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IMPACT OF RAIN-FED RICE CROPPING SYSTEMS ON SOIL FERTILITY IN CENTRAL AND NORTHERN BENIN

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ABSTRACT

Benin has tremendous asset for rice production. However, nationwide, rice production is characterized by a low level of productivity due to inadequate agricultural practices. In order to evaluate the effect of the rain-fed rice cropping systems on soil fertility in northern and central Benin, 362 rain-fed rice farmers were surveyed in the municipality of Banikoara, Kandi, Ouèssè and Glazoué in Benin. Soil samples were taken from the rice fields and analyzed at laboratory for the determination of physicochemical parameters. Three main rain-fed rice cropping systems were identified. In northern Benin, two cropping systems predominated. The system 1 was characterized by no use of fertilizers and use of crop residues as animal feed while in the system 2 less than 100 kg/ha of fertilizers was used and crop residues were also used as animal feed. The predominant cropping system in central Benin, was characterized by use of 100 and 200 kg/ha of fertilizers and crop residues were left in the fields (system 3). The soils of the system 1 had a very low fertility with low organic carbon (0.19 ± 0.12%), low available phosphorus (7.17 ± 3.56 mg/kg) and low potassium exchangeable (0.13 ± 0.10 cmol/kg). The soils of the system 3 which showed low, medium and good fertility in some places with higher average organic carbon (0.88 ± 0.25%), higher available phosphorus (13.03 ± 6.63 mg/kg) and higher potassium exchangeable (0.24 ± 0.08 cmol/kg). The average rice cropped per farmer was around 2 ha in central Benin and less than 1 ha in northern Benin. Farmers' management of soil fertility didn't take account soil specifics conditions and suitable production. To improve the productivity of the cropping systems, it is necessary to determine the optimal doses of fertilizer and incorporate crop residues into the soil to ensure sustainable rice production.

Keywords : rice productivity, animal feed, crop residues, declining of soil fertility

IMPACT DES SYSTÈMES DE CULTURE DU RIZ PLUVIAL SUR LA FERTILITÉ DES SOLS AU CENTRE ET AU NORD BÉNIN

RÉSUMÉ

Le Bénin dispose des potentialités non négligeables pour la production du riz. Cependant, cette production est caractérisée par des faibles rendements dus à des pratiques agricoles inadéquates. Ainsi, dans le but d'évaluer l'effet de ces systèmes de culture du riz pluvial sur la fertilité des sols au nord et au centre Bénin, une enquête a été effectuée auprès 362 producteurs du riz pluvial dans les communes de Banikoara, Kandi, Ouèssè et Glazoué. Des échantillons de sols ont été prélevés au niveau des périmètres rizicoles. Ils ont été ensuite expédiés au Laboratoire des Sciences de sol, Eaux et Environnement pour la détermination des paramètres physicochimiques. Cette enquête a permis d'identifier trois principaux systèmes de culture du riz pluvial. Au nord Bénin, deux systèmes sont majoritairement pratiqués par les producteurs. Le système 1 où les producteurs n'utilisent pas d'engrais et les résidus de récolte servent à l'alimentation des animaux et le système 2 où les producteurs utilisent moins de 100kg/ha d'engrais et les résidus de récolte servent également à l'alimentation des animaux. Par contre au centre Bénin, où le système 3 est plus pratiqué, il y a une utilisation d'engrais à des doses comprises entre 100 et 200 kg/ha et les résidus de récolte sont laissés aux champs. Les sols sur lesquels sont pratiqué le système 1 ont une fertilité très faible avec un faible taux de carbone organique (0,19 ± 0,12%), de phosphore assimilable (7,17 ± 3,56 mg/kg) et de potassium échangeable (0,13 ± 0,10 cmol/kg) contrairement aux sols sur lesquels sont pratiqué le système 3 qui ont une fertilité faible, moyenne et bonne par endroit avec un taux relativement élevé de carbone organique (0,88 ± 0,25), de phosphore assimilable (13,03 ± 6,63 mg/kg) et de potassium échangeable (0,24 ± 0,08 cmol/kg). Les superficies emblavées pour la production du riz avoisinent en moyenne 2 ha au centre Bénin et sont par contre inférieures à 1 ha au nord Bénin. La gestion de la fertilité des sols sous le riz pluvial, telle pratiquée par les producteurs, ne tient donc pas compte des conditions spécifiques des sols et de la durabilité de la production. Ainsi pour améliorer la productivité des systèmes de culture du riz pluvial, il est nécessaire de déterminer des doses optimales des fertilisants et de restituer les résidus de récoltes pour une durabilité des systèmes.

