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Effect of the optimized *Guiera senegalensis* system on crop performance (millet, groundnut) in the northern Peanut Basin (Senegal).

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CRediT authorship contribution statement

Mariama Marcelle DIONE: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing Original Draft, Visualization. **Ibrahima DIEDHIOU:**
5 Conceptualization, Methodology, Writing Review and Editing, Supervision, Project administration, Funding acquisition, Validation. **Richard P. DICK:** Conceptualization, Methodology, Writing Review and Editing, Supervision, Funding acquisition, Validation.
52 **Katim TOURE:** Writing Review and Editing, Funding acquisition. **Amanda L. DAVEY:** Supervision, Project administration. **Mbathio SOGUE:** Investigation. **Daouda SARR:** Investigation. **Nogaye NDIAYE:** Investigation. **Oulimata DIATTA:** Formal analysis,
19 Writing Review and Editing. **Roger BAYALA:** Writing Review and Editing. **Idrissa WADE:** Writing Review and Editing, Funding acquisition.

ABSTRACT

Agroforestry systems combining indigenous shrubs and crops are recognized as promising ways of restoring degraded soils and improving agricultural yields in the Sahel. Research is attempting to optimize these systems to maximize their benefits. In this context, the comparative effect of optimized (OSS) and traditional (TMS) *Guiera senegalensis*
30 management systems on the performance of groundnut (*Arachis hypogaea* L.) and millet (*Pennisetum glaucum* L.) was studied in the Meckhé zone from 2019 to 2022 under farmer conditions. OSS involves increasing the density of *Guiera senegalensis*, cutting and chopping

the biomass, and incorporating it into the soil. This contrasts with TMS, where shrub density is low, and the cut shrub biomass is burned. The trial is a randomized block design with fifteen replications and two treatments. Measurements were taken of height, LAI, NDVI, yield components and rainwater use efficiency. The optimized system improved groundnut and millet growth. It also significantly improved yield components and crop rainwater use efficiency. Overall, compared with the traditional system on the farm, the optimized system increased crop performance.

Key Words: Peanut Basin, *Guiera senegalensis*, Optimized System, Millet, Groundnut, Crop Performance

RESUME

Effet du système optimisé à *Guiera senegalensis* sur la performance des cultures (mil, arachide) dans le Nord Bassin Arachidier (Sénégal).

Les systèmes agroforestiers associant arbustes autochtones et cultures sont reconnus comme prometteurs, pour restaurer les sols dégradés et améliorer les rendements agricoles au Sahel. C'est dans ce contexte que, cette étude a été menée de 2019 à 2022, pour déterminer l'effet du système optimisé à *Guiera senegalensis* sur la performance du mil et de l'arachide en milieu paysan. Le dispositif expérimental est en blocs complets randomisés avec deux traitements (système optimisé à *Guiera senegalensis* et système traditionnel à *Guiera senegalensis*) et quinze répétitions. Le système optimisé consiste à augmenter la densité des arbustes, à découper leur biomasse, et à l'incorporer au sol. Le système traditionnel consiste à maintenir une faible densité d'arbustes dans la parcelle et à brûler leur biomasse quand ils sont coupés. Les mesures ont porté sur la hauteur, le LAI, le NDVI, les composantes du rendement, l'efficience d'utilisation de l'eau de pluie par les cultures. Le système optimisé a amélioré la croissance de l'arachide et du mil. Également, il a amélioré significativement les composantes du rendement et l'efficience d'utilisation de l'eau de pluie des cultures. Globalement, comparé au système traditionnel en milieu paysan, le système optimisé a augmenté la performance des cultures. **Mots clés** : Bassin Arachidier, *Guiera senegalensis*, Système Optimisé Mil, Arachide, Performance des Cultures.

1. Introduction

In Senegal, over 15% of the population faces poverty and food insecurity due to the drop of crop yields combined with population increase (ANSD, 2014; Masson-Delmotte, 2020; Mbow et *al*., 2021).

This situation is due, among other things, to an agriculture dependent on erratic rainfall, coupled with the degradation of most arable land (Sacande, 2018; Sow et *al*., 2020). Indeed, the great drought of 1968 to 1985 was exceptional in its duration and intensity. This resulted in a 300 mm drop in rainfall, and a 200 km southward shift in isohyets, the consequences of which are regression of vegetation cover and denudation of land (Roquet, 2008; Diallo et *al*., 2022). As a result, soils in Senegal have become increasingly poor, and highly vulnerable to erosion (Badiane et *al*., 2000). This phenomenon particularly affects the Peanut Basin, the main millet and groundnut production area, where 47% of land is experiencing some form of degradation (O.D.N.U, 2007; INP, 2013). Yields of these crops, which are of vital economic and social importance, are less than a quarter of world levels (Sow et *al*., 2018; Gérald et *al*., 2020).

A great deal of research has been devoted to combating the growing degradation of the soils of the Groundnut Basin. They have shown that the soils of the Peanut Basin, with their low organic matter content, make little use of mineral fertilization. It is organo-mineral fertilization that enables yields to be improved sustainably (Badiane et *al*., 2000). Unfortunately, the availability of organic matter poses a problem, as crop residues compete with animal feed and domestic uses, while livestock numbers have been considerably reduced (Badiane et *al*., 2000).

In this context, numerous studies have been devoted to the role of agroforestry species in improving and/or maintaining soil organic status and fertility (Ndour et *al*., 2000). On this path, growing interest is noted mainly in two agroforestry shrubs widely distributed in the Sahelian zone, notably *Guiera senegalensis* and *Piliostigma reticulatum* (Chapuis-Lardy et *al*., 2019).

In particular, in Senegal, research efforts devoted to these two shrubs between 1998 and 2016 led to the development of an optimized shrub-crop system (OSS) (Chapuis-Lardy et *al*., 2019). The OSS sequesters more carbon in the soil (Lufafa et *al*., 2008a and 2008b), improves soil quality through nutrient recycling and increased biological activity (Dossa et *al*., 2008; Diedhiou et *al*., 2009; Diedhiou-Sall et *al*., 2013), achieves hydraulic redistribution and thus increases soil moisture thanks to this faculty (Kizito et *al*., 2006, 2007, 2012; Bogie et *al*., 2018). This has a positive impact on crops in terms of improved growth (Bogie et *al*., 2019; Bayala et *al*., 2022), shorter development cycles (Bayala et *al*., 2022) and higher yields (Bright et *al*., 2017; Bright et *al*., 2021). However, the results were obtained under experimental conditions, where the OSS was compared with a system where the crop plots are bare (without any shrubs) and not the peasant system where there is a low density of shrubs. The main objective of this study is to highlight the effect of the optimized *G. senegalensis* management system (OSS) on the performance of groundnut and millet in the Northern Peanut Basin of Senegal. The specific objectives are: (i) to determine the effect of OSS on crop growth and yield; (ii) evaluate the effect of OSS on the efficiency of water use by crops (groundnut and millet).

