Full paper

Four- year experimentation on cereals under direct seeding mulch-based cropping system (DMC) by north Cameroonian farmers

Naudin K.[1], Balarabe O. [2]
[1] SODECOTON/Projet ESA/CIRAD, BP 302 Garoua, Cameroun, krishna.naudin@cirad.fr
[2] SODECOTON/Projet ESA/IRAD, BP 302 Garoua, Cameroun, oumarou.balarabe@sodecoton.cm

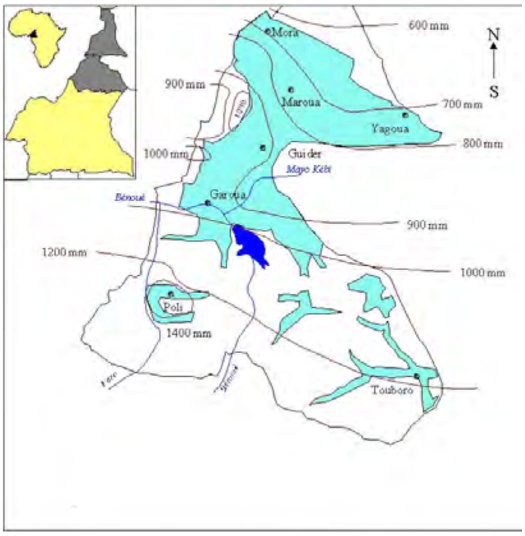
Summary
About 250 farmers have tried comparing cereal cultivation under direct seeding mulch-based cropping systems (DMC) against the traditional cropping practices from year 2001 to 2004. The on-farm tested systems include mixed cropping of a cereal (maize, sorghum, millet) and a cover crop (mucuna, brachiaria, crotalaria, cowpea, dolichos). These mixed cropping practices are done for the following objectives: 1) Produce aboveground biomass to build-up mulch for the following season's crop (mainly cotton). 2) Soil improvement through the physical and chemical (produce N) contribution of the associated plants. 3) Forage production. 4) Weed control. 5) Protect the soil surface against erosion and rain impact. 6) Produce consumable grains for man and animals. Up till present the tested plants meet the above objectives differentially and are adapted to the local agro climatic conditions of North Cameroon (rainfall from 700 to 1200 mm). Thus *Brachiaria ruzisiensis* produces aboveground biomass in quantities (4-5 T/ha even under mixed cropping) and quality (persisting as mulch for over one year after production). Further, it is very efficient in controlling *Striga* and is a good forage crop. However, it can impoverish the soils if its biomass is exported several times without any fertiliser supplements since it is not a nitrogen fixing plant. On the contrary *Crotalaria retusa* is a nitrogen fixing plant and therefore enriching the soils. This plant is less palatable to animals and therefore advantageous to farmers who cannot protect their farmland from pasturing animals in the dry season. It is equally very efficient in controlling weeds. Four years of experimentation has enabled us to produce practical recommendations in mixed cropping on the following : sowing date, crop type, tolerance to herbicides, competition with cereals, etc. This experimentation has also enabled us to see how the various plants tie with the above-mentioned objectives. On-going research work is on the following: 1) Diversifying the range of plant material available, focusing on local varieties. 2) Extending these cropping techniques to cover vertisols covering tens of thousands of hectares in North Cameroon. 3) Introducing these plants at the beginning and at the end of the cycle of the main crop in order to better use early and the late rains.

Key-words : direct seeding mulch-based cropping systems, conservation agriculture, brachiaria, crotalaria, on-farm trial.

Media summary
In North Cameroon various cover crop (*Brachiaria ruzisiensis, Crotalaria retusa, Dolichos lab lab, Mucuna pruriens, Vigna unguiculata*) have been cultivated in association with cereals. They produce biomass for soil cover, they can improve soil and also forage for cattle.

