionalized extension structures in vegetable production. In this perspective, a technical and material contribution from the actors of rural development engaged in the promotion of sustainable agriculture could be necessary to ensure a more remarkable evolution of current agricultural practices towards those favouring a sustainable development of tomato farms. However, such actions could only be developed effectively if they are based on producers' perception of the question of sustainability through their current practices. Such a perception study could be taken into account in a future research.

5. Conclusion

Agroecological sustainability of tomato-producing vegetable farms is of key importance for sustainable development in the northern Benin. The results of this study show that the selected vegetable farms were very unsustainable when we refer to the average agroecological sustainability score of 35.4% achieved.

Whereas this low score is found in all the studied components ofthe agroecological sustainability, the components "Ecological diversity" and "Spatial organization" contribute however, the least to the level of sustainability achieved by all tomato producers with respectively 40% and 15% of the total agroecological sustainability score. The results also reveal that among the two categories of producers resulting from the MCA analysis, it is the category of producers oriented towards organic farming practices that achieved the highest agroecological sustainability score (43.01%) compared to the group of producers using chemical inputs and phytosanitary products (38.35%). This shows that organic farming practices play an important role in achieving agroecological sustainability.

With regard to the different components of sustainability, our results reveal that there is a significant difference in score between the components of agroecological sustainability of producers in category 1 and those of the group of producers using phytosanitary products. But between the “spatial organization” components of the two groups there is no significant difference. It therefore suggests that the practices of “cropping” and “crop rotation” as well the “plot size” are similar in both groups with however little contribution to the agroecological sustainability of vegetable farms in the study area.

If support (actions) is necessary to induce vegetable producers to adopt practices favourable to the sustainable management of their farms, it would however be desirable that the perception of these producers of the question of sustainability be analysed.

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