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Fallow Practices and Agro-Ecological Sustainability of Maize Production Systems in Southern and Center Benin

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ABSTRACT

This paper measures the ecological sustainability of maize production systems in Southern and Center Benin and the effect of fallow practices on the level of ecological sustainability of these systems. The method "Farm Sustainability Indicators (Indicateurs de Durabilité des Exploitations Agricoles: IDEA)" was used to collect data from 400 maize farms in three out of four agro-ecological zones of South and Center Benin. Both statistical and econometric analyses were used. Results showed that maize production systems were in average ecologically sustainable. The organization of the space was the greatest weak point of these production systems. The bar lands zone (AEZ6) had the highest sustainability score while the depression zone (AEZ7) had the lowest. Planted fallows and the association of breeding with maize production had significantly improved the level of farm ecological sustainability while the use of chemical fertilizers and pesticides, as well as the use of improved varieties of seed limited the level of sustainability. These results showed that planted fallows as well as organic inputs and local seed varieties should have to be promoted in maize production systems in order to sustain ecologically maize farms.

KEYWORDS: Ecological Sustainability, planted fallows, IDEA, West Africa

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1. INTRODUCTION

The main goals of agriculture are to ensure the feeding of populations and the supply of the factories in raw materials. To achieve these goals, farmers like all contractors try to maximize their farms productivity based on the intensive use of agrochemicals. Considering that agrochemicals use is believed to damage the environment, this intensive way of production will have negative impact on the agro-ecological sustainability of agriculture. In fact, the Rio Conference (1992) defined sustainable development, as a development which enables the satisfaction of present needs without compromising the capacity of future generations to satisfy their own. Therefore farmers have to converge their efforts for the promotion of sustainable agriculture through high productivity and safeguard of the environment. From that evidence, agricultural policies extend increasingly, the concept of "agriculture ecologically sustainable" to better face environmental problems generated by the agricultural sector in the word [1] Among these problems, climate change, water pollution, soil degradation and loss of biodiversity are the most important in Africa [2]. The ecological sustainability of agriculture integrates several parameters that have to be simultaneously taken into account [3, 4, 5]. Three components namely domestic diversity, organization of the space and farming practices are addressed in the perspective of ecological sustainability [6, 7, 8, 9].

The fallow is a farming practice used in tropical Africa to naturally improve soil fertility and agronomic and ecological potentiality of the area through the regeneration of the bush and arboreous savanna [10].To better play its role, fallow must last a relatively long period [10]. In Beninese agriculture, fallow systems are much practiced. However, these last years, the constant demographic growth caused a land pressure and consequently, the reduction of fallow periods, especially in central and southern part of the country [11]. Moreover, the diversity of structures and species in the fallows evolves from arboreous fallows to fundamentally grassy fallows. According to [11], some fallows can be nude without crop or cultivated in order to bury the vegetation at the end of the season. In that context, one can ask whether or not the practiced fallow can improve the ecological sustainability of agriculture. The present paper aims to answer that question in Southern and Center Benin, where demographic pressure is high [12], with the focus on maize production systems. In fact, maize is the main food crop in the southern and central Benin [13]. In these regions, there are globally three types of fallow: (i) fallow with cashew trees; (ii) fallow with palm trees and (iii) natural fallow, but there are some farmers that do not practice any of these types of fallow [14].

2. MATERIALS AND METHODS

2.1 Original IDEA method of ecological sustainability measurement and an adaptation to Benin maize production systems

According to [5], sustainable agriculture is an agriculture that is able to indefinitely evolve toward a highest utility for human, a best effectiveness of resources employment, and a beneficial equilibrium with the environment for the human welfare and for most of other species. But [3], based on the definition of [4], defined the sustainable agriculture as agriculture ecologically healthy, economically viable and socially just. On the one hand, thanks to the multi-dimensionality of its activities, it contributes to the sustainability of the territory wherein it is practiced and on the other hand, it contributes to the supply of global environmental services which face problems of sustainability [3]. According to IDEA (Farm Sustainability Indicators: *Indicateurs de Durabilité des Exploitations Agricoles*) method, the agricultural sustainability can be measured at three levels: the agro-ecological sustainability; the socio-territorial sustainability and the economic sustainability [6, 7, 9]. Following the IDEA original method, the agro-ecological sustainability of the agriculture is measured using eighteen indicators divided in three components: domestic diversity, organization of the space and farming practices [6, 7, 8, 9]. For each indicator there is a maximal score and for each component there is a peak of thirty-three or thirty-four points for a general total of one hundred points (table 1).

