Improving crop-livestock productivity and household income through the use of contour bunding and agroforestry options

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Contents

Abstract

A field study was carried out at Kani, Noupinesso, and Mpessoba in the Soudano-Sahelian zone of Mali to assess the impact of tillage, soil fertilization, and leguminous crops on runoff, soil erosion, soil moisture, and the growth and yield of cotton, sorghum, and fast-growing tree species. Experiments of 2 types were conducted. The treatments for the first trial consisted of 2 tillage practices (contour bunding (CB) and no contour bunding (NCB) which was the farmers' practice) and 4 types of soil fertilization on cotton (control, organic manure, micro-dose, and recommended dose). The same trial was conducted on 6 different farms. The second trial consisted of 2 tillage practices (CB and NCB) and 3 cultural systems; (sorghum sole crop, soybean sole crop, and intercropped sorghum*soybean); the same trial was conducted on 9 different farms and in the Technology Park of Mpessoba. The experiment was laid out in a Split Plot with 4 replications. CB out-yielded NCB in all the measured parameters.

The percentage of runoff coefficient in NCB plots was 34.89 - 38.79% and was decreased by CB to 17.46 - 21.48%. CB increased the water table dynamic at Noupinesso; the distance of groundwater to soil surface decreased to attain a minimum value of 2.61 m for the measuring tubes in the CB plot, 4.58 m in the NCB plot, and 1.02 m next to the outlet of the watershed. CB increased soil moisture in the horizon 0 - 100 cm at the 3 sites. The differences were high at the horizon 60-100 cm and at the end of the rainy season. The soil horizon (0 - 100 cm) under trees was slightly more humid than outside the trees in NCB, and the difference was higher in the CB plot.

Organic manure increased cotton yield by 25.3% in Remon Sanou's field, biomass yield by 29.66% in the field of Salif Berthe, cotton height and diameter by 72.36% and 34.54% in the trial of Barnabe Traore. The application of manure produced significantly ($p < 0.05$) less cotton growth and production than the applications of micro-dose (T3) and scale doses (T4). The T4 increased cotton yield by 144.79% and T3 by 130.21% in Bourama Dembele's field, and biomass yield by 99.03% and 93.70% respectively in Sekou Berthe's field. The use of CB technology significantly affected the growth and yields of cotton for all the 6 trials. in the field of Barnabe Traore cotton yield was higher by 42.5% in the CB plot compared to the NCB. Cotton height with CB increased by 29.30% in the trial of Bourama Dembele. Micro-dose treatment gave the best profitability as indicated by the VCR in the range of 4 to 8 for the 6 trials.

Intercropping soybean and sorghum increased sorghum growth and yields for all the 9 trials. In some of the trials, yields of sorghum associated with soybean got more than twice the yields of sorghum cultivated alone. The trial of Youssouf Berthe give 1138 kg ha^{-1} grain yield with sole sorghum cultivation and 2325 kg ha^{-1} for the intercrop. The use of tillage methods affected sorghum and soybean growth and yields for all the 9 trials: the use of the CB method increased grain and biomass yield of sorghum and soybean by 50% and their height and diameter by 30%.

The CB technology increased the growth of *Gliricidia sepium* and *Leucaena leucocephala* at the three research sites. Height (+35%), diameter (+25%), and crown radius (+40%) were increased in *Gliricidia* and in *Leucaena* by +58%, +69%, and +50% respectively.
Key words: contour bunding, runoff and erosion, soil moisture, water table, micro-dose, intercropping, fodder plants.

Introduction

Mali is one of the countries in the Sudano-Sahelian zone of West Africa where the general decline in soil fertility is a major constraint to agricultural productivity (Kouyaté et al., 2000). Rather than increasing soil productivity, current farmers' practices, such as hoe tillage, tillage on ridges, conventional tillage, and insufficient or no application of amendments, continue to mine the soil nutrients. Yields of crops obtained by the application of low doses of manures and mineral fertilizers have led to continuous depletion of soil nutrients.

In recent years, both drought or inappropriate rain distribution and demographic pressures have put enormous strain on the natural environment of Kani and Noupinesso. Tree and grass cover has dwindled, with disastrous consequences for the soil which has been left bare to the erosive winds and rains of the tropics. Soil erosion and farming activities that extract nutrients from the soil have caused severe soil degradation in these villages, threatening the security of food and animal feed. Although the region receives substantial rainfall, much is lost during intense storms on soils with low rates of infiltration.

Efforts to address these problems have been directed at assessing the impact of tillage, leguminous plants, and soil amendments on soil and water conservation and crop yield. Of a particular importance is the use of contour bunding technology (CB) in the crop cultivation system. CB is a holistic landscape approach to manage water and capture rainfall on a watershed scale (Gigou et al., 2006). It is a technology developed locally by the Institut d'Economie Rurale (IER) and CIRAD (Gigou et al., 2006). Doumbia et al. (2009) reported that CB retains rain and improves water availability for crops and enhances soil carbon sequestration; it increases deep drainage and groundwater recharge and increases soil organic concentration after 3 years. Traoré et al. (2002) summarized the expected benefits of CB on soil carbon to include the following: (1) reduced losses through erosion of soil and residual carbon, (2) increased growth of trees and crops, especially those that annually shed their leaves, (3) increased crop yields due to increased soil moisture, and (4) increased availability of forage and building material from grasses that stabilize permanent ridges and waterways.

Julio and Carlos (1999) indicated that the soils for agriculture in Mali are characterized by low productivity associated with poor rainfall, low soil fertility, and traditional crop management practices. The judicious use of manure, mineral fertilizer, and leguminous plants may be a credible option for improving soil fertility and crop yields. For the agronomic and economic performance of soil fertilization in Kani and Noupinesso the using of micro-dosing is indeed needed for the production of food and cash crops. However, the beneficial effects of the combined use of mineral fertilizers and manure (compost and farmers' animal manure) under different tillage practices have received less research attention. Such studies are needed to yield the requisite baseline information for the introduction of leguminous plants, micro-dosing, and CB technology into the farming system of smallholder farmers. It is in this context that this study was carried out.

The general objective of the study was to contribute to improve the productivity of fodder plants and cropping systems to maintain food and animal feed security in Kani and Noupinesso.

The specific objectives were as follows.

i. Assess the effect of CB technology on soil runoff and erosion.
ii. Determine the soil moisture and water table dynamic under CB technology practice.
iii. Evaluate growth and yields of crops and fodder plants with the application of CB technology.
iv. Evaluate the effect of the micro-dosing system on crop yields and

determine the efficiency of intercropping sorghum and soybean.

The above specific objectives were formulated to test the hypothesis that

i. The use of the CB technology would reduce soil runoff and erosion.
ii. The CB technology would increase infiltration rate, soil moisture, and recharge the water table.
iii. The use of the CB technology would significantly improve yields of crops and fodder trees.
iv. The micro-dosing technology would significantly improve crop yields and farmers' income; and

the leguminous crop would improve sorghum production.

Achievements

<table>
<tr><td colspan="5">Project Outcome 1: Farmers and farming communities in the project area are practicing more productive, resilient, profitable, and sustainably intensified crop-livestock systems linked to markets.</td></tr>
<tr><td>Output 1.2: Integrated management practices and innovations to improve and sustain productivity and ecosystem services of the soil; land, water, and vegetation resources are developed and disseminated with farmers and development partners in the intervention communities.</td><td>Planned Activities
1. Soil preparation (perfecting of CB technology)
2. Water table, soil moisture, runoff, and erosion measurement
3. Implementation of trials
4. Assessment of CB on the growth of fast growing trees species
5. Determination of the impact of CB technology on crop growth and yield in 40 different farms</td><td>Planned Milestones
1. Strong protection of fodder plants in farmer's field at Kani and Noupinesso
2. Planting of of tree nursery to multiply fodder plants in different farms at Kani and Noupinesso</td><td>Deviation from Planned Milestone
1. Lack of financing
2. No protection of fodder plants against roaming animals</td><td>Achievements towards Output
The CB technology significantly reduced runoff and erosion; increased soil moisture, water table dynamic, crop growth and yields, and tree growth. Intercropping system increased sorghum yield. Micro-dosing increased farmers' income.</td></tr>
</table>

Planned activities

Soil preparation (perfecting of CB technology)

The automatic level (Photo 1. a) and a graduated rule (Photo 1. b) allowed us to determine and construct the contour line using stakes planted at a regular distance.

Photo 1: Implementation of CB technology in farmer's field, Kani, 2018. Photo credit: Kalifa Traore/IER.

A field visit with each farmer allowed us to identify the water circulation routes and the problems of erosion or flooding that occurred. The fields made with CB technology varied in size from 1 to 3 ha/farmer. The implementation of the contour line started 25 m away from the field's upper limit. On the contour lines, a stake was placed every 10 m to define it using 3 to 4 passes - returns of an ox plow to make an earth bund *Ado* 1 m wide (Photo 2. a). The distance between the *ados* was about 50 m. The rows of seedlings or the ridges followed these *ados* for the arrangement to function well (Photo 2. c) and the *ados* were reinforced with a *daba* (Photo 2. b). Self-seeded grasses were usually allowed to grow on the *ados* and fodder plants were planted on two *ados* in each field. In 2018 before the rainy season we carried out maintenance of the *ados* with farmers*.*

Photo 2: (a) Making an *ado* using an ox plow, b) *ado* after a rain event (see water storage), c) *ado* covered by grass during the dry season, Kani, 2018. Photo credit: Kalifa Traore/IER.

Measurement of water table, soil moisture, runoff, and erosion

Monitoring of water table dynamic

A manual piezometer with a sound-light signal coupled with a 50 m graduated tape was used to measure the variation of the water table each week (Photo 3. a, b). The PVC tubes were protected against children by iron covers (a) and secured with padlocks (Photo 3. b).

Photo 3: Measurement of water table dynamic, a) tube protected using a padlock, Noumpinesso and Kani, 2018.) Photo credit: Kalifa Traore/IER.

Monitoring of soil moisture

Measurements were made in CB and NCB fields and displayed directly in volumetric moisture. The moisture measuring tubes were protected from the children by the locked pots (Photo 4 a). Moisture measurements were performed using a TDR probe at an interval of 10 days (Photo 4 b).

Photo 4: Soil moisture measurement in Kani, 2018. Photo credit: Kalifa Traore/IER.

Measurement of runoff and erosion

The principle of the method is that **w**ater flowing over an area of 24 m^2 (30 m × 0.8 m) is collected in a tank with 200-L capacity, to measure its volume after each rainfall that has produced runoff. The tank is graduated with painted lines. To adjust the volume of water collected to the capacity of the receiving tank, a diverter at 1/10 ° was used.

To estimate the overflow of the main tank during the very heavy rains, we used a second tank that collects 1/10 ° of overflow water (10 holes of constant diameter regularly distributed over all around the tank for excess water flow).
The diverter is installed at the location where the runoff water comes out of the measuring plot to keep only one part compatible with the volume of the receiving tanks.

The diverter was formed by an iron cage, sealed by cement in a horizontal position in front of the first tank where the downstream face is perforated with 10 rectangular vertical slots. A chute collects water from one of these slots and leads it to the main receiving tank. The tanks are installed in a pit that was 2 m long, 1.40 m wide, and 1.80 m deep. The bottom and the walls were cemented. The pit was closed by a metal sheet to protect it from rainwater but also protected by blocks from the water that runs nearby (Photo 5. b).

Such a device was installed in the fields of Madou Berthé and Sekou Berthé at Kani. In each site the experimental plot was divided into two parts: the first part was installed in a CB field as the cultivation ridges follow the *ados* and the second one was in an NCB field (farmers' practice). Two repetitions were implemented in the CB part and 2 in the control. Both parties were treated consistently on all field operations and cultivated crops.

For erosion measurement, after each rainfall that has produced runoff, the water collected in the tank is carefully mixed and 3 samples of 1 L were taken (Photo 5 a). These samples are then sent to the laboratory for oven drying and sediment weighing. These data are scaled to determine erosion/ha.

Photo 5: Device for measurement of runoff and erosion at Kani. Photo credit: Kalifa Traore/IER.

Implementation of trials

Experimental design

Two types of experiment were conducted:

- The first trial was a factorial combination of 2 tillage practices (CB technology and NCB or farmers' practice) and 4 types of soil fertilization

  Soil fertilization:

  1- No amendment,
  2- Organic manure OM (5 t ha^{-1}),
  3- Micro-dose = OM (2.5t ha^{-1}) + Complex cotton CC (100 kg ha^{-1}) + Urea (25 kg ha^{-1})

     Recommended dose = OM (5 t ha^{-1}) + Complex cotton CC (200 kg ha^{-1}) + Urea (50 kg ha^{-1})

     The trial was a Split Plot design with four replications; tillage practices made the main plots with soil amendments as subplots. The dimensions of the subplots were 4 x 3 m. The main plots were separated by 1 m wide access using cotton (*Gossypium* sp) N'TA 93- 15 as test crop. The same trial was conducted on 6 different farms (3 at Kani and 3 at Noupinesso).

- The second trial also was a factorial combination of 2 tillage practices (CB and NCB) and 3 farming systems.

  Farming systems:

  1- Sorghum alone
  2- Intercropping sorghum-soybean
  3- Soybean alone

  Amendments used in intercropping:

  - Sorghum: OM (2.5 t ha^{-1}) + Complex cereal CC (50 kg ha^{-1}) + Urea (25 kg ha^{-1})
  - Soybean: OM (2.5 t ha^{-1}) + DAP (50 kg ha^{-1})

Maintenance of trials

Weeding was done 15 and 30 days after seedling; earthing up was done 40 days after seedling ended; the last weeding was done 15 days afterwards. Growth and development (height, diameter, number of capsules), grain yield, and crop biomass yield were determined on the center lines of the research Plots.

Calculations

Land Equivalent Ratio (LER)

The performance of crop intercropping is generally evaluated by:

- Grain yield, biomass yield
- Quality (protein content, etc.)
- The LER = Land Equivalent Ratio

The LER assesses crop intercropping efficiency during its development cycle. It compares the yield of a crop in association to the yield of a crop alone. The LER is the area of monospecific cultures required to achieve the same yield as in combination. It is calculated as follows:

- If LER = 1, there is no difference between the 2 culture modes;
- If LER < 1, there is a loss of yield in association;

- If LER > 1, there is a productive advantage in the association system (PerfCom, 2012).

$$LER = \frac{\text{Yield of intercropped cereal}}{\text{Yield of sorghum sole crop}} + \frac{\text{Yield of intercropped soybean}}{\text{Yield of soybean sole crop}}$$

Value to cost ratio (VCR)

The unsubsidized input costs and the peak prices of the crop were used to calculate the VCR as a first indicator of the acceptability of investment, using the formula of Nziguheba et al. (2010):

$$\text{VCR} = \frac{\text{Y}-\text{Yc}}{X}$$

Where Y is the value of the crop in intervention plots, Yc is the value of the crop harvested in control plots, and X is the cost of inputs (seeds and fertilizers).