Introduction

Geographical context



Map 1 : North and Far-north Cameroon, in blue : cotton culture area

The North and the Far-north provinces of Cameroon are very heterogeneous regarding rainfall (600 to 1400 mm) (Map 1), relief (vast plains and steep mountains) and population density and history (200 hab/km2 in the mountains to 20 hab/km2 in the North). In the semi-arid Far-North, main crops are millet, rainfed sorghum, transplanted sorghum, cotton, cowpea and rice. Major crop rotations are cotton-cereals or cotton-legumes-cereals. Fallow are scarce. Livestock raising is based on transhumance excepted in the more densely populated areas (mountains and east of the province). Average farm size is moderated: 2 to 3 ha.

Institutional context

Cameroon a pilot country

North Cameroon is part of 5 pilot countries (Laos, Madagascar, Tunisia, and Mali) where CIRAD tries to adapt and transfer direct seeding mulch-based cropping systems (DMC) with the assistance of French aid: AFD (Agence française de développement), FFEM (Fond français pour l'environnement mondial), MAE (Ministère des affaires étrangères). The first trials started in 2000 and the project actually began in 2001. The implementation of DMC have been handed over to the fertility section of DPGT project from sodecoton. Since 1994 in 2001 the fertility component of DPGT has 150 000 ha to establish with anti-erosion devices (grass land, stony cordon,). In 2002, the fertility section has been converted into a new project: ESA (Eau, Sol; Arbre) meaning (Water, Soil, Tree) with the objective to extend its activities on a large scale and continue to implement DMC .

Sodecoton the major rural development actor in the area

+ 1 700 agents to assist 380 000 farmers divided into 1 800 farmers association
+ organises the production of over 200 000 ha of cotton trees
+ provides loan of fertiliser, herbicides, and insecticides in each every village
+ purchase at a fixed price the total production before the beginning of the growing season
+ insure picking off seeds and commercialisation of fibre on international market

Agrarian context

The conventional farming system

Now the farming system is based on:

+ A rotation of cotton –maize-groundnut in the north and rotation of cotton-sorghum in the far-north. Most of them are single farming
+ The use of yoking for the crops sown after 20th May (cotton, maize mainly).the crops sown precociously (sorghum, groundnut) are generally planted on non prepared land,
+ The use of fertilisers (NPK and urea)on cotton trees and generally on maize. The use of fertiliser is made easier by the provision on loan and supply right in the village by sodecoton.
+ The exportation of the major part of the cereal stalks by animals (without any contract on manure) and burning of the cotton stems and the remaining stalks non consumed by the animals. This system is of no contribution in term of organic matter.

The livestock situation in northern Cameroon

Document obtenu sur le site Cirad du réseau http://agroecologie.cirad.fr

The traditional Mbororo cattle rearing system is an extensive farming type that utilises transhumance, it needs large land surface for pastoralism. Of the traditional rearer, farmers also rear animal but at small scale. This one serves two purposes: it is used for draught and serves for income (hardly the family benefits from milking). However, the integration of farming and animal husbandry is very poor. The production of fodder is practically inexistent. The contribution of organic manure is not common, due often to lack of means of transport. Soon after harvest, the cattle from the various types of husbandry system, are allowed to feed on the crop residue, the weeds and the sorghum regrowth; this is the common land right. This traditional right is not associated to a manure contract as it the case in other region of Africa south of Sahara.

DMC: Direct seeding mulch-based cropping system
Various practices of minimum or without tillage, cover crops and direct seeding have been studied all over the world. However, Cirad and its partners, have developed cropping systems based on direct seeding with permanent plant cover (DMC: Direct seeding mulched-based cropping system) (Séguy *et al* 2003). In these systems, the soil is never tilled but permanently kept covered by dead or living mulch. The mulch comes from plants that are used as "biological pumps" in intercropping or relay-cropping systems. These plants have strong and deep root systems and can recycle nutrients from deep horizons for subsequent use by the main crop. They also have a high and fast biomass production and are able to grow in adverse conditions such as during the dry season, on compacted soil or under high weed pressure.
There are three main ways of implementing SCV (Séguy, 1998):

1. **Importing mulch from surrounding areas**. These systems are very simple but are labour intensive and improvement of soil structure and nutrient recycling are limited.
2. **Producing the mulch locally**, using natural vegetation, crop residues or a cover crop grown in the field. It requires limited technical skills and labour but the cover crop can compete, in time or space, with the main crop.
3. **Using a cover crop kept alive** but controlled during the main crop cycle. This system is the most efficient but it requires high technical skills and is hardly feasible in semi-arid conditions. Systems with imported mulch usually are adopted first by farmers. Although their performances are limited, farmers can discover the advantages of mulch regarding weeds control, water retention, erosion control, etc. However, for semi-arid conditions, systems based on mulch production in the field can be recommended.

