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Strengthening the Resilience of Rain Fed Maize, Millet and Sorghum based Multiple Cropping Systems in the District of Bla in the Semi-Arid Area of Mali

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ABSTRACT

One experiment was conducted in the district of Bla during the rainy seasons 2015 and 2016. The object was to test in farmer field's technique package susceptible to improve crop yields and income in the context of climate change. The relay cropping of maize-cowpea, the intercropping of millet-cowpea and sorghum-cowpea with and without technique package were assessed in a dispersed blocks experimental design where each farmer was representing one replication. The technique package was involving: confection of diguettes perpendicular to the direction of the slope, use of improved and soaked seed, mineral fertilizer micro dosing and seeding mechanization, plant density, sowing at right date. The practice of technique package has significantly improved crop yields (53% for maize and 75% for cowpea in relay cropping; 73% and 60% for millet and cowpea in intercropping; 49% and 39% for sorghum and cowpea in intercropping). It has allowed improvement in the water use efficiency (62% in the relay cropping, 70% in the intercropping millet-cowpea and 47% in the intercropping sorghum-cowpea). Net benefits of 125 000, 112 000 and 121 000 FCFA/ha were from the relay cropping, intercropping millet and sorghum-cowpea. The anticipation of the practice of recommended agricultural techniques has improved the resilience of the cropping systems. Yield of the cropping systems and farmer's income have been improved in the context of climate change.

Introduction

In recent decades, peasants in Africa's semi-arid tropics have been suffering from the effects of climate change. The average temperature has increased, rainfall varies considerably from one year to another and floods, droughts, cyclones, tsunamis are very frequent events (IPCC, 2007). Agriculture, which contributes 40% of Sahelian countries' GDP, supports half of the world's population (Chetaille et al., 2011).

Sub-Saharan Africa, which has to feed a constantly increasing population, is produced on rainfed land (FAO 1990, Parr and Al 1990). Peasants have extended the cultivated areas to marginal lands and pastoral areas to meet their food needs. Unfortunately, with the absence on farms of water and soil conservation techniques and soil restoration, the drought which has become recurring continues to reduce and sometimes annihilate production. The gap between food consumption needs and food availability is growing daily. Land erosion and desertification have gained a lot of space to make Africa a low-capacity continent adaptability to climate change (Philipp, 2010). Sub-Saharan Africa has become the most vulnerable food security zone (Shapouni and Rosen, 1999). And the high population growth in the Sahel (3%) is causing a deterioration natural resources and places it in the area most vulnerable to future climate fluctuations (UNEP, 2011).

Farmers in the Sahelian zone have designed traditional farming systems (combining millet or sorghum-cowpea crops, corn-cowpea cultivation), have been designed to satisfy dietary habits and support local know-how transmitted from generation in generation. In the cereal-legume farming associations, cowpea, which is the first crop harvested for its seeds, is used as food during the lean season. While in the relay crop, it is corn that is quickly harvested for its seeds to cover the lean season. Cowpeas, harvested well after maize for its leaves, are used to feed draft animals during the months of April to June (the period preceding the installation of the rains). Cowpea varieties are creeping in both systems. They cover the soil and reduce water erosion. The sale and processing of crops is done by women. When there is overproduction, the crops become at the same time food and commercial crops.

In Mali, rainfall is highly affected by variability and climate change. Rainfall decreased by 20% followed by a displacement of 200 km isohyets to the south (Diarra, 2010). Crop rotations and rotations vary from year to year depending on the head's flair for rainfall and agricultural market signals. This characteristic of cropping systems, gives resilience to agriculture practiced in families in a variable climatic context. In a year of good rainfall distribution in space and time, farmers market excess production (Bad / OCDE, 2008).

In the event of poor harvests due to poor distribution of rains, there is famine in the families and an exodus of valid arms. The dependence of agriculture on rainfall makes it vulnerable to the vagaries of the climate which is variable. Despite these facts, the communities have always adapted to this climate change: cropping systems (relay cultivation, crop combinations), rotations and rotations, use of manure, making zai, bunds, use of early varieties.