Statistical analysis

Data were subjected to analysis of variance using GENSTAT version 12 (GenStat Release 12.1 (PC/Windows Vista) Copyright (2009), VSN International Ltd) and significant means were separated with least significant difference (Lsd) at 5% and correlation analysis. Some data were analyzed using the EXCEL software for intermediate and graphical calculations.

Fodder plants

In 2018 the fodder plants were more developed (taller and bigger) about 2 m high (Photo 6 b), and in 2017 the same plants were less than 1 m high (Photo 6.a). Even with farmers' traditional protection of these plants (Photo 9), animals damaged them in open grazing and all the data were taken on the affected plants. With this entire damage problem we still got 2 m of height in Year 2 or we noticed that the plants are growing faster.

Growth and development of fodder plants (height, diameter at base, diameter at 1.30 m, and crown radius) were determined each 15 days from 01 August.

Photo 6: *Gliricidia sepium* (2017 and 2018). Photo credit: Kalifa Traore/IER.

The plants on the *ados* were more developed (Photo 7) compared with plants in the NCB field (Photo 8).

Photo 7: *Gliricidia sepium* on the *ado* in CB at Madou Berthe's field. Photo credit: Kalifa Traore/IER.

Photo 8: *Gliricidia sepium* in NCB at Madou Berthe's field. Photo credit: Kalifa Traore/IER.

Photo 9: Fodder plants protected in Madou Berthe's field. Photo credit: Kalifa Traore/IER.

Determination of the impact of CB technology on crop growth and yield in 40 different farms

We selected 40 different farms to evaluate the impact of CB technology on 4 different crops (sorghum, maize, millet, and cotton) at Kani and Noupinesso.

Analysis, interpretation and discussion of achievements

Results

Runoff and runoff coefficient at Kani

The results show that at Kani, runoff collected in the measuring tank was always higher in the NCB field than the CB field at each rainfall event. Runoff in July and August was more than double in the NCB field compared to the CB field in Madou Berthé's farm and there was the same observation at Sekou Berthé's farm. Runoff in the CB part was less than 37.5 mm while it was above this value in the NCB part (Figs 1, 2).

Runoff coefficient varied from 34.89 to 38.79% in NCB fields and from 17.46 to 21.48% in CB fields. Runoff coefficient was greater in the field of Madou Berthe compared with Sekou Berthé's field for both CB and NCB (Fig. 3).

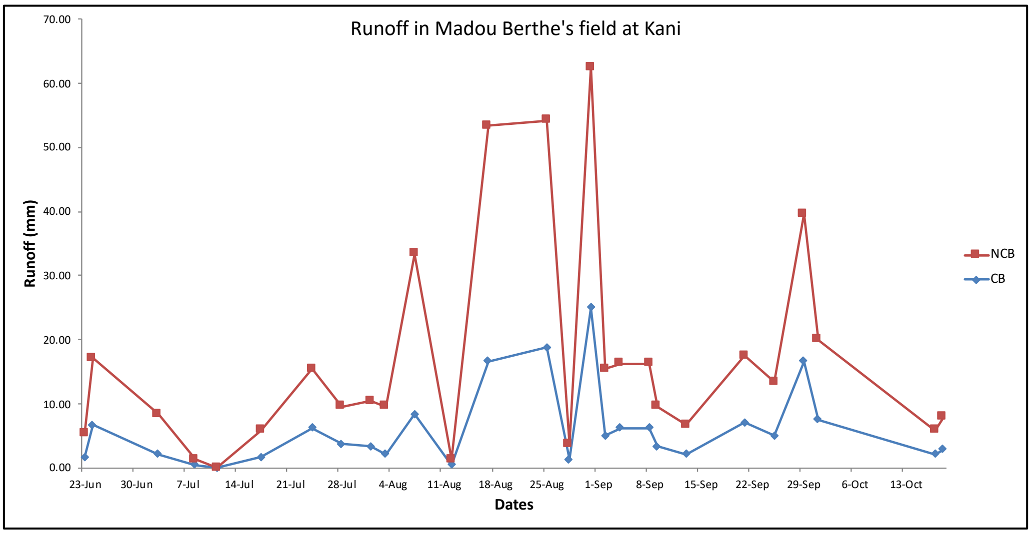

Figure 1: Runoff at Kani in Madou Berthé's field.

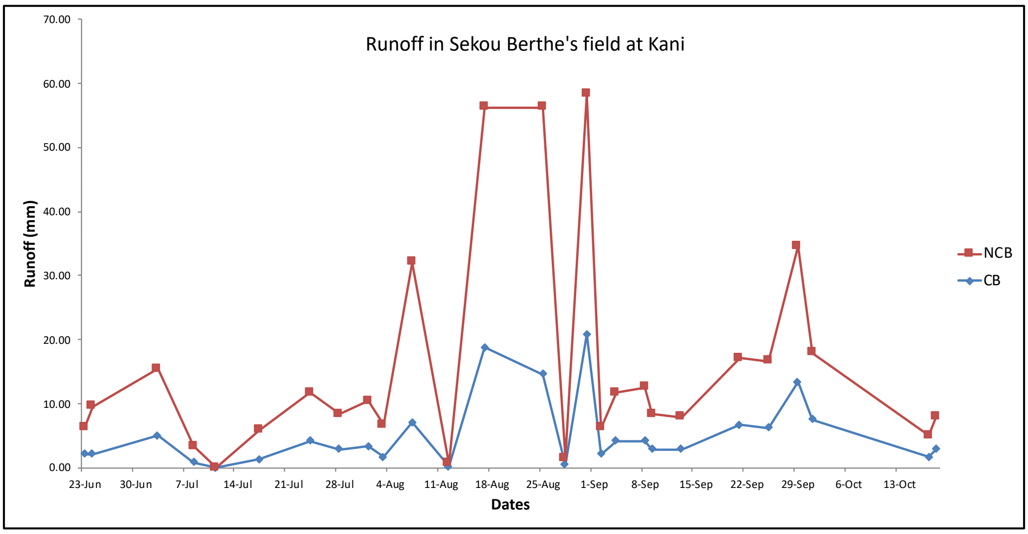

Figure 2: Runoff at Kani in Sekou Berthé's field.

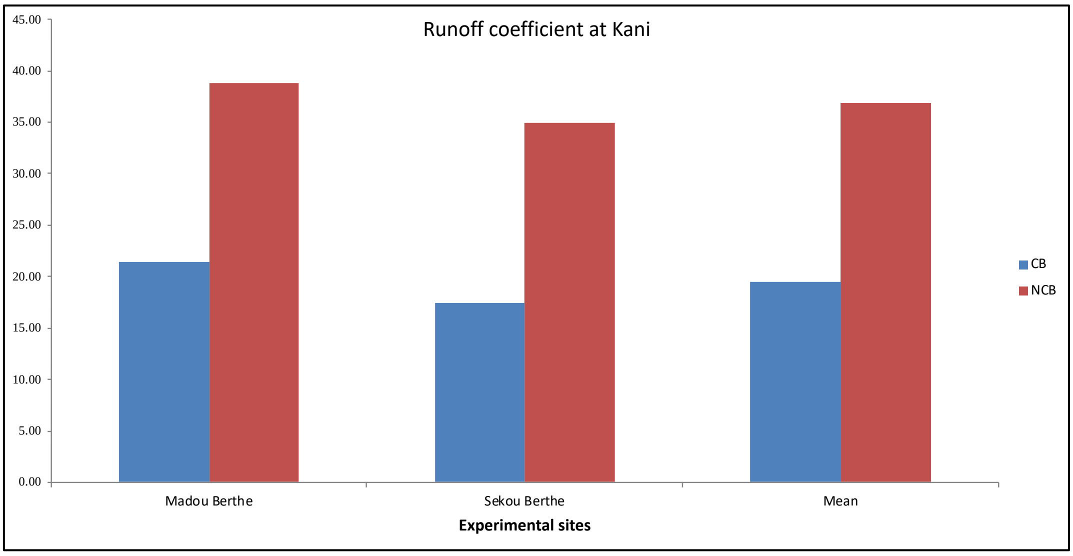

Figure 3: Runoff coefficient at Kani in 2018.

Water table dynamic at Noumpinesso

The CB technology improved the water table dynamic at Noupinesso. The water table increased in volume, i.e., the distance between the groundwater and the soil surface decreased and reached a minimum value of 4.58 m in NCB and 2.61 m in CB at the beginning of September. For the area near the outlet, the minimum observed value was 1.02 m. After this period the groundwater level dropped and the stated distance to the soil surface increased during the rest of the season for all the tubes until November (Fig, 4).

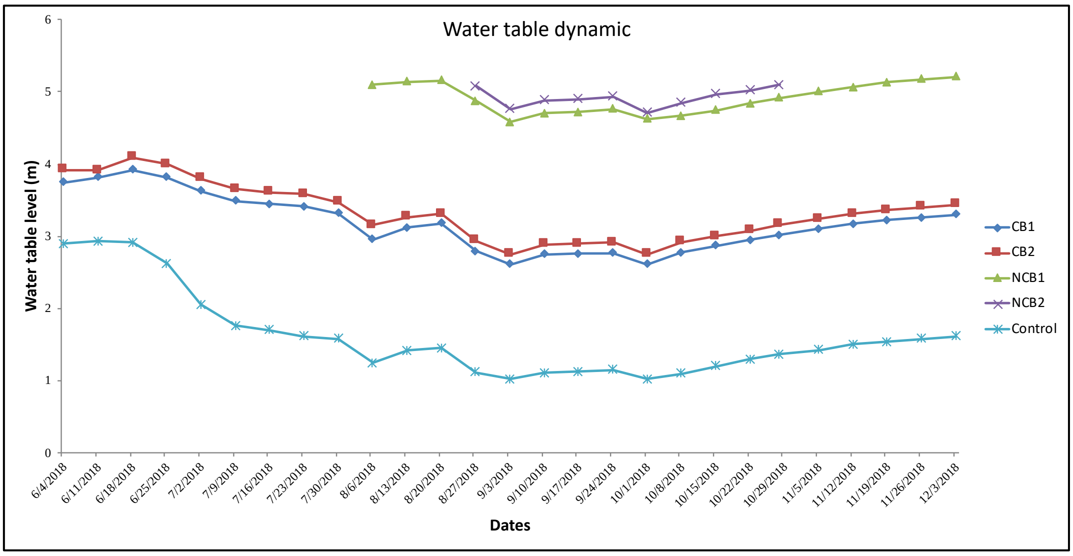

Figure 4: Water table dynamic at Noupinesso in 2018.

Soil moisture

Soil moisture at Kani and Noupinesso

For soil moisture analysis, the dates were chosen to represent the beginning, middle and end of the rainy season.

At Kani and Noupinesso, soil moisture was always higher in the CB plot than the NCB plot and the difference was higher from August to the end of October when rainfall was frequent and heavy (Figs 5, 6). At the end of October at Kani, the maximum of moisture (45.8% in CB and 38.2% in NCB) was observed in the last 100 cm of soil depth. For the other levels (10-90 cm) water content increased from the beginning to the end of the season and reached19.8% for CB and 15.5% for NCB. At the end of the rainy season (10 October), CB increased soil water content in the soil profile at 100 cm from 21 to 36% (Fig. 5).

Figure 6 shows the dynamics of soil moisture at Noupinesso. Here, too, soil moisture was always higher from the middle to the end of the rainy season and at the end at a depth of 100 cm was 40.2% in CB and 31.5% in NCB. The maximum differences of humidity (38.1% in CB and 12% in NCB) at 100 cm depth were obtained at the end of October.

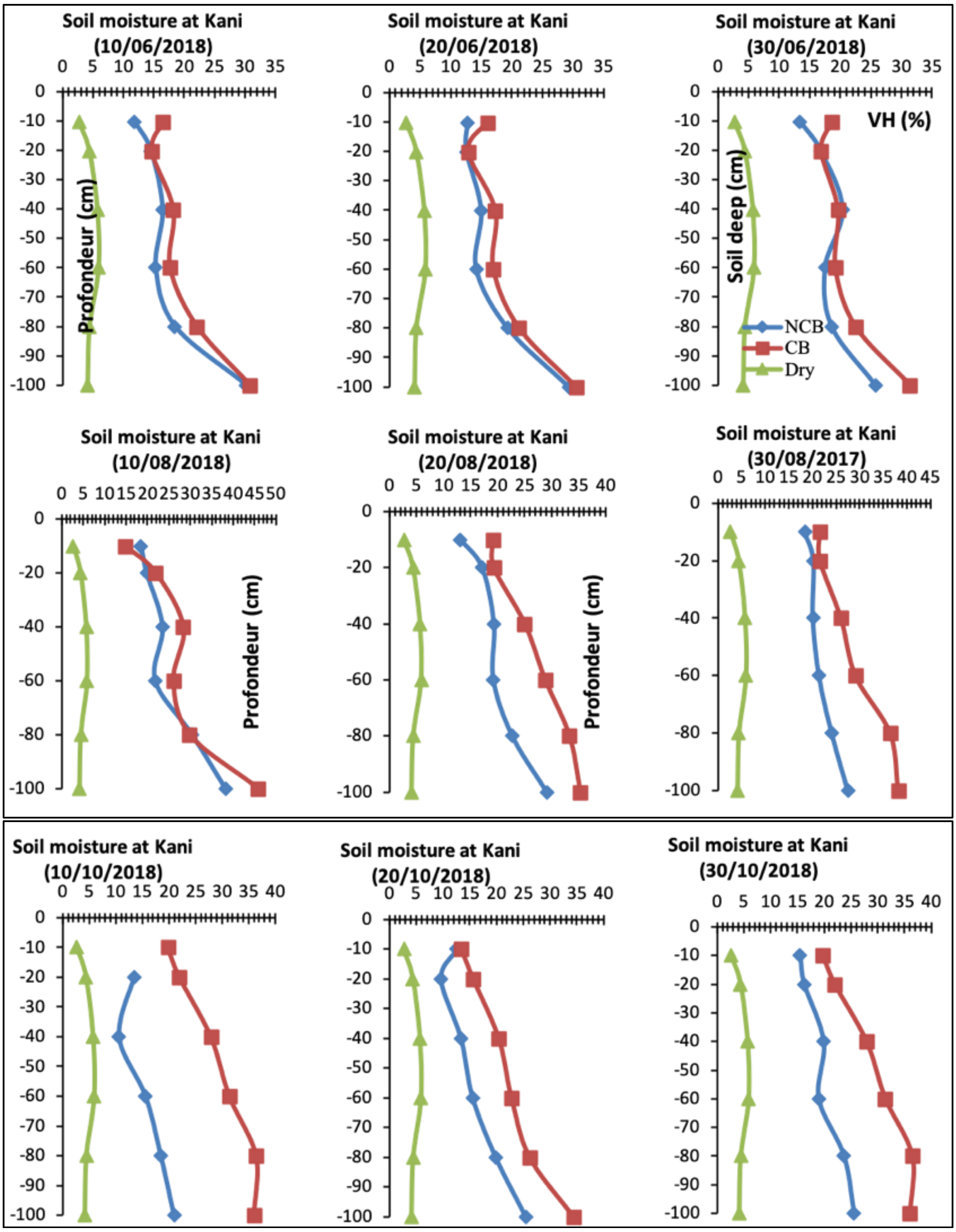

Figure 5: Vertical distribution of soil moisture at Kani in 2018.

