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The Effect of Short Rotation *Desmodium distortum* Planted Fallow on the Productivity of Ultisols in Centre Cameroon

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Summary

In order to investigate the effect of short rotation Desmodium distortum *planted fallow on maize grain yield and soil properties, an experiment was conducted over four consecutive years (1995-1998) at two locations (Minkoameyos in the humid forest zone and Ntui in the forest-savannah transition zone) in Centre Cameroon. The experimental design for each year was made of four replications and three treatments: i) Natural Fallow used as control (NF), ii)* Desmodium *Fallow (DF) and iii) Soybean (*Glycine max*) Rotation (SR). Maize (*Zea mays*) was used as plant test and was planted each year in the first cropping season (March-June) followed by each treatment from July to February. The analysis of variance and mean separation (Tukey's HSD) were used to evaluate the effects of treatments on maize yield and soil chemical properties at the end of the experiment. No treatment could produce relatively more than the first year of the experiment where maize yields were based on 7-8 year-old natural fallow in both sites. However, in Minkoameyos, there was a significant difference (p= 0.043) between the treatments in the fourth year.* Desmodium *plots out-yielded both natural fallow and soybean plots. In Ntui, there was a highly significant difference (p= 0.000) among treatments in the third and fourth years.* Desmodium *plots also out-yielded both natural fallow and soybean plots; while natural fallow plots out-yielded soybean plots. The general trend of productivity was ranked as: DF> NF> SR. Apart from the available P that has shown a highly significant difference (p= 0.000) compared to the initial value and to other treatments, no other significant difference was noticed with other soil properties in both sites. However, the general trend is that most soil chemical properties tended to decrease excepted pH water and available phosphorus. The*

Résumé

Effet d'une courte jachère plantée au *Desmodium distortum* sur la productivité des sols ferrallitiques au Centre Cameroun

Dans le but d'étudier l'effet d'une courte jachère de Desmodium distortum *sur les rendements de maïs et les propriétés du sol, une étude a été conduite pendant quatre années consécutives (1995-1998) dans deux localités du Centre Cameroun. Les deux localités étaient situées l'une en zone de forêt humide (Minkoameyos) et l'autre dans la zone de transition forêt-savane (Ntui). Le dispositif expérimental reproduit chaque année était constitué de quatre répétitions et de trois traitements: (i) Jachère naturelle (JN) utilisée comme témoin, (ii) Jachère plantée au* Desmodium distortum *(JD), et (iii) Rotation avec le soja (*Glycine max*) (RS). Le maïs (*Zea mays*) a été utilisé comme plante test, planté chaque année en première campagne agricole (mars-juin), suivi par chaque traitement de juillet à février. L'analyse de la variance et la séparation des moyennes (méthode Tukey's HSD) ont été utilisées pour évaluer les effets des traitements sur le rendement du maïs grain et sur les propriétés chimiques du sol à la fin de l'essai. Au cours de l'essai, aucun traitement dans les deux sites n'a pu produire plus de maïs grain que la première année où le champ dérivait directement d'une jachère de 7-8 ans. Cependant, à Minkoameyos, une différence significative (p= 0,043) a été observée entre les traitements à partir de la quatrième année. A Ntui, les traitements ont présenté des différences hautement significatives (p= 0,000) en troisième et quatrième années. Dans les deux cas, les parcelles JD ont produit plus que JN et RS. La tendance générale de la productivité des parcelles était: JD> JN> RS. Parmi les propriétés du sol testées, seul le P assimilable a*

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study has shown that, in forest-savannah–transition zone (Ntui), Desmodium distortum *had highly significant effect on maize grain yield from the third year while in the forest zone (Minkoameyos), the effect of* Desmodium *was significant from the fourth year. This therefore, suggests that the* Desmodium *shrub has a potential for improving plant nutrient availability in these soils when used in short rotational fallow system.*

présenté dans les deux sites des différences hautement significatives (p= 0,000) entre les traitements. Cependant, la tendance générale de l'évolution de ces propriétés était à la diminution des valeurs initiales, sauf pour le pH et le P assimilable. L'étude a montré qu'en zone de transition forêt-savane plus qu'en zone de forêt humide, Desmodium distortum *dans les conditions de cet essai était d'un grand potentiel pour l'amélioration de la disponibilité des éléments nutritifs du sol lorsqu'il est utilisé en système de courte jachère en rotation avec le maïs.*

Introduction

Traditionally in the humid tropics, agricultural output was maintained through a long fallow cycle (>10 years) in which the self-regenerating woody vegetation recycled nutrients, maintained soil organic matter and protected the soil from erosion and runoff (11, 13). With the ever-increasing population pressure in many parts of the humid tropics of Cameroon, this practice of long fallow is no longer feasible. In some areas, the fallow cycle has even been reduced to less than five years, leading to declining soil productivity (4, 12).