To produce an important biomass four main options can be proposed:

1. **Reclaiming fallow land**, using natural vegetation (e.g. *Andropogon sp*.) as mulch.
2. **Improving the fallow lands** with, or cultivating, for at least one year, perennial legumes (e.g. *Stylosanthes sp.* or *Crotalaria sp*.) or grasses (e.g. *Brachiaria sp.*) which produce an important biomass and can rapidly regenerate degraded soils. These systems however are adapted only where population density is low enough to allow fallow periods.
3. **Produce biomass at the beginning of the rainy season** just before plantation of the main crop. This kind of system can be done for cotton with 6 to 7 seven months of rain. For culture as cowpea is feasible with a 5 months long rainy season.
4. **Associating**, at least one year over two, **a cover crop to the main crop** in order to produce a sufficient amount of crop residues for the next season. The cover crop grown in association is chosen according to the main crop (usually, association cereal + legume), its main role (soil structure improvement, N –fixation, etc.) and the possible uses for human and/or animal consumption.

All this ways are tried in north Cameroon but this paper will speak only of the last option: associating a cover crop with a cereal.

The experimentation steps in farmer's area
The results shown below are those obtained from experiments in farmer's area. These experiments are part of a large system aiming to implement and extend DMC in northern Cameroon (Naudin *et al* 2005).
The first experiment in farmer's area started in 2001 with 17 farmers. In 2004 about 150 farmers were experimenting DMC (figure 1). They were distributed all over the cotton area of north and far-north Cameroon.

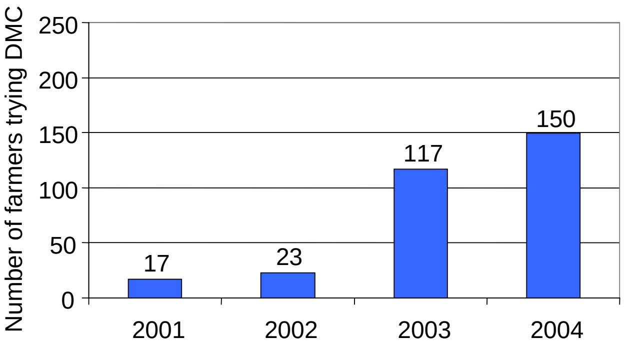


Figure 1 : number of farmer trying DMC in their fields

The fields run by the farmers are neither multi-local trial (repetition of a fixed protocol in different localisation) nor vulgarisation. The objectives for these fields are :

+ To show that DMC are feasible by the farmers using their own means
+ Quantify the impact of DMC in the real milieu under multiple human and physical conditions:
    - in term of yield
    - at economic point of view
    - in term of labour organisation
    - on various indicators :weed, soil characteristics
+ Collection of farmers' opinion about the steps they are asked to follow : how to improve them?
+ Introduce DMC in almost 50 villages in the north and the far-north of Cameroon.

How do the fields look like?

The arrangement of fields varies generally they measure 2 500m^2 and are divided:

+ either into 2 :one part as control(cereal only)and another part DMC (cereal associated to a cover plant)
+ either into 4 : 2 parts as control and 2 parts as DMC comprising two different plants(figure 2)

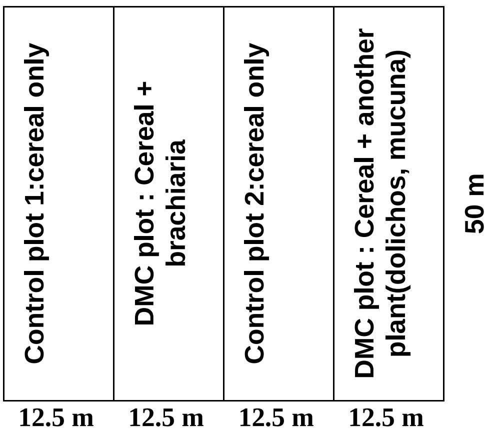


Figure 2 : example of arrangement of experimental fields

What is the contract with the experimenting farmers?

