Comparative Analysis of Rice Performance and Profitability with the System of Rice Intensification (SRI) and Traditional Practices (TP) in Ziguinchor District, Senegal

Pierre C. C. DIEDHIOU¹, Antoine SAMBOU¹*, Ousmane NDIAYE, NGor NDOUR¹, & Seydou K. DIEDHIOU²

¹Department of Agroforestry, AssaneSeck University of Ziguinchor, SENEGAL
²Diocesan Caritas of Ziguinchor, SENEGAL

* Corresponding author: tonysambouegos@yahoo.fr

Doi: https://doi.org/10.47285/far.v2i1.64

Citation: DIEDHIOU, P.C.C., SAMBOU, A., NDIAYE, O., NDOUR, N. & DIEDHIOU, S.K. (2021). Comparative Analysis of Rice Performance and Profitability with the System of Rice Intensification (SRI) and Traditional Practices (TP) in Ziguinchor District, Senegal, Forestry & Agriculture Review, 2(1), 22-36. Doi: https://doi.org/10.47285/far.v2i1.64

Research Article

Abstract
The “System of Rice Intensification” (SRI) represents a sustainable alternative to improve household yields and incomes. This study aimed to evaluate the yields and the profitability of the SRI and the Traditional Practices (TP) in Ziguinchor district, Senegal. A directed sampling based on criteria for selecting the system used and the cultivated varieties common to both systems was applied to collect the yield parameters and yields of paddy rice. Thus, 18 producers in the Badiate, Essyl, and Fanda sites were selected, nine per system and four 1 m² yield squares were installed in each selected producer plot. A total of 72 yield squares, 36 per system, were installed, and an individual questionnaire was randomly administered to 55 producers using at least one of the systems to collect data on rice production and costs. The yield parameters including the number of fertile tillers per m², the number of spikes, the weight of the 1000 grains are significantly higher (p<0.05) in the SRI including yield compared to the traditional system. Transplanting density and plant duration are higher in TP (26±5.6 plants/m² and 26 days) than in SRI (16±0.4 plants/m² and 16 days). The lower the transplanting density, the higher the yield parameters and the yield. The economic profitability, determined based on the benefit/cost ratio, is higher in SRI (1.5) than in TP (1.2). The SRI required a lot of technicality in its implementation and generated more cost of production. However, SRI was more productive and economically more profitable than the traditional system.

Keywords: SRI; Traditional practices; Rice; performance; Productivity; profitability

1. Introduction
Rice is a cereal that plays an important role in food security. It is the staple food of more than half of the world’s population and remains the most widely grown cereal for human consumption (Pascual and Wang, 2017). Thus, in regions such as West Africa, which only covers 60% of its rice needs, a large part of the rice consumed comes from Asia (Boutsen and Aertsen,
In Senegal, despite the efforts noted in terms of improving rice yields, production remains insufficient in relation to the need of a population that is constantly growing and is only asking to produce more (Fall & Dièye, 2008). These deficiencies in production are linked to a lack of material resources, poor technology transfer and dissemination and non-compliance with good rice production practices (Poussin and Boivin, 2002; Zingore et al., 2014). While facing their growing needs, traditional subsistence rice farming communities are increasingly faced with the need to increase their production to meet their monetary needs and provide food for cities (Radanielina, 2010).

However, as the expansion of arable land is less and less possible, the increase in production would require the adoption of new agricultural practices and technologies, which would not only maximize yields but also adapt to climate variability and particularly to rainfall irregularities. This system of rice intensification (SRI) is a combination of the relationship of the soil-water-plant-light elements in a harmonious way that allows the plant to express its production potential hidden by inappropriate farming practices. It is based on some essential practices: transplanting young plants (1 seedling/pot) from 08 to 15 days, intermittent water management, organic amendment, reduction of competition between plants and weeding (Gathorne-Hardy et al., 2016), which could therefore be an effective alternative to increasing rice yields in Basse Casamance (Ziguinchor Province) where small rice farms have difficulty in reaching the two tonnes per hectare (SÈNE, 2018; Jouve, 1992).

Despite the enormous potential that exists in these areas, rice farming, dominated by smallholders, continues to face a lack of equipment and to suffer the adverse effects of climate variability and its corollaries (reduced rainfall duration, land salinization, soil poverty, etc.). It is in this perspective that this work aims to study the yields and evaluate the profitability of the SRI compared to the Traditional Practices (TP) in Basse Casamance.

2. Literature Review
An agricultural production system is defined as "a structured set of labor, land and equipment) combined together to ensure plant and/or animal production with a view to satisfying the objectives and needs of the farmer and his family" (Jouve, 1992). There are two main rice-growing systems: the Traditional Practices (TP) and System of Rice Intensification (SRI).