Mots clés : productivité du riz ; alimentation des animaux, résidus de récoltes, baisse de fertilité du sol

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important food crops worldwide (Jamila *et al.* 2013). It is a staple food crop for more than half of the world population (Md. Anzer and Manoj, 2015) and it accounts for more than 22 % of world's population calorie intake, with Asia and Africa being the largest consuming regions (Flavia *et al.* 2017). Agboh-Noameshie *et al.* (2007) report that during the last three decades, rice consumption in Africa, especially in Benin experienced a drastic increase that has led to a lesser extent to the increase of the national productions. The rice consumption in Benin, constantly increasing and could even reach 45.7 kg per habitant per year (Abel, 2009). In recent decades paddy rice production has increased from 54 901 in 2002 to 250 000 tons in 2014 (MAEP, 2010; Saidou *et al.*, 2014; Konnon *et al.*, 2014). However, the national rice production doesn't cover the rice needs of the population. Benin imports then each year important quantities of rice to meet the needs of its population although it has tremendous assets to produce rice and become self-sufficient (Adegbola *et al,* 2002).

Despite the available potentialities to improve rice production in Benin, the crop records extremely low yield (Adégbola & Sodjinou, 2003; Saïdou & Kossou, 2009 ; Saidou *et al.*, 2014). This low productivity is a direct result of inadequate agricultural practices. In fact, an effective soil nutrient management is an essential component of crop production, responsible for increasing and sustaining crop yield (Flavia *et al.* 2017). Declining productivity stem from improper and inefficient uses of nutrients (Ghosh *et al.* 2014). Inappropriate nutrient management has resulted in imbalance nutrients in the soil. Therefore, there is need to evaluate the influences of rain-fed rice cropping systems on soil fertility to establish a background information for developing better alternative to limit mineral deficiency in rain-fed rice production. In such context, the main question is what are the main rain-fed rice cropping systems in regard to soils fertility management implemented by farmers in Benin? And what are the impacts of these systems on the soils fertility? The goal of this research was to evaluate the effect of the rain-fed rice cropping systems on soil fertility in northern and central Benin.

MATERIAL AND METHOD

Study area

This study was conducted in Benin, located between latitudes 6°10 N and 12°25 N and longitudes 0°45 E and 3°55 E (Akoègninou *et al.*, 2006) and covering a total area of 114763 km^2. The country is subdivided into 12 administrative Departments divided into three geographical zones, namely the south, the center and the north (Akoègninou *et al.*, 2006; Gbaguidi *et al.*, 2015). In this study, northern Benin is represented by Banikoara and Kandi municipalities; Central Benin, by Ouèssè and Glazoué municipalities.

The northern zone of Benin (Department of Alibori) is located between 10°31'19'' and 11°45'00'' of latitude north and between 2°3'00'' and 3°16'30'' of east longitude (Mama *et al.*, 2013) characterized by tropical climate (Hountondji, 2008), whose seasonal rhythm is influenced by the movement of the intertropical front (Afouda *et al.*, 1999 ; Hountondji, 2008). The average annual rainfall is around 850 mm (Mama *et al.*, 2013). The soils are Ferruginous tropical leached concretions on sand-clay sediments. This region is the major cotton growing area in Benin.

The central Benin has a subequatorial climate. It influenced by the southern Sudanian area with a dry season and a rainy season. Average annual rainfall is around 1,100 mm. Ferruginous tropical soils with or without concretions and medium fertility, Vertisols and hydromorphic soils characterize the central Benin (Capo-Chichi, 2006; Kouelo *et al.*, 2012).

Sampling method and data collection

The number of respondents was determined using the normal approximation of the binomial distribution proposed by Dagnelie (1998) :

$Ni = [(U_{1-\alpha/2})^2 \times pi(1-pi)]/d^2$;with $U_{1-\alpha/2}$ the value of the normal random variable for a probability of $1-\alpha/2$, where α being the type I error. For $\alpha = 5$ %, the probability $1-\alpha/2 = 0.975$ and we have $U_{1-\alpha/2} = 1.96$ pi is the proportion of people engaged in rice production in the study environment and d the estimation margin error, which is 5 % for this study. A*i*, the percentage of farmers engaged in rice production in a municipality, A*i* = Ac*i*/At*i* (Ac*i*, the number of farmer of a municipality engaged in rain-fed rice production and At*i* the total number of farmer of all the municipalities). The sample size of each municipality would be: n = A*i**N*i*. In each municipality, farmers were identified using simple random sampling. Thus, in total, three hundred and sixty-two (362) farmers including ninety-six (96), seventy-six (76), ninety-two (92) and ninety-eight (98) in Banokoara, Kandi, Ouèssè and Glazoué respectively. This municipalities were chosen on the basis of rice cultivation by farmers and they also belong to research and development sites of National Institute for Agriculture Research in Benin.