Traditional cropping systems have innate adaptability. But the variability and speed of climate change exerts a new pressure on them that risks stifling their capacity to react (FAO, 2013). armers are currently in an area of climatic variation to which they were not accustomed (Bayen et al., 2011; Sawadogo et al., 2008; Turnbull et al., 2013). Faced with increasing human and climatic pressures on natural resources, farmers must bring innovations in their agricultural practices. The abandonment of fallow land, the absence or poor condition of water collection and retention structures in certain localities (inherited from certain projects) do not allow cropping systems to produce food for the purpose of ensuring food security. It is the crops themselves that are threatened in their existence. It is imperative to strengthen the resilience of agriculture to claim to feed a growing population. Crops must resist and adapt to the effects of climate change to produce good yields.

Faced with this situation, it is the capacity of the cultural systems built for millennia that is questioned. Are they able to ensure food security in families? How should we proceed to minimize the effects of these droughts on the performance of these cropping systems?

Agricultural research has developed many technologies that significantly improve crop yields and farmers' income while preserving cropland (Coulibaly et al., 2010, Traore et al., 2010; Adamou, 2010; Roosel, 1990). Despite these technologies, family farming continues to deteriorate, leading to famine, malnutrition, poverty and the rural exodus of able-bodied workers.

The objective of this research is to test farmers' technical packages that can improve crop yield and income in a climate change context.

Materials and methods

Experimental study site

The experimental sites were in the same agro-ecological zone located in the south of the Bla cercle (Diagram 1). The rainy season starts in June and ends in September-October. The dry season begins with a cold period that continues until February. Many of the traditional long cycle varieties are completing their maturation cycle during this cold period. he rainfall amounts recorded during the last 4 years were (Fig.1): 2014 (718.6 mm), 2015 (886 mm), 2016 (790 mm), 2017 (971.5 mm). The number of rainy days recorded during these years was (fig.2): 48 days in 2015 (9 days in September and 6 days in October); 50 days in 2016 (6 days in September and 4 days in October); 61 days in 2017 (11 days in September and no rain in October). Figs. 1 and 2 show a variability between the rainfall heights and the number of rainy days. This had an impact on the course of the rainy season during the 3 years.