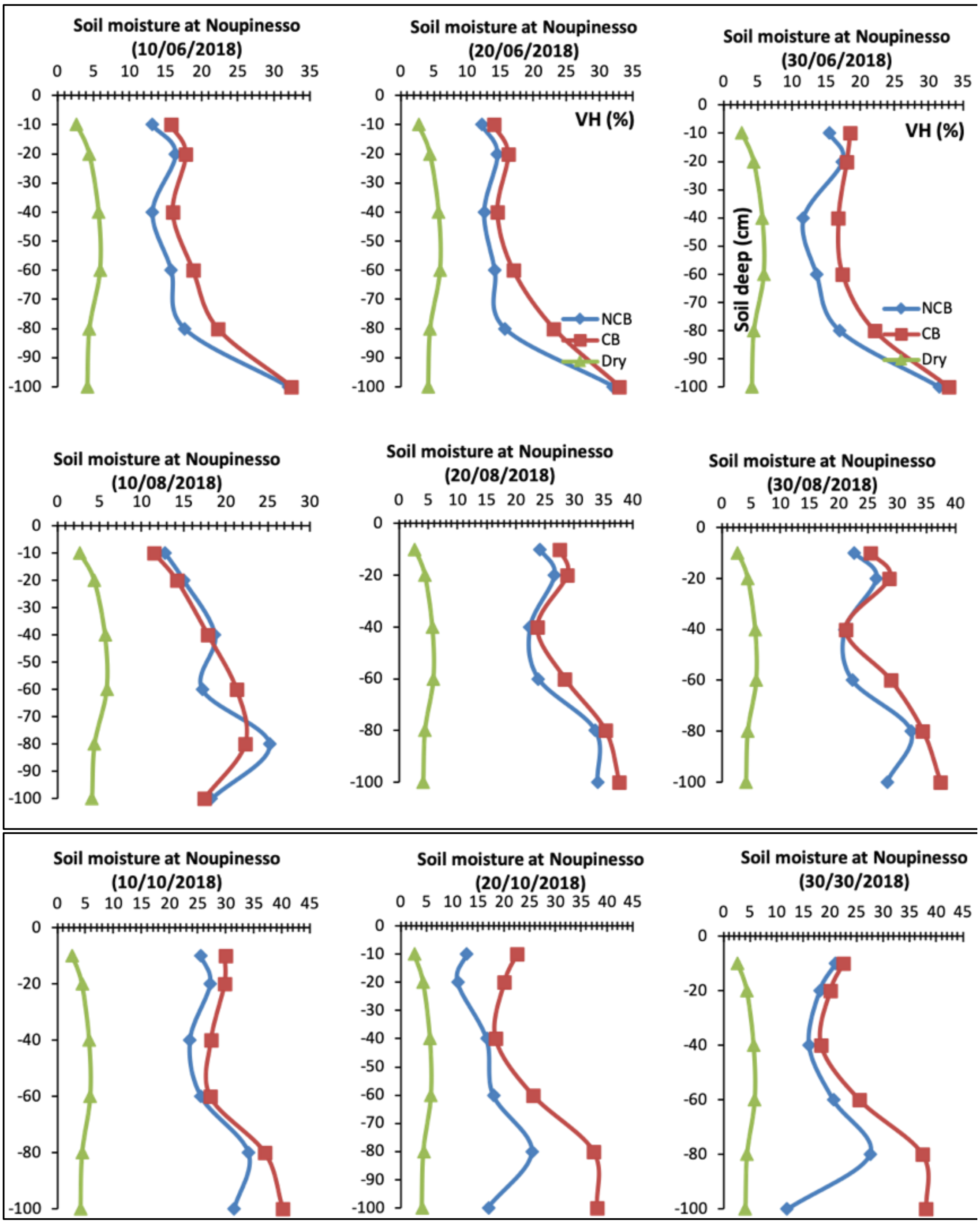

Figure 6: Vertical distribution of soil moisture at Noupinesso.

Soil moisture under and outside fodder plants in CB and NCB fields at Kani

Figure 7 shows that the maximum soil moisture (40.6% under trees and 32.5% outside trees) was obtained at the end of August at 80 cm soil depth when the rainfall was frequent. In CB plots the water content under fodder plants was slightly higher than outside them throughout the rainy season. The maximum soil moisture in superficial profile (10 cm) was 24% in August when rainfall was frequent.

Figure 8 shows the dynamics of soil moisture in the NCB field at Kani. Here too, soil moisture was always higher under the fodder plants than outside them but the difference was higher in CB during all the rainy season. In August a maximum humidity of 37.3% under trees and

30.7% outside trees was observed at the 80 cm depth soil, after which the water content was reduced in October at the end of the rainy season for both, unlike in CB fields.

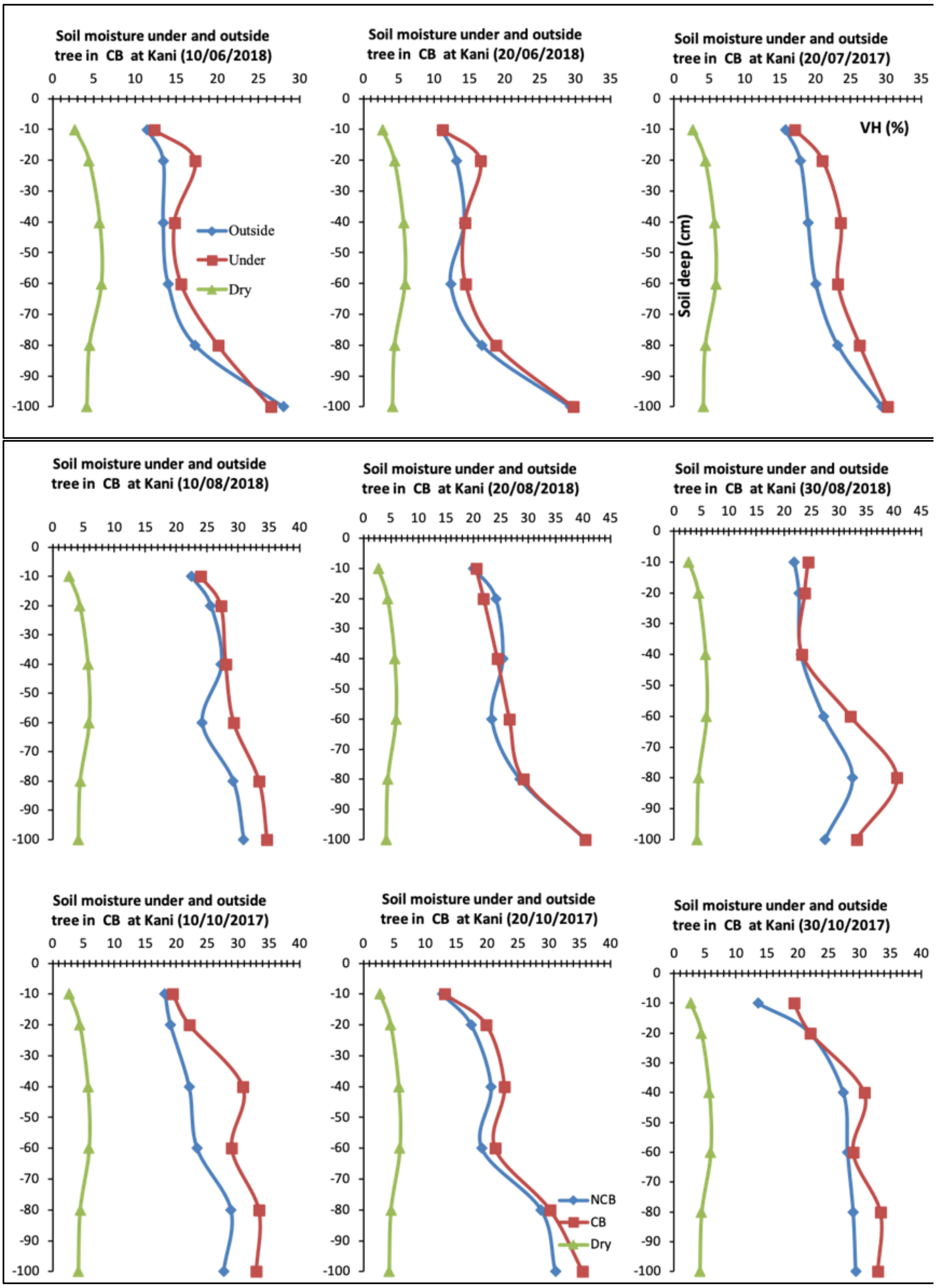

Figure 7: Vertical distribution of soil moisture under and outside fodder plant in the CB field.

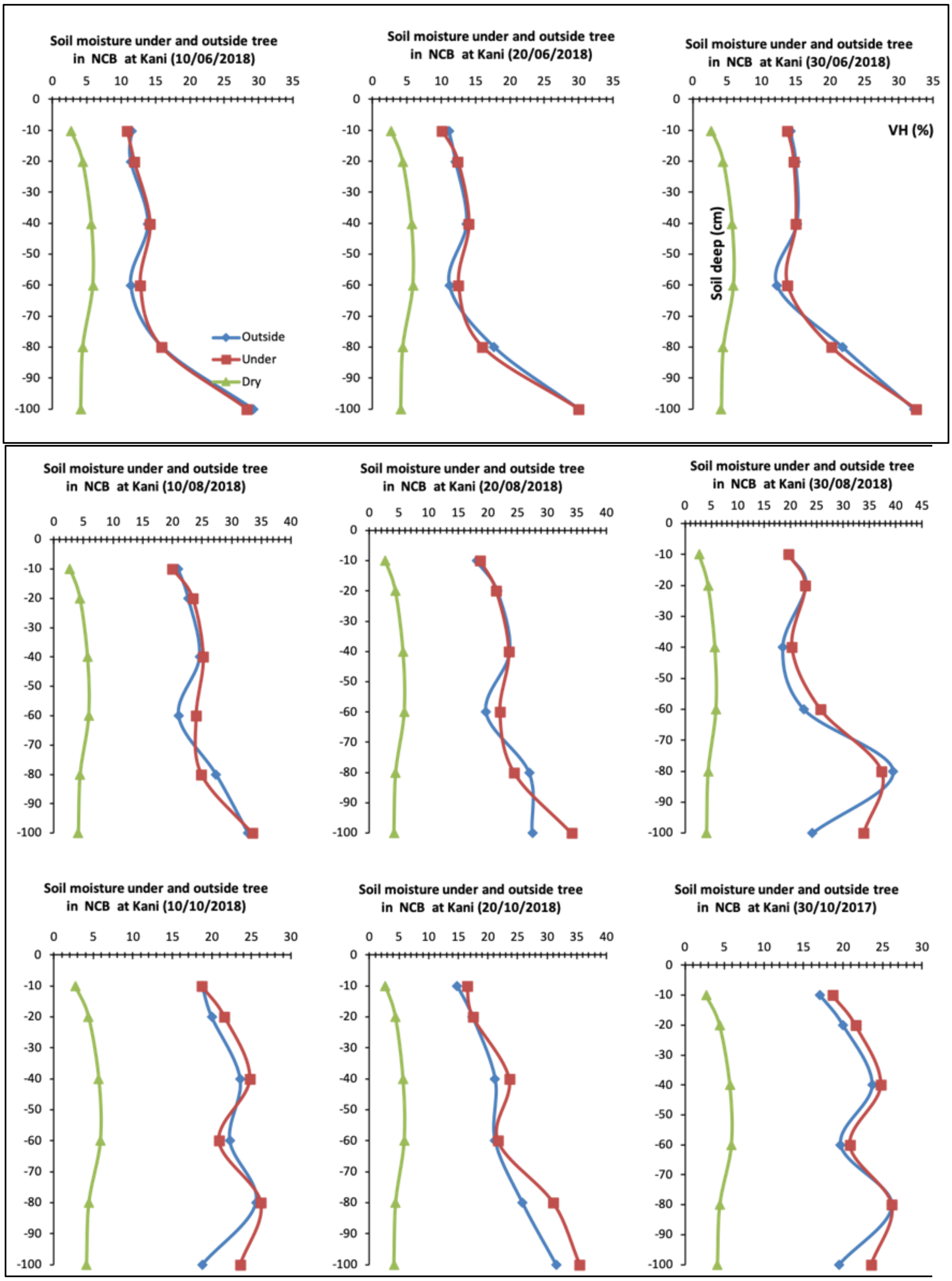

Figure 8: Vertical distribution of soil moisture under and outside fodder plants in NCB field.

Agronomic trials

Soil conservation and soil fertilization trial

Table 1 shows the results of the impact of tillage and soil fertilization on cotton yield that was significantly influenced by both. However, the CB significantly ($p<0.05$) recorded higher cotton yields than the NCB for all the six trials and the highest was obtained in Bourama Dembele's field with 1979.17 kg ha^{-1}. The application of recommended fertilization T4= OM (5 t ha^{-1}) + CC (200 kg ha^{-1}) + Urea (50 kg ha^{-1}) and the micro-dose or T3= OM (2.5 t ha^{-1}) + CC (100 kg ha^{-1}) + Urea (25 kg ha^{-1}) significantly ($p<0.05$) increased cotton yields above the control T1 (no fertilization) and T2= OM (5 t ha^{-1}). The field of Bourama Dembele also recorded again the best cotton yield with 2447.92 kg ha^{-1}.