Data collected include socio-economic characteristics of farmers (age, sex, production experience, cultivated area, contribution to the household income, land tenure system), cultural practices of rain-fed rice farmers, management of soil fertility, the farmers' perception on soil quality. Composite soil samples were taken from the rice fields of farmers and were analyzed at laboratory of Soil Science, Water and Environment in National Institute of Agricultural Research of Benin (INRAB) for the determination of physicochemical parameters.

Soil sampling method

Composite soil samples were collected at a depth of 00-20 cm in the different rice fields. Samples were taken from the soil where only rice is grown. In fact, because of flooding of these soils during the rainy seasons, no crop rotation was carried out on the soils sampled. The elementary samples were collected randomly. At least 16 elementary samples were collected per rice field as recommended by Schvartz *et al.* (2005). These elementary samples were collected to form a composite sample per field and per farmer. In total, 277 composite soil samples were collected from 277 farmer fields out of the 362 farmers surveyed.

Soil fertility assessment

Soil fertility status assessment was based on analysis and interpretation of data such as soil organic matter content, total nitrogen content, available phosphorus and exchangeable potassium content, pH, sum of bases and cation exchange capacity. Soil fertility levels were identified by the method of maximum limitations according to the criteria defined in Table 1

Table 1. Criteria for Evaluating Classes of Soil Fertility (Igué *et al.*, 2013)

Characteristics	Fertility level				
	Very good Degree 0	good Degree 1	medium Degree 2	low Degree 3	very low Degree 4
Organic matter (%)	> 2	2 – 1.5	1.5 - 1	0.5	< 0.5
Total nitrogen (%)	> 0.08	0.08-0.06	0.06-0.045	0.045-0.03	< 0.03
Phosphorus (mg/kg) ($Bray_1$)	> 20	20 - 15	15 - 10	10 - 5	< 5
Potassium (cmol/kg)	> 0.4	0.4 – 0.3	0.3 – 0.2	0.2 – 0.1	< 0.1
Sum of bases (cmol/kg)	> 10	10 - 7,5	7.5 - 5	5 - 2	< 2
Saturation in bases (V)(%)	> 60	60 - 50	50 - 30	30 - 15	< 15
Cation exchange capacity (cmol/kg)	> 25	25 - 15	15 - 10	10 - 5	< 5
pH	5.5-6.5 6.5-8.2	5.5-6.0 6.5-7.8	5.5-5.3 7.8-8.3	5.3-5.2 8.3-8.5	< 5.2 >8.5

Data processing and analysis

Quantitative data from the individual survey were submitted to an analysis of variance (ANOVA) using the *aov* function of R software version 3.5.1. Multiple mean comparisons was performed using the Student Newman-Keuls test (Dagnelie, 1986) with *SNK.test* function of the *Agricolae* package in R (de Mendiburu, 2014). A Multiple Correspondence Analysis (MCA) was performed on cropping system-related survey data with the *MCA* function of the *FactoMineR* package (Husson *et al.*, 2014). This multi-correspondence analysis was followed by an ascending hierarchical classification carried out using the *HCPC* function of *FactoMineR*. This allowed us to identify the dominant cropping systems and the distribution of farmers according to the systems. To analyze the possible links between farming systems and agro-ecological zones, gender and education level, the Chi^2 tests were performed using the Chisq.test function. To identify the determinants of farmers' perception of soil quality, an ordinal polytomic logical regression was carried out between perceptions and variables such as municipality, experience in production, size of households, planted areas, contribution of the rice production to income and the NPK and urea doses using the *vglm* function of

VGAM package (Yee, 2013). Correspondence analysis was performed using the *CA* function of *FactoMineR* package (Husson *et al.*, 2014) to visualize the association between cropping systems and towns and between the level of soil fertility and cropping systems.