In Senegal, there are two types of TP (irrigated and pluvial). However, the pluvial system has several rain-dependent variants (upland, lowland and mangrove). The upland system is characterized by an extensive system with low input use and water control and dominance of traditional varieties and manual operations. It has low productivity, with average yields varying between 0.8 and 1 t/ha, and the varieties are grown in the traditional system generally do not have a high tillering capacity (6 tillers on average) (Bocoum, 1998). The traditional practices of rice cultivation in Casamance are characterized by two types (Mandingue and Diola) (Haddad, 1969). Despite the existing potential in Casamance, rice cultivation is weakened by physical, biotic and socioeconomic constraints linked to the poor organization of seed production, the fragmentation of plots, the lack of adequate soil preparation equipment, and also the absence of a sustainable agricultural policy, which is indispensable for the harmonious promotion of agriculture (Haddad, 1969).

The SRI is an agro-ecological and climate-smart method that allows farmers to produce more crops using less seed and water and fewer purchased inputs. It was discovered in 1983 by Henri de Laulanié (Razafimanantsoa, 2008). It is a crop management approach based on knowledge of the plant leading to improved plant growth and productivity (Styger and Jenkins, 2014). This new system of rice intensification changes the traditional practices of rice cultivation by restoring the potential for the rice to increase production (Zotoglo, 2012). SRI practices are based on four principles that interact with each other to create a synergistic change in the way rice plants grow (Laulanié, 1993; Styger and Jenkins, 2014):
- Promote rapid and healthy seedling establishment (8-15 days).
- Reduce competition between plants
- Create fertile soils rich in organic matter and soil biota
- Manage water with care

SRI practices vary according to local conditions, the underlying principles remain the same everywhere (Akiyoko, 2014; Styger & Jenkins, 2014). In addition, SRI has been studied and evaluated by researchers, international institutions, particularly Cornell University, and rice farmers in a number of countries (50 countries) (Styger and Jenkins, 2014). In addition to reducing production costs and saving seeds, various producers who have experimented with the system have seen their yields increase by 35-100%, thus generating income (Zotoglo, 2012; Gbenou, 2013). Its wide diffusion is mainly linked to increased yields (Hussain et al., 2009; Stoop et al., 2009; Zhao et al., 2009). In Senegal, SRI led to satisfactory results with yields ranging from 3t/ha to 10t/ha while those of control plots varied from 1.2t/ha to 3t/ha (Baldé, 2013).

3. Material and methods

3.1. Study area

This study was carried out in three villages which are Badiate and Essyl located in the municipality of Enampore and Fanda in the municipality of Niaguis (Fig 1). These municipalities belong to the province of Ziguinchor, located in the south of Senegal. The Province of Ziguinchor is geographically located at 12°33' latitude north and 16°16' longitude west and covers a total area of 7339 km². Ziguinchor is characterized by a mean annual rainfall varying between 1400 and 1600 mm. The Sudano-Guinean climate is dominated by two seasons: a long dry season from November to mid-June and a short rainy season from mid-June to October. The economic activities are dominated mainly agriculture, livestock, and fisheries.

![Study area location](source: DTSC, Projection: WGS84 UTM Zone 25N)

3.2. Vegetal material
The vegetal material consists of four rice varieties including Sahel 108, Nerica 4, Nerica 14, and Niamlissou which is a local variety. They are grown in the SRI and TP by producers.

3.3. Experimental design

Yield squares (1 m²) were placed in the producers’ plots and made it possible to collect yield parameters and yields. In each plot, four yield squares of the one-meter side were randomly placed along the diagonals while avoiding the edge effect (Figure 2). A total of 12 yield squares per system for each site with a total of 72 yield squares for the three sites. Stakes were used to materialize the yield squares and their geographical coordinates were recorded using a GPS. In each yield square, the agronomic parameters were recorded (Sanou et al., 2016).

4. Data collection

4.1. Agronomic parameters

A sampling-based on criteria for selecting the practiced system and the cultivated varieties common to both systems was applied to assess the agronomic performance of each system as well as cropping practices. And for this purpose, 18 producers, three of whom were chosen in each site and per system. Agronomic parameters such as plants, fertile tillers, and spikelets density, the weight of 1000 grains, and yields were measured in each system for four rice varieties grown by producers to assess rice productivity in each system.

4.2. Profitability indicators

The sample size was calculated based on the following Fisher equation:

\[
n_f = \frac{n}{\left(1 + \frac{n}{N}\right)}
\]

with

- \(n_f\) = The desired sample size;
- \(N\) = the size of the population;
- \(n = 1 / d^2\), desired accuracy levels (d=10%)

The rice farmers’ population was 77, 48 and 32 respectively in Badiate, Essyl and Fanda. Thus, 55 producers, 20 in Badiate and Essyl and 15 in Fanda, were randomly selected for the survey. A questionnaire was administered to producers who have adopted at least one of the rice
systems at the different sites to assess the economic performance of the systems. Individual interviews were used to collect data on production costs and production (Paraïso et al., 2011). The economic profitability of each system has been calculated on the basis of costs using two indicators (Net Margin (NM) and Benefit/Cost Ration (BCR)) (Agbohessi et al., 2011; Yabi, 2010; Yabi et al., 2012):

4.2.1. **The Net Margin (NM)** is expressed in African Financial Community Franc (AFCF)/ha, the net production margin is obtained by deducting from the gross product in value (GPV) per hectare the total costs (TC) per hectare. It is calculated by the following equation:

\[
NM = \frac{GPV - TC}{2}
\]

The price of paddy rice was estimated at 125 AFCF/kg based on the market cost in Senegal 8.

