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Effect of Organic Manure to Improve Sorghum Productivity in Flood Recession Farming in Yelimane, Western Mali

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Abstract

Agriculture is mainly under rain-fed conditions in Mali, while rainfall is very uncertain. Temperatures is increasingly high, which is a major challenge and detrimental to crop growth and development. Therefore, climate risk management in agriculture (rainfed and flood-recession), is among the most important pillars of food security and resilience of agro-ecosystems. The objective of this study was to address flood recession farming system constraints in Yélimané (Kayes) through the implementation of on-farm agronomic trials to improve crops yields, since very few studies were performed and the use of organic matter was new as an agronomic practice in the cropping system. Prior to trials implementation, soils samples were taken and sent to the Soil-Water-Plant Laboratory of Institut d'Economie Rurale (IER) for physico-chemical analyses. The experimental design was a dispersed randomized complete block design with 4 to 6 replications where each farmer was considered as a replication). Soil Physical characteristics (USDA, 1987) were for Gory site clay loam, f Dougoubara site silty and Yaguiné silty clay. Mean organic matter and nitrogen contents in the 3 sites were deficient. Over the 3 years, the treatments receiving manure alone showed a statistically higher yield.

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(p = 0.001) than the control (+ 47%) which was the farmer practice. The treatment F7 (18 kg ha^{-1} of NPK + 500 kg ha^{-1} of organic manure) gave the highest mean grain yield in 2012, 2013 and 2014, while treatment F0 (0 kg ha^{-1}) gave the lowest mean grain yield. Farmers in Yélimané (46%) argued that they didn't experience organic matter in flood. This information is also valuable for the use of chemical fertilizer because they believe that soils have enough rich nutrients (26% of farmers) because of yearly sediment deposits. 53% of the women prefer to apply their organic manure on their vegetables crops planted in their own garden located around the village and near a water source than in flood plain in which access to land is uncertain for them (15%).

Results obtained can be shared with several NGOs and extension services of the government for up scaling. There is also a need to better analysis women land tenure and the way to improve it since only men decide land allocation in the flood recession zone.

Keywords: Climate Change; organic manure; flood recession farming; on farm experiments; Crops yields; Mali.

1. Introduction

Increasing crop production to meet the population need in Mali, like many Sahelian countries is the main goal to achieve. Mali has experienced accelerated demographic growth rate of more than 3% [1] while its agriculture is confronted with extremely difficult and changing climatic conditions. Climatic change plays a crucial role in resource depletion [2] ending in failed crops or very low yields. However, the inundation of flat land by the Terekole, Kolombine, Magui (TKM) lakes is a great potential for the development of flood recession farming. Floods in this area result from local rain falling directly on the floodplain, or runoff from local streams mainly the surrounding hills. So, flood recession farming is an important component of the agricultural land of the department of Yélimane where low and unreliable rainfall does not guarantee success to rainfed agriculture. Flood recession agriculture is a traditional farming system practiced by farmers living along the TKM lakes. Floods reach the plains in July at the beginning of the rainy season and recede entirely in September. Planting takes place early in the seasonally inundated plain, following the receding flood water.

Yearly flood water of the TKM system inundates a vast alluvial plain of 70 000 hectares including the North-East part of the Kayes region (North-West of Mali) and southern part of Mauritania [3]. Potentially, this area can be cropped after recession of flood waters.

Flood recession farming uses the residual soil moisture that is stored in the soil after annual inundation of floods pain, lake margins or seasonal wetlands [4] which brings nutrient-rich soil with it. Despite these global advantages, several constraints related to birds damages, pest damages, flood insufficiency, low yields of crops, low level of equipment, low levels of certain nutrients such as nitrogen and organic matter exist. Among these constraints, organic matter appears to be one of the most limiting factors of crop production in the area. The authors in [5] reported that in the flood recession system, each year, part of the soil organic matter disappears so that the addition of fresh organic matter is necessary to compensate for these losses, to sustain agricultural production. The author in [6] also reported that in Yelimane flood plain zone, soils are poor in organic matter (0.49%) and nitrogen (0.05%). Because of the high cost of inorganic fertilizer, attention should be towards massive and cheapest strategy to replenish soil nutrients.

Flood recession farming is an important livelihood activity for poor riparian communities in Africa and Asia. It utilizes residual moisture retained within the root zones of crops creating similar conditions like in irrigated farming system [7]. This farming system allowed planting of the most important and adapted crop of the area like sorghum. This crop cultivated in Yelimane area, is confronted to unpredictable rains and floods because of climate change, over exploitation of soil without the use of fertilizer, low number of extension agent and poor equipment of farmers, leading to low yield during these last decennaries [8]. Climate change constitutes nowadays a threat for environment and sustainable development. Poor communities will be the most vulnerable because of their limited adaptation capacity and their great dependence to climate sensitive resources such as water and production systems in general [9] and particularly the sorghum based one like those of Yelimane.

Sorghum (Sorghum bicolor (L.) Moench, belongs to the Tribe Andropogonae of the grass family Poacae , cultivated for its grain, which is used for food, both for animals and humans, and ethanol production and originated from Africa. The author [10] reported that at an early Holocene archaeological site near the Egyptian-Sudanese border, carbonized seeds of sorghum dating of 8,000 years BP have been discovered. In most of the Asian and African countries, sorghum is mainly cultivated for human food [11]. The nutritional values of its grain were 70-80% of starch, 11-13% of protein, 2-5% of fat, 1-3% of fiber and 1-2% of ash [12, 13]. Sorghum is the world's fifth most important cereal crop after rice (Oryza sativa), Wheat (Triticum aestivum L.) maize (Zea mays L,) and barley (Hordeum vulgare L.). According to [14], due to several morphological and physiological properties, sorghum is better drought resistant in comparison with maize, based on its slow growth until the root system is established; it can produce two time higher secondary roots, Silica deposits in the endodermis of the root avoid tissue collapse during drought stress, leaf area is about half that of equivalent maize, evapotranspiration is about half as compared with maize, leaves contain a thicker cuticle and they in- roll completely under drought conditions.