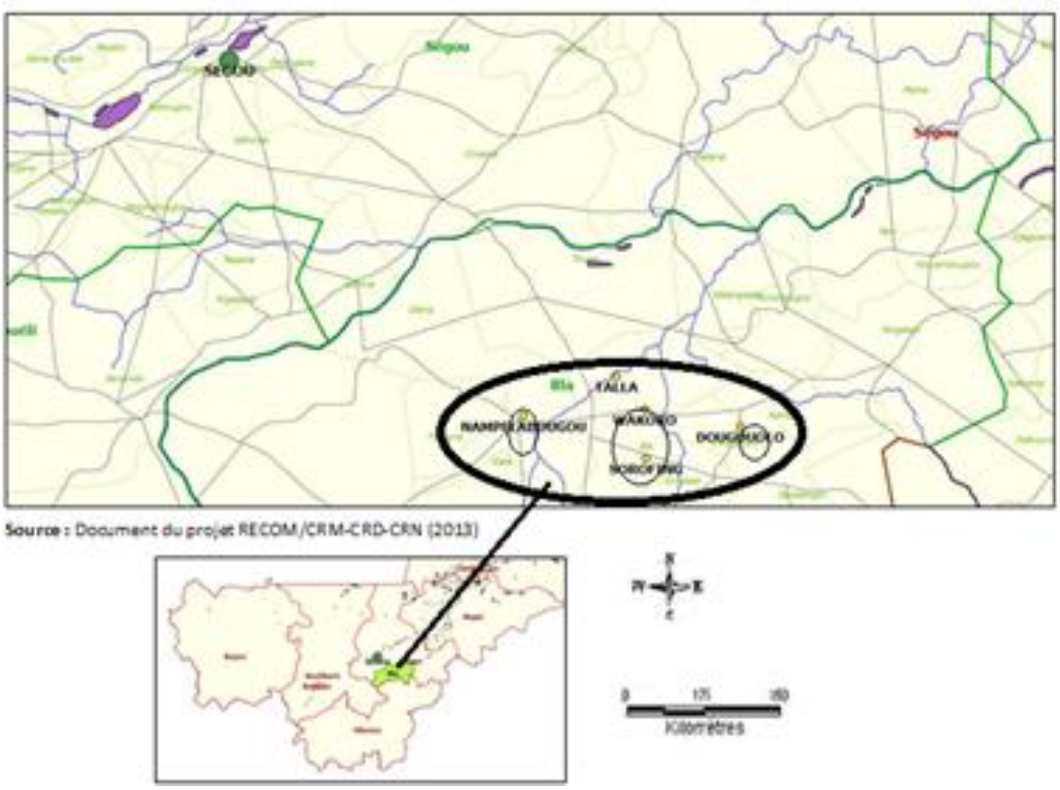

Diagram 1: Experimental sites in the circle of Bla, Mali.

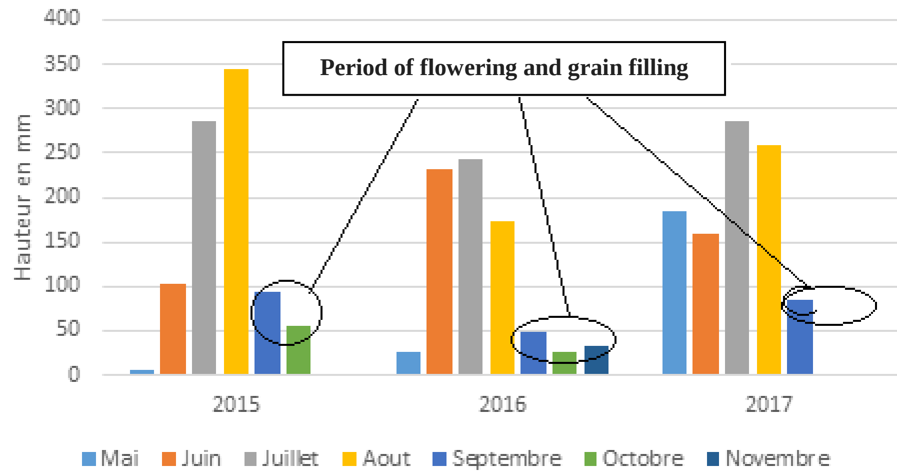

Fig. 1: Monthly rainfall of Bla, Mali.

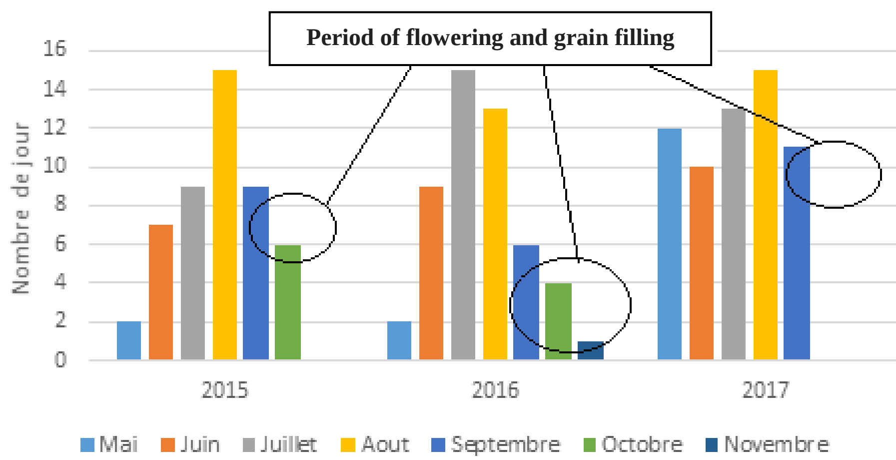

Fig. 2: Number of rainy days per month in Bla, Mali.