4.2.2. **Benefit/cost ratio (BCR)** was determined by the following equation:

\[
BCR = \frac{GPV}{TC}
\]

Where GPV= gross product in value, TC= total costs

The economic profitability analysis was interpreted based on the net margin and the BCR. If the BCR were greater than one, the investment would be positive that one invested franc generates more than one AFCF as a profit, and the activity is said to be economically profitable. Of course, if the BCR were less than 1, the value of the benefits do not cover the value of the costs, therefore the net value of the investment would be negative, then one invested franc generates less than one AFCF as a profit, and the activity is considered economically unprofitable, because the producer earns less than he invests. It is correlated to the net margin.

5. **Statistical analysis**

The yield parameters and yields were subjected to a comparison of averages and an Analysis of Variance (ANOVA) to determine the components and cultivation practices that influence yields. The Fisher test at the 0.05 threshold was used to determine the degree of significance of the parameters measured between the systems. When the differences were significant, Tukey’s test was used for multiple mean comparisons to detect the significant differences of the yield parameters and yields between the systems, the village and the varieties. Statistical significance was fixed at 0.05. A constrained ordination using Principal Component Analysis (PCA) as implemented in R was performed for the relationship between the yield parameters, the yields, and the cultivation practices.

6. **Results**

6.1. **Cultivation and management methods**

Rice cultivation was practiced differently in different areas. In Badiate and Essyl, the men were in charge of preparing the nursery and labour while the women were transplanting. In Fanda, on the other hand, women were fully involved in rice cultivation. The labor equipment was essentially the tractor, the “kadiandou” and the hoe for the SRI. However, the “Kadiandou” was used in Badiate and Essyl and the hoe in Fanda for the TP. The average age of seedlings was 16 days for SRI and 26 days for TP. The transplanting was done in line on a flat surface for the SRI and in a scattered way on ridges (Badiate and Essyl), and on a flat surface (Fanda) for the TP.
The number of seedlings transplanted per hill varied according to the production system in Badiate and Essyl: one seedling per hill for SRI and two to three seedlings for TP. However, the number of seedlings per hill is one in both systems in Fanda. Weeding and water management were practiced in both systems, but frequencies ranging from 25 to 100% are more important in SRI (Table 1). Organic fertilization was the most used in both systems with frequencies varying from 40 to 85%.

**Table 1: Standard paddy cultivation practices and management for SRI and TP**

| Villages | Systems | Age of seedlings (d) | No. of seedlings per hill | Water management (%) | Weeding (%) | Organic fertilization (%) | Inorganic fertilization (%) |
|----------|---------|----------------------|---------------------------|----------------------|-------------|--------------------------|---------------------------|
| Badiate  | SRI     | 14                   | 1                         | 70.59                | 100         | 82.35                    | 29.41                     |
|          | TP      | 28                   | 2                         | 68.75                | 25          | 68.75                    | 25                        |
| Essyl    | SRI     | 16                   | 1                         | 61.54                | 100         | 84.62                    | 69.23                     |
|          | TP      | 24                   | 2                         | 45                   | 50          | 50                       | 40                        |
| Fanda    | SRI     | 17                   | 1                         | 80                   | 80          | 40                       | 6.67                      |
|          | TP      | 27                   | 1                         | 40                   | 60          | 40                       | 0                         |

6.2. Yield parameters

The analysis of variance (ANOVA) showed that the yield parameters according to the systems were significantly different (p<0.05). The number of fertile tillers, the number of filled spikelets, and the weight of the 1000 grains were higher in the SRI. On the other hand, the transplanting density was higher in the traditional system (Table 2).

**Table 2: Average yield parameters by production system**

| Yield parameters | SRI           | TP            | Pr<0,05         |
|------------------|---------------|---------------|----------------|
| seedlings (no./m²) | 16 (±0.4) a   | 26 (±5.6) b   | 5.84 e-16***   |
| Tillers (no./m²)  | 201 (±69.4) a | 159 (±49.6) b | 0.00501**      |
| Spikelets (no./m²) | 1165 (±315.9) a | 790 (±159.5) b | 1.95 e-08***   |
| 1000 grains weight (g) | 24.9 (±2.4) a | 22.7 (±2.0) b | 6.68 e-05***   |

Yield parameters were higher in SRI compared to the traditional system in all villages and were lower in Fanda except for transplanting density (29 plants/m²) (Table 3). There was a significant difference (p<0.05) in transplanting density, number of tillers, number of spikelets, and weight of 1000 grains for Sahel 108 variety between systems. And for the Nerica 14, the difference was only significant for the transplanting density and weight of the 1000 grains parameters. The number of spikelets and the weight of the 1000 grains of the variety Nerica 4 were significantly different between systems (p<0.05) while a significant difference is not observed for the transplanting density parameters (p=0.124) and the number of tillers. The local variety, Niamlissou, had a significant difference (p<0.05) in transplanting density, number of spikelets,
and weight of 1000 grains. The yield parameters were all higher in the SRI compared to the TP (Table 4).