In flood agriculture system in Yelimane, since organic matter and nitrogen were the main limiting factors for sorghum production, application of inorganic fertilizer can improve sorghum performance. But, chemical fertilizer is not affordable to local farmers, consequently, the use of organic manure became a great advantage, because it contains many nutrient required by plant for optimal performance and also helps in improving soil texture and structure [15, 16]. Organic manure are essential constitute of soil, they are present in variety of forms and it comprises of waste and residues from crops and livestock [17]. The adequate use of organic manure in extensively cultivated area of Yelimane and similar flood recession plain can enhance crop production among several advantages as mentioned in the Malian national plan for maintaining soil fertility [18]. One of these adequate uses could be microdosing in opposition to former practice which broadcast fertilizer all over the field. Microdosing is cheapest, well adapted to millet and sorghum and allow a better fertilizer efficiency use and a sustainable increase of crop yield [19], who reported yield increase of 34 to 52% compared to the control in Mali. Similar findings were mentioned by [20] who explained that 25 000 families in Mali, Burkina and Niger observed a substantial improvement of crop yield after a single apply of a pinch between three fingers, about 2 grams.

In Mali in general and Yelimane in particular, very few studies were conducted in flood recession system. Furthermore, indigenous knowledge on soil organic matter management in the region is not well known since the rule in the area is extensive agriculture practice. For these reasons, participatory on-farm research jointly funded by the Norvegian and Malian governments was conducted to study the influence of organic manure on soil physico-chemical properties and sorghum crop performance.

2. Materials and methods

2.1. Site descriptions

Mali is a semi-arid country located in Western Africa at a latitudes of 10 to 25°N, straddling the sub-tropical band called the Sahel. The northern parts of Mali reach well into the dry Sahara desert, while the southern regions experience a wetter, more tropical, climate [21]. The study was conducted from 2012 to 2014 in the Western part of Mali (Kayes region) in the Yelimane circle (Figure 1) with 15°.3'.52" North,10°.33'.57".West as geographical coordinates. Villages involved in in the study site were Gory, Yaguine, Dougoubara, Foungou and Kemala.

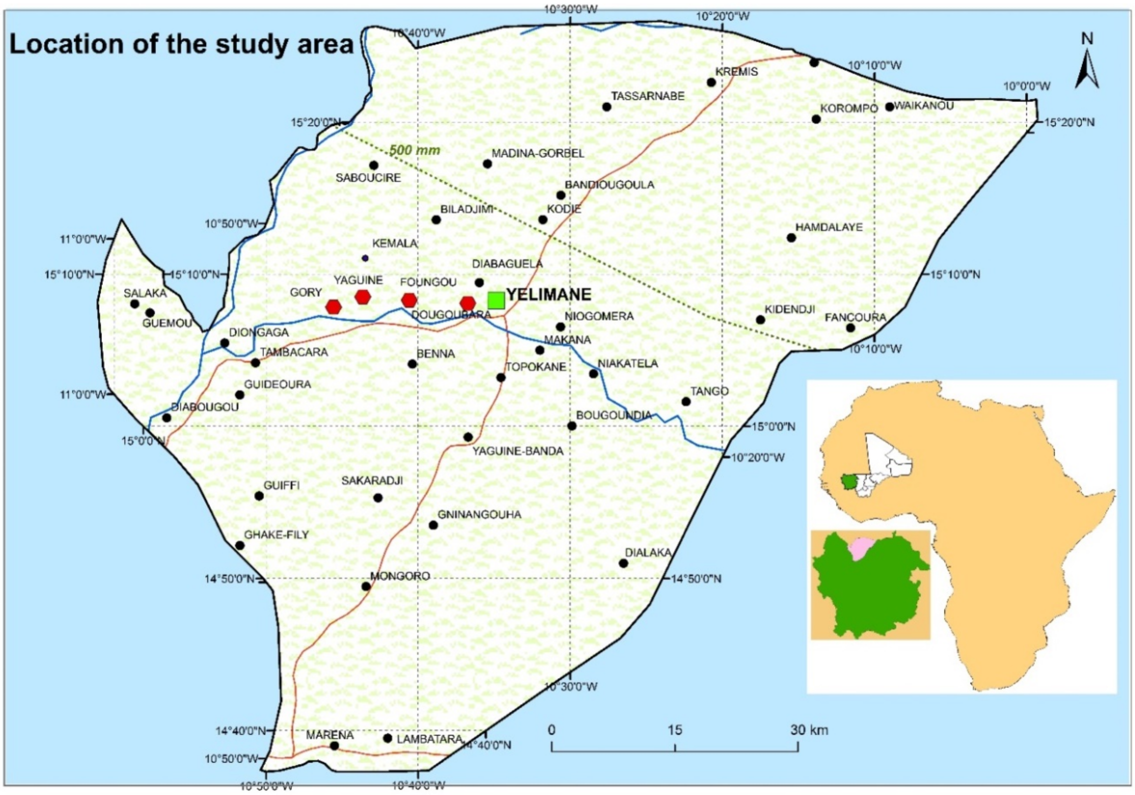

Figure 1: location of the study area in Yelimane, Mali.

2.2. Soil types and sampling technique and vegetation

A transect in each of the villages (Gory, Yaguine and Dougoubara) as representative sites of the floods plains were executed to identify soil type. The dominant soil types are hydromorphic flood plain with gley and pseudogley hydromorphic soils [22] and USDA (*Aqualfs*). Old alluvial plains and terraces also were represented and were characterized as *Plinthic haplustalfs*. Composite soil samples were collected in six farmer's field in May on 0-20 cm depths before the establishment of the experiment in each site. Particle size analysis was done by the hydrometer method [23]; pH was determined by electrometric method in a soil solution with a soil/water ratio of 1/2.5.; soil organic C was determined using modified Walkley-Black wet oxidation method as outlined by [24]; total nitrogen was determined by Kjeldahl digestion method [25]; bases, cation exchange capacity (CEC), and available P were determined as described in [26].