It was thought that the need for a long fallow period to maintain soil productivity in the tropics could be overcome by the use of mineral fertilizers. With this regards, some previous studies had reported the maintenance of soil productivity under continuous cultivation with a judicious use of fertilizer (16). However, some recent reports indicated that soil productivity in the tropics declines even with supplementary fertilizer use (20, 21). In either case, resource poor farmers are seldom able to apply fertilizer at the recommended rate and at the appropriate time because of high cost, lack of credit, delivery delays, and low and variable returns (15). This has led to intensive research on alternative sources of soil nitrogen for crop growth. Fixing nitrogen biologically using leguminous trees and shrubs has proved to be one of the most viable and sustainable alternatives to improve soil productivity and to shorten the fallow period (7, 8, 10, 15, 19).

Short term fallows of leguminous trees and shrubs such as *Calliandra, Gliricidia, Leucaena, Sesbania, Tephrosia, Desmodium*, and *Crotalaria* are being extensively introduced for use in agroforestry systems in Centre Cameroon. To be acceptable, any plant species used in a short fallow management technology should be adapted to soil environment and should yield higher levels of limiting nutrients than the natural bush fallow. This paper reports the results of an experiment carried out over four consecutive years at two locations in Centre Cameroon with the objective to study the possible role of planted *Desmodium distortum* in improving the productivity of maize. *Desmodium distortum* is a nitrogen-fixing shrub legume characterized by the following attributes: fast growth, easily degradable biomass, compatibility with maize crops (no allelopathy to cereals), but a selective adaptability to soil and climatic conditions.

Materials and methods

Experimental sites and design

The study was conducted from 1995 to 1998 at two sites in Centre Cameroon:

– Minkoameyos, a semi-deciduous forest zone, located 3 º51' N and 11 º26' E, at 700 m asl.

– Ntui, a forest-savannah-transition zone, located 4 º26' N and 11 º40' E, at 560 m asl.

The climate in both sites is characterized by two rainy seasons (March-June and September-November). The mean annual rainfall varies from 1500 to 1800 mm in Minkoameyos and from 1200 to 1500 mm in Ntui. The average annual temperature is 24 °C in Minkoameyos and 26 °C in Ntui. Soils in both sites are highly weathered soils grouped to ultisols according to soil taxonomy (17). However, soils of Minkoameyos site have a relative slightly acidic pH (5-5.5) and high content of clay particle size (30% from topsoil compared to 15-20% in Ntui soils).

The agricultural land use system is based on shifting cultivation practices for subsistence food crop production. This fallow-based agricultural system (shifting cultivation) is characterized by two years of mixed food cropping without any fertilizer use, followed by a fallow period of variable duration ranging from 3 years to more than 15 years. The short-fallow vegetation is usually dominated by *Chromoleana odorata* in the semi-deciduous forest zone, and by grass vegetation in the forest-savannah-transition zone.

The experimental design was a randomised complete block with three treatments and four replications per site. The study was conducted during four consecutive years (1995-1998). The three treatments were based on seasonal rotation of three-month maize cropping in the first season (March-June) followed by nine-months short planted-legume-fallow (July-February) of different types:

– T1: maize/natural fallow rotation (control);

– T2: maize/*Desmodium* fallow rotation;

– T3: maize/ soybean crop rotation.

The experimental plots of 8 m x 6 m were organized in randomised complete block design separated by 1 meter within block and 2 meters between blocks in each experimental site. Each study site was then made of 12 experimental units. An experimental unit or plot refers here to the land portion to which a treatment is applied.

Cultural practices, crop management and sampling

At the beginning of the first cropping season of 1995 (March-June), a natural bush fallow (7-8 year-old) plot was cleared at both sites, and burnt. The experimental plots were laid out according to the randomised complete block design as described above. Each experimental plot was planted with maize (*Zea mays*), (var. CMS 8501) at 0.75 m between rows and 0.5 m within row; two seeds per hill. Weeding was done manually with hoe at the fourth and eight weeks after maize planting. After the second weeding, seeds of *Desmodium distortum* legume shrub were evenly broadcasted in the field at 15 kg.ha^{-1} in the treatment T2. After maize harvesting (ten weeks after planting), *Desmodium* was allowed to grow freely until the next cropping season in treatments T2; and natural fallow vegetation in T1. For treatment T3, soybean (*Glycine max*; a local variety) was sown at 0.5 m x 0.25 m spacing at the beginning of the second cropping season (September). In March 1996 (one year later), the nine-month-old *Desmodium* and natural fallow plots were cleared by cutlass and soybean harvested. Each plot was then hand-tilled with hoe and the residues incorporated. Maize was then planted and managed in the same way as in 1995. The same activities were repeated on the same plots at both sites in 1997 and 1998.