Farmer's choice

Corn-cowpea cultivation is widely practiced by affluent peasants. The peasant farmers' organizations have been chosen from among themselves for the management of the corn-cowpea culture, 2 peasants per village or 12 peasants in total (2 peasants x 6 villages). Sorghum or millet is widely practiced by poor peasants. Five peasants were randomly selected per village for the conduct of each crop association (5 peasants per village or 5 x 6 peasants = 30 peasants in total).

Experimental treatments

Two fields of 0.5 hectare each were staked in the field of the collaborating farmer (control field and field with technical package). The control field was the traditional practice of relay culture (cowpea: 1.5 m x 1.5 m, 2 plants / bunch or 8 800 plants / ha, maize 0.6 mx 0.6 m, 2 plants / po or 55,000 plants / ha). The field receives 2-3 t of manure from all sources / ha. The corn variety is an improved variety used for at least 5 years. Cowpea is a creeping local variety with a longer cycle than maize (Fig. 3).

The technical package was tested in the test field: making a dike perpendicular to the direction of the slope, using the improved and tempered seed, mechanizing the micro-dosing of the mineral fertilizer and the sowing, the seeding density, the sowing to good dated. The soaking of the corn and cowpea seeds consisted in moistening the seed for a precise time in order to accelerate the emergence of the seedlings of the soil. The soaking of seed in the water lasts 12 hours for corn, 8 hours for sorghum and millet, 4 hours for cowpea.

In the maize-cowpea relay (Fig. 3), corn seeding was carried out at the seeder and bottom fertilization was carried out during tillage (application of 100 kg DAP / ha on the fly followed a ridging of the field). Maize is sown at 0.75 m between lines and 0.5 m on line and then demigated to 2 plants (53 333 plants / ha). The cowpea is semi-annually at the 5-6 leaf stage of the maize, in each second inter-row of the cereal at the spacings of 0.75 m between lines and 1.0 m on lines then starts at 2 plants / po, ie 13 333 poets and 26 666 plants per ha (scheme 2).

The system receives the maintenance manure (150 kg of urea / ha) in two stages (75 kg / ha at the run and 75 kg / ha at the female bloom). After the second feeding of the manure maintenance, we immediately proceed to the sarclo-ridging of the field. The improved varieties of maize and cowpea are respectively Sotubaka and Sangaraka. Cowpeas are harvested after corn (Fig. 3).

In the millet-cowpea association (Fig. 4), milling of millet and the supply of bottom fertilizer are carried out with the planter-spreader. Millet is sown at 0.75 m between lines and 0.8 m on lines and then starts at 2 plants per plant or 33 333 plants per hectare. The cowpea is sown at the 3-4-leaf stage of millet in each second line and in each second inter-row on the line (Fig. 2). This amounts to 1.5 m between lines and 1.6 m on line and then starts at 2 plants per poquet, i.e., 4 166 plants and 8 333 plants per ha. The association receives only the bottom fertilizer during sowing (32 kg of DAP / ha). The improved varieties used were Toroniou millet C1 and cowpea Korobalen. Cowpeas are harvested before millet (Fig. 4).

In the sorghum-cowpea association (Fig. 5), sorghum seeding and bottom fertilization are carriedout with the planter-spreader. Sorghum is sown at 0.75 m between lines and 0.5 m on lines and then starts at 2 plants / pouch, ie 26 666 pockets and 53 333 plants / ha. Seeding of cowpea is done manually in the 3-4 leaf stage of sorghum. It is sown on each second line and in each second inter-row at 1.5 m between lines and 1.0 m on lines and starts at 2 plants / pouch (6 666 pockets and 13 000 plants / ha) (Fig. 2). The association receives only the micro dose of the bottom manure (53 kg of DAP / ha on sorghum). The improved varieties used are Jakumbè sorghum and Korobalen cowpea (Fig. 4). Cowpeas are harvested before sorghum.