The vegetation of the area was sylvopastoral bushland. The size of bushes was of the order of 2 to 10 m. The main trees and shrubs were *Bauhinia rufescens*, *Acacia seyal*, *Balanites aegypteca, Guiera senegalensis, Hyphaeine tabacco, Ziziphus mucronata, Adansonia dijitata*, *Bauhinia reticulata*, *Acacia tortilis, Calotropis procera*, *Ficus capensis*, *Combretum micranthum*, *Combretum fragrans*, *Acacia Senegal, Borassus aethiopicus, Acacia Albida* and grasses were *Andropogon spp*, *Cenchrus bliflorus, Digitaria spp*. etc.

2.3. Climatic condition

Average rainfall data for 2012- 2013-2014 of Yélimane are shown in Figure 2. 2012 year was rainier than 2013 which was higher than 2014. The area is characterized by annual rainfall ranging from 500 to 600 mm during the study period. Rainfall is unimodal with the maximum rains events occurring in July and August.

Average annual temperatures ranged from minima of 20.2 to 28.5 °C to maxima of 32.9 to 42.5 °C. Evapotranspiration was 6-7 mm day^{-1} in the dry season and 4 mm day^{-1} in the rainy season.

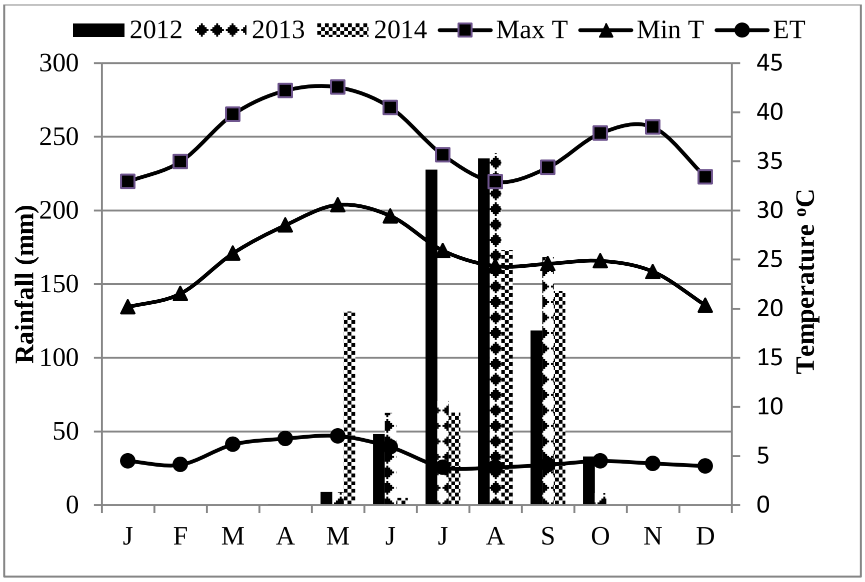

Figure 2: Rainfall in Yelimane, Mali, in 2012- 2013-2014 year

2.4. Rainfall pattern in the study area

Precipitation was analyzed using 33 years continuous long-term average growing season rainfall data to capture inter annual variations. Rainfall anomaly for the various years with respect to the Yelimane districts' average baseline was determined.

2.5. Experimental design

Participatory on-farm experiments were conducted in Yaguine, Gory, Dougoubara, Foungou, and Kémala villages using a randomized block design in which, each replication corresponded to one farmer's field. Number of replications were six in 2012 in three villages (Yaguine, Gory, Dougoubara), six in 2013 in four villages (Yaguine, Gory, Dougoubara, Foungou) and five in 2014 in five villages (Yaguine, Gory, Dougoubara, Foungou, and Kémala).

The experimental area of each experimental replication was 39 m by 5 m (195 m^2). There were eight treatments per replication. Plot size of each treatment was 5m by 4 m (20 m^2) with two border rows. Organic matter (OM) of 500 kg ha^{-1} and mineral fertilizer (NPK containing respectively, 15 units of Nitrogen, 15 units of Phosphorus and 15 of Potassium and Urea) were used. The average C:N ratio of the organic matter was 20, its average carbon content was 47.73 % , nitrogen 1.73%, and its pH was 6.5.

Sorghum seeds were planted two (2) per hill at the depth of 15 cm with a spacing of 1m x 0.5 m. The treatments used in each replication were : 0 kg ha^{-1} as a control (F0), 500 kg ha^{-1} of OM (F1), 6 kg ha^{-1} of NPK (F2), 12 kg ha^{-1} of NPK (F3), 18 kg ha^{-1} of NPK (F4), 6 kg ha^{-1} of NPK +500 kg ha^{-1} of OM (F5), 12 kg ha^{-1} of NPK +500 kg ha^{-1} of OM (F6) and 18 kg ha^{-1} of NPK +500 kg ha^{-1} of OM (F7). NPK and OM were applied at sowing in the same hill with seed but just near after covering seeds with soil to avoid negative germination effect on seed. 4 kg ha^{-1} of urea (46% of nitrogen) were also applied 10 days after sowing in F2 to F7 treatments.

Local variety of sorghum (*Sorghum bicolor* L. Moench) called *Magaleme* in Soninke local language was used for all the experiment in agreement with farmers in order to understand their own sorghum response to fertilizer. During the growing period, experimental plot was weeded only one time using hoes. Crops were harvested 12 weeks after sowing.

At harvest, total panicles, grain and stems sun dry weight were recorded as far as 1000 grains weight obtained using electronic grain counter (NUMIGRAL) and an electronic balance (METTLER 4000).