2. Materials and methods

2.1. Characteristics of study sites

The study was carried out in seven villages (Koul, Lissar, Ndia, Femboule, Ngass, Ndiaye Thioro, and Risso) of Meckhé (16° 39' N and longitudes 15° 4'W) in Peanut Basin of Senegal.

The area's climate is tropical and semi-arid, with one wet season (July to October) and a long dry season lasting around eight months (November to June). Average annual rainfall is 470.87 mm. The average annual temperature ranges between 17 and 35°C (ANACIM, 2021).

The soil is Rubic Arenosol (95% sand) with low content of carbon and nitrogen (0.2% C and 0.15% N) low cation exchange capacity (0.7 meq/100 g) (Oldmen et *al.*, 1993; Khouma, 2002).

Fallow land is mainly shrub with dominant woody species like *Faidherbia albida* Del. A. Chev., *Vachellia tortilis* Forssk., *Balanites aegyptiaca* Del., *Zizyphus mauritiana* Lam. and *Adansonia digitata* L. The herbaceous cover is mainly composed of annual grasses, with a predominance of *Cenchrus biflorus* Roxb. (Dione et *al.*, 2008).

2.2. Plant materials

2.2.1. *Guiera senegalensis*

Guiera senegalensis J. F. Gmel is an indigenous shrub of *Combretaceae* family. It is found from Senegal to Ethiopia, in fallow land, light sandy soils and degraded soils (Kerharo and Adam, 1974; Sanogo, 2012). It generally occurs in bushy clumps rarely exceeding 3 m in height, branched from the stump (Kerharo and Adam, 1974; Reca, 2016). *G. senegalensis* leaves, roots, stem and galls are widely used in traditional pharmacopoeia and veterinary medicine (Tine et *al.*, 2019). During a peak-season, the biomass of G. senegalensis could range from 0.9 to 1.4 Mg C ha^{-1} (Lufafa *et al.*, 2008).

2.2.2. *Arachis hypogaea L.*

Peanut variety used was 55-437. It has a short cycle (90 days). It is tolerant of water deficit, not very sensitive to photoperiod, resistant to aflatoxin and susceptible to acidity, salinity and Cercosporiosis diseases (Schilling, 2001). The crop development is subdivided into five phases: germination, which lasts 3 to 4 days after sowing (JAS), vegetative phase (5 JAS to 25 JAS), flowering (25 JAS to 60 JAS), gynophorization (60 JAS to 90 JAS) and ripening (90 JAS) (Mayeux, 2001; Schilling, 2001). The crop's water requirements are generally met when rainfall is between 500 and 1000 mm, albeit with a good distribution (Schilling, 2001). The crop is more sensitive to water stress during germination, flowering and gynophorization (Schilling, 2001). The potential yield of this variety is 2 T/ha, but its production in the real world hardly exceeds 800 kg/ha (Schilling, 2001; Bello et *al.*, 2019). Shelling yield is 75%. The weight of 100 seeds is between 35 g and 38 g (Schilling, 2001).

2.2.3. *Pennisetum glaucum* L.

The variety of millet used was Souna 3 variety. The development cycle is 90 days. It is drought tolerant and non-photoperiodic, and has a high tillering capacity (Sy et *al.*, 2015). The development cycle is subdivided into vegetative, productive and ripening phases (Kadri et *al.*, 2019). The favorable rainfall of this variety ranges between 350 and 500 mm and the optimal yield is estimated at 2.5 T/ha, but under farmers practice, the yield rarely exceed 500 kg/ha (Bamba et *al.*, 2019; Sy and Kanfany, 2023). The average height of the Souna 3 variety is 245 cm at maturity, while the weight of 1,000 millet grains averages 7.98 g (Bekoye, 2014; Ndir et *al.*, 2014).

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2.3. Experimental design

5

The trial was carried out on the farm for four years (2019 to 2022). The experimental design is a randomized complete block design with fifteen (15) replicates (Table 1). The factor studied is the *G. senegalensis* management system, with two (2) levels: optimized *G. senegalensis* management system (OSS), traditional *G. senegalensis* management system (TMS). The experimental unit is a 250 m^2 elementary plot, 10 m wide by 25 m long. Within a block, the spacing between elementary plots is 3 m.

Table 1. Identification of trial blocks.

Block	Village
P1	
P2	
P3	Lissar
P4	
P5	
P6	Risso
P7	
P8	Ngass
P9	
P10	Femboule

P11	
P12	Ndiaye Thioro
P13	Koul
P14	Ndiaye Thioro
P15	Ndia

The TMS consists in maintaining the current density of shrubs in farmers' fields (120-520 shrubs per hectare). During soil preparing (June), the shrubs are cut and burned. Between the end of July and August 15, shrub regrowth is cut again, and the biomass obtained is deposited between the crop rows.

OSS involves increasing shrub density to 1,200 shrubs/ha, i.e. 30 shrubs per elementary plot. Shrubs are cut as in the TMS treatment, and the biomass is chopped up and incorporated into the soil. The total biomass added to the soil is around 3 T/ha.

2.4. Crop management

The cropping system adopted during the trial is a millet/peanut rotation.

The groundnut trials were conducted in 2019 and 2021 during rainy season. Peanut fields were sown early in August 2019, 2021and 2022 at a 50 cm x 15 cm spacing. NPK fertilizer (6-20-10) was applied at 150 kg/ha rate immediately after sowing. Weeding was carried out whenever necessary.

Millet sowing was carried out manually, from July 14 to 17 in 2020 and from August 08 to 11 in 2022 at 1 m x 1 m spacing. Thinning at 3 plants per hole was carried out between 12 and 15 days after sowing (DAS). NPK fertilizer (15-10-10) was applied at the same time at a rate of 150 kg/ha. Urea was applied with 50 kg/ha at thinning and 30 DAS. Weeding was carried out whenever necessary.

2.5. Measurements and observations

2.5.1. crop growth parameters

Throughout the crop development cycle, the crop height, leaf aera index and NDVI were measured on six plants per plot in 6 repetitions per farmers filed (n=36 measurements per treatment). Measurements were made at 56 and 88 DAS in 2019; 40, 60 and 90 DAS in 2020; 15, 25, 74 and 85 DAS in 2021; 30 and 90 DAS in 2022.

42 Height was measured using a tape measure. For groundnuts, it was measured from soil surface to the collar of the highest apical bud. For millet, it was measured from ground to the last point of ear insertion.

Leaf area index (LAI) was measured with an LP 80 ceptometer, below the canopy, on all four sides of the six plants sampled.

28 The normalized difference vegetation index was measured using a GreenSeeker. The device was placed 60 cm above the highest leaf of the plants monitored.

2.5.2. Crop yield

2.5.2.1. Groundnut (peanut)

Three subplots of 2 m² were harvested randomly in each plot (treatment). Pods were removed from biomass and drying on the sun. Weight average of 100 grains of peanuts was measured in 3 repetitions per subplot.

(1) A sample of peanut biomass was simultaneously removed in each subplot and dried in oven at 105° C. Total of peanut

biomass was calculated through equation

$$(1) PTs = \frac{PEms * PHT}{PEmh}$$

with *PTs*: Total weight of dry biomass; *PEms*: Average weight of dry samples; *PHt:* Total weight of wet biomass; *PEmh*: Average weight of wet samples.