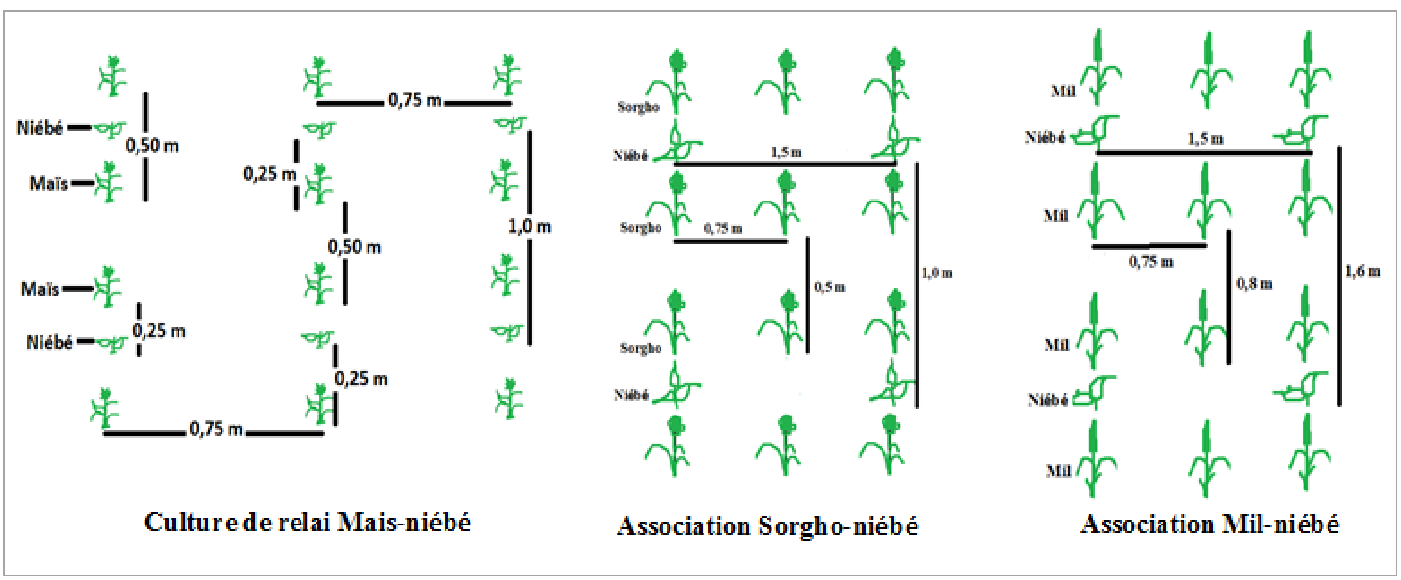

Fig. 3: Seeding arrangement in crop associations tested in Bla, Mali.

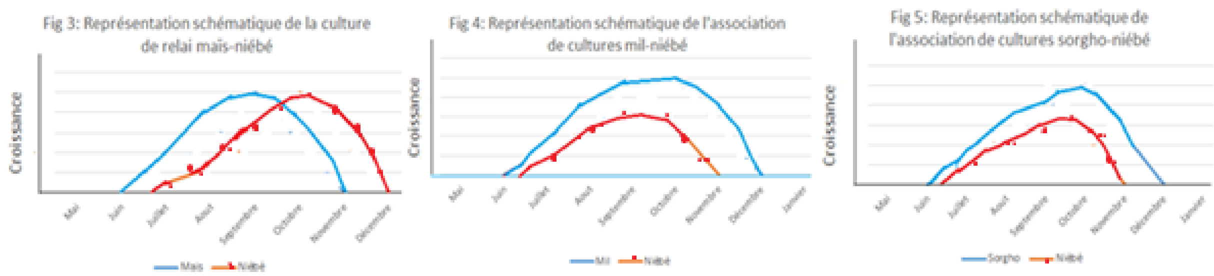

Fig. 4: Representation schematique de la culture de relai mais-niebe.