However, the original IDEA method was used following a given geographical and territorial reality. So it is unrealistic to believe that this original method is suitable to all cases without adjustment [6]. In that respect, focus groups were organized in the study area with farmers' leaders and extension officers [2]. The first goal of these group discussions was to choose based on participative methods with stakeholders, suitable indicators to measure agro-ecological sustainability of their production systems. The second goal was to define with these stakeholders, suitable maximum values for these indicators. Based on the results from group discussions, all components and indicators of agro-ecological sustainability derived from the original IDEA method were convenient to measure agro-ecological sustainability of agriculture in Southern and Center Benin (table 1). However, it comes out that the maximum values of all indicators of the original IDEA did not fit to measure the level of agriculture agro-ecological sustainability in Southern and Center Benin. To overcome this limitation, the maximum values were adapted to field realities using participative methods (table 1). Finally, the weight of each specific data necessary to measure each indicator [6, 7] was adapted to the novel maximum values using proportionality methods.

Table No. 1: "Indicators and components of farm agro-ecologic sustainability"

Components	Indicators		Maximum value from original IDEA method	Maximum value adapted IDEA method	Maximum total value for each component
	Description	Code			
Domestic diversity	Diversity of annual and temporary crops	A1	14	14	33
	Diversity of perennial crops	A2	14	12	
	Animal diversity	A3	14	12	
	Enhancement and conservation of genetic heritage	A4	6	10	
Organization of the space	Cropping patterns	A5	8	10	33
	Dimension of fields	A6	6	8	
	Organic matter management	A7	5	6	
	Ecological buffer zones	A8	12	8	
	Measures to protect the natural heritage	A9	4	7	
	Storage rate	A10	5	2	
	Fodder area management	A11	3	2	
Farming practices	Fertilization	A12	8	9	34
	Organic processing	A13	3	3	
	Pesticides	A14	13	14	
	Animal well-being	A15	3	3	
	Soil resource protection	A16	5	5	
	Water resource protection	A17	4	4	
	Energy dependence	A18	10	8	
Grand total					100

Source: Adapted from [6]

2.2 Study area

Located between 9° 30' N and 2° 15' E [15], Benin is a West African country, bordered at north by Niger, at north-west by Burkina-Faso, at south by the Atlantic Ocean, at east by Nigeria and at west by Togo. Administratively, Benin counts twelve departments. But according to[16], agro-climatically, it counts height Agro-Ecological Zones (AEZ). The study zone (South and the Centre Benin) covered height departments: Zou, Collines, Ouémé, Plateau, Atlantique, Littoral, Mono and Couffo. There are four AEZ in these regions: Cotton zone of Centre Benin (AEZ 5); zone of bar lands (AEZ 6); depression zone (AEZ 7) and fishing zone (AEZ 8).

This research targeted the following departments: Atlantique, Plateau, Couffo, Zou and Collines. In each department, two municipalities were selected, the one with the largest cultivable surface and the other with the lowest cultivable surface doing a total of ten selected municipalities. In each municipality, two villages were selected with the help of the extension agents of the Ministry of Agriculture, Breeding and Fishing. The selection criteria were the level of urbanization and the geographic position. Twenty villages were then selected in the ten municipalities distributed in three AEZ (AEZ 5, AEZ 6 and AEZ 7) out of the four AEZ of South and Centre Benin (figure 1).