2.6. Gender issues

Semi-structured interviews involving 140 farmers were conducted in tree studied villages with similar cropping system. The survey questionnaire focused on reasons why farmers do not widely use organic matter and mineral fertilizer in flood recessing farming, on which production system and crop they use fertilizer, the opinion of women on the issue and their land ownership in the flood recession system and crop types planted.

2.7. Statistical analysis

Analyses of variance of collected data were made using MINITAB statistical software (Release 14 for Windows) models. Effects of treatments were considered significant at the probability threshold of p < 0, 05. Newman-Keuls test was used for significant mean differences between treatments.

3. Results

3.1. Rainfall trend in Yélimané district

Rainfall regimes occur around July through September with a mean annual rainfall of about 500 mm. Figure 3 shows the rainfall anomaly for the various years with respect to Yélimané district's average baseline. It indicates clearly that there was high inter-annual rainfall variability. From 1950 to 1971, Yélimané district experienced an annual rainfall above the average baseline of 497 mm, with the exception of 1956 and 1968 which received respectively an annual average of 453 and 382 mm. From 1971 to 2015 which represented 44 years period, only 13 years were above the average baseline. Rainfall amount varied in this period, from 8 mm above to 223 mm below the average baseline. The lowest annual rainfall was recorded in 1972, 1984, 1995, 1998 and 2002. The two first years (1972 and 1984) were particularly catastrophic in Mali resulting in many deaths tools both in livestock and human.

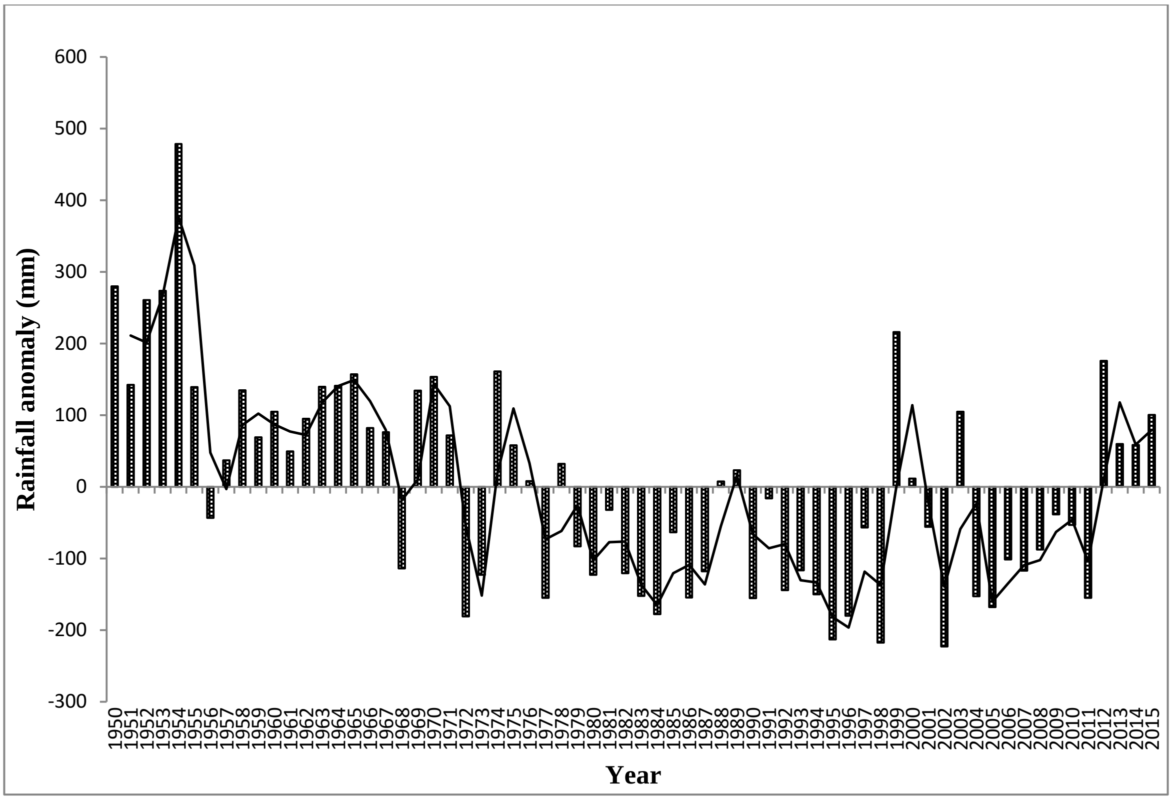

Figure 3: Annual Rainfall Anomalies in Yelimane District from 1950 to 2015

3.2. Soil characteristics

3.2.1. Soil physical properties

In horizon (0–20 cm), soil color was blackish grey (10YR 7/1) in Gory and Yaguine and brownish grey in Dougoubara (10YR6/3). On all 3 sites, sand, silt and clay content were variable (Table 1). For the Gory site, soils contained on average 23.5, 36.7 and 47.7 % respectively for sand, silt and clay. At Dougoubara, average contents were 40.8, 38.1 and 21% and concerning Yaguiné site, the mean contents were 33.3, 34.8 and 29%. Average sand content in Dougoubara site was 74% higher than that of Gory site and 23% more than Yaguine site. The levels of silt are very close. Regarding clay content, Gory site was at least 2 folds of Dougoubara and 64 % higher than Yaguine. Bulk densities varied from 1.61 (Gory site) to 1.45 (Yaguine sites) with intermediate value of 1.48 for Dougoubara site.

Table 1: Physical properties of soils (±SE) from the sites of Gory, Dougoubara and Yaguiné, district of Yelimane (Kayes), Mali.