Agronomic evaluation

The statistical analysis of the crop yields and the realization of the tables and graphs of illustration were made using the software INSTAT V3.6 and Excel.

Efficient use of rainwater

This variable measures the ability of the cropping system to convert water into grain or biomass of plants. It includes both the use of water stored in the soil and the rain received during the growing season (GRDC 2009). It is determined by the formula below:

Efficient use of rainwater (RWUE) = Total yield of grain or biomass in kg / Total rainfall in mm

Economic analysis

The partial budget was used to evaluate the different cropping systems. These are the costs that vary from one treatment to another that have been taken into account. It estimates the cost and benefit of changes to one part of the farm while all other parts remain the same.

Table 1. Information on the price of grain to the producer of Bla at the time of harvest.

	Corn	Millet	Sorghum	Cowpea
CFA / kg	40	50	50	60

Results and discussion

Maize-cowpea culture

Maize yield varied significantly between treatments (Table 2). Reducing the amount of rain in 2016 resulted in a significant reduction in corn yield in the association. We recorded an average reduction of 84% maize yield in the control treatment versus 26% in the treatment with the technical package. The yield of the relay crop (cowpea) showed a 14% improvement in control treatment against a 41% improvement in treatment with the technical package. The density of cowpea is twice as high in the improved treatment. The technical package outperformed the control treatment during the two years of experimentation. The improved package practice resulted in an improvement in maize yield of 53% and cowpea by 75%.

Table 2. Yield of maize and cowpea in the maize-cowpea relay cropping system at Bla in Mali.

Treatments	2015		2016		Average in kg/ha	
	Corn	Cowpea	Corn	Cowpea	Corn	Cowpea
Control	1462	343	796	401	1129	372
Technical package	2687	1916	2137	1122	2412	1519
ES	377	313	176	42		
Probability	0,002	0.005	0,000	0,000		

Association of millet-cowpea crops

Millet yield varied significantly between treatments (Table 3). A reduction in millet yield was observed in 2016 with the reduction of the annual amount of rain. This reduction was 12% and 33% respectively in the control and improved treatment. The yield of the additional culture was improved by 55% in the control treatment and 83% in the improved treatment. The technical package outperformed the control treatment during the two years of experimentation. The improved package practice resulted in 73% improvement in millet yield and 60% in cowpea.

Table 3. Yield of millet and cowpea in the millet-cowpea intercropping in Bla, Mali.

Treatments	2015		2016		Average in kg/ha	
	Millet	Cowpea	Millet	Cowpea	Millet	Cowpea
Control	572	200	511	449	541.5	324.5
Technical package	2300	234	1733	1377	2016.5	805.5
ES	160	21	141	64		
Probability	0,000	0.302	0,000	0,000		

Association of sorghum-cowpea crops

Sorghum yield varied significantly between treatments (Table 4). A reduction in sorghum yield was observed in 2016 with the reduction in the annual amount of rain. This reduction was 108% and 34% respectively in the control and the improved treatment. The yield of the additional culture was reduced by 147% in the control and 35% in the improved treatment.

The technical package outperformed the control treatment during the two years of experimentation. The improved package resulted in 49% improvement in sorghum yield and 39% in cowpea.

Table 4. Yield of sorghum and cowpea in the sorghum-cowpea intercropping at Bla in Mali.

Treatments	2015		2016		Average in kg/ha	
	Sorghum	Cowpea	Sorghum	Cowpea	Sorghum	Cowpea
Control	1079	1268	519	513	799	890.5
Technical package	1785	1713	1335	1267	1560	1465
ES	483	205	58	48		
Probability	0.182	0,037	0,000	0,000		

Efficient use of rainwater

Corn-cowpea cultivation

RWUE values varied between years and between the traditional and improved corn-cowpea system (Table 5). By moving from a rainy year to a less rainy one, there is a reduction in the efficient use of rainwater. This reduction is 34% in the traditional system and 26% in the improved system.