Table 2 shows biomass yields for the six trials. The results are similar to the cotton yield but the highest biomass yield for soil fertilization was obtained with the application of T4 and T3. For 6 trials, those of Bourama Dembele and Sekou Berthe give the best yield of 4687.50 kg ha^{-1}. Bourama Dembele got the top in CB for tillage practice with 3953.12 kg ha^{-1}

Soil tillage and soil fertilization significantly ($p<0.05$) increased cotton height as well as the yields of cotton biomass. The trial of Sekou Berthe had always the taller plants, 1.440 m in T4. In the CB plot in the field of Remon Sanou (Table 3) they were 1.350 m.

Applying soil fertilization significantly ($p<0.05$) increased cotton diameter of 4 out of the 6 trials; soil tillage significantly ($p<0.05$) increased cotton diameter for 5 trials. The big diameters were in Remon Sanou's field in T4 (18.60 mm) and CB (16.45 mm) (Table 4.).

Table 5 contains the number of capsules by plant; soil fertilization significantly ($p<0.05$) affected cotton capsule numbers for all trials but only a part of the trial of Remon Sanou. Soil tillage also has not significantly ($p<0.05$) affected cotton capsule numbers in a part of the trials of Bourama Dembele and Remon Sanou. The high number of capsules by plant was noticed in the field of Remon Sanou in T4 (23 capsules/ plant) and in the field of Bourama Dembele and Remon Sanou in CB (21 capsules/plant). Table 6 shows the value to cost ratio (VCR) for the 6 trials. The highest values were found in T3 of all trials and the high value of 5(8) was obtained in the field of Bourama Dembele and Remon Sanou.

Table 1: Cotton yield in Kani and Noupinesso, 2018.

Farmers	Cotton yield kg/ha					
	Soil fertilization					
	T1	T2	T3	T4	F.pr (0.05)	L.s.d
Sékou Berthé	843.75	1031.25	1666.67	1760.42	<.001	150.095
Salif Berthé	895.83	1010.42	1625.00	1635.42	0.005	256.783
Barnabé Traoré	822.92	947.92	1593.75	1687.50	0.019	453.528
Bourama Dembélé	1000.00	1218.75	2302.08	2447.92	0.006	519.769
Remon Sanou	864.58	1083.33	1822.92	1927.08	0.016	514.100
Sita Berthé	760.42	968.75	1437.50	1520.83	0.019	380.870
	Soil conservation					
	CN	NCB	F.pr (0.05)	L.s.d	CV(%)	
Sékou Berthé	1510.42	1140.62	0.002	106.133	3.6	
Salif Berthé	1427.08	1156.25	0.018	181.573	6.2	
Barnabé Traoré	1484.38	1041.67	0.022	320.693	11.3	
Bourama Dembélé	1979.17	1505.21	0.026	367.532	9.4	
Remon Sanou	1661.46	1187.50	0.025	363.524	11.3	
Sita Berthé	1338.54	1005.21	0.029	269.316	10.2	

Table 2: Cotton biomass yield in Kani and Noupinesso, 2018.

Farmers	Biomass yield kg/ha					
	Soil fertilization					
	T1	T2	T3	T4	F.pr (0.05)	L.s.d
Sékou Berthé	2145.83	2593.75	4156.25	4270.83	0.012	943.092
Salif Berthé	1229.17	1593.75	2770.83	3125.00	0.002	419.979
Barnabé Traoré	1656.25	2385.42	3197.92	3437.50	0.004	504.026
Bourama Dembélé	2156.25	2781.25	4395.83	4687.50	0.002	558.662
Remon Sanou	1291.67	1604.17	2281.25	2479.17	0.085	1016.646
Sita Berthé						
	Soil conservation					
	CN	NCB	F.pr (0.05)	L.s.d	CV(%)	
Sékou Berthé	3718.75	2864.58	0.027	666.867	9.0	
Salif Berthé	2369.79	1989.58	0.027	296.970	6.1	
Barnabé Traoré	2963.54	2375.00	0.013	356.400	5.9	
Bourama Dembélé	3953.12	3057.29	0.005	395.034	5.0	
Remon Sanou	2281.25	1546.88	0.047	718.877	16.7	
Sita Berthé						

Table 3: Height of cotton crop in Kani and Noupinesso, 2018.

Farmers	Crop height (m)					
	Soil fertilization					
	T1	T2	T3	T4	F.pr (0.05)	L.s.d
Sékou Berthé	0.780	0.910	1.280	1.440	0.018	0.3140
Salif Berthé	0.715	0.810	1.100	1.155	0.002	0.1079
Barnabé Traoré	0.615	1.060	1.375	1.410	0.001	0.1435
Bourama Dembélé	0.9150	1.0300	1.3550	1.4150	<.001	0.08495
Remon Sanou	0.870	1.050	1.390	1.435	0.015	0.2594
Sita Berthé	0.715	0.875	1.305	1.395	0.005	0.2111
	Soil conservation					
	CN	NCB	F.pr (0.05)	L.s.d	CV (%)	
Sékou Berthé	1.262	0.942	0.019	0.2220	8.9	
Salif Berthé	0.987	0.903	0.038	0.0763	3.6	
Barnabé Traoré	1.265	0.965	0.003	0.1015	4.0	
Bourama Dembélé	1.2900	1.0675	0.001	0.06007	2.3	
Remon Sanou	1.350	1.022	0.011	0.1835	6.9	
Sita Berthé	1.188	0.958	0.016	0.1493	6.2	

Table 4: Diameter of cotton crop in Kani and Noupinesso, 2018.

Farmers	Crop diameter (mm)					
	Soil fertilization					
	T1	T2	T3	T4	F.pr (0.05)	L.s.d
Sékou Berthé	8.78	10.38	13.45	14.45	0.003	1.494
Salif Berthé	9.000	10.050	13.850	13.900	<.001	0.3843
Barnabé Traoré	8.83	11.88	15.58	16.00	0.002	1.603
Bourama Dembélé	10.43	11.65	15.00	16.60	0.058	4.488
Remon Sanou	10.66	12.45	16.62	18.60	0.058	5.734
Sita Berthé	10.07	10.65	14.89	15.25	0.002	1.242
	Soil conservation					
	CN	NCB	F.pr (0.05)	L.s.d	CV(%)	
Sékou Berthé	12.75	10.78	0.009	1.056	4.0	
Salif Berthé	12.288	11.113	<.001	0.2718	1.0	
Barnabé Traoré	14.69	11.45	0.003	1.133	3.9	
Bourama Dembélé	15.02	11.81	0.049	3.173	10.5	
Remon Sanou	16.45	12.72	0.061	4.055	12.4	
Sita Berthé	13.92	11.51	0.003	0.878	3.1	

Table 5: Number of cotton capsules /plant in Kani and Noupinesso, 2018.

Farmers	Mean of capsules number/plant					
	Soil fertilization					
	T1	**T2**	**T3**	**T4**	**F.pr (0.05)**	**L.s.d**
Sékou Berthé	9.00	11.00	14.50	15.50	0.034	3.898
Salif Berthé	9.00	10.00	15.50	17.00	0.011	3.375
Barnabé Traoré	7.50	12.50	17.00	17.50	0.004	2.832
Bourama Dembélé	10.00	11.00	18.50	20.00	0.033	6.464
Remon Sanou	10.0	13.5	20.0	23.0	0.091	11.08
Sita Berthé	9.50	11.00	15.50	17.00	0.002	1.837
	Soil conservation					
	CN	**NCB**	**F.pr (0.05)**	**L.s.d**	**CV (%)**	
Sékou Berthé	14.25	10.75	0.027	2.756	9.8	
Salif Berthé	14.50	11.25	0.023	2.387	8.2	
Barnabé Traoré	16.00	11.25	0.005	2.002	6.5	
Bourama Dembélé	17.00	12.75	0.060	4.570	13.7	
Remon Sanou	20.5	12.8	0.051	7.84	20.9	
Sita Berthé	14.25	12.25	0.016	1.299	4.4	

Table 6: Value to cost ratio (VCR) in Kani and Noupinesso,2018.

Farmers	Soil fertilization	VCR
Sekou Berthe	T2	3
	T3	5
	T4	3
Salif Berthe	T2	2
	T3	4
	T4	2
Barnabe Traore	T2	2
	T3	5
	T4	2
Bourama Dembele	T2	4
	T3	8
	T4	4
Remon Sanou	T2	4
	T3	6
	T4	3
Sita Berthe	T2	3
	T3	4
	T4	2

Soil conservation and intercropping system trials

Table 7 presents the results of sorghum and soybean grain yield impacted by soil tillage and intercropping. The use of soil conservation and intercropping system significantly ($p<0.05$) affected sorghum and soybean grain yield. Intercropping the 2 crops produced higher grain yield than sole crops in the 9 trials. Higher grain yield (2546.88 and 2250.00 kg ha^{-1}) of sorghum was obtained in the intercropping plot in the Technology Park of Mpessoba and 2083.33 and 2045.83 kg in Tiemeko Berthe's field

Highest soybean grain yield (2187.50 kg ha^{-1}) was obtained in the intercropping plot in the field of Boukary Berthe and also 2166.67 kg ha^{-1} in the CB plot of the field. Intercropping sorghum and soybean gave an enormous advantage for all trials, and the trial at the Technology Park was more advantageous with a higher LER equal to 4.

The results of sorghum panicle yield were comparable to the sorghum grain yield (Table 8). The best results were in the Mahamadou Bathily's field with 3197.92 kg ha^{-1} in the intercropping plot and 3020.83 kg ha^{-1} in the CB plot.

Soil tillage and fertilization significantly ($p<0.05$) affected the both sorghum and soybean biomass (Table 9). Sorghum biomass weighed 7916.67 kg ha^{-1} in the intercropping plot and 6165.62 kg ha^{-1} in CB plot in the Technology Park of Mpessoba. The highest soybean biomass yield was 2906.25 kg ha^{-1} in the intercropping plot of the Technology Park and 3041.67 kg ha^{-1} in the CB plot in the field of Oumar Berthe.

We found similar results for the diameter and the height of crops, where soil tillage and fertilization significantly ($p<0.05$) increased height and diameter of both sorghum and soybean (Tables 10, 11). The mean of the taller sorghum was in Oumar Berthe's field with 3.54 m in the intercropping plot and 3.67 m in the CB plot. The mean of the taller soybean was in the field of Oumar Berthe with 1.015 m in the intercropping plot and 1.100 m in the CB plot.

The trial at the Technology Park showed a bigger sorghum diameter with 21.10 mm in the intercropping plot and 21.62 mm in the CB plot. We found the bigger soybean diameter (12.72 mm) in the intercropping plot in the field of Oumar Berthe and 14.29 mm in CB plot in the field of Boukary Berthe.

Table 7: Grain yield and Land Equivalent Ratio (LER) of intercropping sorghum-soybean.

	Grain yield (kg/ha)					**LER**
	Farming systems					
	Pure sorghum	**Sorghum-soybean**	**F.pr (0.05)**	**Lsd**		
Youssouf Berthé	1167.00	1958.00	0.148	2382.4		3
Oumar Berthé	1343.75	1864.58	0.305	3441.264		3
Tiéméko Berthé	1239.58	2250.00	0.072	1455.919		3
Boukary Berthé	1218.75	1968.75	0.07	1058.850		3
Amadi Bathily	1166.67	1552.08	0.215	1720.632		3
Mahamadou Bathily	1385.42	2072.92	0.019	264.713		3
Blaize Sanou	1281.25	1666.67	0.017	132.356		2
Basil Sanou	1333.33	1656.25	0.180	1191.207		3
Mpessoba	1098.96	2546.88	0.038	1085.322		4
	Soil conservation					
Farmers	**CB sorghum**	**NCB sorghum**	**F.pr (0.05)**	**Lsd**	**CV (%)**	
Youssouf Berthé	1760.00	1365.00	0.282	2382.4	12.0	
Oumar Berthé	2083.33	1125.00	0.175	3441.264	16.9	
Tiéméko Berthé	2020.83	1468.75	0.130	1455.919	6.6	
Boukary Berthé	1770.83	1416.67	0.147	1058.850	5.2	
Amadi Bathily	1531.25	1187.50	0.239	1720.632	10.0	
Mahamadou Bathily	1958.33	1500.00	0.029	264.713	1.2	
Blaize Sanou	1604.17	1343.75	0.025	132.356	0.7	
Basil Sanou	1656.25	1333.33	0.180	1191.207	6.3	
Mpessoba	2045.83	1600.00	0.121	1085.322	4.7	

Table 8: Grain yield of intercropping soybean- sorghum.

Farmers	Grain yield (kg/ha)				
	Farming systems				
	Pure soybean	Soybean-Sorghum	F.pr (0.05)	Lsd	
Youssouf Berthé	979.17	1416.67	0.060	529.425	
Oumar Berthé	1072.92	1343.75	0.144	794.138	
Tiéméko Berthé	1020.83	1322.92	0.066	397.069	
Boukary Berthé	1281.25	2187.50	0.304	5956.033	
Amadi Bathily	1302.08	1708.33	0.113	926.494	
Mahamadou Bathily	1260.42	1864.58	0.022	264.713	
Blaize Sanou	1375.00	1614.58	0.028	132.356	
Basil Sanou	1302.08	1781.25	0.110	1058.850	
Mpessoba	932.29	1510.42	0.239	2898.603	
	Soil conservation				
Farmers	**CB Soybean**	**NCB Soybean**	**F.pr (0.05)**	**Lsd**	**CV(%)**
Youssouf Berthé	1406.25	989.58	0.063	529.425	3.5
Oumar Berthé	1500.00	916.67	0.068	794.138	5.2
Tiéméko Berthé	1500.00	843.75	0.030	397.069	2.7
Boukary Berthé	2166.67	1302.08	0.316	5956.033	27.0
Amadi Bathily	1697.92	1312.50	0.119	926.494	4.8
Mahamadou Bathily	1791.67	1333.33	0.029	264.713	1.3
Blaize Sanou	1718.75	1270.83	0.015	132.356	0.7
Basil Sanou	1739.58	1343.75	0.132	1058.850	5.4
Mpessoba	1430.21	1012.50	0.318	2898.603	18.7

Table 9: Panicle yield of intercropping sorghum-soybean.