Sites	Gory (n= 6)	Dougoubara (n= 6)	Yaguiné (n= 6)
Sand%	23.5 ± 2.891	40.8 ± 4.581	33.3 ± 3.650
Silt %	33.17 ± 2.540	38.1 ± 4.360	34.8 ± 4.090
Clay%	43.67 ± 1.661	21 ± 1.841	29 ± 2.552
Bulk density (g/cm3)	1.59 ± 0.029	1.48 ± 0.015	1.45 ± 0.023
Texture	Clay loam	silty	Silty clay

Values are means ±SE (standard error)

3.2.2. Soil chemical properties

Soils pH (H2O) varied from 6.2 in Yaguine to 7.3 in Dougoubara (Table 2). ECEC values were almost the same between the 3 sites (11 in Gory and 12 in Dougoubara and Yaguiné).

Table 5 shows that average organic matter of the 3 sites was 5% of C. No soil of the 3 sites shows nitrogen content higher than 1%.

C / N ratio of soil varied little depending on the site and was on average between 9.62 in Yaguiné and 11.45 in Dougoubara. Phosphorus level in Dougoubara was at least double of those in Yaguine and Gory.

The K content varied from 0.08 to 0.85 on all 3 sites and was, two times higher in Gory and Yaguine than in Dougoubara. Mg content varied from 0.45 to 4.80 meq / 100 g and was, for Gory Yaguiné taken together, 36% higher than at Dougoubara (Table 5). Mg/K varied from 5 (Gory) to 15 (Yaguine).

The calcium content ranged from 0.99 to 9.70 meq / 100g. On average, calcium base saturation rate in soils was 63% in Gory and Yaguiné compared to Dougoubara with 46%. In all 3 sites, Ca / Mg ratio which can inform on soil quality was 2. On average, the (Ca + Mg) / K was 16 in Gory and 27 in Dougoubara.

Table 2: Chemical properties (± SE) of soils from the sites of Gory, Dougoubara and Yaguiné, district of Yelimane (Kayes), Mali.

Sites	Gory	Dougoubara	Yaguine
pH H_20	6.75 ± 0.150	7.33 ± 0.201	6.23 ± 0.202
pH KCL	5.7 ± 0.091	6.5 ± 0.111	5.5 ± 0.170
Organic Matter (% C)	0.42 ± 0.046	0.41 ± 0.090	0.62 ± 0.041
Total N (%)	0.05 ± 0.009	0.05 ± 0.012	0.06 ± 0.004
C:N	8.95 ± 1.980	11.5 ± 3.180	10.28 ± 1.087
Available P (ppm)	10.43 ± 2.270	27.53 ± 3.288	11.08 ± 0.349
Exchangeable K (meq/100g)	0.62 ± 0.069	0.33 ± 0.090	0.62 ± 0.069
Exchangeable Ca (meq/100g)	7.09 ± 1.261	5.49 ± 1.249	7.54 ± 0.527
Exchangeable Mg (meq/100g)	3.51 ± 0.629	2.71 ± 0.625	3.67 ± 0.288
Exchangeable Na (meq/100g)	0.13 ± 0.029	0.25 ± 0.035	0.12 ± 0.055
ECEC (cmol kg^{-1})	11 ± 1.710	12 ± 2.201	12 ± 0.302

Values are means ±SE (standard error)

3.3. Sorghum grain yield

Average crop yield varied from 657 in 2012 to 1646 kg ha^{-1} in 2013 (Table 3). Results revealed significant difference (<0.001) among treatments. Over the 3 years, the treatments receiving compost or manure alone showed statistically higher yield (p = 0.001) than the control (+ 47%) which is the farmer practice. It appears also, that treatment F7 (18 kg ha^{-1} of NPK + 500 kg ha^{-1} of organic manure) gave the highest mean grain yield in 2012, 2013 and 2014, while treatment F0 (0 kg ha^{-1}) gave the least mean grain yield. The benefit compared to the control was 490 kg ha^{-1} in 2012, 1668 in 2013 and 878 kg ha^{-1} in 2014. In 2012, F7 was followed by F6 (12 kg ha^{-1} of NPK and 500 kg ha^{-1} of organic manure) which was statistically higher than the other treatments (F5, F4, F3, F2, F1), while it was statistically similar to them in 2013 and 2014.

3.4. Sorghum straw yield

Table 3 shows average straw yield, which varied from 2971 to 4398 kg ha^{-1}. Results showed that in 2012, there were significant difference (p<0.001) among treatments and F7 (18 kg ha^{-1} of NPK and 500 kg ha^{-1} of organic manure) gave the highest mean biomass yield. This was statistically similar to F6 and F5 (which combined mineral and organic manure) followed by F4, F3, F2, F1 while the control which is treatment F0 gave lower mean sorghum straw yield. Result revealed also no significant difference (p<0.98 in 2013 and 0.4 in 2014) among treatments while arithmetic mean straw yield was greater than 2012.

3.5. Thousand sorghum seeds weight

Table 3 shows thousand grain weight (TGW) of sorghum from 2012 to 2014. The result indicates that treatment

F7 (18 kg ha^{-1} of NPK and 500 kg ha^{-1} of organic manure) gave the highest mean TGW while the F0 gave the least TGW. The benefit was respectively +21.5, +32 and +31.5% in 2012, 2013 and 2014. The results indicated that there were significant differences among treatments ($p<0.0001$). In 2012, F7 was statistically similar to F6 and F5 which were followed by other treatments (F4. F3, F2, F1), while in 2013 and 2014, they were lower. Also, a significant decrease of the TGW was observed in 2013 and 2014 from the treatment F4 to F0.