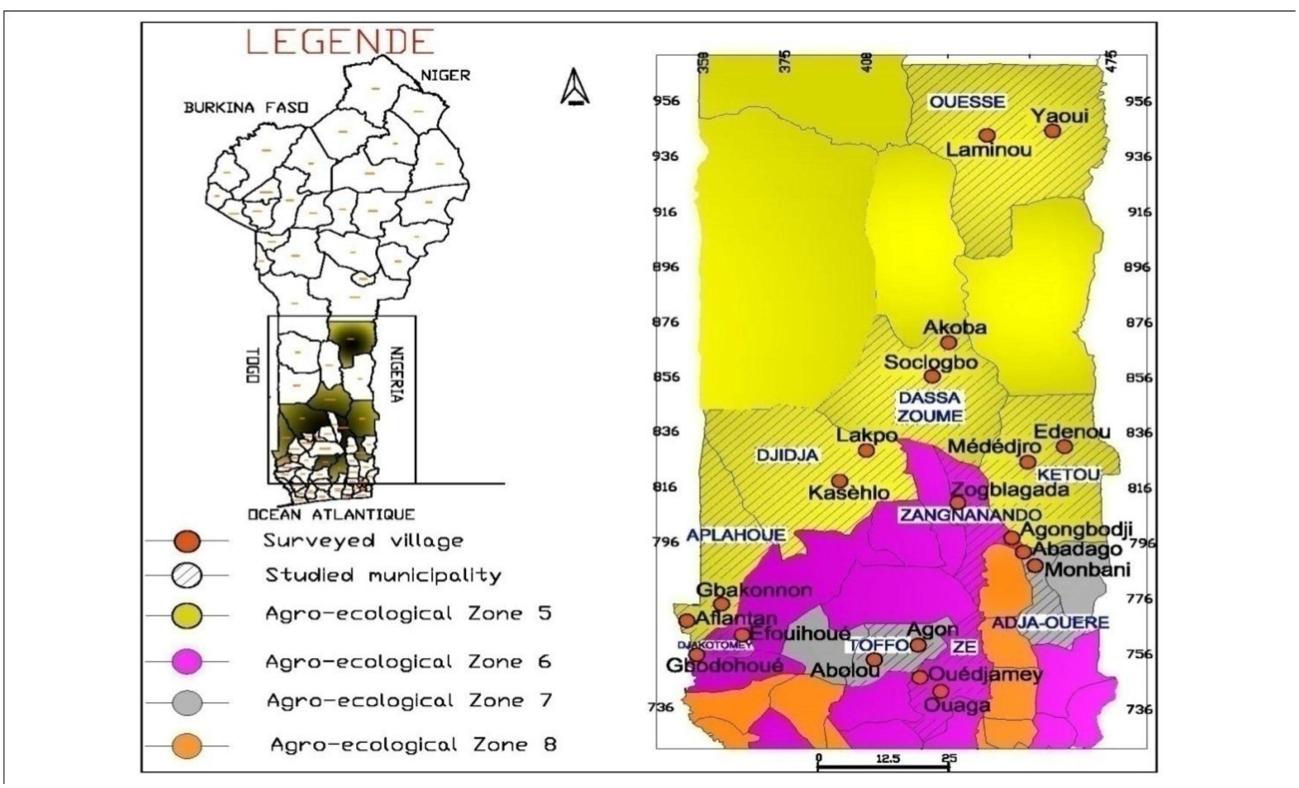

Figure 1: "Map of the study showing study villages"

2.3 Sampling and data collection

In each selected village, producers were stratified based on farm sizes in small, medium and big producers. Twenty producers were selected in each village. The proportion of each stratum in the sample was calculated based on its proportion in the village. In each stratum, producers were randomly selected. In total, four hundred producers were selected using random and stratified sampling techniques.

The adapted IDEA method was used as a tool for data collection at producers' level. Required data were collected using a semi-structured questionnaire derived from the original IDEA questionnaire. Data collected were relative to farmers' socio-economic and demographic characteristics, components of measurement of agro-ecological sustainability from the adapted IDEA (different fallows in practices in maize production).

2.4 Methods of Data analysis

Two main types of analysis were made for assessing the level of farm agro-ecological sustainability. We started by the calculation of the score of agro-ecological sustainability for each indicator based on the adapted IDEA and then by mean comparison test, the difference between indicators was pointed out. An econometric modeling approach was used later to determine the effect of fallow practices on the level of farm agro-ecological sustainability.

2.4.1 Calculations and statistical tests

The scores of each indicator, each component as well as the aggregated scores for the whole farm agro-ecological sustainability were calculated following the adapted IDEA method [6, 7, 9]. Means comparison tests were made to identify the variation of scores across regions or AEZ [17, 18]. Finally, average scores were summarized in graphs.

2.4.2 Model specification

To determine the effect of fallow practices on the level of agro-ecological sustainability, an econometric model was used [19, 20]. In fact, the score of agro-ecological sustainability was the dependent variable in the model. This variable is a set of positive values (one hundred at most). The main explanatory variables were the types of fallow. These dummy variables were of small variability. In this case, the suitable model for a good robustness is the log-log model [19].

Let's suppose that LNSUSTECi is the naperian logarithm of the agro-ecological sustainability score of the farm i; FALCASHi is the practice of fallow with cashew trees in the farm i; FALPALMi is the practice of fallow with palm trees in the farm i; FALNATi is the practice of natural fallow in the farm i; Xi are the set of others characteristics of the farm i and *f* is a function.