At maturity of maize, the four middle rows of each plot were harvested and grain yield adjusted to 15% moisture content.

Prior to the establishment of the experimental plots in 1995, composite soil samples were collected at 0-15 cm depth at each site (each constituting of 10 cores made at random points throughout the whole experimental site). In 1998, soil samples were similarly collected under each of the 24 experimental units at the same depth.

Soil laboratory determinations and statistical analysis

All the soil samples collected were analysed for pH, organic carbon, total nitrogen, exchangeable cations and available phosphorus. pH water was determined with soil/water ratio of 1:2.5. Organic carbon was determined by the Walker & Black method, and the total nitrogen by the Kjeldahl digestion method. Exchangeable bases were determined using the percolation method of extraction, and available P by Bray-II method. All these methods are described in Anderson and Ingram (2).

The analysis of variance and mean separation (Tukey's HSD) were used to evaluate the effects of treatments on maize yield and soil properties at the end of the experiment. For all the statistical analyses, the Syststat Software Package (18) was used. The relative changes in soil characteristics between 1995 and 1998 were calculated as follows: $X\% = 100*(X_{1998}-X_{1995})/X_{1995,}$ where X is the soil characteristic dealing with. The size of *Desmodium* and soybean treatment effects was computed as the yield difference between natural fallow rotation and these treatments.

Table 1

Maize grains yield at Minkoameyos and Ntui from 1995 to 1998.
Each value is the Least Square Mean (kg.ha^{-1}) of n= 4 replications

Treat	Minkoameyos					Ntui				
	Year					Year				
	1995	1996	1997	1998	Mean	1995	1996	1997	1998	Mean
NF	4446	3131	4408	2454b	3610	3310	2355	2490b	2526b	2670
DF	4449	3382	4511	2966a	3827	3496	2494	2921a	3127a	3010
SR	4576	3097	4232	2393b	3575	3428	2153	2133b	1782c	2374
Mean	4490	3203	4384	2604	3671	3411	2334	2515	2478	2685
SE	232	232	232	232	112	137	137	137	137	112
CV%	9	12	11	19	23	8	15	18	25	25

Keys: Treat= Treatments; NF= Natural Fallow plot; DF= *Desmodium* Fallow; SR= Soybean Rotation; SE= Standard Error; CV%= Coefficient of Variation;

Characters with the same letter are not significantly different at 95% confidence interval, compared with the other treatments for the same year. Number of samples for an annual mean= 12; Number of samples for a treatment mean in four years= 16; Number of samples for a site four-year mean (mean of means)= 48.

Results and discussions

Evolution of maize grain yield with time

Maize grain yields for each treatment during the four years of the experiment are shown in table 1.

At the beginning of the experiment in 1995, maize grain yield was recorded from each experimental land unit that was to support treatments. The results in table 1 show no significant difference between these experimental units in both sites. The coefficients of variation (CV) were rather the lowest (8-9%) in the first year (1995) compared to the following years (12 to 25%). This led to conclude that there was no significant gradient in soil fertility within experimental sites, and all the treatments could be evaluated on the same basis for maize yield as well as for soil properties changes.

From this first year and onwards, Minkoameyos site has shown to be significantly (p= 0.000) more productive in maize grain yield (4490 $kg.ha^{-1}$) than Ntui site (3411 $kg.ha^{-1}$) in the first year, and 3671 $kg.ha^{-1}$ and 2693 $kg.ha^{-1}$ for overall mean in four years. This highly significant difference is hard to explain because there was no significant difference between soil chemical properties of the two sites. However, some slight climatic difference exists between the two sites (see section on the experimental sites). Some soil physical properties also may play a role in the productivity of the two sites since Minkoameyos soil was more clayey than the Ntui soil. However, no soil physical property was monitored in this study to allow a right conclusion.

The maize yields in table 1 show that no treatment could produce relatively more than the first year of the experiment (1995) where maize yields were based on 7-8 year-old natural fallow in both site. Maize yields of the second year (1996) were lower than that of the two following years in both sites. This may suggest that the effect of treatments was only effective as from the third year. However, during the fourth season (1996) maize yield was also slightly affected by a dry spell that occurred at the silking stage at Minkoameyos.