Table 3: Average yield parameters by production system and by site

| Village | System | Seedlings (no. /m²) | Tillers (no./ m²) | Spikelets (no./m²) | 1000 grains weight (g) |
|---------|--------|---------------------|-------------------|-------------------|-----------------------|
| Badiate | SRI    | 16 (±0.3) b         | 188 (±53.8) a     | 1271 (±293.7) a    | 26.2 (±2.2) a         |
|         | TP     | 24 (±5.3) a         | 163 (±48.1) b     | 739 (±89.8) b      | 23.5 (±1.6) b         |
| Essyl   | SRI    | 16 (±0.3) b         | 230 (±54.6) a     | 1226 (±260.9) a    | 23.3 (±0.0) a         |
|         | TP     | 25 (±4.4) a         | 176 (±41.0) b     | 911 (±165.7) b     | 21.3 (±0.0) b         |
| Fanda   | SRI    | 16 (±0.6) b         | 184 (±89.9) a     | 997 (±340.5) a     | 25.4 (±3.1) a         |
|         | TP     | 29 (±6.0) a         | 140 (±54.0) a     | 722 (±141.8) b     | 23.2 (±2.7) b         |

Table 4: Average yield parameters by production system and by variety

| Systems | Varieties | Plants (no. /m²) | Tillers (no./m²) | Spikelets (no./m²) | 1000 grains weight (g) |
|---------|-----------|------------------|------------------|-------------------|-----------------------|
| SRI     | Sahel 108 | 16.12 (±0.5)b    | 224 (±58.5)a     | 1251 (±286.6)a    | 23.33 (±0.0)a         |
|         | Nerica 14 | 16.25 (±0.5)b    | 144.25 (±119.0)a | 7507 (±383.0)a    | 29.67 (±0.0)a         |
|         | Nerica 4  | 16.25 (±0.5)a    | 176.8 (±29.3)a   | 1244 (±205.5)a    | 28.67 (±0.0)a         |
|         | Niamlisso | 16 (±0.0)b       | 139.5 (±25.7)a   | 971.8 (±77.2)a    | 26.67 (±0.0)a         |
| TP      | Sahel 108 | 27.96 (±5.3)a    | 179.5 (±44.1)b   | 802.8 (±183.5)b   | 21.33 (±0.0)b         |
|         | Nerica 14 | 22.5 (±3.1)a     | 90.5 (±38.5)a    | 823.5 (±105.4)a   | 27 (±0.0)b            |
|         | Nerica 4  | 18.75 (±2.7)a    | 140.2 (±8.3)a    | 701 (±71.5)b      | 25 (±0.0)b            |
|         | Niamlisso | 24.5 (±2.8)a     | 127 (±12.1)a     | 773 (±92.6)b      | 24.33 (±0.0)b         |

6.3. Yields
The analysis of variance showed a significant difference (p= 5.61e-07) between the yields of the production systems. SRI was more productive than TP. Indeed, the average yields were 394.47 g/m² for SRI and 227.47 g/m² for TP. Average yields were highly variable within and between systems. They were more variable in SRI with a large difference of 600 g/m² between producers (minimum = 67 g/m² and maximum = 786 g/m²) (Figure 3a). However, there was no significant difference in yields between villages for the same system. Yields were higher in the SRI. Badiate had the highest yields (459.6 g/m²) followed by Essyl (392 g/m²) and Fanda (330 g/m²) in the SRI.
On the other hand, yields are higher in Essyl than in Badiate for TP. The lowest yields were recorded in Fanda with average values of 330 g/m² for SRI and 203 g/m² for TP (Figure 3b). Comparing the yield between the varieties, the analysis of yield variance showed a significant difference between yields (p=0.01). Sahel 108 (333.8 g/m²) was the most productive followed by Nerica 4 (323.2 g/m²), Nerica 14 (237.5 g/m²), and Niamlissou (235.4 g/m²). Yields were highly variable within the same variety characterized by large standard deviations. However, the greatest variation in yields was also observed in the Sahel 108 with a minimum of 106 g/m² and a maximum of 786 g/m². A significant difference was noted between yields of Sahel 108, Niamlissou, and Nérica4. However, there was no significant difference between the yields of Nerica 14. The yield of varieties increased for Sahel 108 by 2/3, Nerica 4 by twice (200 g/m²), and Niamlissou by 100 g/m² from PT to SRI (Figure 3c). The Principal Component Analysis (PCA) showed that there was a strong and positive correlation between the number of fertile tillers and yield (r=0.65) and the number of spikelets and yield (r=0.90). On the other hand, the transplanting density influenced negatively the number of spikelets, the weight of the 1000 grains, and the rice yield. This decrease in yields is correlated with high density (Table 5 and Figure 4). Based on the people’s perception, the analysis of variance showed a significant difference (p=0.0207) between yields. The average SRI yields were higher than those of the traditional system with values of 2093.02 kg/ha and 1523.02 kg respectively (Figure 5a). The yields of Badiate and Essyl were significantly different (p<0.05). However, no significant difference (p=0.846) was observed in Fanda. Rice yields were higher in the SRI system except in Fanda where they were lower. For SRI, the higher yields were recorded in Badiate (2694 kg/ha) followed by Essyl (2589 kg/ha) and Fanda (982.5 kg/ha). While in ST, the best yields were obtained in Essyl (1890 kg/ha) followed by Badiate (1206 kg/ha) and Fanda (1072 kg/ha) (Figure 5b).
Figure 3: Variation of yields by production system (a), site (b) and variety (c)
Table 5: Correlation matrix (Pearson) of yield parameters and yields