RESULTS

Characteristics of rain rice farmers

Fifty-six percent (56 %) of the 362 respondents were engaged in agriculture (crop production and/or breeding) alone while 44 % combined agricultural activity with other activities such as craft, commerce and service provision. Eighty-one percent (81 %) of the respondents were male and 19 % were female. Fifty-four percent (54 %), 24 %, and 22 % of farmers were illiterate, primary school leavers and secondary school or tertiary school leavers, respectively. The age of farmers varied between 17 and 80 years and from the households size ranged from 4 to 12 peoples. There was no significant difference between the municipalities in terms of age, household size, available and harvested areas, the time of land use and experience of farmers (Table 2). Significant difference in rice planted areas per farmers was found between the municipalities. Rain-fed rice production is more important in the central where the highest cropped area per farmers were recorded (2.03 ± 0.98 ha in Ouèssè) compared to the northern region where the lowest rice planted area was recorded (0.58 ± 0.44ha in Kandi). Eighty-seven percent (87 %) of farmers do not belong to any farmers based organization. Seventy-nine percent (79 %) of the farmers grew rain-fed rice for self-consumption and marketing whereas 13 % and eight percent grew rice for own consumption and exclusively for marketing, respectively.

Most farmers (80 %) reported that they earned significant income from rice production. Heritage was the commonest (85 %) for the respondents. Eighty-seven percent (87 %) of farmers self-funded their rice production while 13 % had access to loans from microfinance institutions and individual lenders. Thirty-seven percent (37 %) of farmers used only family labor for rice production. whereas, 60 % of the farmers relied on family labor and hired labor for at least one cropping operation. Only three percent of farmers relied exclusively hand casual employee labor for rice production.

Table 2. Socio-economic characteristics of rain rice farmers by towns

Town	Age (years)	Household size (person)	Available area for agriculture (ha)	Area exploited for agriculture (ha)	Rice planted Area (ha)	Experience in rice production (years)	Duration of exploitation of the land to grow rice (years)
Banikoara	38.33±10.22a	6.66±2.46a	10.32±8.12a	9.37±7,36a	0.85±0.76b	10.28±6.51a	10.20±6.22a
Kandi	39.75±6.60a	6.30±2.82a	10.84±10.02a	9.42±5.42a	0.58±0.44b	10.56±7.35a	9.86±6.01a
Ouèssè	39.43±9.98a	7.02±1.62a	13.46±6.28a	11.06±5.45a	2.03±0.98a	8.45±5.48a	8.56±5.59a
Glazoué	38.45±5.31a	7.26±1.45a	9.90±7.12a	8.35±6.04a	1.95± 1.24a	7.73±3.70a	7.73±3.70a
P-value	0.78	0.237	0.109	0.222	< 0.0001	0.06	0.09

The means followed by the same alphabetical letters and for the same variables are not significantly different (P > 0.05) according to the Student Newman-Keuls test.

Rain-fed rice Cropping Systems

Rain-fed rice sowing periods varied from one area to another. In northern Benin, most farmers usually plant rice from mid- July to early August. In central Benin, rice was sown in July by most farmers. Thirty-eight percent (38 %) of farmers purchased seeds from official structures and 16 % purchased from the local market. Forty-four percent (44 %) of farmers used own saved seeds. Forty-eight (48 %) of farmers use improved varieties compared to 52 % who used local varieties. Seventy-eight percent (78 %) and 22 % of rice farmers produced wetland and upland rice, respectively.

The multiple correspondence analysis performed on cropping systems variables (variety type, tillage method, sowing mode, type of rice cultivation, NPK dose, urea dose and utilization of crop residues) shows that the first four (4) axis account for 58.94 % of the information related to these variables which are also correlate with the axis (Table 3). This amount of information explained by these axes is enough to obtain sufficiently distinct systems from each other through an ascending hierarchical classification.

Three cropping systems emerged from the ascending hierarchical classification results (Figure1). System 1 includes farmers who didn't use or used less than 50 kg/ha of NPK fertilizer and urea, adopted local varieties, practiced direct sowing and left crop residues in the fields. The system 2 includes farmers who used NPK fertilizers and urea at doses between 50 and 100 Kg/ha. They practiced harness tillage with direct sowing of local varieties and use crop residues as animal feed. System 3 is characterized by farmers who used NPK and urea fertilizers at doses between 100 and 200 kg/ha. They practiced manual tillage or tractor tillage with direct sowing or sometimes nurseries with improved seeds and crop residues are left in the fields. Farmers who used NPK and Urea fertilizer doses below 50 kg/ha, practiced manual tillage and then left crop residues in the fields are opposed to farmers who used more than 50 kg/ha of NPK fertilizer and urea and practiced harness or tractor tillage (Figure 2). Farmers who adopted system 2 were opposed to those who adopted the system 3 (Figure 2). System 2 was the most widely adopted, with 49% of the surveyed rice farmers followed by system 3 (29% of farmers). In all of those rice cropping systems, crop rotation wasn't practiced. Farmer grown rice on the same soil each years because of flooding during rainy seasons that didn't allow them to grow another crop.