Effects of treatments on maize grain yield

The effects of the treatments (DF and SR) on maize grain yield were evaluated from the second year (1996) to the fourth year (1998) of the experiment as compared to the control (NF). The effects of different treatments are presented in tables 1 and 2.

The general trend of productivity could be ranked as: DF> NF> SR at the end of the experiment.

In Minkoameyos, no significant difference was observed among treatments in the second and third years (1996 and 1997). In the fourth year (1998), there was a significant difference (p= 0.043) among treatments. *Desmodium* plots out-yielded natural fallow plots by 25% and soybean plots by 28%. There was no significant difference between NF and SR, even though SR produced 5% less than NF (Table 2). The significant increase in maize yield only from the third year indicated that the effect of the treatments was not immediate in the conditions of Minkoameyos. The three treatments were then more efficient as resulting from an accumulative residual effects from the previous seasons. Synchronisation of nutrients release and plant take up may have played an important role in improving crop yield. This result however, corroborates early study by Tonye *et al.* (19) who found that *Cajanus cajan* used in the similar conditions was effective only in the third year in improving maize grain yield around the Minkoameyos areas.

Table 2

Size of *Desmodium* and soybean treatment effects (in $kg.ha^{-1}$) as compared to natural fallow rotation.

Values in brackets show the effects in percentage (%)

	Minkoameyos		Ntui	
	DF	SR	DF	SR
1996	251 (8)	-34 (-1)	139 (6)	-202 (-9)
1997	103 (2)	-176 (-4)	431 (17)	-357 (-14)
1998	512 (21)	-61 (-3)	601 (24)	-744 (-29)
Mean	217 (6)	-60 (-2)	340 (13)	-296 (-11)

Keys: DF= Desmodium rotation; SR= Soybean rotation.

In Ntui, highly significant differences occurred among the treatments in the third year (p= 0.009) and in the fourth year (p= 0.000). *Desmodium* plots out-yielded NF by 50% and SR by 52% (Table 2), while NF plots produced more maize grain yield than SR plots. These changes in maize grain yield in Ntui followed the same pattern as noticed at Minkoamoyos, but with a higher productivity rate (Table 2). The *Desmodium* fallow rotation appeared to be more productive at the Ntui conditions.

Similar results reported by Balasubramanian and Nguimgo (3) indicated that grain yield of maize in the following season was 89% higher with *Mucuna* and 52% with *Crotalaria* compared to maize grain yield (827 $kg.ha^{-1}$) after natural fallow in Rwanda. Also in Nigeria, *Tephrosia candida* plots produced more maize grain and stover yields than natural bush fallow plots (5), and maize/cowpea rotation treatment produced the lowest maize grain yield compared to natural and *Leucaena* fallows (9). The lowest yield obtained in SR plots at both sites may be attributed to the difference in the quantity of vegetal biomass incorporated in soil during cropping. In fact, DF and NF plots could produce more biomass than SR plots. This shortage of incorporated biomass may result to a rapid deterioration of soil physical properties in SR

Table 3

Soil properties (0-15 cm layer) before and at the end of the experiment, and rates of changes occured in various plots in 1998 after 4 years cropping (expressed as X%= 100*(X_{1998}-X_{1995})/X_{1995})

		Minkoameyos						Ntui					
		pH water	OC %	Nt %	C/N	P av (ppm)	Sum Bases	PH water	OC %	Nt %	C/N	P av (ppm)	Sum Bases
1995	Initial	5.4	1.90	0.17	11.2	2.0	5.07	5.5	1.78	0.13	13.7	7.0	5.57
1998	NF	5.80	1.90	0.16	12.2	8.9a	4.81	6.17	1.43	0.11	13.1	9.9a	4.04
	DF	5.69	1.43	0.15	10.0	4.5b	3.96	6.07	1.57	0.11	14.3	9.0b	3.82
	SR	5.54	1.79	0.15	12.3	7.6c	3.77	6.09	1.48	0.15	12.9	12.4c	3.38
	SE	0.10	0.09	0.02	1.03	1.30	0.59	0.03	0.06	0.03	1.76	1.49	0.11
% of changes	NF	7	0	-6	9	345a	-5	12	-20	-15	-4	41a	-26
	DF	5	-25	-12	-11	125b	-22	10	-12	-15	4	29b	-31
	SR	3	-6	-12	10	280c	-26	11	-17	15	-6	77c	-39

Keys: NF= Natural Fallow plot; DF= *Desmodium* Fallow; SR= Soybean rotation; SE= Standard Error; OC%= Organic Carbon percentage; Nt%= total Nitrogen percentage;

P av.= available Phosphorus;

Characters with the same letter are not significantly different at 95% confidence interval, compared with the other treatments for the same soil property.

due to continuous cultivation and resulting exposure of soil surface to heavy showers at the beginning of each cropping period.