Farmers	Panicle (kg/ha)							
	Pure sorghum	Sorghum-soybean	F.pr (0.05)	CB sorghum	NCB sorghum	F.pr (0.05)	Lsd	CV(%)
Youssouf Berthé	1520.83	2541.67	0.078	2239.58	1822.92	0.186	1588.276	6.2
Oumar Berthé	1885.42	2500.00	0.387	2916.67	1468.75	0.183	5426.608	19.5
Tiéméko Berthé	1854.17	3041.67	0.022	2864.58	2031.25	0.032	529.425	1.7
Boukary Berthé	1864.58	3062.50	0.017	2687.50	2239.58	0.044	397.060	1.3
Amadi Bathily	1781.25	2281.25	0.251	2291.67	1770.83	0.242	2647.126	10.3
Mahamadou B	2062.50	3197.92	0.176	3020.83	2239.58	0.25	4103.045	12.3
Blaize Sanou	2125.00	2427.08	0.066	2458.33	2093.75	0.054	397.069	1.4
Basil Sanou	29.463	29.463	0.063	2562.50	2104.17	0.058	529.425	1.8
Mpessoba	1526.04	3236.46	0.052	2835.42	1927.08	0.097	1773.574	5.9

Table 10: Biomass yield of intercropping sorghum-soybean.

Farmers	Biomass yield (kg/ha)				
	Farming systems				
	Pure sorghum	Sorghum-soybean	F.pr (0.05)	Lsd	
Youssouf Berthé	3385.42	5416.67	0.016	661.781	
Oumar Berthé	4322.92	5520.83	0.136	3308.907	
Tiéméko Berthé	2968.75	4895.83	0.119	4632.470	
Boukary Berthé	2989.58	5572.92	0.021	1058.850	
Amadi Bathily	2677.08	4062.50	0.128	3573.620	
Mahamadou Bathily	3125.00	5104.17	0.225	9264.941	
Blaize Sanou	2531.25	3270.83	0.347	5691.321	
Basil Sanou	2864.58	4166.67	0.076	1985.344	
Mpessoba	3366.67	7916.67	0.051	4685.413	
	Soil conservation				
Farmers	**CB sorghum**	**NCB sorghum**	**F.pr (0.05)**	**Lsd**	**CV (%)**
Youssouf Berthé	4531.25	4270.83	0.126	661.781	1.2
Oumar Berthé	5937.50	3906.25	0.81	3308.907	5.3
Tiéméko Berthé	4895.83	2968.75	0.119	4632.470	9.3
Boukary Berthé	5104.17	3458.33	0.032	1058.850	1.9
Amadi Bathily	4166.67	2572.92	0.111	3573.620	8.3
Mahamadou Bathily	5208.33	3020.83	0.205	9264.941	17.7
Blaize Sanou	3364.58	2437.50	0.287	5691.321	15.4
Basil Sanou	4166.67	2864.58	0.076	1985.344	4.4
Mpessoba	6165.62	5117.71	0.215	4685.413	6.5

Table 11: Biomass yield of intercropping soybean-sorghum.

Farmers	Biomass yield (kg/ha)				
	Farming systems				
	Pure soybean	Soybean-Sorghum	F.pr (0.05)	Lsd	
Youssouf Berthé	1937.50	2385.42	0.265	2514.770	
Oumar Berthé	2416.67	2885.42	0.323	3308.907	
Tiéméko Berthé	2072.92	2270.83	0.282	1191.207	
Boukary Berthé	2302.08	2322.92	0.972	6088.390	
Amadi Bathily	2239.58	2843.75	0.066	794.138	
Mahamadou Bathily	2177.08	2875.00	0.291	4367.758	
Blaize Sanou	2343.75	3052.08	0.379	6088.390	
Basil Sanou	1510.42	2333.33	0.104	1720.632	
Mpessoba	2403.12	2906.25	0.090	913.258	
	Soil conservation				
Farmers	**CB Soybean**	**NCB Soybean**	**F.pr (0.05)**	**Lsd**	**CV (%)**
Youssouf Berthé	2395.83	1927.08	0.254	2514.770	9.2
Oumar Berthé	3041.67	2260.42	0.205	3308.907	9.8
Tiéméko Berthé	2875.00	1468.75	0.042	1191.207	4.3

Boukary Berthé	2604.17	2020.83	0.438	6088.390	20.7
Amadi Bathily	3562.50	1520.83	0.019	794.138	2.5
Mahamadou Bathily	2895.83	2156.25	0.277	4367.758	13.6
Blaize Sanou	2843.75	2552.08	0.652	6088.390	17.8
Basil Sanou	2375.00	1468.75	0.094	1720.632	7.0
Mpessoba	2816.67	2492.71	0.139	913.258	2.7

Table 12: Crop height of intercropped sorghum-soybean.

Farmers	**Height (m)**				
	Farming systems				
	Pure sorghum	**Sorghum-soybean**	**F.pr (0.05)**	**Lsd**	
Youssouf Berthé	2.750	3.440	0.064	0.8894	
Oumar Berthé	2.86	3.54	0.270	3.875	
Tiéméko Berthé	2.555	3.060	0.118	1.2071	
Boukary Berthé	2.2250	3.1800	0.003	0.06353	
Amadi Bathily	2.015	2.560	0.052	0.5718	
Mahamadou Bathily	2.450	3.075	0.164	2.0965	
Blaize Sanou	1.765	2.250	0.085	0.8259	
Basil Sanou	2.00	2.53	0.372	4.447	
Mpessoba	2.895	3.190	0.158	0.9530	
	Soil conservation				
Farmers	**CB sorghum**	**NCB sorghum**	**F.pr (0.05)**	**Lsd**	**CV (%)**
Youssouf Berthé	3.240	2.950	0.151	0.8894	2.3
Oumar Berthé	3.67	2.73	0.199	3.875	9.5
Tiéméko Berthé	3.020	2.595	0.140	1.2071	3.4
Boukary Berthé	3.0000	2.4050	0.005	0.06353	0.2
Amadi Bathily	2.585	1.990	0.048	0.5718	2.0
Mahamadou Bathily	3.165	2.360	0.129	2.0965	6.0
Blaize Sanou	2.255	1.760	0.083	0.8259	3.2
Basil Sanou	2.53	2.00	0.372	4.447	15.5
Mpessoba	3.265	2.820	0.106	0.9530	2.5

Table 13: Crop height of intercropped soybean-sorghum.

Farmers	Height (m)				
	Farming systems				
	Pure soybean	Soybean-Sorghum	F.pr (0.05)	Lsd	
Youssouf Berthé	0.8300	0.9950	0.019	0.06353	
Oumar Berthé	0.930	1.015	0.460	0.9530	
Tiéméko Berthé	0.700	0.850	0.126	0.3812	
Boukary Berthé	0.790	0.930	0.218	0.6353	
Amadi Bathily	0.5700	0.7250	0.061	0.19059	
Mahamadou Bathily	0.655	0.785	0.190	0.5082	
Blaize Sanou	0.650	0.755	0.149	0.3177	
Basil Sanou	0.645	0.775	0.097	0.2541	
Mpessoba	0.640	0.815	0.126	0.4447	
	Soil conservation				
Farmers	**CB Soybean**	**NCB Soybean**	**F.pr (0.05)**	**L.s.d**	**CV (%)**
Youssouf Berthé	0.9850	0.8400	0.022	0.06353	0.5
Oumar Berthé	1.100	0.845	0.182	0.9530	7.7
Tiéméko Berthé	0.980	0.570	0.46	0.3812	3.9
Boukary Berthé	0.985	0.735	0.126	0.6353	5.8
Amadi Bathily	0.7550	0.5400	0.044	0.19059	2.3
Mahamadou Bathily	0.825	0.615	0.120	0.5082	5.6
Blaize Sanou	0.775	0.630	0.109	0.3177	3.6
Basil Sanou	0.805	0.615	0.067	0.2541	2.8
Mpessoba	0.810	0.645	0.133	0.4447	4.8

Table 14: Crop diameter of intercropped sorghum-soybean.

Farmers	Diameter (mm)				
	Farming systems				
	Pure Sorghum	**Sorghum-soybean**	**F.pr (0.05)**	**Lsd**	
Youssouf Berthé	18.165	20.375	0.012	0.5082	
Oumar Berthé	17.55	20.15	0.097	5.082	
Tiéméko Berthé	15.900	19.350	0.018	1.2706	
Boukary Berthé	15.48	19.66	0.032	2.668	
Amadi Bathily	14.25	17.05	0.177	10.165	
Mahamadou Bathily	17.25	19.14	0.096	3.621	
Blaize Sanou	14.98	17.48	0.051	2.541	
Basil Sanou	16.42	19.77	0.087	5.845	
Mpessoba	18.42	21.10	0.157	8.577	
	Soil conservation				
Farmers	**CB sorghum**	**NCB sorghum**	**F.pr (0.05)**	**Lsd**	**CV (%)**
Youssouf Berthé	19.875	18.665	0.021	0.5082	0.2
Oumar Berthé	20.55	17.15	0.075	5.082	2.1
Tiéméko Berthé	20.225	15.025	0.012	1.2706	0.6
Boukary Berthé	19.84	15.30	0.029	2.668	1.2
Amadi Bathily	17.55	13.75	0.132	10.165	5.1
Mahamadou Bathily	20.09	16.30	0.048	3.621	1.6
Blaize Sanou	17.60	14.85	0.046	2.541	1.2
Basil Sanou	18.79	17.40	0.203	5.845	2.5
Mpessoba	21.62	17.90	0.114	8.577	3.4

Table 15: Crop diameter of intercropped soybean-sorghum.

Farmers	Diameter (mm)				
	Farming systems				
	Pure soybean	Soybean-Sorghum	F.pr (0.05)	Lsd	
Youssouf Berthé	10.00	12.44	0.180	9.021	
Oumar Berthé	11.13	12.72	0.233	7.751	
Tiéméko Berthé	10.22	12.67	0.141	6.988	
Boukary Berthé	10.93	12.96	0.275	11.944	
Amadi Bathily	10.23	12.25	0.161	6.671	
Mahamadou Bathily	10.525	12.000	0.011	0.3177	
Blaize Sanou	9.35	10.60	0.362	10.165	
Basil Sanou	9.45	11.40	0.275	11.436	
Mpessoba	7.900	10.350	0.039	1.9059	
	Soil conservation				
Farmers	**CB Soybean**	**NCB Soybean**	**F.pr (0.05)**	**Lsd**	**CV (%)**
Youssouf Berthé	12.18	10.27	0.227	9.021	6.3
Oumar Berthé	13.45	10.41	0.126	7.751	5.1
Tiéméko Berthé	13.85	9.05	0.075	6.988	4.8
Boukary Berthé	14.29	9.60	0.126	11.944	7.9
Amadi Bathily	13.00	9.47	0.094	6.671	4.7
Mahamadou Bathily	13.300	9.225	0.004	0.3177	0.2
Blaize Sanou	10.78	9.18	0.295	10.165	8.0
Basil Sanou	11.68	9.18	0.220	11.436	8.6
Mpessoba	9.900	8.350	0.061	1.9059	1.6

Effect of CB technology on growth of *Gliricidia sepium* and *Leucaena leucocephala* at Kani, Noupinesso, and the Technology Park at Mpessoba

Before the rainy season, animals in open grazing damaged fodder plants used in the research (*G. sepium* and *L. leucocephala*) even though they were protected with the traditional grill. The data were collected on the new branching.

During the rainy season CB increased growth of both trees at the three sites of research. The *Gliricidia* of Mpessoba was more developed (4.88 m height, 72.8 mm base diameter). It was planted in 2015 (Figs 10, 12). The fodder plants that were taller (2.08 m CB, 1.27 m NCB) and bigger (42 mm CB, 23.2 mm NCB) were found in November when the plants of Kani and Noupinesso were in their second year (Figs 9, 11). We noticed a larger growth in CB plots than in NCB from August to September; the larger growth of 1.57 m was found in the field of Madou Berthe and of 3.72 m at Mpessoba in the Technology Park (Figs 13, 14).

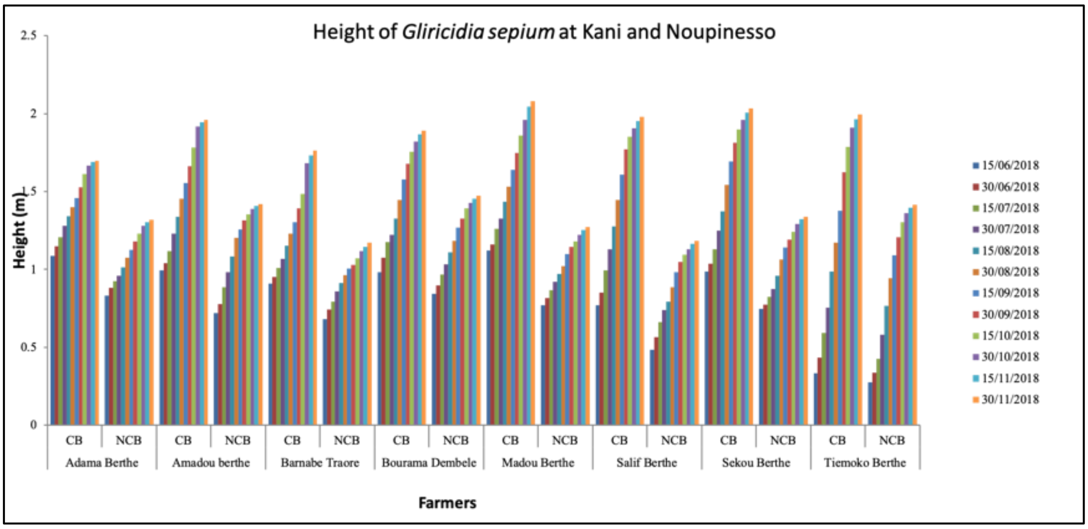

Figure 9: Height of *G. sepium* in different fields at different times of the rainy season at Kani and Noupinesso.