2.5.2.2. Millet

A subplot of 80 m² was established in each elementary millet plot for the yield.

Grain yield was measured after harvesting the ears at physiological maturity. Three samples of 1,000 grain were weighed to determine the average weight of 1,000 millet grains. The yield of straw was measured inner the subplot. Three samples of millet biomass were collected for oven-drying at 105°C for 48 hours. Total millet biomass was calculated using equation (1).

2.5.3. Determination of water use efficiency

To determine rainwater use efficiency (kg/ha/mm), the method described by Bright *et al.* (2017) was used. This involved dividing the total biomass or the total amount of grain harvested by the total rainfall recorded during the crop season: 326.6 mm (2019), 661.98 mm (2020), 297.1 mm (2021) and 482.5 mm (2022).

2.5.4. Data analysis methods

Statistical analyses were performed with R studio software (R Core Team, 2022), and Excel 2016 spreadsheet (Microsoft Office) was used to produce all figures. The agricolae package (Mendiburu and Yaseen, 2020) was used to highlight the effect of treatments (OSS and TMS) on agro-physiological parameters, as well as millet and groundnut yield components, and crop nutrient and water use efficiency based on the general linear model:

$Yij = \mu + Ti + Bj + \varepsilon ij$,

where Yij is the analysed variable of crop ij, μ is the overall mean, Ti is the fixed effect of treatment i, Bi is the fixed effect of the plot, εij represent the residual errors assumed to be independent and following a normal distribution (0, σ^2).

Each plot represents a replicate or block. Significant differences were determined at *p-value* ≤ 0.05. Assumptions about heterogeneity of variance and normality of residual errors were validated by residual and quantile plots. Analysis of the separation of means between the OSS and TMS treatments was performed using Tukey's test. Except for crop water use efficiency in 2022, the non-parametric Wilcoxon test was used, as the distribution of the variables did not follow a normal distribution. Pairwise comparisons of least squares means were presented with error bars representing 95% confidence intervals.

3. Results

3.1. Effect of the optimized *Guiera senegalensis* system on crop growth parameters

3.1.1. Height

OSS had a significant effect on millet height in 2020 and 2022. Thus, in 2020, OSS significantly (*p-value* ≤ 0.005) improved millet height by 59.07% and 10.28% during the tillering and bolting phases respectively (Fig. 1c). In 2022, OSS significantly increased millet height by 59.48% and 24.23% at tillering and ripening stages respectively (Fig. 1d).

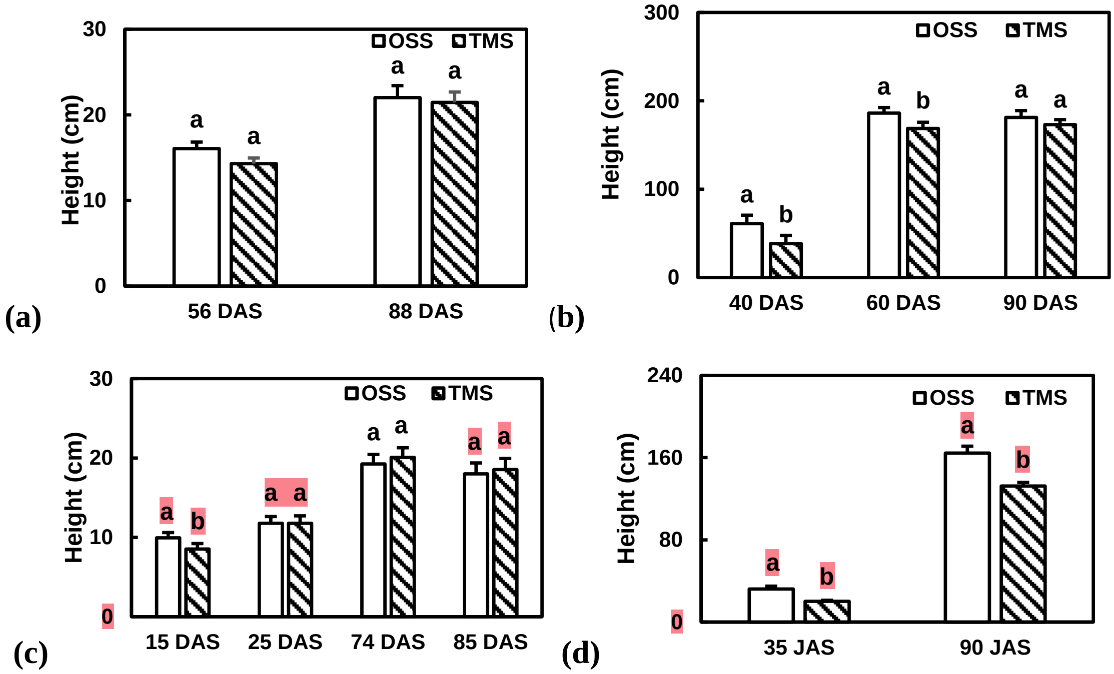

Figure 1. Effect of *G. senegalensis* optimized system on crop height evolution (a: groundnuts in 2019; b: millet in 2020; c: groundnuts in 2021; d: millet in 2022).

OSS: Optimized *G. senegalensis* management system, TMS: Traditional *G. senegalensis* management system; n = 36 per treatment and per measurement date; DAS: Days after sowing. For each measurement date, the means of the treatments assigned the same letter are not statistically different at the 5% threshold with Tukey's test.

3.1.2. Leaf Area Index (LAI)

Shrub management had no significant influence on LAI for groundnut in 2021 and millet in 2022 for all crop development stages except ripening in 2021 (Figs. 2a and 2b). At this last stage, OSS improved LAI by 178.85% compared with TMS (Fig. 2a).

Millet leaf area index was not significantly improved by OSS in 2022. However, maxima were recorded in plots receiving OSS, with an increase of 7.01% and 28.24% during the tillering and ripening phases respectively (Fig. 2b).

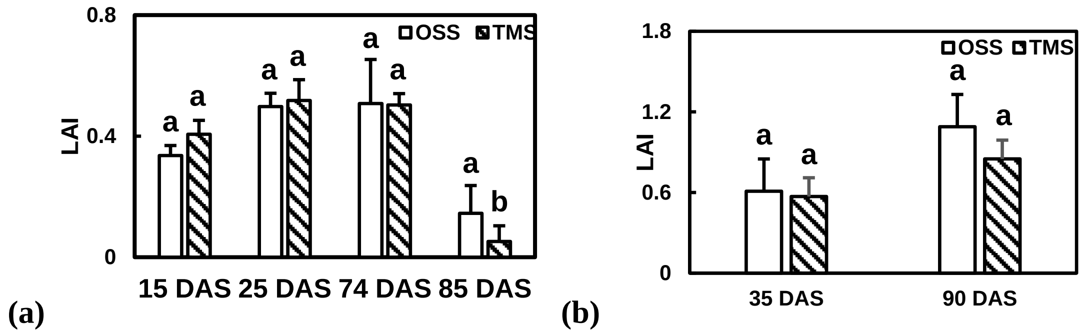

Figure 2. Effect of the optimized *G. senegalensis* system on changes in leaf area index (LAI) of groundnut in 2021 (a) and millet in 2022 (b).