Table 3. Correlation coefficients between canonical axis and variables characteristic of cropping systems

Variable	Axis1	axis2	axis3	Axis4
NPK dose	0.39	0.30	0.56	0.15
Urea dose	0.30	0.38	0.70	0.04
Type of rice cultivation	0.11	0.33	0.05	0.21
Type of variety	0.50	0.00	0.01	0.03
tillage method	0.40	0.59	0.15	0.048
Seeding mode	0.28	0.01	0.09	0.08
Use of crop residues	0.41	0.56	0.15	0.63

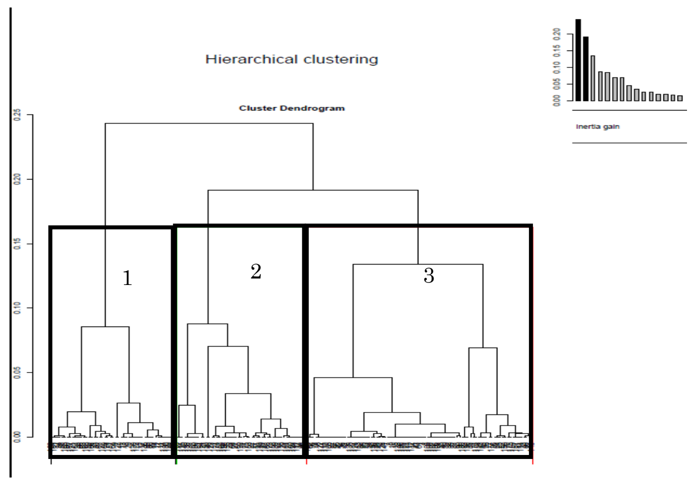


Figure1. Dendrogram relating to the ascending hierarchical classification

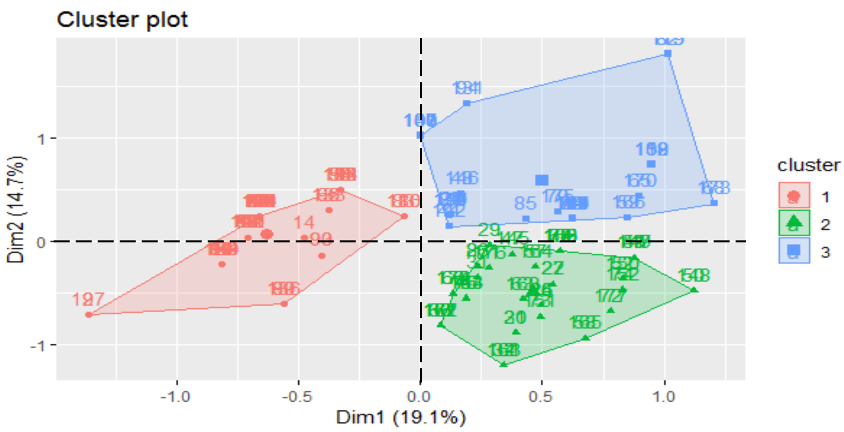


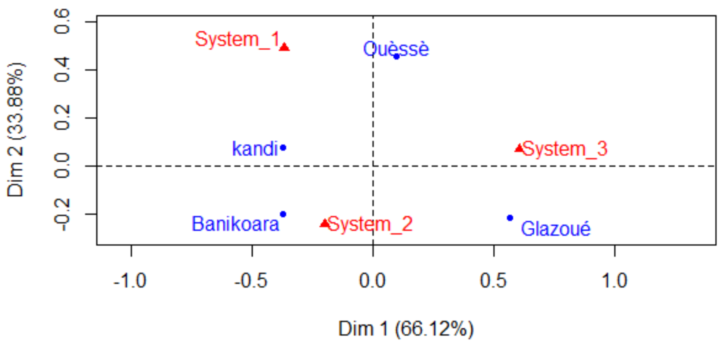
Figure 2. Grouping of farmers in the plan (Axis 1, Axis 2)