| Variables                        | Plants density | Number of fertile tillers | Number of Spikelets | 1000 grains weight (g) | Yield (g/m²) |
|----------------------------------|----------------|---------------------------|---------------------|------------------------|--------------|
| Plants density                   | 1              |                           |                     |                        |              |
| Number of fertile tillers        | -0.2647        | 1                         |                     |                        |              |
| Number of Spikelets              | -0.6303        | 0.6663                    | 1                   |                        |              |
| 1000 grains weight (g)           | -0.5679        | -0.3928                   | 0.0708              | 1                      |              |
| Yield (g/m²)                     | -0.5979        | 0.6568                    | 0.9072              | 0.0869                 | 1            |

Figure 4: Relationships between yield parameters and yields

Where B=Badiate; E=Essyl; F=Fanda; SRI=System of Rice Intensification; PT=Traditional Practices; S108=Sahel 108; N4=Nerica 4; Niam=Niamissou; N14=Nerica 14.
6.4. Economic Profitability

6.4.1. Production costs

The total production costs of rice mainly concern labor, transplanting, harvesting, inputs (fertilizers), and other expenses such as and whatever the producers' consumption needs. The total production costs of the SRI system were higher than those of the traditional practices with total average values of 176644 and 145741 AFCF for SRI and TP respectively. The largest loads were encountered in Badiate in the SRI system. Labour and transplanting operations were those that required more work in any village except Fanda. Labor loads were higher in the SRI system in all villages (Table 6).

Table 6: Total rice production costs for SRI and TP (AFCF)

| Villages | System | labour | transplanting | harvesting | Other expenses | Organic fertilizers | Inorganic fertilizers | Total costs |
|----------|--------|--------|---------------|------------|---------------|---------------------|----------------------|-------------|
| Badiate  | SRI    | 89176  | 49882         | 41412      | 17647         | 5965                | 3313                 | 207395      |
|          | ST     | 50375  | 34500         | 27500      | 17688         | 4000                | 5498                 | 139560      |
| Essyl    | SRI    | 88462  | 40308         | 23692      | 15077         | 4938                | 9255                 | 181732      |
|          | ST     | 65800  | 41000         | 29400      | 11800         | 2990                | 2752                 | 153742      |
| Fanda    | SRI    | 71600  | 52000         | 15200      | 0             | 980                 | 1024                 | 140804      |
|          | ST     | 52000  | 52000         | 37600      | 400           | 1920                | 0                    | 143920      |
| Mean cost| SRI    | 83079  | 47397         | 26768      | 10908         | 3961                | 4531                 | 176644      |
|          | ST     | 56058  | 42500         | 31500      | 9963          | 2970                | 2750                 | 145741      |
6.4.2. Economic profitability analysis

The total production costs of the SRI system are the highest. The higher the production costs, the higher the yields increased and the profits increased also except in Fanda. Rice production is more profitable in Essyl (141893 AFCF) compared to Badiate (129355 AFCF). It was in Essyl where rice cultivation was most beneficial to the population regardless of the production system, although a producer in SRI earns more than 59385 AFCF more than the one who practices TP. Economic analysis between the systems showed that SRI was eleven times more beneficial than TP in Badiate. In Fanda, rice cultivation is not profitable because of the negative Net Margin. Because the production costs were higher than the GPV and the BCR was less than one (Table 7).

| Villages | System | TC (AFCF /ha) | Yield (kg/ha) | GPV (AFCF /ha) | N M (AFCF /ha) | BCR |
|----------|--------|---------------|---------------|----------------|----------------|-----|
| Badiate  | SRI    | 207395        | 2694          | 336750         | 129355         | 1.6 |
|          | ST     | 139560        | 1206          | 150750         | 11190          | 1.1 |
| Essyl    | SRI    | 181732        | 2589          | 323625         | 141893         | 1.8 |
|          | ST     | 153742        | 1890          | 236250         | 82508          | 1.5 |
| Fanda    | SRI    | 140804        | 982.5         | 122812.5       | -17991.5       | 0.9 |
|          | ST     | 143920        | 1072          | 134000         | -9920          | 0.9 |
| Mean     | SRI    | 176644        | 2088.5        | 261062.5       | 84418.5        | 1.5 |
|          | ST     | 145741        | 1389.3        | 173662.5       | 27921.5        | 1.2 |

7. Discussion

7.1. Yield parameters and Yields

The transplanting density depended on the production system. It was higher in TP than in SRI. In Burkina Faso, Sanou et al. (2016) showed that the number of plants per hill was 20 to 26% lower in SRI than the Rice Growers’ Habitual Practices plots. The number of tillers was higher in the SRI at all sites and was strongly influenced by the transplanting density. Various comparative studies between SRI and conventional practices have shown similar cases in the difference in tillers production (Gani et al., 2002; Krishna, 2008; Bagayoko et al., 2017). Indeed, the higher the transplanting density, the more the tillering capacity of the plants increased. This would be related to the competition of plants for light and nutrients due to the high densities observed in TP. This hypothesis was confirmed by Thakur et al. (2010) who stipulated that transplanting a plant per inch as well as spacing between plants contributed to reducing competition. Also, the growth rate of a group of tillers is itself affected by the level of competition to which the stand is subjected (Pigeaire, 1981).