LNSUSTECi= f(FALCASHi, FALPALMi, FALNATi,Xi) *(1)*

According to [6], a set of Xi variables namely type of seed (TYPSE), use of chemical fertilizers (FERTCHEM), use of pesticides (WEEDKIL), agro-forestry practice (AGROFOR), breeding practice (BREED) and mechanization of activities (MECAGRO) can affect the level of agro-ecological sustainability of a farm i. In addition to these variables, we inserted in the model, the naperian logarithm of the available surface (LNSURAVAIL); the naperian logarithm of the duration of field exploitation (LNTIM) and the naperian logarithm of the proportion of sold maize (LNPSOL), indicator of production goal. According to [21], some important farmers' characteristics such as agro-ecological zone (AEZ); sex of the farmer (GEND); age (AGE); education (EDUC); contact with public extension service (CSCDA); contact with project (CPROJECT) and contact with agricultural research center (CRESEAR) can affect farm performance. Therefore, these variables were included in the model. The age of the producer was inserted using naperian logarithm (LNAGE). The variables AEZ 5, AEZ 6 and AEZ 7 were used as a dummy variable and included in the model with AZE5 as a base. As result, the mathematical specification of the empirical model can be expressed as follow:

$$LNSUSTBECi = \lambda_0 + \lambda_1 FALCASHi + \lambda_2 FALPALMi + \lambda_3 FALNATi + \lambda_4 AEZ6i + \lambda_5 AEZ7i + \lambda_6 CSCDAi + \lambda_7 CPROJECTi + \lambda_8 CRESEARi + \lambda_9 TYPSEi + \lambda_{10} FERTCHEMi + \lambda_{11} WEEDKILi + \lambda_{12} AGROFORi + \lambda_{13} BREEDi + \lambda_{14} EDUCi + \lambda_{15} GENDi + \lambda_{16} MECAGROi + \lambda_{17} LNAGEi + \lambda_{18} LNSURAVAILi + \lambda_{19} LNTIMi + \lambda_{20} LNPSOLi + \mu_i \quad (2)$$

with μ_i = error terms

The equation (2) was estimated using Ordinary Least Square (OLS) method. λi were the parameters to be estimated. The signs of λ_1, λ_2 and λ_3 represented the effects of the types of practiced fallows on the level of maize farm agro-ecological sustainability in Southern and Center Benin.

3. RESULTS AND DISCUSSION

3.1 Agro-ecological sustainability of maize production systems in southern and Center Benin

Results from the means comparison tests showed that scores of each component of farm agro-ecological sustainability differed between regions and agro-ecological zones (AEZ) in maize farming systems in Southern and Center Benin (Table 2). In fact, the t value of Student and the F value of Fisher were significant at the statistical threshold of 1% or 5% for all components (table 2). In addition, the total score of agro-ecological sustainability varied significantly only with the AEZ (table 2). Results revealed that maize production systems were relatively agro-ecologically sustainable (figure 2). While maize farming systems were more sustainable in AEZ 6, they were less sustainable in AEZ 5 (figure 2). In terms of agro-ecological sustainability, the component “organization of the space” was the principal weak point of the maize production systems while the component “farming practices” was the principal strength point (figure3 and figure 4). In general, the score of “organization of the space” was less than 10/33 while the one of “farming practices” was more than 28/33 (figure 3 and figure No. 4).

These results have corroborated with those of other researchers. [2] defined and applied the Participatory Indicator Based (PIB) approach to select suitable indicators with stakeholders as well as threshold values for these indicators. They found that maize farming was sustainable in Northern Benin as the average value of the score of sustainability was above the threshold values. Although these authors used different measures, they found that maize farming was agro-ecologically sustainable in northern Benin. Besides, in terms of geographical repartition, the present research completes the one of [2] but with different locations.

Table No. 2: “Results of comparison tests of agro-ecologic sustainability scores”

Agro-ecological sustainability		Comparison by region		Comparison by Agro-ecological Zone (AEZ)	
		T test of Student	Significance (P value)	ANOVA test of Fisher	Significance (P value)
Component	Domestic diversity	5.33	0.00	34.82	0.00
	Organization of the space	-7.19	0.00	9.22	0.00
	Farming practices	-3.83	0.00	4.97	0.01
Total index of farm agro-ecologic sustainability		0.41	0.68	18.37	0.00

Moreover, the average score of agro-ecological sustainability of maize production systems in northern Benin is about 55/100 [2] while it is about 62/100 in southern and central Benin. [22] assessed the agro-ecological sustainability of agriculture in Gogounou municipality (northern Benin) using IDEA techniques and found as well that farmers practice an agro-ecologically sustainable agriculture.