The value reduction of RWUE is higher in the traditional system. In 2015 and 2016, the improved relay culture system resulted in respective improvements in RWUE value of 61 and 63%. This improvement was the best year of rainfall deficit.

Table 5. Information on the efficient use of rainwater in corn-cowpea relay cropping in Bla, Mali.

Treatments	2015 (rain = 886mm)			2016 (rain = 790 mm)		
	Corn (kg grain / ha)	Cowpea (kg grain / ha)	RWUE (kg grain / mm of rain)	Corn (kg grain / ha)	Cowpea (kg grain / ha)	RWUE (kg grain / mm of rain)
Witness	1462	343	2.03	796	401	1.51
Technical package	2687	1916	5.19	2137	1122	4.12

Association of millet-cowpea crops

In the millet-cowpea association, we noted during the deficit year, an improvement of RWUE of 28 and 27% respectively in the control and improved systems (Table 6). The rain deficit has led to an improvement in RWUE and this improvement is the best in the improved system. The practice of the improved crop association resulted in an improvement of RWUE of 70% in 2015 and 2016.

Table 6. Information on the efficient use of rainwater in the millet-cowpea intercropping by farmers in Bla, Mali.

Treatments	2015 (rain = 886mm)			2016 (rain = 790 mm)		
	Mil (kg grain / ha)	Cowpea (kg grain / ha)	RWUE (kg grain / mm of rain)	Mil (kg grain / ha)	Cowpea (kg grain / ha)	RWUE (kg grain / mm of rain)
Control	572	200	0.87	511	449	1.21
Technical package	2300	234	2.86	1733	1377	3.94

Association of sorghum-cowpea crops

The rain deficit resulted in a reduction of RWUE in the sorghum-cowpea combination (Table 7). This reduction was more marked in the traditional system (102% versus 20% in the improved system). During the two years, the improved practice of combining sorghum and cowpea crops resulted in a RWUE improvement of 33% in 2015 and 61% in 2016. The best value of RWUE was observed in a year of rainfall deficit.

Table 7. Information on the efficient use of rainwater in the sorghum-cowpea intercropping by farmers in Bla, Mali.

Treatments	2015 (rain = 886mm)			2016 (rain = 790 mm)		
	Sorghum (kg grain / ha)	Cowpea (kg grain / ha)	RWUE (kg grain / mm of rain)	Sorghum (kg grain / ha)	Cowpea (kg grain / ha)	RWUE (kg grain / mm of rain)
Control	1079	1268	2.65	519	513	1.31
Technical package	1785	1713	3.95	1335	1267	3.29

Economic analysis

Variable loads varied greatly between traditional and improved crop association systems and between crop association systems. Tillage and fertilizers are an important part of the loads (Table 8). In the traditional system, the farmer sows on a simple ridging that does not follow the contour made at the beginning of the rainy season. While in the technical package, it is the earth bunds that are first made contour and then the ridges are made along the bunds.

In the relay crop, tillage and fertilizer costs increased from 86% in the traditional to 62.9% in the improved. In the mil-niebe association, they go from 77% in the traditional to 61% in the improved. And in the sorghum-cowpea association, they are 87% in the traditional and 61% in the improved.

Total variable loads were reduced by 13% in the corn-cowpea crop. While they increased 64.5% in the millet-cowpea association and 22.3% in the sorghum-cowpea association. Millet and sorghum are considered by farmers as subsistence crops. They produce them in traditional cropping systems and most of the cropping techniques are carried out by social groups of mutual aid. Despite an increase in costs, these systems yielded considerable net benefits (112 000 F for the mil-niébé association and 121 000 F for the sorghum-niébé association). This is an indication that these cropping systems have an economic potential that policymakers, extension workers and peasants can grasp.