Rice plants in the SRI plots were much more productive in spikelets by more than 19%. Indeed, in the SRI, young plants were transplanted rather and reach the production phase, especially at the maturation stage, contrary to what was observed in TP. Sanou et al. (2016) found a difference in the average number of grains filled per panicle in the plots of producers who have adopted the SRI and Usual practices of rice farmers in Burkina Faso. In Indonesia, Hidayati and Anas (2016) also showed that all yield parameters with a higher number of grains per inch in SRIs than in conventional system plots. The results of this study showed a distinction between the yield parameters of the varieties according to the system. The Sahel 108 variety has a higher tillering capacity and a higher number of spikes followed by the Nerica 4 and Niamlissou. The local variety recorded the lowest parameters except for the weight of the 1000 grains, which
was higher than the Sahel 108. Nerica 14 had the lowest average tillering, however, its grain weight was the highest. Besides, Sahel 108 has a large tillering and several spikes. The number of tillers was one of the parameters used to distinguish rice varieties (Kouakou, 2017). The results of this study showed a distinction between system performances. There was an increase in yield (22%) in SRI compared to traditional practice (Zhao et al., 2009).

7.2. Factors influencing rice yield
Concerning cultural practices, it was noted that the level of adoption of the SRI principles has not been 100% effective. Rice practices varied from one system to another and strongly influenced yields (Bagayoko et al., 2017). Indeed, a negative correlation was noted between the duration of nursery plants and yield and a positive correlation between organic fertilizers and yield. The duration of the plants in the nursery reduced their production capacity and had a negative influence on yield. The intermittent water management in plots allowed weeds to grow quickly because of the low water level, unlike in the traditional system where plots were practically permanently flooded. This would inhibit the development of weeds. Analysis of these factors has enabled us to identify that differences between potential and actual yield were related to biophysical factors, cultural practices and socio-economic conditions, or technology transfer and diffusion (FAO, 2004). The rice practices (fertility, water, weed management, etc.) interacted to determine yield (Husson et al., 2004). The low yields in PT could be linked to late planting by farmers (Deschenes & Dubuc, 1981) but also to poor soils because there was little organic and mineral amendment. The lack of yields in the TP system was caused by the late planting (Dobelmann, 1976). The low yields were related to non-compliance with the technical itineraries and crop schedules recommended by extension (Ndiiiri et al., 2013). The average yields of SRI in Fanda according to survey data were very low, which clearly showed that the system did not meet the expectations of some producers. According to producers, the valley was not cultivated from 1992 to 2017 due to the conflict in the area. This could be explained by the presence of iron toxicity in producers’ plots, leading to yield losses (Gnago et al., 2017). One of the main factors explaining the difference in yields would be related to transplanting young plants because competition for nutrients reduces plant performance and therefore leads to lower yields. A case study on the physiology of SRI plants compared to conventional system showed that transplanting young plants into SRI minimizes the effect of transplant shock and competition for nutrients, water, and light (Hidayati and Anas, 2016). The final yield resulted from the interaction between the characteristics of the varieties, environmental factors, and conditions and cultural practices (IRRI, 1984; Ameziane El Hassani and Persoons, 1994).

7.3. Production cost and Profitability
Rice production was labor-intensive and also required a lot of transplanting. The village of Badiate used more labor than the other villages. However, there was not a large gap in the average labor difference between the systems. This decrease in the SRI workforce would be due to the experience of producers in transplanting young plants. Indeed, many producers in the village of Essyl have confirmed that the longer the SRI was practiced, the shorter the time required for transplanting. In Madagascar, Uphoff (2007) has shown in this dynamic that as farmers gain experience, they reduce the need for labor. The profitability of rice cultivation was determined by total production costs and yields obtained at the end of the harvest. Lower production costs and higher yields provided producers with a return on investment. Among rice production operations, labor was the most labor-intensive in all areas and therefore generated the highest costs. Concerning total production costs and yields, the survey results showed that the average cost per producer was higher in SRI than in TP. Although the SRI generated an
excess of expenses, it nevertheless generated a greater benefit than the TP (Gathorne-Hardy et al., 2016).