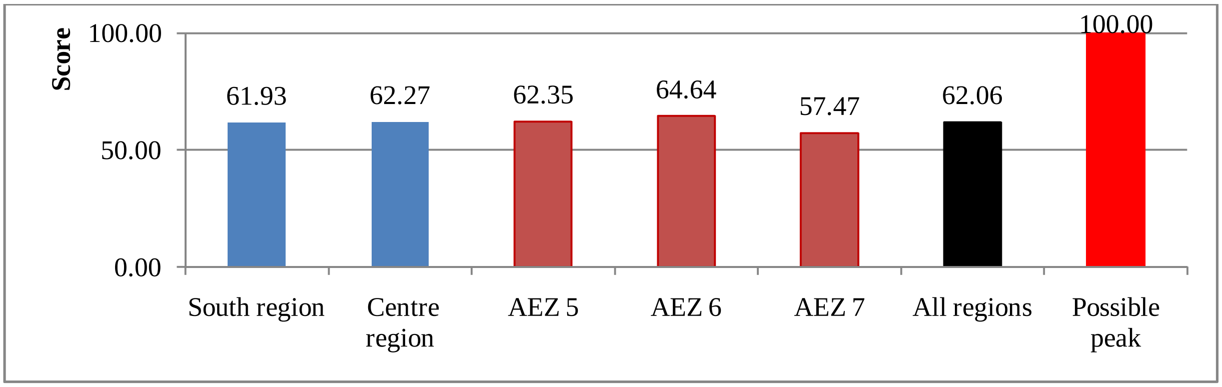

Figure 2: "Agro-ecological sustainability scores of maize production systems in Southern and Center Benin"

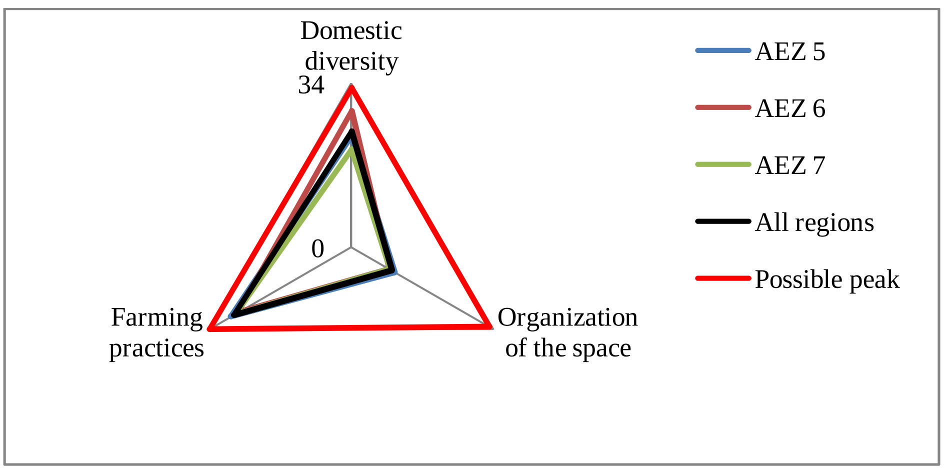

Figure 3: "Scores of Agro-ecologic sustainability components in AEZ of South and Centre Benin"

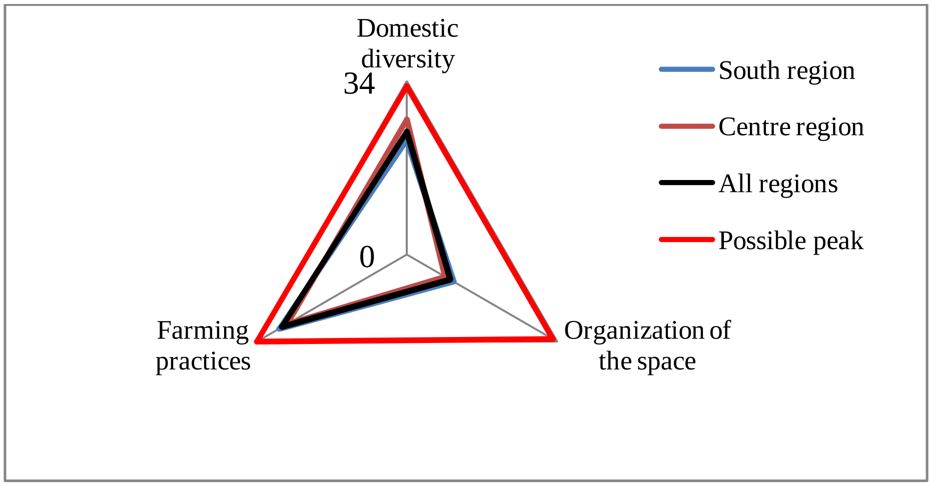

Figure 4: "Scores of components of Agro-ecological sustainability in Southern and Center Benin"