Table 3: Effects of fertilization (Fert) on crop grain, straw yield (kg ha^{-1}) and thousand grain weight during 3 years

Year	2012			2013			2014		
Fert	Grain kg ha^{-1}	Straw kg ha^{-1}	TGW (g)	Grain kg ha^{-1}	Straw kg ha^{-1}	TGW (g)	Grain kg ha^{-1}	Straw kg ha^{-1}	TGW (g)
F0	497 d	1967 d	25.27 e	793 bc	4450	23.65 g	901 bc	3200	23.94 g
F1	562 cd	2790 bc	27.15 de	1451 b	4367	25.72 f	1214 b	3520	25.66 f
F2	555 cd	2672 c	27.9 cd	1163 b	4267	26.7 e	1001 bc	3253	26.86 e
F3	598 cd	2961 bc	28.36 bcd	1529 b	4517	27.8 d	1076 bc	3827	27.9 d
F4	623 c	3061 bc	29.08 abc	1630 b	4617	28.67 c	1249 b	3507	28.78 c
F5	643 c	3133 abc	29.68 ab	1905 ab	4033	29.55 b	1169 b	3387	29.7 b
F6	793 b	3420 ab	30.11 ab	2237 ab	4333	30.05 b	1288 b	3400	30.42 b
F7	987 a	3764 a	30.71 a	2461 a	4600	31.32 a	1779 a	3853	31.5 a
Pr	<0.001	<0.001	<0.0001	<0.001	0.98	<0.0001	<0.001	0.4	<0.0001
Mean	657	2971	28.53	1646	4398	27.93	1210	3493	28.09
SD	107	577	1.87	380	931	0.66	276	522	0.61
CV	16.2	19.4	6.5	23.0	21.1	2.3	22.8	14.9	2.1

a, b: values in the same column with different letters are significantly different at P = 0.05

SD: standard deviation (kg ha^{-1}), TGW: thousand grain weight, CV (%): coefficient of variation, Pr: Probability

3.6. Socio-economic data

Survey revealed that most farmers do not apply organic matter to crop in flood recession farming. In the studied sites, organic manure is generally kept in heaps and scarcely watered. In many cases, this leads to immature organic fertilizer which was weakly used in flooding recession system. The reasons given by farmers to explain these situations are mentioned in Figure 4.

Farmers in Yélimané (46%) argued that they didn't experience organic matter in flood. This information is also true for chemical fertilizer utilization because they believe that soils are enough rich in nutrients (26% of farmers) because of yearly sediments deposits. Some farmers (20) explained that organic fertilizer was almost used in rainfed plots which were poor soils, while 10% of farmers think that biomass production is very small to meet the demand of both rainfed and flood recession farming systems.

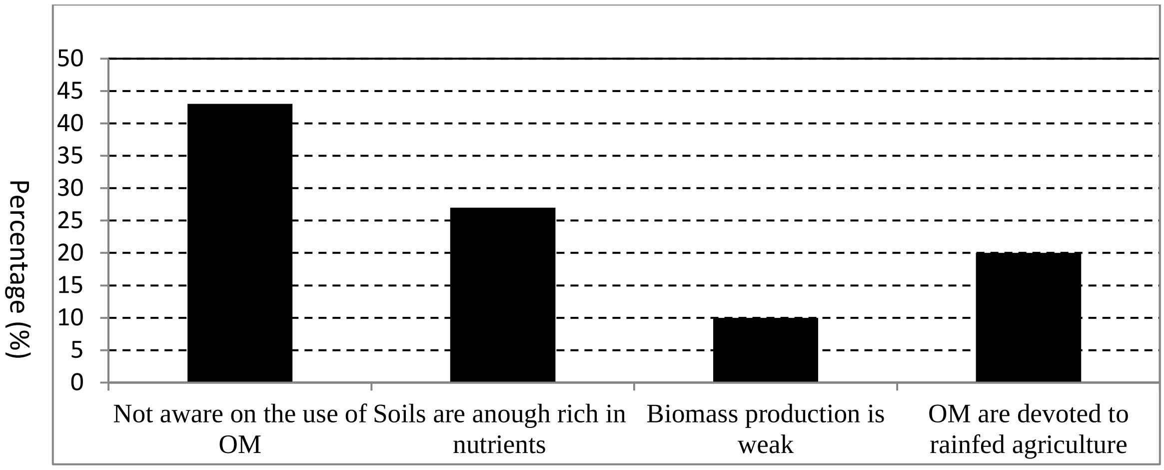

Figure 4: Reasons for weak utilization of organic fertilizer in flood recession farming system by males farmers in Yélimané (Kayes), Mali

On the question of why limited women as household head (senior and junior), working in the flood recession system, doesn't use at all organic manure on their crop. Several answers were given (Figure 5). The main reason (53%) was that women prefer to apply their organic manure on vegetables crop they plant in garden located near the villages and water source. Women think vegetable gardening is more profitable for them than cereals planting in the flood plain area. In addition to this, they argued that generally, they do not have or have very small plots in flood plain (15% of farmers). Some women (5%) explain the situation by the higher cost of chemical fertilizer, but also on limited access (5%) to organic materials. Other reasons mentioned by women were the overlapping between vegetable gardening and flood recession farming (15%) combined with the higher labor- demand (5%) for taking stover in the villages and lack of carts (3%).