The farmer that agrees to carry out experiment on a field, receives from the project :

+ The seeds of the cover plant
+ The advice on how to run the field, and regular visit by the technician(at least 2 times every month)
+ The chemicals for seed treatment, if they were not able to get them on loan from the sodecoton store(rare)
+ A compensation in kind (bag of cereal) in case the yield is poor on the DMC field because of poor advice by the project technician(rare)
+ An operating subsidy to install a live fence from seedling plants if he wishes.

The entire work is carried out by the farmer himself, member of his family or labourers paid by him. Once a farmer starts the experiment, he will be assisted as far as he wishes. This is how some have been assisted since 2001. The selection of farmers has been done at the beginning through a network of farmers that are

involved in other activities of ESA project or through the local representatives of sodecoton. Therefore once the collaboration starts with 1 or 2 farmers in a village, the rest of the villagers can make their request to try the DMC in their farm on their own. In practice, the information network of sodecoton being dense, the farmer demands overflow, we have limited the number of farmers in order to promote quality rather than quantity. In 2004 the 200 farmers dispersed over 50 villages, were assisted by 4 technicians + 2 engineers. At this stage of implementation it is important to have a reasonable number of fields with a very good follow-up, than having a large numbers of fields with farmers poorly advised.
During the first year of intervention in a village ; we try as much as we can to make the volunteers to visit our experimental sites (Naudin *et al* 2005, Seugé *et al* 2005) or other farmer fields. After that visit, the farmers that still show interest to try DMC are aware of what they are embarking on. In addition, they can select during the visit, the type of plant they will like to associate with their cereal. In general, we advice that during the first year, each farmer should try at least two different types of plant; and in a village all the farmers should not choose the same type of plants. The objective here is to enable them select the suitable plant. After observation made from one's field or from the neighbouring field. From the second year of collaboration with the project, the farmer selects the plants of his choice (according to available seed resources) and suitable rotation.

What is the interest of this process?

+ Demonstration of interest in practicing DMC under real condition by the farmers
+ Feed-back information by the farmers on practicability and interest of proposed system
+ Test of the proposed system under multiple human and physical conditions
+ Demonstration of DMC in almost 50 villages in the north and far-north of Cameroon

What are the limits of this process?

+ Expensive follow-up(villages are too scattered and access condition sometimes difficult)
+ Risk of miss –guidance if itinerary is not followed carefully
+ It is difficult to extrapolate make generalities from the obtained results, because several parameters vary from one field to another(soil, rainfall, sowing date, species, weed control)

Pictures 1and 2 : farmers' fields, two years rotation in Mambang village 2003: sorghum,2004:cotton. left plot DMC : sorghum + *Brachiaria ruziensis* in 2003 and cotton on mulch in 2004, right: control plot : sorghum direct sowing on bear land in 2003, cotton after ploughing in 2004. Notice the effect of *Brachiaria ruzisiensis* on striga and the growing of cotton on DMC over the tilled one.

Plants associated to cereals

Table 1 :main plants associated to cereals with advantages, inconveniences, and modalities of implementation