Characterization of the cropping systems according to the socio-economic groups

Analysis of variance revealed no significant difference between the cropping systems in terms of ages of farmers, household sizes, and area available to farmers. But, there was a significant difference between the cropping systems in terms of areas allocated to rice production (Table 4). Moreover, the independence test Chi² showed that the choice of a cropping system by a farmer depended strongly of its municipality (Chi² = 42.3762 ; $p < 0.0001$). This choice was independent of his level of education (Chi² = 8.4918 ; p = 0.2042) and gender (Chi-square = 1.8091 ; p = 0.4047). The results of the correspondent analysis (Figure 3) showed that the farmers of Banikoara and Kandi practiced more the systems 1 and 2 while the system 3 was predominant in Glazoué and Ouèssè. However there were some farmers of Ouèssè who practiced the system 1 and other of Glazoué who practiced the system 2.

Table 4. Socio-economic characteristics of rain-fed rice farmers according to cropping systems

System	Ages (years)	Household size (person)	Available area for agriculture (ha)	Rice area (ha)	Experience in rice production (years)	Duration of land use to grow rice (years)
System_1	39.73±9.72a	6.91±2.36a	12.16±7.83a	1.17±0.88b	10.04±7.62a	9.59±6.10a
System_2	38.33±8.10a	6.67±2.22a	11.02±8.82a	1.27±1.16b	9.45±5.79a	9.61±5.95a
System_3	39.26±7.22a	7.18±1.64a	10.38±5.93a	1.83±1.10a	7.81±3.95a	7.8 ±3.95a
P-value	0.633	0.358	0.56	0.004	0.091	0.136



The averages followed by the same alphabetical letters and for the same variables are not significantly different (P> 0.05) according to the Student Newman-Keuls test.

Figure 3. Representation of systems and towns in the plan (Axis 1, Axis 2)

Perception of farmers on soil quality

The farmers differentiate four levels of fertility of the soils they exploit (good fertility, medium fertility, low fertility and very low fertility). The results of ordinal logistic regression (Table 5) showed that variables such as: the rice planted area, the contribution of rice to income, the doses of NPK fertilizer and Urea, had a significant impact on the perception of farmers on the quality of their soil ($|z| > 2$). In fact, as the rice planted area increased and/or when the contribution of rice to income was high, farmers gave a good appreciation of the soil. However, when the amount of fertilizer NPK applied was high, the farmers perceived that their soils were poor.

Correspondence analysis (Figure 4a) shows that the rice farmers in Banikoara and Kandi considered their soils to be of medium fertility, low and very low fertility. Overall, farmers in Ouèssè and Glazoué considered their soils as fertile. However, there were some farmers in Ouèssè who perceived their soil as being of moderate or low fertility. Farmers who practiced the system 3 perceived that their soil as being fertile while farmers who adopted the systems 1 and 2 considered that their soils are moderately and/or poorly fertile (Figure 4b).

Table 5. Factors that influence farmer's perception on soil fertility

variables	coefficients	Z-Value
Sex / man	-0.23	-0.37
Level of education	-0.26	-1.04
Household size	0.15	1.37
Membership in a group	-0.40	-0.59
Planted area for rice	-0.72	-2.22*
Rice growing	0.77	1.42
Contribution of rice to income	-0.95	-2.42*
Experience in production	0.02	0.16

variables	coefficients	Z-Value
Duration of land use	0.00	0.01
Evolution of yields	0.15	0.33
Local variety	0.24	0.50
Type of tillage	0.38	0.74
Manual method	-0.45	-0.82
Method by the tractor	16.52	0.01
NPK fertilizer dose	0.02	2.54*
Urea fertilizer dose	-0.01	-2.36*

*Significant at the 0.05 level

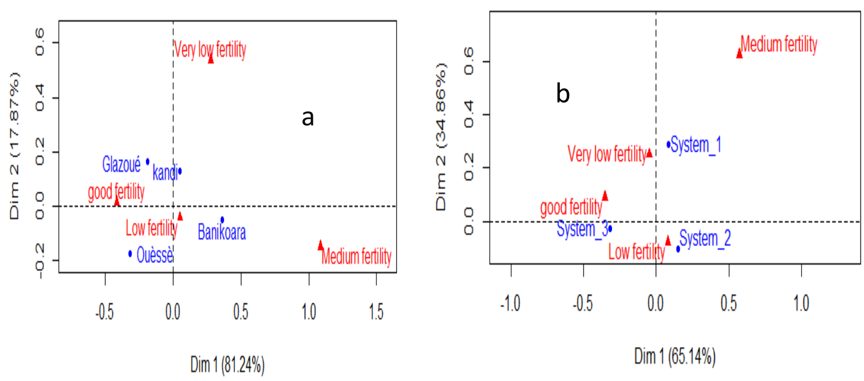


Figure 4a & 4b. Representation of the perceptions of farmers on soil fertility according to the towns (a) and cropping systems (b) in the plan (Axis 1, Axis2)