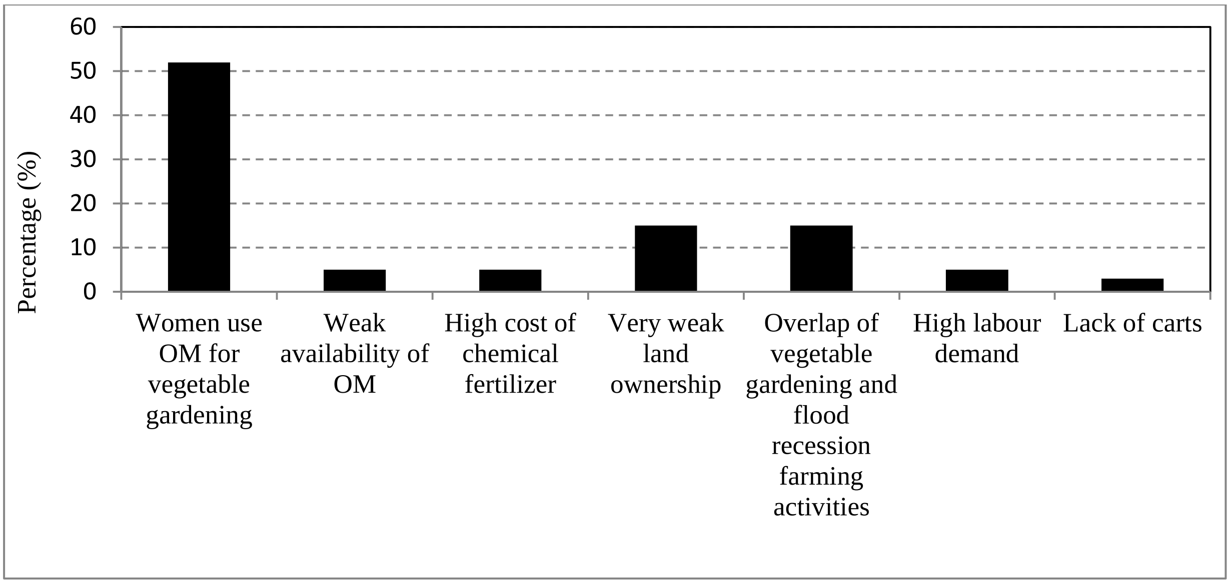

Figure 5: Reasons for weak utilization of organic fertilizer in flood recession farming system by females farmers in Yélimané (Kayes), Mali.

4. Discussion

4.1. Rainfall trend in Yélimané district

In Yélimané, rainfalls vary from year to year and were unpredictable. It indicates clearly that there was high inter-annual rainfall variability. This situation could impact negatively crop production since the maximum area under flooding is related to rain water which is a key element in the amount of available area for recession farming from year to year. In this study, the anomalies values in 2012, 2013 and 2014 were all positive. These observations were supported by [27] who widely reported similar trends when studying relation between climate and soil productivity in Soudanian and Sahelian zone of Africa.

4.2. Soil physical and chemical properties

Soil physical characteristics qualify, according to [28], were for Gory site clay loam, those of Dougoubara site silty and finally those of Yaguiné as silty clay. The bulk densities were below the limit level of 1.9 g/cm3 where root growth is usually stopped compared to a normal range of bulk densities for clay is 1.0 to 1.6 g/cm3 and a normal range for sand is 1.2 to 1.8 g/cm3 [29]. Findings are similar with those of [30] who reported that soil organic Carbon has a direct impact on the bulk density of soil. They highlighted that High bulk density is an indicator of low soil porosity and soil compactness which can result in shallow plant rooting and poor plant growth, influencing crop yield and reducing vegetative cover available to protect soil from erosion. In this study, bulk densities were moderate (1.45- 1.61 g cm^{-3}), indicating that soil was slightly compacted and could restrict root development. Gory site shows poor organic matter content this is why the bulk density is greater in agreement with that reported by [31]**.** Basically, soil pH influences crops production through its effects on chemical factors and biological processes. Soil pH varied from weakly acid in Gory and Yaguine to neutral in Dougoubara according to the classification reported by [15, 32]. These values were seen as optimum since nutrients uptake by most crops occurs at a soil pH near 7.0 [33].

Soil organic matter content is a good indicator of soil fertility level. In this study, mean %C level was about 0.5% and was qualified consequently as poor since it is below the critical level of 0.6% reported by [15] which is a critical level of soil structural stability. Low levels of organic matter and nitrogen as in our study may leads to significant physical deterioration of soil, accelerated erosion and a decline in crop yields. This weakness in organic matter content is related to low supply of these nutrients by farmers. Our findings are in agreement with those of [5] who reported that in flood recession system, every year a part of the soil organic matter disappears so that addition of fresh organic matter is necessary to compensate for these losses to sustain agricultural production.

Nitrogen content was also considered as low, the critical value being 1%. This deficiency may affect crop performance when soil acidity is not adequately managed. The C- to- N ratio suggest that soil in Yaguine (C-to-N =9) gave higher mineralization and nitrogen availability while that of Dougoubara have good mineralization and nitrogen availability (C-to-N =11). It is generally accepted that C-to-N ratios between 8 and 12 were considered to be the most favorable, implying a relatively fast mineralization of nitrogen of the organic materials.

[34]. Soils have high levels of phosphorus, in all 3 sites, higher than the critical value of 7 ppm as reported by [35] for Malian soil. The CEC values which were about 12 were much closed to the critical value of 12 cmol (+) kg^{-1} and considered as medium. Similar results were also reported [36] for Nigerian soil where an interval of 6 to 12 cmol (+) kg^{-1} was defined as soil with medium CEC level. This means that it is not necessary to apply standard phosphorus rate as recommended by extension services; a little quantity to maintain soil fertility can be envisaged for these soils.

The Ca/Mg ratio (2) corresponds to an acceptable balance between the nutrients in the soil. Mg/K ratio (5 to 15) was defined as good balance between nutrients. The same trend was observed with the (Ca + Mg) / K ratio which was also considered as optimal. In fact, [37] reported that Ca/Mg varying from 1.5 to 5 and Mg/k varying from 2 to 5 was optimal. The (Ca + Mg) / K inform that balances and interactions between nutrients are optimal for values between 15 and 30 for Gory site (16) and Dougoubara (27) fit in this interval. However, the Yaguiné site (45) shows a balance described as strong. In such cases the events could cause antagonism and absorption blockages when the content of a base is weak or non-Sufficient.

4.3. Crop yield

Variation in yields between the three years can be attributed to the difference in the total rainfall since yields for crops grown on the floodplain are highly dependent on flood levels [38], but also on heavy and general bird invasion especially in 2012. Bird (*Quelea quelea, Passer luteus, Quelea érythrops et Ploceus cuculatus*) damage was recognized in the area as a major biotic constraints and the Malian government used plane to fumigate bird nests or detonators to scare birds , but this program ended 20 years ago. These observations were already supported by [39], who reported that *Quelea-quelea* was declared as a "public calamity" throughout the territory of the Federation of French West Africa and specification was made to encourage the public authorities to mobilize resources and means available to combat birds and protect crops.