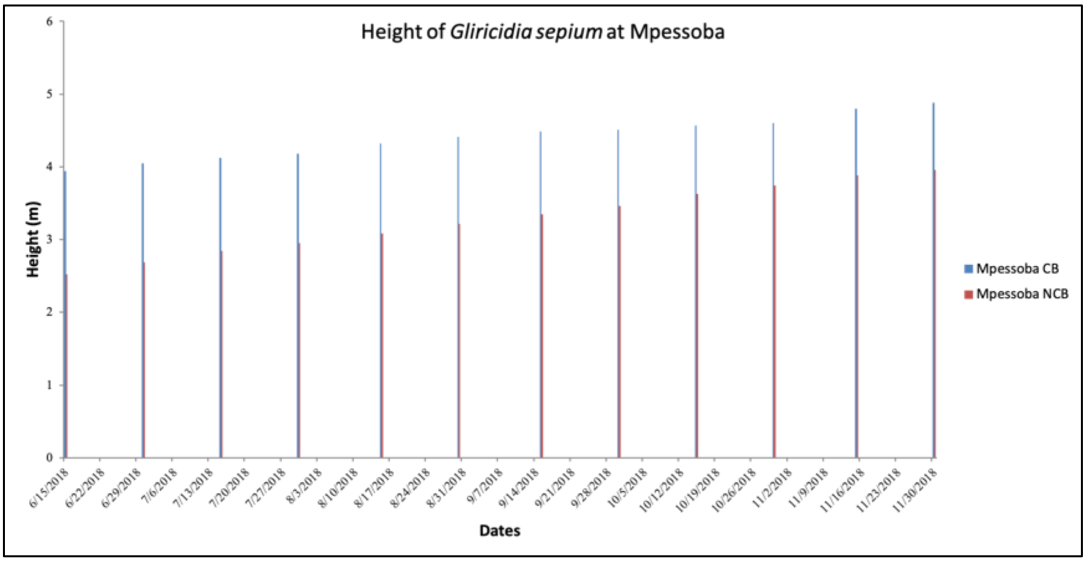

Figure 10: Height of *G. sepium* in different fields at different times of the rainy season at Mpessoba.

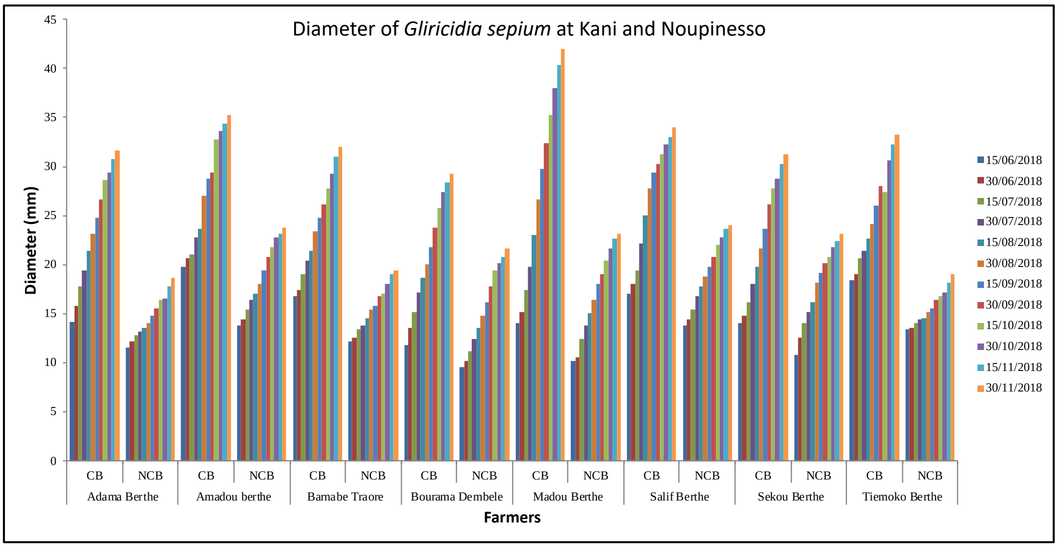

Figure 11: Base diameter of *G sepium* in different fields at different times of the rainy season at Kani and Noupinesso.

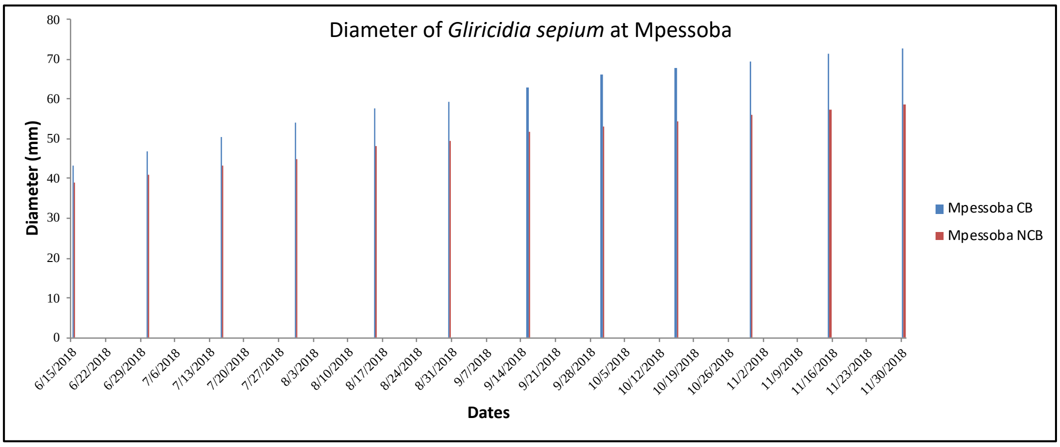

Figure 12: Base diameter of *G. sepium* in different fields at different times of the rainy season at Mpessoba.

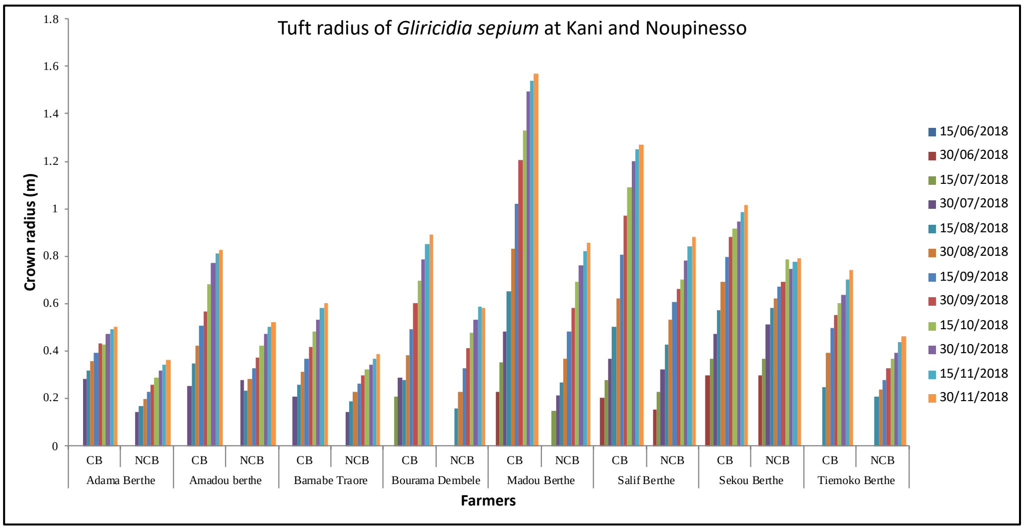

Figure 13: Crown radius of *G. sepium* in different fields at different times of rain season at Kani and Noupinesso.

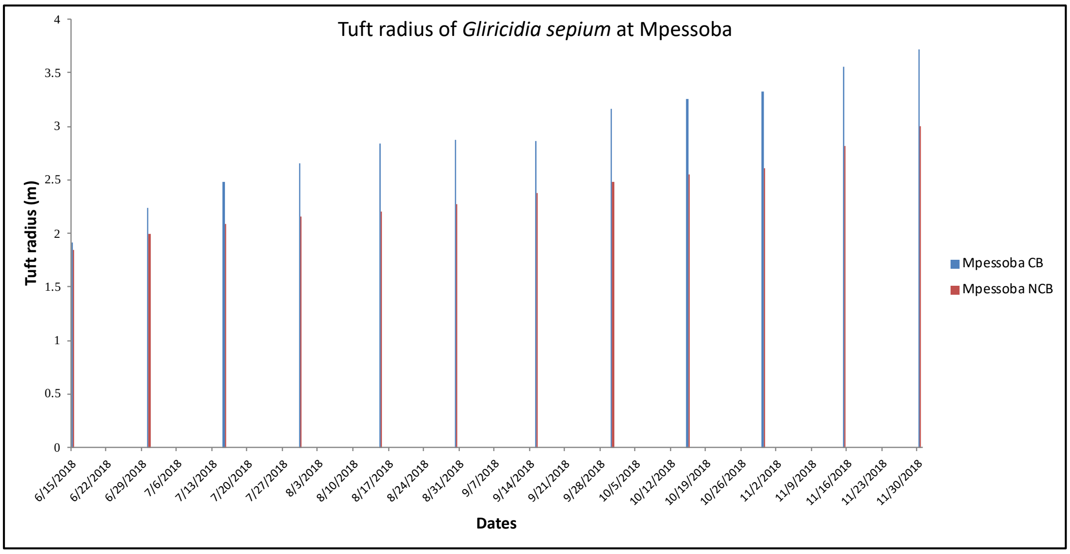

Figure 14: Crownradius of *G. sepium* in different fields at different times of rain season at Mpessoba.

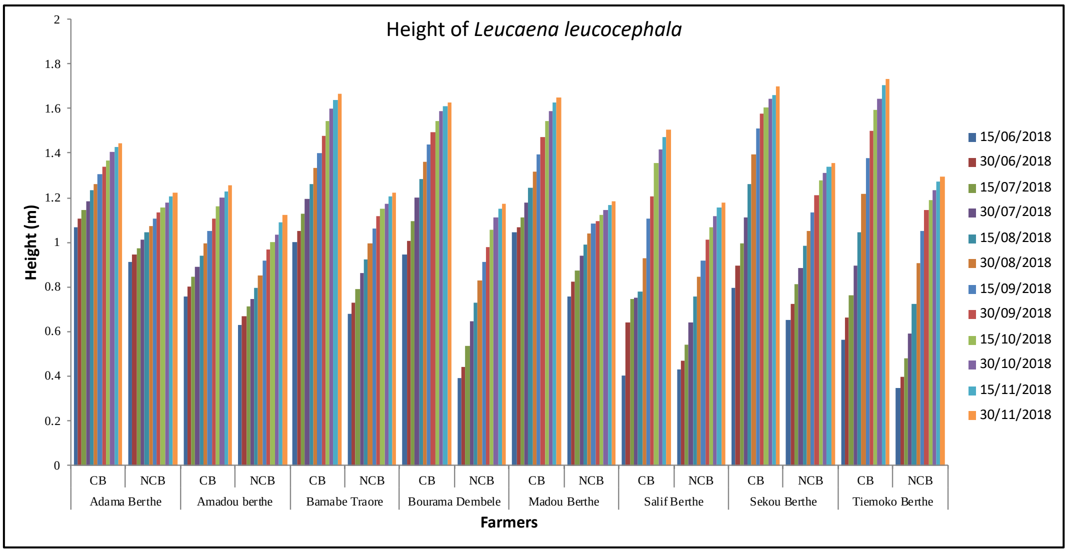

Figure 15: Height of *L. leucocephala* in different fields at different times of the rainy season at Kani and Noupinesso.

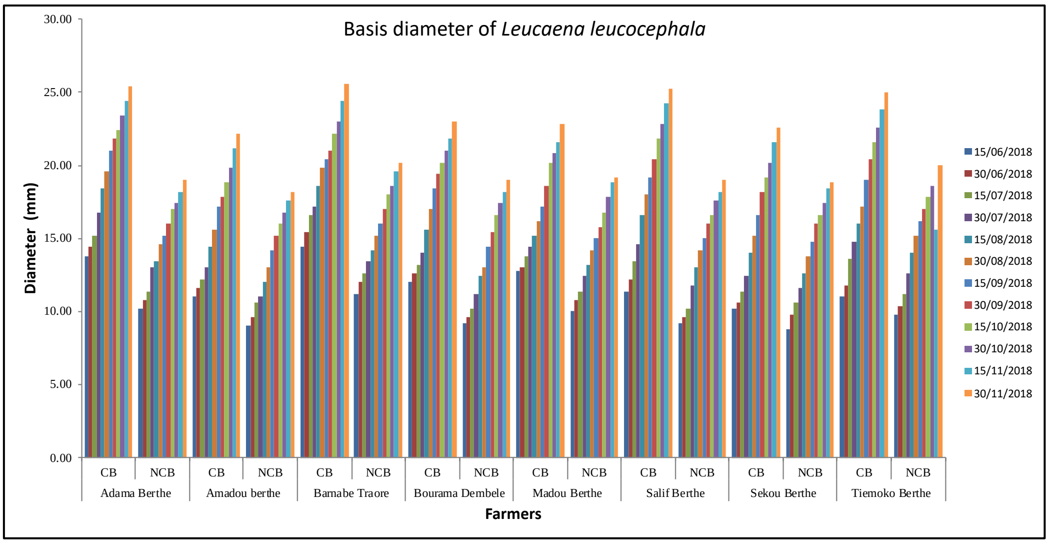

Figure 16: Base diameter of *L. leucocephala* in different fields at different times of the rainy season at Kani and Noupinesso.

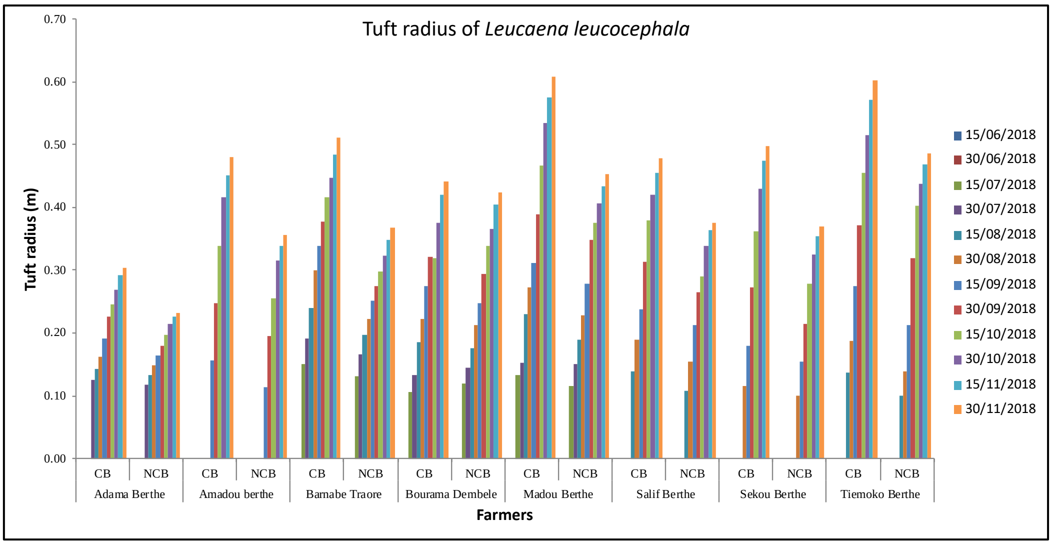

Figure 17: Crown radius of *L. leucocephala* in different fields at different times of the rainy season at Kani and Noupinesso.