	*Crotalaria retusa*	
	Seeds easily available. Highly improve the soil strength and supplement nitrogen. Protect against weeds. Adapted to several milieus. Doesn't need protection in dry season.	Poor forage production. Seeds need hot water treatment for better shoot.
	1 or 2 rows of crotalaria between 2 rows of cereals (0.8*0.25m) sowing shifted by 1 month	
	*Brachiaria ruzisiensis*	
	Good hay production(quality and quantity fodder production) Protect against weeds (striga) Improve soil strength, deep rooting Adapted to several milieus, Resistant to termites	Compete with cereal Can export a lot of nutrient if totally grazed At times difficult to grow Poor seed production Needs protection in dry season
	1 row of brachiaria in between 2 rows of cereals(0.8*025m) sowing shifted 1 week to 10 days	
	*Mucuna pruriens*	
	High seed production Good shoot and fodder production Seeds consumable by humans and animals (if treated) Rapid secondary effect (nitrogen supplement)	Congestion of inter rows. Less adapted to poor and stony soils Poor biomass residue for mulching. Needs protection in dry season.
	1 row of mucuna in between 2 rows of cereals(0.8*08m) sowing when cereal at knee level	
	*Vigna unguiculata*	
	Seeds consumable Good fodder Improve soil strength (nitrogen supplement) Seeds resist without treatment (Cowpea Chad) Adapted to several milieus.	Needs insecticide treatment for the production of seeds. "Fragile biomass" Needs protection in dry season.
	1 row of Cowpea in between rows of cereals (0.8*08m), sowing when cereal at knee level	
	*Dolichos lablab*	
	Seeds consumable by humans and animals Long cycle, deep rooting	Adapted to several milieus. Congestion of inter rows Poor biomass residue for mulching, Needs protection in dry season.
	1 row of Dolichos in between 2 rows of cereals (0.8*08m), sowing when cereal at knee level	

Agronomic results

Aerial biomass

The primary objective of associating cover plants to cereals is for the production of aerial biomass that will serve as cover. Figure 3 and 4 show the quantity of dry biomass obtained from farmers fields, of maize or sorghum associated or not to brachiaria or to crotalaria.

Maize is mainly cultivated in the north province of Cameroon, zone with high rainfall (from 900 to 1110mm). Under these conditions, brachiaria and crotalaria produce more biomass, they produce as much as the maize. Addition of a cover plant in between the cereals wills double the production of aerial biomass on the field. The production of biomass by the cover plant is regardless of that of the cereal, since it produces more biomass on DMC fields than on control .

Sorghum is mainly cultivated in the far-north province where there is less rainfall(700 to 900mm). Under these conditions, the production of biomass by brachiaria is still better (2948kg/ha on average).however, the one of crotalaria drops (863kg/ha on average). Under such conditions the growth of crotalaria is not satisfactory. To solve this problem we intend to sow it on two rows instead of one in between the cereals .

A part of the quantity of biomass it is also important to look at the quality. Maize straw disappear very fast from the soil surface while sorghum straw can resist longer. Therefore in the north province, sorghum stalk produced since 2002 are still present on the soil in 2005 after hardship from 3 dry and 2 rainy seasons. This resistance is interesting for the conservation of soil coverage. In return this residue with high C/N ratio can be responsible for the depletion of nitrogen on the crop.

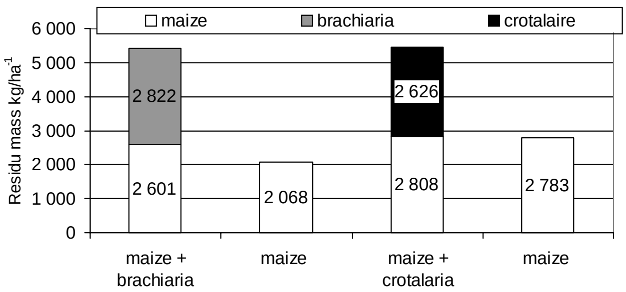


Figure 3 : biomass from maize, crotalaria and brachiaria. 13 fields (13 control plot and 13 DMC plots)

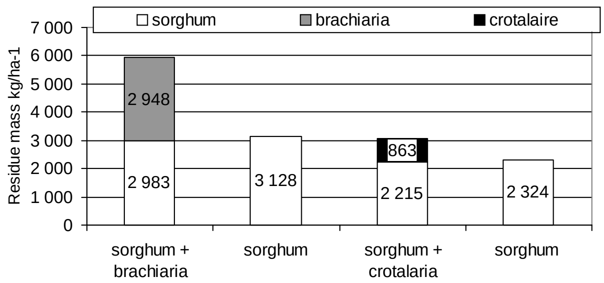


Figure 4 : biomass from sorghum, crotalaria and brachiaria. 23 fields (23 control plot and 23 DMC plots)

Photo 1 : April 2005, straw from cereals cultivated in 2002. Left: maize. Right: sorghum.