OSS: Optimized *G. senegalensis* management system, TMS: Traditional *G. senegalensis* management system; n = 36 per treatment and per measurement date. DAS: Days after sowing. For each measurement date, the means of the treatments assigned the same letter are not statistically different at the 5% threshold with Tukey's test.

3.1.3. NDVI

In 2020 and 2022, OSS had a significant effect on millet NDVI during the tillering phase (40 DAS in 2020 and 35 DAS in 2022) (*p-value* ≤ 0.01). This parameter increased by 18.71% in 2020 and 78.57% in 2022 (Fig. 3a and Fig. 3c).

Groundnut NDVI was not significantly affected by OSS (*p-value* ≥ 0.35) during the vegetative (15 DAS), flowering (25 DAS) and ripening (85 DAS) phases. However, at gynophorization (74 DAS), this effect was significant (*p-value* = 0.008), with NDVI rising from 0.287 to 0.343 (Fig. 3b).

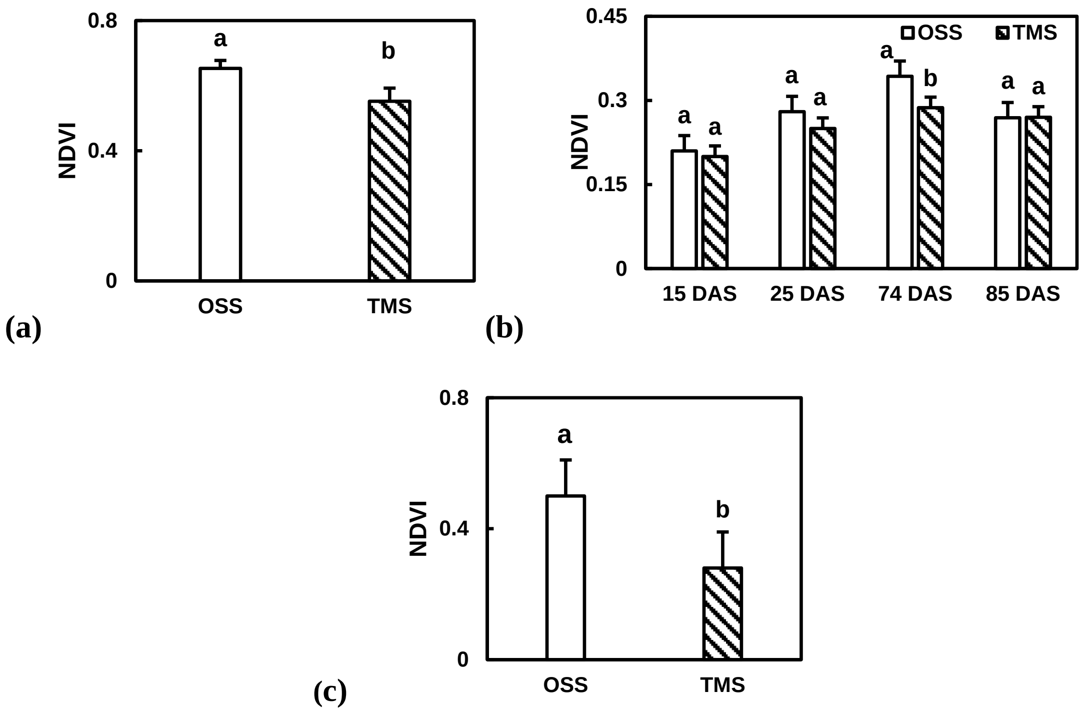

Figure 3. Effect of the optimized *G. senegalensis* system on changes in normalized difference vegetation index (NDVI) for millet in 2020 (a) and 2022 (c), and for groundnut in 2021 (b).

OSS: Optimized *G. senegalensis* management system, TMS: Traditional *G. senegalensis* management system; n = 36 per treatment and per measurement date. DAS: Days after sowing. For each measurement date, the means of the treatments assigned the same letter are not statistically different at the 5% threshold with Tukey's test.

3.2. Effect of the optimized *Guiera senegalensis* system on crop yields

3.2.1. Effect of optimized *Guiera senegalensis* system on peanut yield

In both 2019 and 2021, there were no significant differences between the OSS and TMS treatments for any of the yield parameters measured, including pod yield, haulm yield and 100-seed weight (Table 2).

Table 2. Effect of *G. senegalensis* optimized system on peanut yield components (n=15).

Peanut Yield				
	2019			2021
	Biomass (kg/ha)	Pod (kg/ha)	100-seeds Weight (g)	Biomass (kg/ha)
OSS	290.3[a] ± 122.15	123.9[a] ± 81.13	27.5[a] ± 3.32	2278.8[a] ± 1088.279
TMS	292.8[a] ± 165.44	108.5[a] ± 76.58	27.4[a] ± 3.25	2186.1[a] ± 1111.684
Treatment	0.93	0.17	0.89	0.65
Block + Treatment	0.001 **	1.4e-5 ***	8.4e-5 ***	0.0005 ***

*OSS: Optimized G. senegalensis management system, TMS: Traditional G. senegalensis management system. Values ± standard deviation. Means marked with the same letter are not statistically different at the 5% level using Tukey's test. * : significant difference. ** : highly significant difference. *** : highly significant difference.*

3.2.2. Effect of optimized *Guiera senegalensis* system on millet yield

By 2020, OSS had improved all millet yield except 1000-kernels weight. Straw increased by 17.23% (1840.71 kg/ha vs. 1570.08 kg/ha). Grain weight improved by 32.3% (*p-value* = 0.01). The maximum weights of 1,000 millet kernels were recorded on plots receiving the OSS treatment, representing an improvement of 2.86%. In 2022, OSS improved harvested straw by 32.4% (*p-value* = 0.02), total grain weight by 30% (*p-value* = 0.28), and weight of 1,000 millet kernels by 19.87% (Table 3).

Table 3. Effect of *G. senegalensis* optimized system on millet yield (n=15).

	Millet Yield					
	2020			2022		
	Straw (kg/ha)	Grain weight (kg/ha)	Weight of 1,000 kernels (g)	Straw (kg/ha)	Grain weight (kg/ha)	Weight of 1,000 kernels (g)
OSS	1840.71^a ± 446.93	697.51^a ± 285.22	6.83^a ± 0.48	1145.88^a ± 1019.9	96.98^a ± 77.29	7.18^a ± 1.03
TMS	1570.08^b ± 453.8	527.22^b ± 216.35	6.64^a ± 0.76	866.09^b ± 1222.5	74.5^a ± 64.69	5.99^b ± 3.2
Treatment	0.02 *	0.01 *	0.187	0.0231 *	0.2814	0.01961 *
Block + Treatment	0.008 **	0.00526 **	0.003**	3.96e-05 ***	0.0181 *	0.18

3 *OSS: Optimized G. senegalensis management system, TMS: Traditional G. senegalensis management system. Values ± standard deviation.*

16 *Means marked with the same letter are not statistically different at the 5% level using Tukey's test. * : significant difference. ** : highly significant difference. *** : highly significant difference.*

3.3. Effect of optimized *Guiera senegalensis* system on rainwater use efficiency of mature crops

In 2019, rainwater use efficiency by groundnut biomass is improved by 31.25% (*p-value* = 0.171), while in 2021 this improvement is 12.11% (*p-value* = 0.0347) (Fig. 4a). The efficiency of rainwater use by peanut seeds was only achieved in 2019, so OSS increased the value by 15.15% (Fig. 4b). In 2020 and 2022, rainwater use efficiency by millet biomass is improved by 17.3% and 30.26% respectively (Fig. 4c). Millet grain rainwater use efficiency increased by

56.25% and 61.54% between 2020 and 2022 (Fig. 4d).