Impact of CB technology on crop growth and yield in 40 different farms at Kani and Noupinesso

For each case at Kani as in Noupinesso, CB increased crop growth and yield. It increased the yield of sorghum grain and biomass by more than 50% and height by more than 30% in the fields of Barnabe Traore, Kassim Dembele, Tiemeko Berthe, and Tidiane Dembele (Table 16). In each millet field, the yields were increased by more than 30% (Table 17) and we found similar results in the other fields of maize and cotton (Tables 18, 19). The high value of CV is due to the large difference of yields between the 2 treatments, sometimes more than double.

Table 16: Impact of CB on sorghum growth and yields in Kani and Noupinesso, 2018.

Farmers	Sorghum grain yield (kg ha^{-1})				
	Soil conservation technology				
	CB	NCB	Mean	Standard deviation	CV (%)
Amadou Berthé	1583,33	1166,67	1375,00	294,62	21,40
Barnabé Traoré	1791,67	500,00	1145,84	913,35	79,70
Amady Bathily	2083,33	1125,00	1604,17	677,64	42,20
Kassim Dembele	2291,67	1083,33	1687,50	854,43	50,60
Jean Sanou	1958,33	1125,00	1541,67	589,25	38,20
Tiémoko Berthé	1666,67	750,00	1208,34	648,18	53,60
Tidiane Dembélé	1875,00	708,33	1291,67	824,96	63,90
Filigence Sanogo	1250,00	750,00	1000,00	353,55	35,40
Farmers	**Sorghum straw yield (kg ha^{-1})**				
	Soil conservation technology				
	CB	**NCB**	**Mean**	**Standard deviation**	**CV (%)**
Amadou Berthé	5833,33	2708,33	4270,83	2209,71	51,70
Barnabé Traoré	7916,67	1125,00	4520,84	4802,44	106,20
Amady Bathily	3125,00	1791,67	2458,34	942,81	38,40
Kassim Dembele	14583,33	6250,00	10416,67	5892,55	56,60
Jean Sanou	12500,00	8750,00	10625,00	2651,65	25,00
Tiémoko Berthé	2916,67	1250,00	2083,34	1178,51	56,60
Tidiane Dembélé	4583,33	2916,67	3750,00	1178,51	31,40
Filigence Sanogo	5625,00	3958,33	4791,67	1178,51	24,60
Farmers	**Sorghum height (m)**				
	Soil conservation technology				
	CB	**NCB**	**Mean**	**Standard deviation**	**CV (%)**
Amadou Berthé	4,20	2,63	3,42	1,11	32,50
Barnabé Traoré	3,48	1,87	2,68	1,14	42,60
Amady Bathily	2,91	1,99	2,45	0,65	26,60
Kassim Dembele	5,69	3,35	4,52	1,65	36,60
Jean Sanou	4,94	4,03	4,48	0,65	14,40
Tiémoko Berthé	2,71	1,82	2,27	0,63	27,80
Tidiane Dembélé	4,05	2,57	3,31	1,05	31,60
Filigence Sanogo	2,17	1,83	2,00	0,24	12,00

Table 17: Impact of CB on maize growth and yields.

Farmers	Maize grain yield (kg ha^{-1})				
	Soil conservation technology				
	CB	**NCB**	**Mean**	**Standard deviation**	**CV (%)**
Bakary Berthé	3125,00	1958,33	2541,67	824,96	32,50
Lassina Traoré	4166,67	1291,67	2729,17	2032,93	74,50
Bourama Dembélé	4125,00	3416,67	3770,84	500,86	13,30
Souleymane Traoré	3250,00	1833,33	2541,67	1001,74	39,40
Klegna Coulibaly	3500,00	2500,00	3000,00	707,11	23,60
Michel Sanou	2375,00	1291,67	1833,34	766,03	41,80
Abdoulaye Sanou	4166,67	2583,33	3375,00	1119,59	33,20
Remon Sanou	3000,00	1666,67	2333,34	942,81	40,40
Lassina Goïta	6041,67	4166,67	5104,17	1325,82	26,00
Farmers	**Maize straw yield (kg ha^{-1})**				
	Soil conservation technology				
	CB	**NCB**	**Mean**	**Standard deviation**	**CV (%)**
Bakary Berthé	3750,00	2500,00	3125,00	883,88	28,30
Lassina Traoré	9166,67	3958,33	6562,50	3682,85	56,10
Bourama Dembélé	5625,00	3958,33	4791,67	1178,51	24,60
Souleymane Traoré	7916,67	4583,33	6250,00	2357,03	37,70
Klegna Coulibaly	5833,33	3500,00	4666,67	1649,91	35,40
Michel Sanou	4791,67	2708,33	3750,00	1473,14	39,30
Abdoulaye Sanou	7083,33	4583,33	5833,33	1767,77	30,30
Remon Sanou	5416,67	3333,33	4375,00	1473,14	33,70
Lassina Goïta	8750,00	5000,00	6875,00	2651,65	38,60
Farmers	**Maize height (m)**				
	Soil conservation technology				
	CB	**NCB**	**Mean**	**Standard deviation**	**CV (%)**
Bakary Berthé	2,41	1,83	2,12	0,41	19,30
Lassina Traoré	2,39	1,76	2,08	0,45	21,50
Bourama Dembélé	2,56	1,84	2,20	0,51	23,10
Souleymane Traoré	2,48	1,91	2,20	0,40	18,40
Klegna Coulibaly	2,89	2,44	2,67	0,32	11,90
Michel Sanou	2,79	2,05	2,42	0,52	21,60
Abdoulaye Sanou	2,86	2,09	2,48	0,54	22,00
Lassina Goïta	2,64	2,39	2,52	0,18	7,00

Table 18: Impact of CB on millet growth and yields.

Farmers	Millet grain yield (kg ha^{-1})				
	Soil conservation technology				
	CB	**NCB**	**Mean**	**Standard deviation**	**CV (%)**
Seni Berthé	1041,67	750,00	895,84	206,24	23,00
Madou Coulibaly	1750,00	1000,00	1375,00	530,33	38,60
Bakary Coulibaly	2833,33	916,67	1875,00	1355,28	72,30
Jack Coulibaly	2708,33	1875,00	2291,67	589,25	25,70
Chaka Dembélé	2291,67	1291,67	1791,67	4242,64	39,60
Dramane Coulibaly	2291,67	1416,67	1854,17	618,72	33,40
Dramane Sylla Berthé	1458,33	958,33	1208,33	353,55	29,30
Mory Berthé	1458,33	750,00	1104,17	500,86	45,40
Ousmane Coulibaly	1125,00	500,00	812,50	441,94	54,40
Bourama Sanogo	1416,67	916,67	1166,67	353,55	30,30
Sékou Berthé	1541,67	958,33	1250,00	412,48	33,00
Farmers	**Millet biomass yield (kg ha^{-1})**				
	Soil conservation technology				
	CB	**NCB**	**Mean**	**Standard deviation**	**CV (%)**
Seni Berthé	2708,33	1250,00	1979,17	1031,20	52,10
Madou Coulibaly	7916,67	2916,67	5416,67	3535,53	65,30
Bakary Coulibaly	9583,33	3958,33	6770,83	3977,48	58,70
Jack Coulibaly	7083,33	3958,33	5520,83	2209,71	40,00
Chaka Dembélé	3750,00	2500,00	3125,00	883,88	28,30
Dramane Coulibaly	9166,67	6250,00	7708,34	2062,40	26,80
Dramane Sylla Berthé	3541,67	2208,33	2875,00	942,81	32,80
Mory Berthé	5416,67	2708,33	4062,50	1915,09	47,10
Ousmane Coulibaly	3541,67	1458,33	2500,00	1473,14	58,90
Bourama Sanogo	5416,67	3750,00	4583,34	1178,51	25,70
Sékou Berthé	5833,33	2708,33	4270,83	2209,71	51,70

Table 19: Impact of CB on cotton growth and yields.

Farmers	Cotton yield (kg ha^{-1})				
	Soil conservation technology				
	CB	**NCB**	**Mean**	**Standard deviation**	**CV (%)**
Nagna Biry	1333,33	1041,67	1187,50	206,24	17,40
Madou Berthé	2208,33	1458,33	1833,33	530,33	28,90
Salif Berthé	1791,67	1250,00	1520,84	383,02	25,20
Sita Berthé	1750,00	1000,00	1375,00	530,33	38,60
Harouna berthé	2083,33	1375,00	1729,17	500,86	29,00
Adama Berthé	2000,00	1458,33	1729,17	383,02	22,20
Youssouf Berthé	1875,00	708,33	1291,67	824,96	63,90
Sidy Traoré	2791,67	1541,67	2166,67	883,89	40,80
Doulaye Goïta	2000,00	1333,33	1666,67	471,40	28,30
Zé Madou Berthé	1500,00	708,33	1104,17	559,79	50,70
Boukary Berthé	1583,33	833,33	1208,33	530,33	43,90

Bourama Berthé	1750,00	958,33	1354,17	559,79	41,30

Farmers	Cotton Biomass yield (kg ha^{-1})				
	Soil conservation technology				
	CB	NCB	Mean	Standard deviation	CV (%)
Nagna Biry	2708,33	1875,00	2291,67	589,26	25,70
Madou Berthé	3125,00	1875,00	2500,00	883,88	35,40
Salif Berthé	3125,00	1875,00	2500,00	883,88	35,40
Sita Berthé	2291,67	1458,33	1875,00	589,26	31,40
Harouna Berthé	2791,67	1833,33	2312,50	677,64	29,30
Adama Berthé	3333,33	1875,00	2604,17	1031,20	39,60
Youssouf Berthé	2500,00	833,33	1666,67	1178,51	70,70
Sidy Traoré	4166,67	2916,67	3541,67	883,88	17,80
Doulaye Goïta	1875,00	1458,33	1666,67	294,63	17,70
Zé Madou Berthé	1458,33	916,67	1187,50	383,02	32,30
Boukary Berthé	1958,33	1000,00	1479,17	677,64	45,80
Bourama Berthé	3333,33	1708,33	2520,83	1149,05	45,60

Discussion

Impact of CB technology on runoff and runoff coefficient at Kani

At Kani, the runoff collected in the measuring devices was always greater in the NCB plot than in CB for all the rain events of the season. The system of CB technology is a holistic landscape approach to managing water and capturing precipitation at the watershed scale. Our findings corroborate those of Kablan *et al.* (2008) who reported that the main roles of CB are the capture and recycling of precipitation in treated fields in the watershed, and assistance in the evacuation of excessive rainfall and destructive surface fluxes that can trickle into the fields as the application of CB reduced rain runoff by 22 to 61%.

The runoff coefficient varied from 17.46 to 21.48% in the CB plots and from 34.89 to 38.79% in the NCB plots. Runoff coefficient in CB was higher in the field of Madou Berthe (4%) compared to that of Sekou Berthe. This situation is due to the fact that the slope is steeper in Madou Berthe's field (around 3%) compared to around 1.5% for Sékou Berthé, but also in the sandy-gravelly texture in the first field compared to the sandy-silty one of Sekou Berthe. Akbarimehr and Naghdi (2012) reported that the length of the slope has a significant effect on flow volume; however, further analysis has shown that increasing the length of the slope can lead to increased runoff ($p < 0.05$); the slope may affect the volume of runoff. In addition, there was a linear relationship between the volume of runoff, the length, and the inclination of the slope. This conclusion was also made by Jordan-Lopez *et al.* (2009) who reported that slopes with a steeper percentage may increase runoff volume.

Impact of CB technology on water table dynamic at Noupinesso

The water table increased in volume, i.e., the distance to the soil surface decreased and at the beginning of September attained a minimum value of 2.75 m for the measuring tubes in the CB plot, 4.71 m in the NCB plot, and 1.02 m next to the outfall. This situation could be explained by deep infiltration of the maximum rainfall observed in August and September to increase the recharge of groundwater. This conclusion corroborates that of Kablan *et al.* (2008) who reported that CB recharged the groundwater from 1 to 26% during the rainy season in Fansirakoro.

Effect of CB technology on soil moisture at Kani and Noupinesso

At Kani and Noupinesso, soil moisture was always higher in the CB plot than in the NCB plot. The CB technology is applied for the reduction of runoff which therefore increases infiltration and soil moisture as demonstrated by the work of Dembélé (2013) and Traore et al. (2017b) who also reported an average difference in moisture of 10.5% in favor of CB plots in comparison with NCB plots.

At Kani, the soil moisture was always higher under fodder plant area than outside the area because the trees were planted on the ados that captured the maximum quantity of runoff. Similarly, Kablan *et al.* (2008) noted that CB increased soil moisture in areas explored by plant roots by 16 to 64% compared with NCB. Our results are also in agreement with those of Doumbia *et al.* (2012) who mentioned 17% water storage in CB plots in the 80-160 cm profile horizons and 12.7% in the first 80 cm.

At the end of the season, the soil moisture was at least 25% explaining a real water supply potential for the trees of the park as reported by Kablan *et al.* (2008) in an assessment of the effects of CB on the soil water dynamic in Siguidolo and Fansirakoro. These observations were in agreement with those reported by Traore et al. (2017a) when studying farmer's perception on CB in Cinzana area in Mali.

Effect of soil amendments on cotton growth and production at Kani and Noupinesso

The use of manure (T2) without other amendments significantly ($p < 0.05$) increased cotton growth and production compared with no amendment. The manure increased cotton yield by 25.3% in Remon Sanou's field, biomass yield by 29.66% in the field of Salif Berthe, cotton height and diameter by 72.36% and 34.54% in the trial of Barnabe Traore. The application of organic amendments to a cropping system has been shown to increase crop yields as well as improve soil nutrient levels.

This observation supports the finding of Duncan and Jayne (2016) that significant yield responses to manures from composted and raw feed lots and composted poultry manure, were obtained in cotton production. This potentially indicates that the use of the manures provided the soil with the resilience to be able to recover more quickly and meet crop nutrient demand better after this event. The quantity of manures applied was the minimum rate recommended for optimum crop production (Bationo and Mokwunye, 1991).

The application of manure produced significantly ($p < 0.05$) less cotton growth and production than the applications of micro-dose (T3) and scale doses (T4). Cotton yield was increased in T4 to 144.79% and in T3 by 130.21% in Bourama Dembele's field, biomass yield by 99.03 and 93.70% respectively in Sekou Berthe's field.

Muhammad *et al.* (2014) reported that the results of the experiment indicated that application of the recommended dose of NPK produced higher seed cotton yield (2660 kg ha^{-1}) and when followed by ½ NPK+FM-Fermented (2523 kg ha^{-1}) differed significantly from other treatments. There was a positive increase of N, P, and K concentration in cotton leaves and in soil due to the combined application of ½ NPK+FM-Fermented.