Fertility level of rain-fed rice soils based on analysis of soil samples in the laboratory

The analysis of variance carried out on the soil chemical parameters (organic carbon, total nitrogen, assimilate phosphorus, exchangeable potassium, cations sums, cation exchange capacity and pH) of various cropping systems (Table 6) revealed significant difference between the cropping systems. In fact, the soils of the system 3 had higher organic carbon content than those of system 2 and system 1. The organic carbon content of system 1 soils was very low (0.19 ± 0.12). The highest nitrogen content was recorded in the system 2 (Table 6). Phosphorus content was similar across the cropping systems. The highest potassium content was recorded in system 2 and system 3. The cation exchange capacity of system 3 soils was significantly higher compared to that of system 1 and system 2 soils.

The Chi square test carried out between the municipalities and the soil fertility level sampled showed that there was a strong dependence between the soil fertility level and the municipalities ($Chi^2 = 60.11$; $p < 0.0001$). The correspondence analysis (figure 5) revealed that overall the soils of sampled in Ouèssè and Glazoué had good, medium and low fertility levels, and the soils of Banikoara and Kandi had a very low level of fertility. In summary the soil of Ouèssè and Glazoué (central Benin) had better fertility levels compared to those of Banikoara and Kandi (northen Benin).

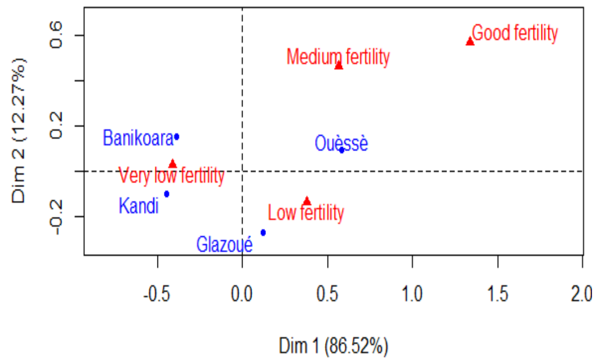


Figure 5. Representation of fertility levels and towns

Table 6. Physicochemical characteristics of rice soils of different towns

Cropping systems	CO (%)	Total nitrogen (%)	P ass. (mg/kg)	K ec. (cmol/kg)	Sum of cations (cmol/kg)	CEC (cmol/kg)	pH (1 / 2.5)
System 1	0.19±0.12c	0.07±0.014c	7.17±3.56b	0.13±0.10b	5.10±3.16a	5.82±2.83b	6.67±0.23a
System 2	0.46±0.34b	0.10±0.03a	10.04±4.65a	0.23±0.15a	3.53±2.09b	5.85±1.76b	5.59±0.69b
System 3	0.88±0.25a	0.08±0.02b	13.03±6.63a	0.24±0.08a	4.79±1.89a	6.40±1.53a	5.46±0.39b
P-Value	< 0.0001	< 0.0001	0. 047	< 0.0001	< 0.0001	0.0487	< 0.0001

The means followed by the same alphabetical letters and for the same variables are not significantly different (P> 0.05) according to the Student Newman-Keuls test.

DISCUSSION

Rice is predominantly grown by men. Indeed, land tenure rights restricted women access to land according to the customary rule (Balogoun *et al.*, 2014 ; Saïdou *et al.*, 2007) and men are the only ones who can inherit land from their parents (Balogoun *et al.*, 2015). In addition, rice production is characterized by activities that require enough physical effort. Similar results on the dominance of men in rice production were also reported by Balaro *et al.* (2014) in Benin. It is also noted that only farmers of central Benin, allocate an average area more than 1ha to rice production. This corroborates with Vigne (2011) results, who showed that in Benin, rice production is mainly practiced by smallholder farmers. Fall (2016) considers that the individualism that characterizes the farms doesn't encourage the availability of large land areas to arrange and exploit. In a study analyzing the impacts of policies and strategies implemented by the State in the rice sector since 2008, Balaro *et al.* (2014) report that the rice planted areas per farmer in Benin do not generally exceed one hectare (1 ha). Similarly, in sub-Saharan Africa, rice production is done on small farms of 0.5 to 3ha per household (Saïdou *et al.*, 2014). Rain-fed rice production is more intense in central Benin than in northern Benin.