Table 8. Cost that vary in the cropping systems in farmers' fields in the district of Bla, Mali.

Items	Relay cropping Maize-cowpea		Intercropping Millet-cowpea		Intercropping Sorghum-cowpea	
	Control	**Pitching technique**	**Control**	**Pitching technique**	**Control**	**Pitching technique**
Cost that vary						
Land management FCFA / ha (5000F / j)	10,000	15,000	10,000	15,000	10,000	15,000
Mineral fertilizer FCFA / ha (180 F / kg)	0	23,940	0	7,380	0	11,880
Organic fertilizer FCFA / ha (10F / kg)	50,000	0	0	0	20,000	0
Cost of rent (Machine for sowing & applying fertilizer) FCFA (7500F / d)	0	7,500	0	7,500	0	7,500
Labor for sowing FCFA / ha (1000F / j)	6000	2000	3000	1000	3000	2000
Labor for applying fertilizers FCFA / ha (1000F / j)	4000	2000	0	2000	1500	2000
Improved seed FCFA / ha	0	11,500	0	3,800	0	6,000
Total cost that vary FCFA/ha	70,000	61,940	13,000	36,680	34,500	44,380

Seed of millet and sorghum = 200 FCFA / kg but = 300 FCFA / kg cowpea = 400 FCFA / kg.
Corn-cowpea relay (control corn: 1129 kg / ha, PT maize: 2412 kg / control cowpea: 372 kg / ha, cowpea PT: 1519 kg / ha) PT = test plot.
Mil-cowpea intercropping (Mil control: 541 kg / ha, Mil PT: 2016 kg / ha, control cowpea: 324 kg / ha, Niébé PT: 805 kg / ha).
Sorghum-cowpea intercropping (Sorghum control: 799 kg / ha; Sorghum PT: 1560 kg / ha; Control cowpea: 890 kg / ha; Niébé PT: 1465 kg / ha).

The traditional practice of corn-cowpea cultivation and associations of millet and cowpea crops were less productive during these years of experimentation. The yield reduction in these systems results from the fact that they do not include a strategy to reduce vulnerability and crop exposure to hazards. While the improved technical package has shown that the risk of crop yield loss can be greatly reduced. Soaking of seeds, digging of clay along the contour, use of improved varieties, sowing on specialized service boards, microdosing of fertilizer are strategies in the improved package that have reduced vulnerability and exposure of crops to hazards. The results of this test show us that it is possible to improve the use of rainwater by plants. In a field of culture, this improvement involves identifying and correcting the factors that limit the growth of crops: the supply of nutrients to plants, the fight against diseases and weeds, the practice of water conservation techniques and soils, choice of variety and good sowing date (Bowman and Scott, 2009).

The effects of climate change will remain a serious threat to food security as long as producers continue to not practice climate risk reduction techniques in their annual crop year plans (DARA Foundation 2013, Turnbull et al., 2013). The production of a farmer who practices a system of vulnerable cultivation will not allow him to feed any more reason than to sell an overproduction (Dembélé, 2001; IFRC, 2002; UNISDR, 2016). There is not a single method risk reduction adapted to all regions. Risk reduction methods vary by context, area of intervention (Leprun, 1985; Cameron, 2014).

Conclusion

Innovative farming practices have improved the yield of rainfed crops by reducing the effects of drought. The remarkable results of these alternative practices facilitate the construction of a resilient family agriculture. But the ability of producers to practice this innovation can be local. The measures to be taken for a broad acceptance of all these practices would be: supply of inputs (seeds, fertilizer, seeder-spreader, water level), training on the construction of diguette earth contour. This should be done by sensitizing farmers and farmer organizations, local decision-makers, governmental and non-governmental organizations on the benefits and benefits of these practices in solving the problem of food insecurity and environmental risk reduction. Nowadays, these two points constitute the major stakes in tropical semi-arid countries.

Conflict of interest statement

Authors declare that they have no conflict of interest.

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