8. Conclusion
Rice cultivation played an important role in local people’s lives. Despite its role in food security, local production remained low due to low yields, linked on the one hand to rainfall variability and on the other hand to a lack of material resources and especially to inappropriate agricultural practices. The duration of the plants in the nursery, transplanting density, organic amendment, and weeding were the main factors influencing yield. Thus, despite the high costs of implementing the SRI, it was more productive and economically profitable than TP. SRI was therefore a sustainable alternative to improving yields and increasing household incomes in the context of climate change. In the future, it would be important to repeat the study in the station to properly study the requirements of the SRI in terms of inputs and working time, to adapt the system to local conditions, and to study the limiting factors (biotic and abiotic) related to low yields in the Fanda Valley.

Conflict of Interest: The authors declare no conflict of interest.

REFERENCES
Agbohessi, P. T., Toko, I. I., Yabi, J. A., Dassoundo-Assogba, J. F., & Kestemont, P. (2011). Charactérisation des pesticides chimiques utilisés en production cotonnière et impact sur les indicateurs économiques dans la Commune de Banikoara au nord du Bénin. International Journal of Biological and Chemical Sciences, 5(5), 1828-1841.

Akiyoko (2014). Les principes et pratiques fondamentaux du SRI et le modèle SRI élaboré pour adaptation aux conditions locales de la commune de Banikoara, 13p.

Ameziane El Hassani, T., & Persoons, E. (1994). Agronomie moderne–Bases physiologiques et agronomiques de la production végétale. Édition Hatier-AUPELF. UREF, 544.

Bagayoko, M., Traore, G., & Samake, O. (2017). Variabilité spatiale des rendements du riz en système de riziculture intensive (SRI) en zone office du Niger au Mali. Agronomie Africaine, 29(2), 137-147.

Baldé (2013). Le système de riziculture Intensif. AGRIDAPE revue sur l’agriculture durable à faibles apports externes, volume 29 N°1, Burkina Faso, 36 pages.ISSN : 0851-7932.

Bocoum M. L. (1998). Atelier de présentation des résultats de recherche collaborative sur le thème riziculture dans les régions de Basse et Moyenne Casamance, du Sénégal oriental et de haute Casamance à Tambacounda. Mars, 226p.

Boutsen, S., & Aertsen, J. (2013). Peut-on nourrir l’Afrique de l’Ouest avec du riz. MO papers(74).

Deschenes, J. M., & Dubuc, J. P. (1981). Effets de L’humidité du Sol, Des Dates de Semis et Des Mauvaises Herbes Sur Le Rendement Des Cereales. Canadian Journal of Plant Science, 61(4), 851-857.

Dobelmann, J. P. (1976). Riziculture pratique 1: riz irrigué. Presses universitaires. Paris.

FAQ (2004). "Riz et limitation de l’écart de rendement". Rome. www.fao.org/rice.

Fall, A. A., & Dièye, P. N. (2008). Impact des cours mondiaux du riz sur la sécurité alimentaire au Sénégal. Réflexions Perspect. ISRA, 6(6).

Fall, A. (2015). Synthèse des Etudes sur l’Etat des Lieux Chains de Valeur Riz au Sénégal. Rapport Consultation VECO.

Gani, A., Rahman, A., Dahono, R., & Hengsdijk, H. (2002). Synopsis of water management experiments in Indonesia. Wafer-wise rice production, 29-38.

Gathorne-Hardy, A., Reddy, D. N., Venkatnarayana, M., & Harriss-White, B. (2016). System of Rice Intensification provides environmental and economic gains but at the expense of social sustainability—A multidisciplinary analysis in India. Agricultural Systems, 143, 159-168.

Gbenou P. (2013). Evaluation participative du Système de Riziculture Intensive dans la bassevallée de l’Ouémé au Bénin. Thèse de doctorat en GéographieetGestion de l’environnement, Universitéd’Abomey-Calavi, 213p.

Gnago, A. J., Kouadio, K. T., Tia, V. E., Kodro, A. P., & Goulivas, A. V. (2017). Évaluation de deux variétés de riz (CK73 et CK90) à la Toxicité Ferreuse et à quelques contraintes biotiques à Yamoussoukro (Côte d’Ivoire). Journal of Applied Biosciences, 112(1), 11035-11044.

Haddad G. (1969). Proposition d’une classification des rizières aquatiques de la Casamance. Agronomie Tropicale 24:393-402.

Hidayati, N., & Anas, I. (2016). Photosynthesis and transpiration rates of rice cultivated under the system of rice intensification and the effects on growth and yield. HAYATI Journal of Biosciences, 23(2), 67-72.
Hussain, A., Bhat, M. A., Ganai, M. A., & Hussain, T. (2009). Comparative performance of system of rice intensification (SRI) and conventional methods of rice cultivation under Kashmir valley conditions. *Indian Journal of Crop Science, 4*(1and2), 159-161.

Poussin, J. C., & Boivin, P. (2002). Performances des systèmes rizicoles irrigués sahiéliens. *Cahiers Agricultures, 11*(*1*).

Husson, O., Castella, J. C., Ha, D. T., & Naudin, K. (2004). Diagnostic agronomique des facteurs limitant le rendement du riz pluvial de montagne dans le nord du Vietnam. *Cahiers Agricultures, 13*(*5*), 421-428.

IRRI (1984). “Manuel de riziculture”. Los baijos, Laguna, Philippines, ISBN 971-104-090-5, 221p.