Effects of treatments on soil chemical properties

Soil chemical properties of the experimental plots were measured at the beginning and at the end of the experiment in order to evaluate the treatment effects on soils of the two sites. One representative sample from each study site was analysed in 1995, while in 1998, soil samples were analysed from treatment plots. Table 3 shows the results of these analyses and the rates of changes that had occurred in these soils during the experiment.

Apart from the available phosphorus that has shown a highly significant difference (p= 0.000) compared to the initial value and to other treatments, no other significant difference was noticed with other soil properties in both sites. However, the general trend is that most soil chemical properties tended to decrease excepted pH water and available phosphorus. These two exceptions may have also played an important role in the productivity of maize under different treatments. Available phosphorus increased more in Minkoaomeyos. However, the trend of changes could be ranked as: NF> SR> DF in both sites. pH water increased from 3 to 10% in both sites. Sum of bases decreased by 5 to 40% and the organic matter by 6 to 25%.

The actual knowledge is that the presence of ash from burn vegetation as it was done at the beginning of this experiment has several important effects on soil (12, 14). The amounts of plant-available nutrient status of the soil are increased as a result of the fire-induced release of organically bound nutrients such as K, Ca, Mg, and P. The dissolution and leaching of white ash results in soil pH values increase by 5 to 10%, which promote changes in soil mineralogy, and presumably, other materials with pH-dependent charge. A study conducted on an ultisol on the Minkoameyos area by Ambassa-Kiki and Nill (1), showed that traditional mixed cropping preceded by manual land preparation produces less runoff and soil loss after four years of cropping, and conserves for longer period a lower bulk density. This comparison was made with treatments that involve sole cropping preceded by the use of heavy machinery for land preparation.

Soil fertility in *Desmodium* plots was associated with higher maize grain yield in the third year in Minkoameyos and in the second and third year in Ntui. Similar results were obtained in Nigeria by Gichuru (5) with *Tephrosia candida.* Also soil under natural fallow tended to have higher pH and exchangeable Ca. This corroborates earlier works by Juo *et al*. (6) and Gichuru (5). A tendency of low pH was observed at both sites under soybean/maize rotation plots, indicating an earlier increase in soil acidity due to continuous cultivation. In Nigeria, Mulongoy *et al.* (9) rather observed a decrease in pH and exchangeable Ca and an increase in total acidity in maize/cowpea treatment compared to natural and *Leucaena* fallows.

The general trend of a relative low level of soil properties changes after the four years cropping should be ascribed to the effect of residues incorporation that acted as source of soil and crop nutrient replenishment during the experiment. How far could this process work for the benefit of soil productivity? The

Table 4

Ratio of production returns to land management practices in time: (Average yield of 1995)/(yield of each treatment)

	Land management practices							
	Minkoameyos				Ntui			
Year	SC	NF	DF	SR	SC	NF	DF	SR
1995	1	–	–	–	1	–	–	–
1996	Fallow	0.70	0.75	0.69	Fallow	0.69	0.73	0.63
1997	Fallow	0.98	1.05	0.94	Fallow	0.73	0.85	0.62
1998	Fallow	0.55	0.66	0.53	Fallow	0.74	0.91	0.52
Total	1	+2.23	+2.46	+2.16	1	+2.16	+2.49	+1.77

Keys: SC= Shifting Cultivation; NF= Natural Fallow plot; DF= *Desmodium* Fallow; SR= Soybean rotation.

continuation of the study would have to allow setting up the limitation or the asymptotic boundary.

Production returns analysis and conclusion

The production returns ratio of each land management practices is shown in table 4.

The production returns ratio was computed by dividing the average maize yield in 1995 by the yield produced from each treatment each year. In the normal shifting cultivation system, maize is cropped once and the piece of land is left to fallow after all the associated crops are harvested in one or two years. The production of a piece of land during the four years of this experiment was increased with an additional maize grain of 1.80 to 2.50 times the yield from a one-year maize cropping in shifting cultivation (Table 4). DF rotation produced the highest ratio (2.50) in both sites. These results showed that the cultural practices used in this experiment could be a suitable alternative to shifting cultivation. The study has shown that, in forest-savannah–transition zone (Ntui), *Desmodium distortum* had highly significant effect on maize grain yield compared to natural fallow and soybean rotation in the third and the fourth year while in the forest zone (Minkoameyos), the effect of *Desmodium* was significant in the fourth year. This therefore, suggests that the *Desmodium* shrub has a potential for improving plant nutrient availability in these soils when used in short rotational fallow system.

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