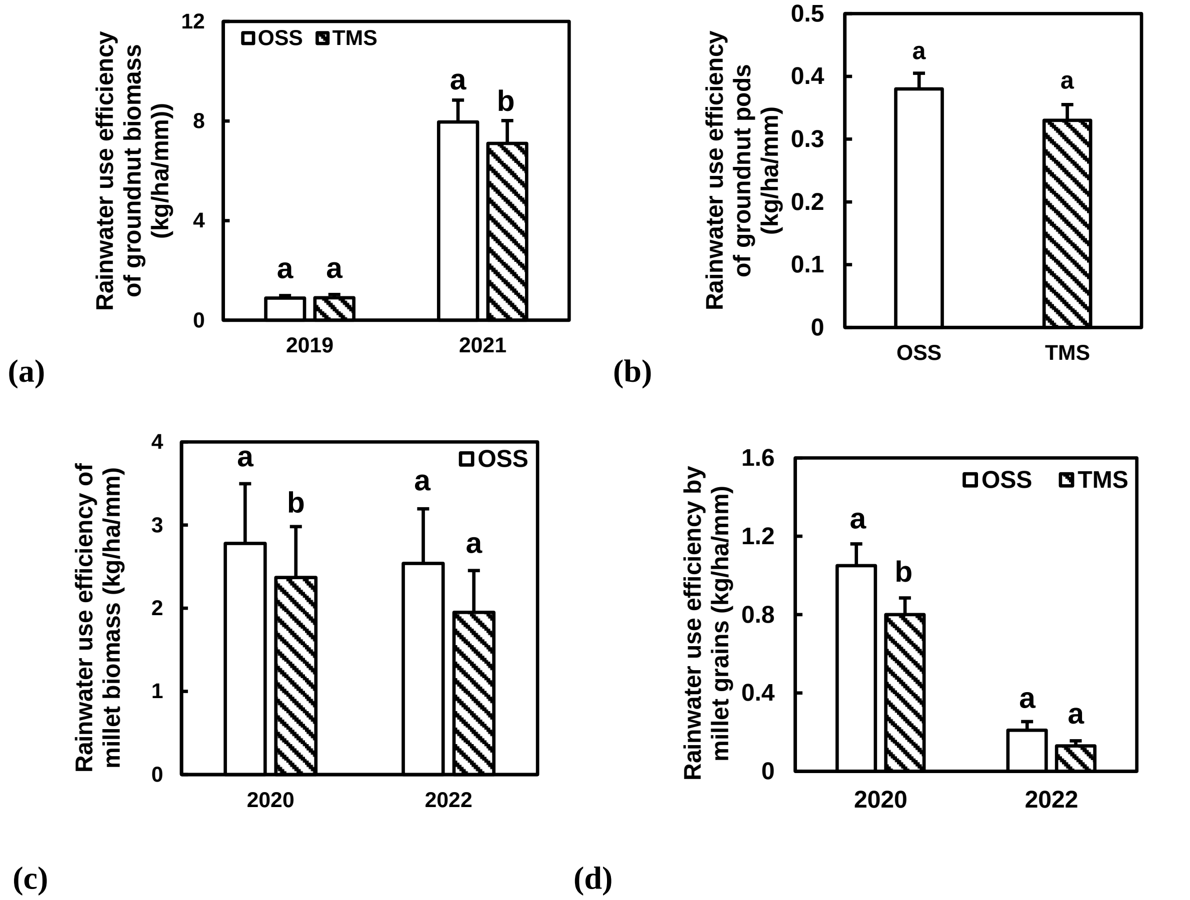

Figure 4. Effect of *G. senegalensis* optimized system on rainwater use efficiency by groundnut biomass (a) and seeds (b) in 2019 and 2021; and millet biomass (c) and seeds (d) in 2020 and 2022.

4. Discussion

The main aim of this study was to determine the effect of the optimized *G. senegalensis* system (OSS) on crop performance (millet and groundnuts) in the farming environment of the Northern Peanut Basin.

It revealed that, compared with the traditional *G. senegalensis* management system (TMS), the OSS improves rainwater use efficiency by mature groundnut and millet.

The rainwater use efficiency of mature groundnut biomass improved by 21.68%. For millet, it increased by 23.78% for biomass and 58.9% for grain.

Bright et *al.* (2021) obtained similar results, comparing OSS with treatments without shrubs on the Keur Matar Aram site (Senegal) under soil-climatic conditions similar to those in our study area. Rainwater use efficiency by millet increased by 50% for millet grains and 107% for groundnut pods.

The increase in rainwater use efficiency by mature crops may be due to the improvement in soil physical properties induced by the addition of *G. senegalensis* biomass. The latter should increase the amount of particulate organic matter in the soil, which promotes soil aggregation; this in turn leads to increased porosity and improved water storage and availability for crops (Kizito et *al.*, 2007; Dossa et *al.*, 2012; Bright et *al.*, 2021). The presence of shrubs has also been shown to reduce drainage losses and evapotranspiration by 50% (Kizito et *al.*, 2007). In addition, *G. senegalensis* provides favorable moisture conditions for crop development, even before sowing, due to the hydraulic redistribution capacity assigned to *G. senegalensis* (Kizito et *al.*, 2012; Bogie et *al.*, 2018).

It has shown that, compared with the traditional *G. senegalensis* management system (TMS), OSS improves crop growth and yields, most notably in millet, even under conditions of low rainfall.

OSS improved millet height growth by 33.26% in 2020 and 2022, and groundnut height growth by 2.35% in 2021. It has improved groundnut yields to a lesser extent in 2019 (pod weight) and 2021 (haulm weight). It has increased all millet yield components by at least 2.86%.