There are three main cropping systems in rain-fed rice production in northern and central Benin. These systems differ mainly in the type of variety used, the method of tillage practiced, the method of sowing, the NPK and, urea doses and the use of crop residues. The choice of one of those systems is strongly dependent of municipality of residence of the farmers. Thus, the farmers of northern Benin (Banikoara and Kandi) adopt the system 1 which is characterized by no application or application of less than 50 Kg/ha of NPK and urea and crop residues are left in the fields. They also choose system 2 which is characterized by using NPK and urea at doses of 50 to 100 kg/ha, harness tillage with direct sowing of local varieties and crop residues are used as animal feed. Farmers in the central Benin practiced the system 3, which is characterized by using NPK and urea at doses between 100 and 200 kg/ha and crop residues are left behind. The both first cropping systems mainly practiced in northern Benin use a very low fertilizer dose. These doses are lower than those recommended which are 200 kg/ha NPK (15; 15; 15) and 75 kg/ha of urea 46 % (Yabi, 2013). Almost all the farmers of this system do not incorporate crop residues in the soil. However, the incorporation of these crop residues in the soil restores most of the nutrients absorbed by the crop (Zingore *et al.*, 2014). According to these authors, for each ton of paddy produced, 20 kg of nitrogen (N), 11 kg of P_2O_5 and 30 kg of K_2O are exported by rice crop but rice straw and stubble contains about 40 % nitrogen (N), 33 % phosphorus (P), 85 % potassium (K), 44 % sulfur (S) and 85 % silicon (Si) absorbed by the rice. Sossa *et al.* (2014) have also shown that incorporating crop residues on the soil contributes to increase soil fertility. The farmers practicing system 3 use relatively most fertilizer doses (100 to 200 kg/ha), although they do not take into account the rice need in fertilizers that could guide mineral fertilization. These results are partly substantiated those of Adegbola *et al.* (2002), who also showed that rice cropping systems in central Benin use more fertilizer than northern Benin. In the north, farmers prefer to use fertilizers for cotton grow than for rice. Most rice farmers in northern Benin also practiced cattle breeding. They, therefore, prefer to use crop residues as animal feed in the dry season, instead of incorporating them in soil.

Regardless of the system, farmers used no organic fertilizers in rice production. Even if mineral fertilizers contributes to enhance crop productivity, their exclusive use doesn't favor soil sustainability. Bado (2002) reports that mineral fertilizers alone aren't sufficient to maintain in the long term, soil fertility or increase crop yield. Exclusive application of mineral fertilizers leads to an increase in soil acidity, a deterioration of physical status and a decrease in soil organic matter (Konaté *et al.*, 2012). To ensure sustainable soil use, it is important to adopt integrated soil management by combining the use of mineral and organic fertilizers and good agronomic practices.

The farmers in the central Benin consider that the soil has a good level of fertility, unlike those in the northern, which consider that the soils have average, low and sometimes very low levels. It is also found that farmers' perceptions depend on income generated from the production and the planted area. However, analyzes of soil samples show that the soils of northern Benin towns have very low fertility because the farmers do not use fertilizers and the crop residues are exported and uses as animal feed. In addition, these soils have a low organic carbon content compared to the soils in central Benin, where farmers frequently used fertilizers and crop residues are left on the farm. This result shows the effect of the export of crop residues on soil organic carbon and cation exchange capacity. It is obvious that this practice, which exports crop residues, contributes to declining soil fertility.

CONCLUSION

Most of the rain-fed rice farmers are young and illiterate men. The rain-fed rice production areas are larger in central Benin than in northern Benin. Heritage is the primary mode of access to land.

Three main cropping systems are practiced by rain-fed rice farmers. In northern Benin, farmers use a little amount of mineral fertilizer, practice harness tillage and crop residues are used for animal feed. In the same area, some farmers don't use mineral fertilizers at all. In central Benin, farmers use mineral fertilizers at doses close to the recommendation even if this doses are weak and don't take account the needs and soil conditions. It should be noted, however, that these systems degrade soil fertility. This degradation of soil fertility is well perceived by farmers. The determinants of this perception are mainly, income from production, rice planted area, and quantities of mineral fertilizer used. Thus to improve the cropping systems productivity, it is important to determine the adequate doses of fertilizer according to the needs of rice, the local condition and soil quality.

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