Yields

If the combination of cereal to cover plants cans anable production of biomass, this shall not be against cereal yield. Figure 3 et 4 show differences in term of yield between the control (sorghum or maize only) and the DMC part (sorghum/maize combined with brachiaria or crotalaria).for maize we can notice that brachiaria seems to have an influence on the maize, since the yield is poor in 8 fields over 15, 10 to 30 % on the DMC part compared to control. The combination of brachiaria to maize is very delicate to handle, but those who know how to go about it can practice it without any effect on the maize. crotalaria does not compete with maize. Fields that have poor yield on DMC part are those poorly managed, but not because of crotalaria. For sorghum we can notice the high number of fields with better yield (15/29) than those with poor yield (7/29) with brachiaria. Sorghum is less sensitive than maize to the competition with brachiaria.

Concerning crotalaria, fields that show poor cereal yield are mostly due to carelessness, not because of crotalaria competition.

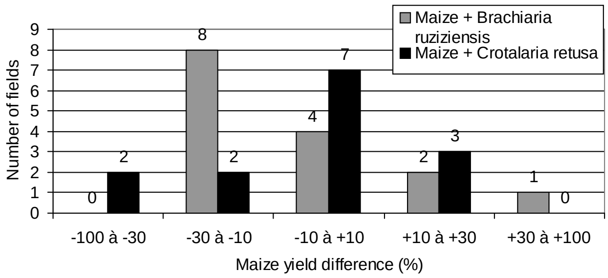


Figure 5 : maize yield difference between DMC and control plot. 30 fields

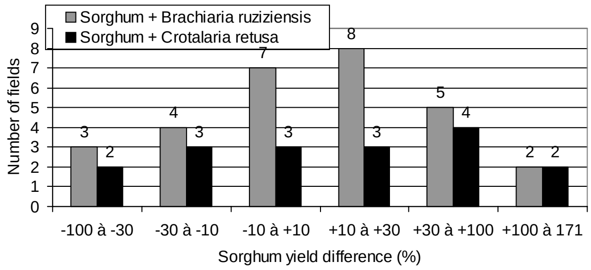


Figure 6 : sorghum yield difference between DMC and control plot. 45 fields

It can be surprising to note that for 22 fields over 29, the sorghum yield is equivalent if not more, while it is cultivated in combination to brachiaria. Several parameters can explain this phenomenon, but generally due to residual effects of the previous year. Table 2 shows sorghum yield according to the amount of residue present on the soil during sowing of the cereals. These residues come from cereals of 2 previous years on the same field, weeds and eventually the stems of last year cotton. These residues are present only in small quantity, but can have a significant impact on water management (Scopel *et al* 1999). In this study, we have not directly quantify, the effect of residues on water infiltration and evaporation, but we know that these phenomenon mostly determine the yield in the far- north province of Cameroon(Soutou *et al* 2005) .even if the standard deviations remain important, we can notice that in most cases the yields in term of cereals positively match to the quantity of mulch present on the soil during sowing .therefore most of DMC fields on 2/3 can produce two times more stems and leaves (sorghum+brachiaria) while maintaining or increasing the production of sorghum. This is mostly due to the fact that on these fields, water is more valorise than field on bare land (Soutou *et al* 2005).

Table 2: sorghum yield according to rate of soil coverage with residues during sowing of cereal. Even the control can be slightly covered during sowing, if done without tiling. However this cover will disappear during weeding and ridging, while remain on DMC where the soil is untouched.

Estimate of coverage At sowing(T/ha)	Yield	DMC brachiaria	Control brachiaria	DMC crotalaria	Control crotalaria
0	Average	1 020	791	692	783
	Standard deviation	641	717	545	606
	Number of plot	11	14	6	9
1	Average	1 282	1 325	1023	991
	Standard deviation	655	491	334	403
	Number of plot	12	5	8	5
2	Average	1 635	1 603	1 461	482
	Standard deviation	549	570	904	-
	Number of plot	5	3	2	1
3	Average	2 400		754	
	Standard deviation	-		-	
	Number of plot	1		1	

Weed coverage

Weed coverage on DMC parts has been recorded every 10 days from sowing to harvest. It is estimated on visual scale varying from 0 to 9(2=7% soil coverage by weeds, 3=15%, 4=30%, 5= 50%). Either on maize or sorghum fields, controls is generally more covered with grasses than DMC fields almost through out the cycle (figure 3 and 4). On the other hand, the evolution of the grasses is different on maize fields, situated in the north with high rain fall and the one of sorghum situated in the far-north with less rain fall.