Effect of CB technology on cotton growth and production at Kani and Noupinesso

The use of CB technology significantly affected the growth and yields of cotton for all the 6 trials. In the field of Barnabe Traore cotton yield was higher in the CB plot by 42.5%

compared to NCB. CB increased cotton height by 29.30% in the trial of Bourama Dembele. Contour ridge tillage increases soil nutrient and available soil moisture for crop uptake and enhanced crop growth (Li *et al.,* 2008). In a related study, Khlifi (2008) showed that dry matter yield in the CR plot was higher than in the control.

Effect of soil amendments on cotton value cost ratio

Any treatment that has a VCR greater than 2 is reported to be profitable. Heerink (2005) stated that, technically, VCR greater than 2 would imply the profitability of fertilizer as long as other inputs were not altered with the use of fertilizer. Among the soil amendments, the micro-dose treatment gave the best profitability as indicated by the VCR in the range of 4 to 8 for the 6 trials.

In spite of its contribution to increased crop yield, the micro-dose is less costly than scale fertilizer doses. Micro-dose application on sorghum improves farmers' income. Average income was found to be 100,385 FCFA/ha with local sorghum varieties (yield increase of 57%) and 184,625 FCFA/ha with improved varieties (yield increase of 160%) compared with fertilizer application (IDRC, 2014). With the application of rain water harvesting (RWH), profitability of the micro-dosing technique with the improved variety increased to 284%.

These represent a VCR of 1.3 for the local sorghum and 3.8 for the improved variety. When micro-dosing was associated with RWH techniques, the VCR increased to 2.6 for local sorghum and to 6.9 for improved varieties (IDRC, 2014). The VCR for T4 was lower than that of sole manure because of the high prices of the component inorganic fertilizers. However, contrary results have been reported by several studies.

Evaluation of intercropping system sorghum-soybean

The association of soybean with sorghum increased sorghum growth and yields for all the 9 trials. The intercropping system increased sorghum yield by 24% in the trial of Basil Sanou and 85.5% in trial of Tiemoko Berthe in Year 2 of research. It added 60% of biomass yield in the field of Youssouf Berthe, 23.78% of sorghum height at the trial of Oumar Berthe, and 10.19% at the trial at Mpessoba. The intercropping for the 9 trials was profitable with the LER varying from 2 to 4.

A general assumption in intercropping cereals with legume crops is that the legume, when associated with the specific Rhizobium, may have most of its N supplied through fixation of atmospheric N, leaving the soil available N for the companion cereal (Saberi, 2018). There is evidence that leguminous plants can benefit the intercrop cereals in the same season through N excretion and nodule decomposition (Bonetti R, 1991). There is marked variation among legume species in the ability to supply N (Senaratne, 1995).

These results corroborate those of Saberi (2018) who indicated that the mean comparison of dry forage of sorghum associated with soybean also increased by 24.01% in Gorgan and 26.12% in Aliabaad, and that the LER of 1 row sorghum 1 row soybean was better than sole-cropped sorghum. The importance of cropping cereals to legumes was widely reported by Traore (1998).

Effect of CB technology on intercropping sorghum-soybean

The use of tillage methods affected sorghum and soybean growth and yields for all the 9 trials, although the use of the CB method increased grain and biomass yield of sorghum and soybean (+50 %) and their height and diameter (+30). Contour ridges as a result of the increased infiltration of rainfall, increased water availability, improving crop growth and reducing erosive runoff as shown in long-term studies initiated by Gigou *et al.* (2006) and Kablan *et al.* (2008) in soil water storage studies.

These findings document the increased soil water content resulting in increased crop yields. Yields may increase by as much as 50% for millet, sorghum, and maize (Gigou *et al.,* 2006). Traore *et al.* (2004) reported that the effects of contour ridges on millet yields have been variable. Relative to the control, the contour ridge increased millet grain yield in Mali by 27% (1998), by 2% (1999), and by 60% in 2000.

The observed improvement in grain yield following contour ridging is attributable to the capacity of the tillage method for moisture conservation. Soil moisture conservation is vital for smallholder cropping systems (Falkenmark *et al.,* 2001; Irshad *et al.,* 2007). The conserved moisture supplies water to the crop at the end of the rainy season when plants are flowering and grain filling.

Impact of CB technology on fodder plants growth

After 3 years the *Gliricidia* in the Technology Park at Mpessoba had height 4.88 m, diameter 72.8 mm, and crown radius 3.72 m on the *ados;* 3.95 m height, 58.6 mm diameter, and 3 m of tuft radius in NCB. After one year at Kani and Noupinesso, the *Gliricidia* and *Leucaena* had 2.08 and 1.7 m height, 42 and 25 mm diameter, and 1.55 et 0.60 m tuft radius respectively on the *ados*; and 1.41 and 1.35 m height, 24 and 20 mm diameter, and 1.01 and 0.50 m tuft radius respectively in NCB.
We took these data on what was left of *gliricidia* and *leucaena* after the damage caused by roaming animals, so we can notice that the these are both fast growing tropical trees; Craig and John (2006) reported that the initial growth of *Gliricidia* is rapid (up to 3 m in the first year).

The CB technology increased growth of *G. sepium* and *L. leucocephala* at the 3 research sites., Gigou *et al.* (2000) mentioned that the water balance is improved with CB application, and the soil profiles are wetter, which is favorable to the associated trees. The height, diameter, and tuft radius of *Gliricidia* were increased by +63.52 %, +74.74 %, and +44.32 % respectively; and in *Leucaena* by +39.36 %, +32.63 %, and +37.84%.

With a semi-arid climate, CB farming reduces soil erosion and substantially increases the infiltration of rainfall. This results in increased growth of crops and trees associated with the crops, valued trees of shea butter (*karite*) and other species inside cropped fields that benefit from the increased water from CB. This aids growth both existing trees as well as the germination and establishment of young trees (Traore *et al.,* 2006).

At the end of the rainy season (November), fodder plants stated dropping their leaves. *Gliricidia* and *Leucaena* are valuable water conservation resistant to drought because in the dry season they lose most of their leaves, reducing the loss of water by evaporation.

Impact of CB on crop growth and yield at Kani and Noupinesso

The technology of CB increased sorghum, millet, maize, and cotton growth and yield more than 30% in 40 different fields at Kani and Noupinesso. This technology was adopted by farmers of Kani and Noupinesso by increasing crop yield in 2015, when we noticed that the CB significantly increased crop yield in 10 different fields.

Synthesis

Conservation of soil and water was improved by cropping systems using CB and new cultural systems such as intercropping sorghum and soybean. These cultural systems allow crop diversification and also increase profitability for farmers with all LER higher than 1. Increasing crop productivity (grain, residues, fodder) by the use of CB is a way to ensure food security in the changing West African climate but also a way to produce manure by feeding animals. Growth of fast-growing nitrogen-fixing tree species showed better development and better environmental conditions by mitigation of greenhouse gases through carbon sequestration. These advantages of these technologies must be sustained in the households of the study area by training a technical team in villages so that they can continue after the project's life time. This has not been done because of funding problems but some collaborative farmers have been trained on related issues.

Conclusion

The study has shown that the use of CB technology and soil amendments significantly reduced runoff and erosion, improved soil moisture and water table dynamic as well as the growth and yield of cotton, sorghum, soybean, and fodder plants. CB increased soil moisture and the growth, biomass and grain yields of crops and trees more than NCB which was the farmers' practice.

The use of CB technology significantly reduced rain runoff at Kani; runoff coefficient varied from 34.89 to 38.79% in NCB fields and from 17.46 to 21.48% in the NCB plots. The water table increased in volume as the distance to the soil surface decreased and attained a minimum value of 2.61 m for the measuring tubes in the CB plot, 4.58 m in the NCB plot, and 1.02 m next to the outfall in September.

At the end of October at Kani, the maximum of moisture (45.8% in CB and 38.2% in NCB) was observed in the last 100 cm of soil depth. For the other levels (10 to 90 cm) water content increased from the beginning to the end of the season and attained 19.8% for CB and 15.5% for NCB. At the end of the rainy season (10 October), CB increased soil water content in the soil profile at 100 cm from 21 to 36%.

The maximum soil moisture (40.6% under trees and 32.5% outside trees) was obtained at the end of August at 80 cm soil depth when the rainfall was frequent. In CB, water content under fodder plants was slightly higher than outside them during all rainy season. The maximum soil moisture in a shallow depth (10 cm) was 24% in CB in August when rainfall was frequent. Soil moisture in the NCB field at Kani was always higher under fodder plants than outside them but the difference was higher in CB during all rainy season.

Organic manure increased cotton yield by 25.3% in Remon Sanou's field, straw yield by 29.66% in the field of Salif Berthe, and cotton height and diameter by 72.36% and 34.54% in the trial of Barnabe Traore. The application of manure produced significantly ($p < 0.05$) less cotton growth and production than the applications of micro-dose (T3) and scale doses (T4). The T4 increased cotton yield by 144.79% and T3 by 130.21% in Bourama Dembele's field, straw yield by 99.03% and 93.70% in Sekou Berthe's field.

The use of CB technology significantly affected the growth and yields of cotton for all the 6 trials. In the field of Barnabe Traore, cotton yield was higher in CB plot by 42.5%. Compared to the NCB, CB increased cotton height by 29.30% in the trial of Bourama Dembele. The micro-dose treatment gave the best profitability as indicated by the VCR in the range of 4 to 8 for the 6 trials.

The intercropping system increased sorghum grain yield by 24% in the trial of Basil Sanou and by 85.5% in the trial of Tiemoko Berthe in Year 2 of research. It added 60% of biomass yield in the field of Youssouf Berthe, 23.78% of sorghum height at the trial of Oumar Berthe, and 10.19% at the trial in Mpessoba. The intercropping for the 9 trials was profitable with the LER varying from 2 to 4. The CB method increased grain and biomass yield of sorghum and soybean (+50 %) and their height and diameter (+30 %), and also increased sorghum, maize, millet, and cotton growth and yield by more than 30% in 40 different fields.

The CB technology increased growth of *G. sepium* and *L. leucocephala* at the three sites of research. Gigou *et al.* (2000) mentioned that with CB application, the water balance is improved, and the soil profiles are wetter, which is favorable to the associated trees. The height of *Gliricidia* was increased by +63.52%, diameter by +74.74%, and crown radius by +44.32%; for *Leucaena* the increases were +39.36%, +32.63%, and +37.84% respectively.

Capacity building

Two-degree students, one of whom was aiming at a Bachelor's and the other at a Master’s, have completed their training with us in Kani. The topic was the evaluation of CB technology on soil and crops.

Problems/challenges and measures taken

We have some challenges to the good continuation of our research in the coming years, mainly from a funding problem. As livestock feed is a concern in this area, we have a huge problem for the effective protection of fodder plants in the rural area; after a good example with about 10 farmers, the method will be adopted.

Partnership/linkages with other projects

Sorghum varieties used came from ICRISAT dual purpose Program

Lessons learned

Farmers were asking for the CB technology since its immediate effect on the ground was seen from Year 1 of implementation. The technology of CB reduced runoff and erosion recharged the soil water table, increased soil moisture, and consequently increased crop and tree growth and yield.

Monitoring and Evaluation

Feed the Future indicators

FtF indicator	Annual target	Progress toward target	Segregation	Explanation
1.1. Producers' organization	1	1	1	All men
women's groups,				
New	1	1	1	All men
1.2. Land under improved technology (ha)	20	20	1	All men
Crop genetics (maize, p'pea, sorghum, cotton, bambara, g/nut, livestock forages)	1	4	1	All men
Soil-related	1	1	1	All men
water management	1	1	1	All men
climate mitigation or adaptation	1	1	1	All men
New	20	20	1	All men
Male	40	44	1	All men
1.3. Producers	2	2	1	All men
Male	2	2	1	All men
Female				
1.4. Producers' organization	2	2	1	All men
New/continuing	2	2	1	All men
1.5. Number of farmers applying new technology	40	43	1	All men
Sex	1	1	1	All men
Male	40	43	1	All men
Female				All men
1.8. Producers' organization	2	2	1	All men
Male	2	2	1	All men
Female				All men
1.9. Producers' organization	2	2	1	All men
New				
1.10.1 phase 1- Number of technologies	1	1	1	All men
1.10. Phase 2 - Number of technologies	2	4(CB, Tree,Intercropping, micro dosing)	1	All men
1.11. Male		55	1	All men
Female				All men

Custom indicators

FtF indicator	Annual target	Progress toward target	Segregation	Explanation
1.1. Producers' organization	1	2	1	All men
women's groups,				
New	1	1	1	All men
1.2. Land under improved technology (ha)	4	4	1	All men
Crop genetics (maize, pigeonpea, sorghum, cotton, bambara, g/nut, livestock forages)	2	2	1	All men
Soil-related	1	1	1	All men
water management	1	1	1	All men
climate mitigation or adaptation	1	1	1	All men
New				All men
Continuing	4	4	1	All men
Sex	1	1	1	All men
Male	4	4	1	All men
1.3. Producers	4	4	1	All men
Sex	1	1	1	
Male	4	4	1	All men
female				
1.4. Producers' organization	2	2	1	All men
New/continuing	2	2	1	All men
1.5. Number of farmers applying new technology	40	43	1	All men
Sex	1	1	1	All men
Male				All men
Continuing	4	4	1	All men
1.8. Producers' organization	2	2	1	All men
Sex	1	1	1	All men
Male				All men
1.9. Producers; organization	2	2	1	All men
New /continuing	2	2	1	All men
1.10.1 phase 1- Number of technologies	1	1	1	All men
1.10. Phase 2-Number of technologies	2	2	1	All men
1.11. Male	15	15	1	All men
Female				All men

Success stories

The CB technology has been successful in Senegal, Burkina-Faso, Niger, and the Sahelian zone of Mali. For instance, in Senegal as well as in Mali, this technology has increased soil moisture by more than 10%, soil carbon and also crop yields by more than 30%. The same technology had also reloaded the water table and affected the foliage and fruiting trees in different fields at Sikidolo in Mali. An NGO (AMEDD) gave assistance to farmers against implementation fees of 10 US$.

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Links for further reading

1. Gender Capacity Assessment Report - https://cgspace.cgiar.org/handle/10568/72524
2. Annotated Bibliography of Gender in Agriculture – a Reference Resource for Africa RISING Researchers - https://cgspace.cgiar.org/handle/10568/77488
3. Gender Analysis in Farming Systems and Action Research: A Training Manual https://cgspace.cgiar.org/handle/10568/100149