3.1.1 Domestic diversity

As a general picture, maize production systems in Southern and Center Benin showed high score for the component of "domestic diversity". This can be explained by the combination of three types of diversity namely good diversity of annual and temporary crops (A1), good diversity of perennial crops (A2) and a good animal diversity (A3). It is meaningful to mention that maize farming presented mainly good score of sustainability taking into account the aforesaid component (figure 5). However, one of the indicator named "enhancement and conservation of genetic heritage" (A4), had low score value and then can be considered as the principal weak point among all these indicators.

These results tally with [22]. In fact, [22] focused on the whole production system and showed that the component "domestic diversity" contributes strongly to the level of agro-ecological sustainability of farming systems in northern Benin.

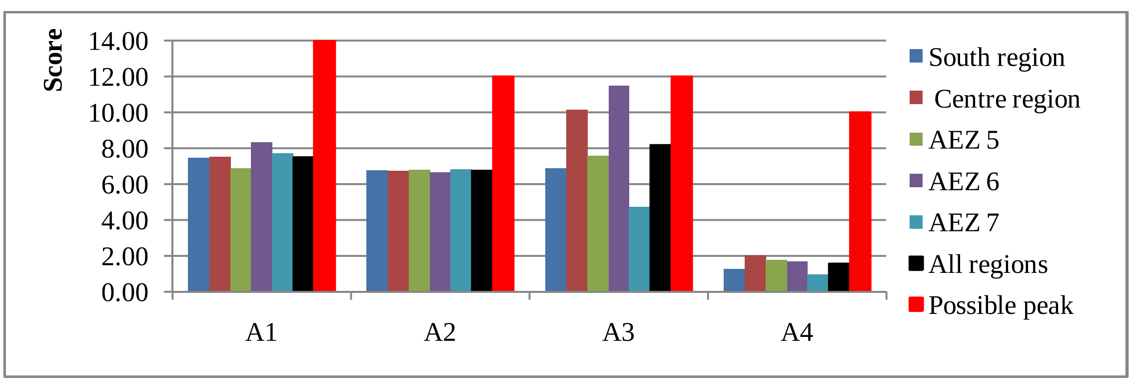

Figure 5: "Scores of domestic diversity indicators"

3.1.2 Organization of the space

On the whole, organization of the space was a major weak point of the agro-ecological sustainability of maize production systems in Southern and Center Benin. Indeed, apart from the indicator “dimension of fields” (A6) for which almost all farms obtained very good score they got weak scores values for other indicators of this component (figure 6). There were some indicators such as “ecological buffer zones” (A8), “stocking rate” (A10) and “fodder area management” (A11) for which all producers obtained zero as score value (figure 6). These results have corroborated with those of [22] who showed that the component “organization of the space” is the principal weak point of that sustainability level. In northern Africa, [23] showed that the component “organization of the space” is the principal weak point in the agro-ecological sustainability of milk producers in Tunisia. However, [24] pointed out also that the organization of the space is a weak point of some farmers but the strength point of some others in organic olive production systems in Tunisia.

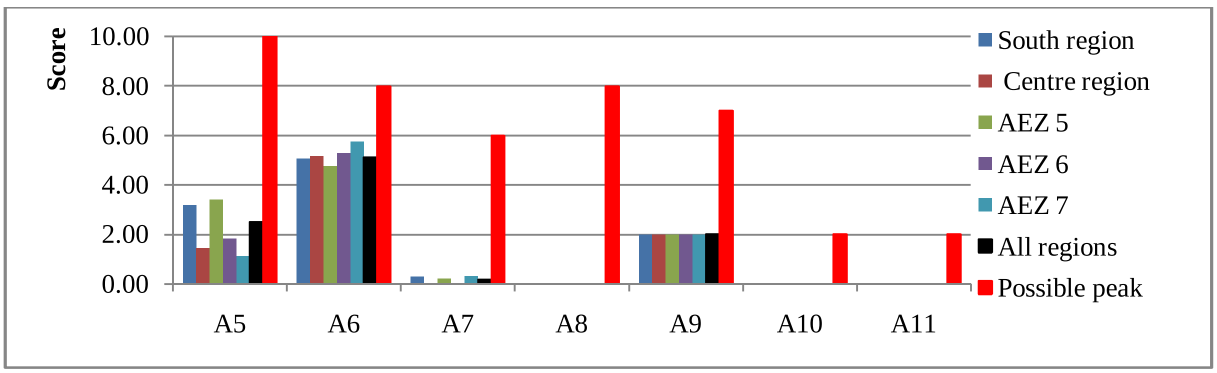

Figure No. 6: “Scores of indicators of organization of space”