These on-farm results corroborate those of Dossa et *al*. (2012), Bright et *al*. (2021) and Bayala et *al*. (2022) obtained under semi-controlled conditions in the same agro-ecological zone in Senegal. These authors have shown that the presence of *G. senegalensis* promotes the growth of millet and groundnuts and improves their yields. For example, Bayala et *al*. (2022) showed that OSS increased millet height by 230% during the vegetative phase, compared with treatments without shrubs. Also, in a long-term study (2004 to 2016) by Bright et *al*. (2021), an increase in millet yield by OSS of 126% was observed. The improvement in crop growth and yields would thus be due to a combination of several factors. *G. senegalensis* does not compete with crops for water and mineral nutrition, as 95% of the shrub's roots are located between 0.2 and 0.5 m, and the shrub preferentially uses water located above 0.9 m (Kizito et *al*., 2006). In addition, this system is also able to improve the water and mineral nutrition of crops. Thus, OSS has the capacity to provide a significant amount of organic matter, in the order of 2.9 to 8.3 Mg/ha/year (Lufafa et *al*., 2008a; Bright et *al*., 2021). This organic matter is the most limiting factor in Sahelian agroecosystems (Lahmar et *al*., 2012). Thus, its increase favors microbial activity, which induces nutrient mineralization and aggregate formation (Diedhiou et *al*., 2009; Dossa et *al*., 2012; Diedhiou-Sall et *al*., 2013); leading to increased availability of nutrients (N, P, K) to plants through their release, storage and retention. Aggregate formation thus improves soil structure, and increases water availability for plants (Dossa et *al*., 2012; Lahmar et *al*., 2012; Bright et *al*., 2021).

G. senegalensis also is able to redistribute water, as 5% of its roots can reach the water table (Kizito et *al*., 2006; Bogie et *al*., 2018). In addition, the reduction in soil surface temperature, due to the mulch effect of undecomposed *G. senegalensis* biomass and the cooling effect induced by water redistribution, improves the germination rate and also prevents the denaturation of certain proteins; this leads to better development during the vegetative phase (Bright et *al*., 2021).

To these factors can be added the improvement in rainwater and nutrient use efficiency by crops, induced by the improved availability of nutrients, as well as of soil water, the increase in carbon sequestration potential, particularly of carbon derived from particulate organic matter, which are strongly linked to improved crop productivity (Bright et *al*., 2021).

On the farm, OSS was found to be better than the traditional *G. senegalensis* management system for supporting millet and groundnut productivity under Sahelian conditions; this is due to the high density of *G. senegalensis* shrubs and the way these shrubs are managed. However, the effect of OSS on these crops noted in this study, is less conclusive than that reported by previous work (Dossa et *al*., 2012, Bright et *al*., 2021 Bayala et *al*., 2022). Unlike these works, where OSS is compared with treatments without shrubs, in the present work, the traditional management system features a low shrub density (120 to 520 shrubs/ha).

5. Conclusion

This study showed the effect of the optimized *Guiera senegalensis* management system (OSS) on the performance of groundnut and millet under farmer conditions, in the northern

Peanut Basin, compared with the traditional *Guiera senegalensis* management system (TMS). OSS improved the growth, yield and rainwater nutrition of peanuts and millet at maturity.

OSS significantly improved groundnut height, except during periods of water stress. OSS also increased LAI from the flowering phase onwards, as well as the rainwater use efficiency of the peanut, and accentuated the NDVI of the peanut during the first three phases, particularly at gynophorization. In addition, groundnut yield components such as pod weight and weight of 100 groundnut seeds in 2019, and straw weight in 2021, were also improved thanks to OSS.

For millet, OSS induced better millet height growth, improved NDVI during the tillering phase, and LAI during the tillering and ripening phases in 2020 and 2022. Grain and straw yields, as well as the weight of 1,000 millet kernels, were improved by OSS, even in years of low rainfall (2022). In addition, OSS has improved rainwater use efficiency, particularly for grain.

By improving soil quality, OSS has succeeded in improving the performance of peanuts and millet on the farm, and in supporting crop growth and yield. In this way, the sustainability of Sahelian agro-ecosystems has been enhanced, and the food security of local populations strengthened.

6 However, further research is needed to determine the economic performance taking into account the additional labour time of the optimized *G. senegalensis* management system.

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Acknowledgements

The authors would like to thank the U.S. Agency for International Development (USAID) and the Peanut Innovation Lab (PIL) for financial support. We thank Dame Sy, Dominique

Manga, Papa Omar Dieye, Bakary Manga, Khardiatou Sadio and Moussa Dione of ENSA for helping in data collection. We also thank all the growers for their commitment and interest in this work.

This {study/website/report/etc.(specify)} was made possible by the support of the American people to the Feed the Future Peanut Innovation Lab through the United States Agency for International Development (USAID). The contents are the sole responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government.

Program activities are funded by the United States Agency for International Development (USAID) under Cooperative Agreement No. 720-0AA-1-8C-A00003.

References

Agence Nationale de la Statistique et de la Démographie (ANSD). (2014) : Recensement Général de la Population et de l'Habitat, de l'Agriculture et de l'Elevage, Rapport Définitif, RGPHAE 2013. 418 pages.

Agence Nationale de l'Aviation Civile et de la Météorologie (ANACIM). (2021) : Base de données du département de Tivaouane de 2000 à 2021.

Badiane A. N., Khouma M., & Sène M. (2000) : Gestion et transformation de la matière organique. *Synthèse des travaux menés au Sénégal depuis 1945*. 134 pages.

Bamba B., Gueye M., Ngom D., Ka S. L., Diop B., & Kanfany G. (2019) : Caractérisation des pratiques locales du mil sanio [*Pennisetum glaucum* (L.) R. Br] en zone soudanienne humide au Sénégal. *International Journal of Biological and Chemical Sciences*, *13*(2), 1054-1063. DOI: 10.4314/ijbcs.v13i2.38.

Bayala R., Diedhiou I., Bogie N. A., Bright M. B., Badiane Y. N., Ghezzehei T. A., & Dick R. P. (2022) : Intercropping with *Guiera senegalensis* in a semi-arid area to mitigate early-season abiotic stress in A. hypogea and P. glaucum. *Journal of Agronomy and Crop Science*, *208*(2), 158-167. DOI: https://doi.org/10.1111/jac.12568.

Békoye B. M. (2014) : Caractérisation physico chimique et technologique des variétés de mil *pennisetum glaucum* (l.) R. Br.) Ouest africaines. *European Scientific Journal*, *10*(30).

Bello C. A., Aimée T., Salissou O., Laoual S. M. (2019) : Fiche technico-économique pour la culture pure de l'arachide. Région de Zinder. Version 1. 3 pages.

Bogie N. A., Bayala R., Diedhiou I., Conklin M. H., Fogel M. L., Dick R. P., & Ghezzehei T. A., (2018) : Hydraulic redistribution by native sahelian shrubs: bioirrigation to resist in-season drought. *Frontiers in Environmental Science*, *6*, 98. DOI: https://doi.org/10.3389/fenvs.2018.00098.

Bogie N. A., Bayala R., Diedhiou I., Dick R. P., & Ghezzehei T. A. (2019) : Intercropping with two native woody shrubs improves water status and development of interplanted groundnut and pearl millet in the Sahel. *Plant and soil*, *435*, 143-159. DOI : https://doi.org/10.1007/s11104-018-3882-4.