On the maize field (figure 3) grasses grow at the end of the cycle, because when maize get to maturity, the leaves start fading, this allow light to pass through, at the same time rain continue falling (up to a month and a half after maize maturity). If the inter-rows are not occupied by a cover plant, weeds can grow easily and produce seeds, increasing as such the invasion potential for the following years. On the other hand, on DMC fields, during maturity of the maize, it is the cover plant that occupies the inter-rows, preventing as such the weeds to produce seeds. Since every year weeds are prevented to ripe on the fields, their impact is gradually lessened.

On sorghum fields, we don't notice invasion of fields at the end of cycles because rain stops early in the far-north province, and the sorghum maturity, where leaves dehiscence is reached later than that of maize. On sorghum, a brachiaria effect is more spectacular and impresses the farmers more. In a field where brachiaria covers the inter-row of sorghum, striga is absent while it can infest each sorghum stalk on the neighbouring control field (figure 9)

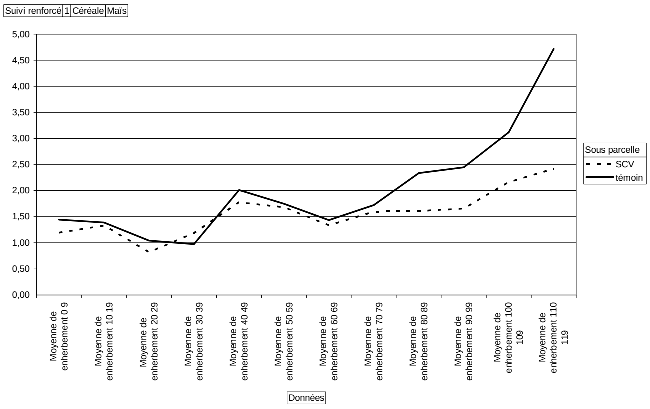


Figure 7 : weed infestation in maize field: control and DMC plot. Weed score : 2=7% of soil covered by weed, 3= 15 %, 4=30 %, 5=50 %. (13 fields, 42 plots)

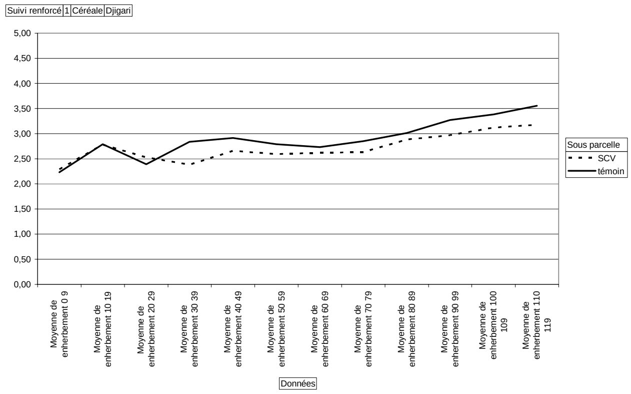


Figure 8 : weed infestation in sorghum field : control and DMC plot. Weed score : 2=7% of soil covered by weed, 3= 15 %, 4=30 %, 5=50 %. (26 fields, 86 plots)

Work organisation

If we expect the combination of cover plant to be easily accepted by the farmers, it is preferable that it should not represent a tedious extra work. In DMC the extra work consist of sowing of the cover plant and manual weeding instead of mechanical weeding. In return, tilling and ridging are abolished and the number of weeding decreased. Generally the surplus and the gain in work load are balanced on averagely well managed fields. However for the farmers that master the technique very well, or have 3 to 4 years into DMC, the gain are more important than the extra work. This explains the profile of fig 9, representing the classification of farmers fields according to differences in working time spend between the DMC and control parts.