Jouve P. (1992). Le diagnostic du milieu rural, de la région à la parcelle : approche systémique des modes d’exploitation agricole du milieu. Montpellier, France. Cnearc, Etudes et travaux du Cnearc n. 6, 39 p.

Kouakou, K.P.M. (2017). “Evaluation des possibilités de culture du riz pluvial et risques climatiques associés au Sénégal. Thèse unique de doctorat En Biologie. Physiologie et Pathologies végétales, spécialité : Production et Protection des végétaux”, UCAD, 101p.

Krishna, A. (2008). Influence of system of rice intensification (SRI) cultivation on seed yield and quality. *Karnataka J AgricSci, 21*(3), 369-372.

Laulanié H. (1993). Le système de riziculture intensive malgache. *Tropicura, 11*(*3*):110-114.

Ndiri, J. A., Mati, B. M., Home, P. G., Odongo, B., & Uphoff, N. (2013). Adoption, constraints and economic returns of paddy rice under the system of rice intensification in Mwea, Kenya. *Agricultural water management, 129*, 44-55.

Paraïso, A., Sossou, A. C. G., Yegbemey, R. N., & Biaou, G. (2011). Analyse de La Rentabilité de la Production du Fonio (Digitaria exilis S.) dans la Commune de Boukombe au Benin. *Journal de la Recherche Scientifique de l'Université de Lomé (Togo) Série A, 13*, 27-37.

Radanielina, T. (2010). Diversité génétique du riz (Oryzasativa L.) dans la région de Vakinankaratra, Madagascar. *Structuration, distribution éco-géographique & gestion en situ* (Doctoral dissertation).

Pascual, V. J., & Wang, Y. M. (2017). Impact of water management on rice varieties, yield, and water productivity under the system of rice intensification in Southern Taiwan. *Water, 9*(1), 3.

Pigeaire, A. (1981). Contribution à l’analyse de l’élaboration du rendement du riz pluvial: éléments de description de l’histoire d’un peuplement de thalles (variété IRAT 13)-modélisation du nombre potentiel d’épillets d’un peuplement de panicles.

Razafimanantsoa, R. (2008). Analyse de l’échec et de la diffusion du Système de Riziculture Intensive à Madagascar. *Mémoire de DESS en développement local et gestion des projets, Université d’Antananarivo*.

Sanou, A. G., Dembele, K. D., Ouédraogo, I., & Dakooou, D. (2016). Problématique de mise en œuvre du système de riziculture intensif dans les périmètres rizicoles irrigués de Karfiguélia et de la vallée du Kou au Burkina Faso. *International Journal of Biological and Chemical Sciences, 10*(6), 2693-2709.

SÈNE, A. M. (2018). Dégradation des rizières des bas-fonds dans un contexte de changement climatique en Basse Casamance (Sénégal). *Espace Géographique & Société Marocaine*, (20/21).

Stoop, W. A., Adam, A., & Kassam, A. (2009). Comparing rice production systems: A challenge for agronomic research and for the dissemination of knowledge-intensive farming practices. *Agricultural Water Management, 96*(11), 1491-1501.

Styger E. & Jenkins D. (2014). *Manuel Technique sur le SRI en Afrique de l'Ouest*. Version 2 – Août 2014 SRIGRice / CNRSGRIZ / PPAAO, 60p.

Thakur, A. K., Rath, S., Roychowdhury, S., &Uphoff, N. (2010). Comparative performance of rice with system of rice intensification (SRI) and conventional management using different plant spacings. *Journal of Agronomy and Crop Science, 196*(2), 146-159.

Uphoff, N. (2007). Reducing the vulnerability of rural households through agroecological practice: Considering the System of Rice Intensification (SRI). *Mondes en développement*, (4), 85-100.

Yabi, A. J. (2010). Analyse des déterminants de la rentabilité économique des activités menées par les femmes rurales dans la commune de Gogounou au Nord-Bénin. *Annales des Sciences Agronomiques, 14*(2), 221-239.

Yabi, A. J., Paraïso, A., Ayena, R. L., & Yegbemey, R. (2012). Rentabilité économique de production agricole sous pratiques culturales de gestion de la fertilité des sols dans la commune de Ouaké au nord-ouest du Bénin. *Annales des Sciences Agronomiques, 16*(2), 229-242.

Zingore, S., Waihegi, L., & N’Diaye, M. K. (2014). Guide pour la gestion des systèmes de culture de riz. *Consortium Africain pour la Santé des Sols, Nairobi*. *Le Consortium Africain pour la Santé des Sols (ASHC)*, 60.

Zhao, L., Wu, L., Li, Y., Lu, X., Zhu, D., & Uphoff, N. (2009). Influence of the system of rice intensification on rice yield and nitrogen and water use efficiency with different N application rates. *Experimental Agriculture, 45*(3), 275-286.

Zotoglo K. (2012). Raifort de formation des formateurs en SRI au Sénégal. Bethesda, MD: projet ATP, Abt Associates Inc. Juin, 27p

© 2021 by the authors. Licensee *Scientific Research Initiative, Michigan*, USA. This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).