Soil fertility is important for crop production. Chemical soil analysis indicates that soils were higher in almost all the nutrients analyzed. This result agrees with the finding of [40] who reported that the sediment load in the flooding water flows is high, carrying fine particles to floodplains. Therefore floodplain soils have alluvial deposit characteristics (Vertisoils, Fluvisoils, Gleysoils and Cambisoils) with high fertile silt content. However, in this study nitrogen and organic matter were deficient in Yélimané soils. This may explain crop response (significant difference among fertilizer treatments) to nutrients application through organic manure. This agrees with the findings of [41] in tropical semiarid zone of India, who opinioned that organic manure supply macro-, secondary and micronutrients to plants (high nitrogen, phosphorous and potassium), improve soil permeability to air and water, and increase the proportion of water-stable aggregates in the soil. It is readily available than the mineral fertilizer and its effect on the soil is stable, slow in releasing nutrition to crop. Values from this study were higher than yield values of 400-700 kg ha^{-1} obtained by small-holder farmers in semi-arid zones in sub-Saharan Africa as reported by [4]. The authors in [7] mentioned that the low yields in small-holder farming were generally associated with low and unreliable rain fall, and limited application of fertilizers in the flood recession farming in the Okavango Delta in Botswana. The authors in [42] also reported a mean yield of 450 kg ha^{-1} in the vast alluvial plain down streaming from Bakel but the total production depends on flooded area. For instance, the flooded surface area varied from 180,000 hectares during the rainy year of 1950 to less than 10,000 hectares during the drought year of 1972 in West Africa. Mean value from Yelimane over the 3 years is consistent with the value of 637 – 1100 kg ha^{-1} reported by [43] in the flood recession zone of the department of Matam in Senegal.

Except 2012 where the combination of organic manure and microdose of mineral fertilizer out yielded the other treatment, sorghum straw yields didn’t differs among treatment opposed to grain yields case. This can be explained by the valorization of fertilizer in the reproductive part of the plant at the expense of its vegetative parts. Sorghum dry biomass yields from the current study were lower than those of 12.85t ha^{-1} reported by [44], when studying the effect of mulching on sorghum yield and biomass in flood recession agriculture which is an excellent alternative for sorghum production in the dry season.

Sorghum 1000 grains weight was significantly different among treatments. This is consistent with the results of on-farm research implemented in the area by [45] who also mentioned the effect of organic manure and micro dosing in 1000 grain weight. This suggests that among the factors determining yield increase, a better grain filling leading to heavy grain can be cited.

4.4. Farmers opinions

In Yélimané zone, free grazing is the rule. Huge number of livestock coming from Mauritania and the neighboring villages grazes through the floods plains including sorghum straw. To avoid this, farmers remove their biomass before the onset of the transhumance. Similar observations were already mentioned by [46] during their works, in the Senegal River Valley, the conditions of the transition from the traditional farming systems (rainfed agriculture, flood recession agriculture, fishing and cattle-breeding) to a radically new system based on irrigation. Majority of farmers indicated that they don’t have adequate equipment like cart to transport their organic material at home where animals will be fed to produce manure in the park. Sorghum straw is also used as building material for huts, hangars or gardens which are important for animals and human protection against heat during the dry and hot season. Some of the local hunters burn sorghum straw to kill small animals like hares (*Lepus capensis*), Lesser Cane-rat (*Thryonomys gregorianus*) etc.

Farmers stated they were not much aware of the use of fertilizer in flood recession agriculture which is in agreement with the observations of [4] who mentioned that flood recession agriculture is based on natural irrigation and natural fertilization, so that the only inputs were labor and land. In the area, labor is a main input for better installation of crop and yields increase. This is why women were particularly solicited during the sowing period (mid-October) to the harvest (February- March).

Women do gardening in the dry and cold season starting from mid-October and ending in March; exactly the same period as the flood recession agriculture occurs. This explain why they use small amount of organic manure they produce in vegetable instead of flood agriculture in which their land ownership is very limited.

Women stated that they don't have adequate equipment, for example cart to carry sorghum straw even if their males household head allow them to. This farming female situation is consistent with that reported by [47] in flood recession agriculture in Fadama areas in north-central Nigeria who mentioned that culturally, women do not own land. He stated that a woman is allowed to either cultivate her husband's land, or her father's or both. This means that women have no sole ownership over the lands they cultivate and ownership rights can be withdrawn by the husband or the father at any time.

5. Conclusion

Soils in floods plain of Yélimané were poorly supplied in Nitrogen and organic matter which are key elements for crop production. Therefore there is a need to apply these nutrients to improve crops yields under high inter-annual rainfall variability, which is a driver for maximizing area under flooding.

Results showed that sorghum grain yield is significantly greater in plots combining organic manure and microdose of mineral fertilizer. It appears that in flood recession agriculture in Yélimané, low yields in farmer's fields are mainly assimilated to limited application of fertilizers. A fertilizer rate of 18 NPK + 500 OM gave a mean yield of about 1200 kg ha^{-1} other 3 year experiment.

Data from this study are convincing factors for launching awareness activity for the majority of farmers who not apply chemical fertilizers in water recession agriculture. Training is needed to help develop low-cost improved technologies for better productivity of organic manure to increase crop performance. For example, this could include ways and when to harvest straw, implement, fill and follow up the compost pit.

Without secure land tenure, female farmers are unwilling to make necessary investments to undertake farming in water recession system. Improvement or changes in land tenure regimes which is based on traditional systems of property rights can be an entry point to motivate women for flood plain cropping.

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