Bright M. B., Diedhiou I., Bayala R., Assigbetse K., Chapuis-Lardy L., Ndour Y., & Dick R. P. (2017) : Long-term *Piliostigma reticulatum* intercropping in the Sahel: crop productivity, carbon sequestration, nutrient cycling, and soil quality. *Agriculture, Ecosystems & Environment*, *242*, 9-22. DOI: https://doi.org/10.1016/j.agee.2017.03.007.

Bright M. B., Diedhiou I., Bayala R., Bogie N., Chapuis-Lardy L., Ghezzehei T. A., ... & Dick R. P. (2021) : An overlooked local resource: Shrub-intercropping for food production, drought resistance and ecosystem restoration in the Sahel. *Agriculture, Ecosystems & Environment*, *319*, 107523. DOI: https://doi.org/10.1016/j.agee.2021.107523.

Chapuis-Lardy L., Badiane Ndour N.Y., Assigbetse K., Diédhiou I., Balaya R., Cournac L., Founoune-Mboup H., Mc Spadden Gardener B., Ghezzehei T., Jourdan C., Bright M.B., Bogie N., Debenport S., Delay C., Diakhaté S., Sambou D.M. et Dick R.P. (2019) : Les cultures vivrières associées aux arbustes natifs : un modèle adapté au climat sahélien. Agroforesterie et services écosystémiques en zone tropical, p.191 à 203.

De Oliveira Silva A., Ciampitti I. A., Slafer G. A., & Lollato R. P. (2020) : Nitrogen utilization efficiency in wheat: A global perspective. *European Journal of Agronomy*, *114*, 126008. DOI: https://doi.org/10.1016/j.eja.2020.126008.

Diallo S., Faye M., & Nacro H. B. (2022) : La variabilité pluviométrique et ses impacts sur les rendements et les surfaces cultivées dans le bassin arachidier de la région de Thiès (Sénégal). Vertigo-la revue électronique en sciences de l'environnement. DOI : https://doi.org/10.4000/vertigo.34710.

Diedhiou S., Dossa E., Badiane A., Diedhiou I., Sène M., Dick R.P. (2009) : Decomposition and spatial microbial heterogeneity associated with native shrubs in soils of agroecosystems in semi-arid Senegal. Pedobiologia 52, 273–286. DOI : https://doi.org/10.1016/j.pedobi.2008.11.002.

Diedhiou-Sall S., Dossa E. L., Diedhiou I., Badiane A. N., Assigbetsé K. B., Ndiaye Samba S. A., ... & Dick R. P. (2013) : Microbiology and macrofaunal activity in soil beneath shrub canopies during residue decomposition in agroecosystems of the Sahel. *Soil*

Science Society of America Journal, *77*(2), 501-511. DOI: https://doi.org/10.2136/sssaj2012.0284.

Dione M., Diop O., Dièye P. N., & Ndao B. (2008) : Caractérisation et typologie des exploitations agricoles du Sénégal, Tome 3 : Bassin arachidier, Études et Document vol. 8, N°3, ISRA, Dakar, Sénégal. 31 pages.

Dossa E. L., Khouma M., Diedhiou I., Sène M., Kizito F., Badiane A. N., ... & Dick R. P. (2009) : Carbon, nitrogen and phosphorus mineralization potential of semiarid Sahelian soils amended with native shrub residues. *Geoderma*, *148*(3-4), 251-260. DOI: https://doi.org/10.1016/j.geoderma.2008.10.009.

Dossa E. L., Diedhiou I., Khouma M., Sène M., Lufafa A., Kizito F., ... & Dick R. P. (2012) : Crop productivity and nutrient dynamics in a shrub (*Guiera senegalensis*)–based farming system of the Sahel. *Agronomy journal*, *104*(5), 1255-1264. DOI: https://doi.org/10.2134/agronj2011.0399.

Dossa E. L., Diedhiou I., Khouma M., Sène M., Badiane A. N., Ndiaye Samba S. A., ... & Saxena J. 2013. Crop productivity and nutrient dynamics in a shrub-based farming system of the Sahel. *Agronomy Journal*, *105*(4), 1237-1246. DOI: https://doi.org/10.2134/agronj2012.0432.

Gérard F., Affholder F., Mane N. F., & Sall M. (2020) : Impact de différentes politiques publiques sur l’intensification agroécologique et les inégalités de revenu dans le Bassin arachidier du Sénégal. In *Impact de différentes politiques publiques sur l'intensification agroécologique et les inégalités de revenu dans le Bassin arachidier du Sénégal* (pp. 1-76). Agence française de développement. DOI : https://doi.org/10.3917/afd.gerar.2020.01.0001.

Godinot O. (2014) : *Proposition de nouveaux indicateurs d'efficience d'utilisation de l'azote à l'échelle du système de production agricole et du territoire*. Thèse. Agrocampus Ouest, Université Européenne de Bretagne. 136 pages.

Institut Nationale de Pédologie (INP). (2013) : Atelier de lancement du partenariat sur les sols. 15 p. Disponible sur http://www.FAO.org/fileadmin/user_upload/GSP/docs/West_africa_partner/Senegal_Ndene.pdf. Consulté le 10 janvier 2023.

Kadri A., Halilou H., & Karimou I. (2019) : Culture du mil [*Pennisetum glaucum* (L) R. Br] et ses contraintes à la production : une revue. *International journal of Biological and Chemical Sciences*, *13*(1), 503-524. DOI: 10.4314/ijbcs.v13i1.40.

Kerharo J., & Adam J. G. 1974. La pharmacopée sénégalaise traditionnelle : plantes médicinales et toxiques.

Khouma M. (2002) : Les grands types de sols du Sénégal. *Rapport sur les Ressources en Sols du Monde (FAO)*. Sous-Comité ouest et centre africain de corrélation des sols pour la mise en valeur des terres, FAO, Rome (Italy). Div. de la Mise en Valeur des Terres et des Eaux. - Rome (Italy) : FAO, 2002. Réunion. 14 Sous-Comité Ouest et Centre Africain de Corrélation des Sols pour la Mise en Valeur des Terres, Réunion. 14 Sous-Comité Ouest et Centre Africain de Corrélation des Sols pour la Mise en Valeur des Terres, Abomey (Benin),9-13 Oct. (2000).- ISBN 92-5-204803-0. 17 pages.

Kizito F., Dragila M., Sène M., Lufafa A., Diedhiou I., Dick R. P., ... & Ndiaye, S. (2006) : Seasonal soil water variation and root patterns between two semi-arid shrubs co-existing with Pearl millet in Senegal, West Africa. *Journal of arid environments*, *67*(3), 436-455. DOI: https://doi.org/10.1016/j.jaridenv.2006.02.021.

Kizito F., Dragila M., Sène M., Diedhiou I., Lufafa A., Dick R.P., Selker J., Cuenca R., Dossa E. (2007) : Soil water balance of annual crop–native shrub systems in Senegal's Peanut Basin: the missing link. Agric. Water Manag. 90, 137–148. DOI: https://doi.org/10.1016/j.agwat.2007.02.015Get rights and content.