3.1.3 Farming practices

This component was the most important strength point of maize production systems in Southern and Center Benin. For some indicators such as “pesticides” (A14), “animal well-being” (A15), “water resource protection” (A17) and “energy dependence” (A18), the producers have obtained very good scores values (7). In contrast, they obtained weak scores values for some indicators namely “fertilizers” (A12) and “organic effluents processing” (A13). Some farmers performed badly- and then have zero score values in regards to “soil resource protection” (A16). Therefore, this indicator is the potential weak point in the component of “farming practices”. According to [22], the component “farming practices” is an important strength point of the level of agro-ecological sustainability of farming systems in northern Benin. That result in northern Benin tallies with those obtained in this research in Southern and

Center Benin. In northern Africa, [23] showed that the component "farming practices" is the principal strength point in the agro-ecological sustainability of milk producers in Tunisia. Moreover, [24] highlighted that farming practices are the most important component in terms of contribution to the level of agro-ecological sustainability of organic olive production farms in Tunisia. In view of all these results, we can assert that African farmers utilize good farming practices which strongly contribute to the ecological sustainability of their production systems.

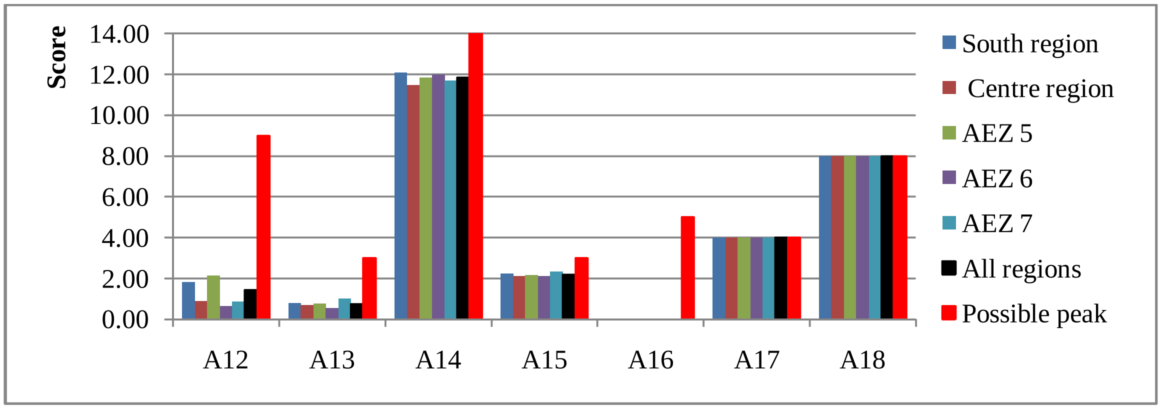

Figure No. 7: "Scores of farming practices indicators"

3.2 Effect of fallow practices on the level of agro-ecological sustainability of maize production systems in southern and center Benin

The estimation of the econometric model of equation (2) enabled to identify the factors affecting the level of agro-ecological sustainability of maize production systems (fallow practices) in Southern and Center Benin. Results showed that the model is globally significant at the statistical threshold of 1% (table 3). Durbin-Waston statistics indicated the absence of significant autocorrelation between error terms. More than 49% (adjusted R^2= 0.49) of the variation in the level of agro-ecological sustainability were explained by the explanatory variables introduced in the model (table 3). Only fallow with palm trees (FALPALM) presented a significant positive effect on the level of maize farming agro-ecological sustainability at the statistical threshold of 1% (table 3). Thus, maize producers of South and Center Benin who practiced fallow with palm trees presented relatively high agro-ecological sustainability scores. Though fallow with cashew trees (FALCASH) did not show significant effect on the level of agro-ecological sustainability level, it had positive effect (table 3). Therefore, planted fallow practices improved the level of agro-ecologic sustainability of maize production systems. As for natural fallow (FALNAT) practices, they had negative non-significant effect on the score of agro-ecological sustainability (table 3) and then unplanted fallow practices decreased the level of agro-ecological sustainability.