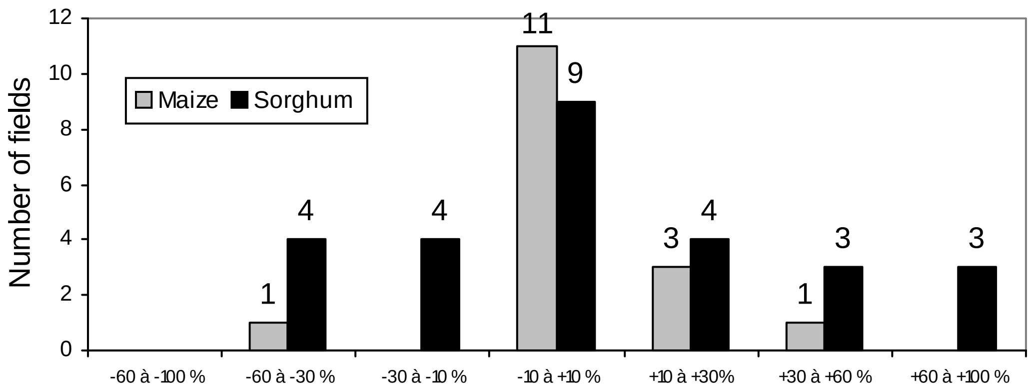


Figure 9: classification of farmers fields according to differences in working time spend between the DMC and control fields. (27 pairs of fields of sorghum, 16 pairs of fields of maize).

Conclusion and perspectives

The 4 years experimentation with the farmers anable us to improve on the selection of plants to combine with cereals. These plants are cultivated for many objectives : production of biomass for mulching, production of biomass for animals, and to improve the soil. There is no standard plant, each posses specific characteristics and shall fulfil environmental conditions and farmers objectives .the one commonly used are: *Brachiaria ruziziensis*, *Crotalaria retusa*, *Vigna unguiculata*, *Dolichos lablab*, *Mucuna pruriens*. *Brachiaria ruzisiensis* is a poacea, it is not part of the plants usually associated to cereals; however we noticed that it has interesting characteristics: stem resistance to termites, better coverage even with less biomass, high competition with striga, strong roots .the records on water management (Soutou *et al* 2005) confirms that it is one of the best that can precede cotton to improve physical soil properties. C*rotalaria*

retusa is a wild leguminous that is equally interesting for the production of aerial biomass, through is digging action on the soil and nitrogen supply. In addition it is easy to cultivate in combination to cereals than brachiaria and it can excellently precede cotton. A part of the effects on the next crop, we noticed that combination of cover plants help to achieve interesting results in short term with mulch. The combined plants to the crops compete with weeds. The effect of weeds being less, weeding decreases.
The activities of the following years will consist of many topics.

+ Try to find out in the surrounding environment plants that can serve as cover plants
+ Better quantification of effects of each plant on physical and chemical fertilisation of soil and on weeds. state recommendations on differential fertilisation according to plants used during rotation
+ Continue to work out farming systems combining production of fodder and production of biomass to cover the soil
+ Design technical steps using the cover plants to produce biomass, in not 1 of every 2 years, but just before or after the main crop in the same year.

Bibliography

Naudin K., Balarabe O., Séguy L., Guibert H., Charpentier H., Boulakia S., Abou Abba A., Thézé M. (2005) A Four-year timeframe to develop and begin extension of direct seeding mulch-based cropping systems, in the cotton belt of North Cameroon. This congress

Séguy L, Bouzinac S, Scopel E, Ribeiro F. New concept for sustainable management of cultivated soils trghought direct seeding mulch-based cropping systems: the CIRAD experience, partership and networks. Extended summary. 2 World congres on conservation agriculture, FBPP, CAAPAS, Foz de Igaçu, Brasil.

Seugé C, Naudin K, Aboubakary, Dugué P, Havard M. (2005) Natural resources and land-use management: conditions for the adoption of mulch-based cropping system by migrant farmers in the Benoué river basin (North Cameroon). This congress

Scopel E., Chavez Guerra E., Tostado J.M. (1999) Le semis direct avec paillis de résidus dans l'ouest mexicain : une histoire d'eau ? Agriculture et développement no 21 pp 71-21.

Soutou G, Naudin K, Scopel E. 2005. Crop water balance in conventional and direct seeding mulch-based cropping systems in North Cameroon. This congress