Kizito F., Dragila M., Sène M., Brooks J.R., Meinzer F.C., Diedhiou I., Diouf M., Lufafa A., Dick R.P., Selker J., Cuenca R. (2012) : Hydraulic redistribution by two semi-arid shrub species: implications for Sahelian agro-ecosystems. J. Arid Environ. 83, 69–77. DOI: https://doi.org/10.1016/j.jaridenv.2012.03.010.

Lahmar R., Bationo B. A., Lamso N. D., Guéro Y., & Tittonell P. (2012) : Tailoring conservation agriculture technologies to West Africa semi-arid zones: building on traditional local practices for soil restoration. Field crops research, 132, 158-167. DOI: https://doi.org/10.1016/j.fcr.2011.09.013.

Lufafa A., Diédhiou I., Samba S. A. N., Sène M., Khouma M., Kizito F., ... & Noller J. S. (2008a) : Carbon stocks and patterns in native shrub communities of Senegal's Peanut Basin. *Geoderma*, *146*(1-2), 75-82. DOI: https://doi.org/10.1016/j.geoderma.2008.05.024.

Lufafa A., Bolte J., Wright D., Khouma M., Diedhiou I., Dick R. P., ... & Noller J. S. (2008b) : Regional carbon stocks and dynamics in native woody shrub communities of Senegal's Peanut Basin. *Agriculture, ecosystems & environment*, *128*(1-2), 1-11. DOI: https://doi.org/10.1016/j.agee.2008.04.013.

Masson-Delmotte V., Pörtner H. O., Skea J., Zhai P., Roberts D., & Shukla, P. R. (2020) : Giec. Changement climatique et terres émergées. Rapport spécial du GIEC sur le changement climatique, la désertification, la dégradation des sols, la gestion durable des terres, la sécurité alimentaire et les flux de gaz à effet de serre dans les écosystèmes terrestres. Résumé à l'intention des décideurs. 39 pages.

Mayeux A. H. (2001) : Dossier technique sur les normes de production de stockage et la distribution de semences d'arachide en milieu paysannal. Atelier de Formation-échange, Projet Germplasm Arachide (GGP). http://agritrop.cirad.fr/487586/.

Mbow C., Halle M., El Fadel R., & Thiaw I. (2021) : Land resources opportunities for a growing prosperity in the Sahel. *Current Opinion in Environmental Sustainability*, *48*, 85-92. DOI: https://doi.org/10.1016/j.cosust.2020.11.005.

Mendiburu F. D., & Yaseen M. (2020) : Agricolae: statistical procedures for agricultural research. R package version 1.4. 0.

Moll R. H., Kamprath E. J., & Jackson W. A. (1982) : Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization 1. *Agronomy journal*, *74*(3), 562-564. DOI : https://doi.org/10.2134/agronj1982.00021962007400030037x

Ndir K. N., Ndoye M., Ndiaye S. (2014) : Caractérisation agro-morphologique de neuf (09) variétés de mil (*pennisetum glaucum* l.) élites –ISRA, dans la zone du bassin arachidier : cas de la région de Thiès (Sénégal). Conférence : ERA USAID Workshop, 2014. At Dakar, Sénégal.

Ndour Y. B., Fardoux J., & Chotte J. C. (2000) : Statut organique et microbiologique de sols ferrugineux tropicaux en jachère naturelle (Sénégal). La Jachère en Afrique Tropicale : rôles, aménagement, alternatives : 1. Actes du séminaire international, Dakar, 13-16 avril 1999. Floret Christian (ed.), Pontanier Roger (ed.). fdi:010024596. p.354 à 360.

Oldeman L. R., & Van Engelen, V. W. P. (1993) : A world soils and terrain digital database (SOTER)—An improved assessment of land resources. Geoderma, 60(1-4), 309-325.Olivry, J. C. (1987). Les conséquences durables de la sécheresse actuelle sur l'écoulement du fleuve Sénégal et l'hypersalinisation de la basse Casamance. The Influence of Climate Change and Climatic Variability on the Hydrologie Regime and Water Resources, 501-512. DOI: https://doi.org/10.1016/0016-7061(93)90033-H.

R Core Team (2020) : R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Réseau National des Chambres d'Agriculture (RECA) du Niger (2016) : Le sabara (*Guiera senegalensis*), espèce oubliée des programmes de revégétalisation des plateaux et glacis ? (Note technique / Gestion des ressources naturelles). 4 pages.

Rostamza M., Chaichi M. R., Jahansouz M. R., & Alimadadi A. (2011) : Forage quality, water use and nitrogen utilization efficiencies of pearl millet (Pennisetum americanum L.) grown under different soil moisture and nitrogen levels. *Agricultural Water Management*, *98*(10), 1607-1614. DOI : https://doi.org/10.1016/j.agwat.2011.05.014.

Roquet D. (2008) : Partir pour mieux durer : la migration comme réponse à la sécheresse au Sénégal. *Espace populations sociétés. Space populations societies*, (2008/1), 37-53. DOI : https://doi.org/10.4000/eps.2374.

Sacande M., Parfondry M., & Martucci A. (2018) : Situation de référence biophysique et socio-économique : le point de départ de l'Action contre la désertification. FAO. ISBN 978-92-5-130986-5. Rome (Italy). 63 pages.

Sanogo, R. (2012) : *Guiera senegalensis* J.F. Gmel. In Medicinal Plants/Plantes Médicinales, Schmelzer GH, Gurib-Fakim A (Ed.). Wageningen, Pays Bas.

Schilling R. (2001) : Données agronomiques de base sur la culture arachidière. OCL. Oléagineux Corps gras Lipides, ***8*** *(3) : 230-236. DOI : https://doi.org/10.1051/ocl.2001.0230*.

Seghieri J. (2017) : Systèmes agroforestiers soudano-sahéliens. Tradition ou innovation ? Institut de la Francophonie pour le Développement Durable, Liaison Energie-Francophonie, 105 : 92-96. www.ifdd.francophonie.org

Sow S., Thiam A., Mendy P., Ndiaye S., & Cabral F. J. (2018) : Variation de la production agricole et sa valeur ajoutée par rapport à la pluviosité au Sénégal. *Afrique SCIENCE*, *14*(4), 16-30.

Sow S., Faye B., & Mendy P. (2020) : Analyse des effets de la pluviométrie sur le PIB Agricole au Sénégal. Agronomie Africaine, 32(3), 343-351.

Sy O., Fofana A., Cisse N., Noba K., Diouf D., Ndoye I., ... & Elwegan E. (2015) : Étude de la variabilité agromorphologique de la collection nationale de mils locaux du Sénégal. *Journal of Applied Biosciences*, *87*, 8030-8046.

Sy O., Kanfany G. (2023) : Variétés de mil à double usage – Souna Saloum, Souna Sine et Souna Baol (article exclusif sur le Web). MITA (coraf.org). Consulté le 23 février 2023.

Tine Y., Diop M., Ndoye I., Diallo A., & Wele A. (2019) : Revue bibliographique sur la composition chimique et les activités biologiques de *Guiera senegalensis* JF Gmel. (*Combretaceae*). *International Journal of Biological and Chemical Sciences*, *13*(7), 3449-3462. DOI: 10.4314/ijbcs.v13i7.37