The variables such as AEZ, breeding (BREED), duration of soil exploitation (LNTIM) and proportion of sold maize (LNPSOL) presented significant positive effects while contact with research center (CRESEAR), use of improved seed (TYPSE), use of chemical fertilizers (FERTCHEM) and use of herbicides (WEEDKIL) presented significant negative effects (table 3). Consequently, the use of improved seed, chemical fertilizers and herbicides decreased the level of agro-ecological sustainability while the integrated system including breeding and maize production improved the level of agro-ecological sustainability. To our knowledge there are no studies that analyze the factors affecting the agro-ecological sustainability level of farming systems in Africa and this constitutes a limitation. Using an analysis of factors affecting the level of ecological sustainability, this research shows that the practice of planted fallows affects positively the level of ecological sustainability of maize production systems in Southern and Center Benin (West-Africa). Hence, it brings a scientific contribution to the knowledge on the ecological sustainability of agriculture.

Table 3: "Factors affecting the level of agro-ecologic sustainability"

Variables	Description	Statistics[1]	Model	
			Coefficients	Standard error
CONSTANT	Constant	-	3.85(34.97)***	0.11
FALCASH	Did the farmer practice the fallow with cashew trees? (1=yes, 0=no)	41.50%	0.03(1.29)	0.02
FALPALM	Did the farmer practice the fallow with palm trees? (1=yes, 0=no)	21.80%	0.09(3.58)***	0.02
FALNAT	Did the farmer practice the natural fallow? (1=yes, 0=no)	13.50%	-0.00(-0.23)	0.02
AEZ6	Zone of bar lands (1=yes, 0=no)	30.00%	0.07(3.75)***	0.02
AEZ7	Zone of depressions (1=yes, 0=no)	50.00%	-0.01(-0.49)	0.02
CSCDA	Contact with the public extension service (1=yes, 0=no)	83.50%	0.02 (1.04)	0.02
CPROJECT	Contact with the agricultural development projects (1=yes, 0=no)	5.80%	0.03(1.35)	0.02
CRESEAR	Contact with an agricultural research center (1=yes, 0=no)	32.50%	-0.04(-2.30)**	0.02
TYPSE	What type of seed did the producer use? (1=improved, 0=local)	46.70%	-0.13(-9.14)***	0.01
FERTICHEM	Did the farmer use chemical fertilizers? (1=yes, 0=no)	82.80%	-0.07(-4.06)***	0.02
WEEDKILL	Did the farmer use chemical wide killers? (1=yes, 0=no)	56.20%	-0.02(-1.86)*	0.01
AGROFOR	Did the farmer practice agro-forestry? (1=yes, 0=no)	70.00%	0.02(0.68)	0.02
BREED	Did the farmer associate the breeding to the maize production? (1=yes, 0=no)	81.30%	0.06(4.08)***	0.01
EDUC	Did the farmer receive any formal education? (1=yes, 0=no)	46.00%	0.01(1.24)	0.01
GEND	Gender of the farmer (1=male, 0=female)	89.50%	-0.01(-0.34)	0.02
MECAGRO	Did the farmer practice mechanized agriculture? (1=yes, 0=no)	11.80%	-0.01(-0.66)	0.02
LNAGE	Naperian logarithm of farmer age (year)	3.74 (0.24)	0.01(0.33)	0.03
LNSURAVAIL	Naperian logarithm of available surface (ha)	1.82 (0.90)	0.01(0.93)	0.01
LNTIM	Naperian logarithm of duration of maize field utilization (year)	2.57 (0.74)	0.03(3.20)***	0.01
LNPSOL	Naperian logarithm of sold proportion of produced maize (%)	3.90 (0 .40)	0.04 (2.58)**	0.02
Number of observation			376	
F (20 ; 355)			19.20***	
Adjusted R^2			0.49	
Durbin-Waston			1,37	

()= statistic t of Student, *, **, ***=respectively significant at the threshold of 10%, 5%, and 1%

1: Percentage of yes (or percentage of the modality 1) for dummy variables and mean (standard deviation) for the quantitative variables

4. CONCLUSION

The goals of the present paper was to assess the ecological sustainability of maize production systems in Southern and Center Benin (West-Africa) as well as the effect of fallow practices of the level of agro-ecological sustainability. Results show that maize production systems are in average, ecologically sustainable. In addition, the planted fallow practices affect positively the level of farm ecological sustainability. Two components of agro ecological sustainability such as “farming practices” and “domestic sustainability” are the strength points of the maize production systems while the component “organization of the space” is the weak point of these systems in terms of contribution to the level of ecological sustainability. Therefore agricultural policies makers should promote planted fallow practices in Benin production systems in order to improve the ecological sustainability of agriculture.

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