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Cropping Systems Effects on Sustainable Maize Crop (*Zea mays* L.) Production on Depleted Tropical Soil

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ABSTRACT
Nutriments depletion in tropical soils is a limiting factor for agricultural productivity. This study aims are to identify appropriate cropping systems which could optimize maize grains yield and prevent from soil nutrients depletion. Field trials were conducted in Southern Togo ferralsol including Mucuna and pigeon pea cover crops in three cropping systems in randomize triplicate split plot design. Cropping systems tested consisted of continuous maize and atypical relay of maize-mucuna and maize-pigeon pea represented in main plot with different mineral fertilizer rates in sub-plot. Results showed that maize grains yield ranged from 3.00 to 6.83 Mg.ha^{-1} during the first season and from 3.02 to 5.85 Mg.ha^{-1} during the second season. Mucuna increased maize grain yield by 38-57% compared to continuous maize while pigeon pea increased yield by 30-49%. Nitrogen and P budget showed 93% N and 10% P losses in continuous maize system then 28% N and 11% P losses in maize–pigeon pea system while just 26% N and 7% P were lost in maize–mucuna system. Maize-mucuna atypical relay seem to be the best approach to produce high maize yield and to reduce soil nutrient depletion.

Keys words: *Cover crops, Cropping system, Nutrients depletion, Maize yield*

INTRODUCTION
Basically, Africa's soils and climates are less auspicious for agriculture[5]. West Africa, mainly costal side, is characterized by ferralsol whom notorious infertility is a phenomenon accentuated by demographic pressure[18,19,21]. Several agricultural production systems are practiced in West Africa but usually based on cereal crops such as maize[8]. Maize is a main crop in West Africa region and a staple food of these populations[15,24]. It is essentially produced by farmers in various complex cropping systems from monoculture to agroforestry associated or not with mineral fertilizers. The main source of soil degradation and infertility in Sub-Saharan Africa remains the nutrients depletion by runoff[8].

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It is possible to face soil nutrients depletion and enhance agriculture productivity by using cover cropping technologies. Studies showed that, in Africa, organic matter incorporation in soil coming from perennial fast growth legumes as *Leucaena* sp., *Cajanus cajan*, *Sesbania sesban* or *Glyricidia sepium* resulted in a meaningful improvement of soil fertility[2,3,13,14]. Otherwise, several legumes are able to increase soil exchangeable bases status, P content and available Ca. The main contribution of cover crops to soil was its fertility enhancement by yearly N addition and other nutrients. It is estimated that legumes can added to soil 50 $kg.ha^{-1}.an^{-1}$ of nitrogen[1,9]. In good cropping conditions (1000-2500 $mm.an^{-1}$ of rainfall, 19 - 27°C temperature, pH≤4,5 and an elevation between 0-1600 m), mucuna release to soil 7-9 $Mg.ha^{-1}.an^{-1}$ of dry biomass which had 2.96% N content, 0.32% P content and 1.57% K content[7,16,31].

This represents a lot of nutrients contribution around 207-266 kg N ha^{-1}, 22-29 kg P ha^{-1} and 110-141 kg K ha^{-1}. Togo is characterized also by a galloping demography for 2.58% per year[6] and by notorious soil fertility deterioration. According to IFDC (2006)[15], 47kg NPK are lost per hectare per year in Togolese soils. It had a strong negative impact on cereal production which is in decrease by about 1% during last two decades. Maize grain production, a staple food in Togo, is in decrease by about 0.8% in last few years[24]. Efficient nutrients management for best crops productivity was an important stage to face hunger and, at the same time, to promote a sustainable agriculture. The challenge was to increase crops productivity without compromising soil fertility. Using local available agriculture inputs and minimizing mineral fertilizers use are the way to reach this aim[24]. This vision requires both soil and crop management approaches different from those ordinarily practiced and a good understanding and management of nutrients dynamics. Managing cover crops resources can allow farmers to enhance soil fertility and to increase crops production. The objective of this study is to identify an appropriate cropping system able to support maize grain production and to prevent from soil nutrients depletion.

MATERIALS AND METHODS

Site description

Study was conducted at Agronomic Experimentations Station of Agronomy High School at University of Lomé, Togo (6°22'N, 1°13'E; altitude = 50m, slope <1%). Soil in place was a ferralsol[22] and cover 47% of Togolese land in the coastal side. Top soil was well drained with a density of 1.6[25], organic matter content (<1%) and K (<0.2 $cmol.kg^{-1}$) were weak, total P was around 250 - 300 $mg.kg^{-1}$, total N was 0.05 – 0.1% with a C/N ratio ranged from 7 to 11, sum of exchangeable bases was between 2.82-3.92 meq/100g, Cationic Exchange Capacity (CEC) was between 3-4 $meq.kg^{-1}$ and a pH was acid and ranged from 5.2 to 6.8[27,28]. Trial site climate was an Equatorial Guinean type and bimodal with 900-1200mm for rainfall and 24-30°C for temperature[26,27].

The land was a plot having long year continuous maize cropping without fertilizers.

Experimental design

The experimental design was randomized triplicate split plot design in order to assess spatial variability[29,30]. Cover crops were in the main plot and the sub-plot received mineral fertilizer. Treatments were as follow: $MaN_0P_0K_{60}$, $MaN_{40}P_0K_{60}$, $MaN_{40}P_{30}K_{60}$, and $MaN_{80}P_{30}K_{60}$, $MuN_0P_0K_{60}$, $MuN_{40}P_0K_{60}$, $MuN_{40}P_{30}K_{60}$, and $MuN_{80}P_{30}K_{60}$ and $CaN_0P_0K_{60}$, $CaN_{40}P_0K_{60}$, $CaN_{40}P_{30}K_{60}$, and $CaN_{80}P_{30}K_{60}$ where Ma, Mu and Ca designed maize, mucuna and pigeon pea respectively. The three cropping systems studied were based on two usual production systems in West Africa (monoculture and relay cropping) and contained (i) maize monoculture, (ii) maize-mucuna relay and (iii) maize-pigeon pea relay. Here, culture relay system used is not an ordinary one. It is an atypical rotation that spreads one on four cropping seasons which correspond to two years production calendars in southern Togo. This atypical relay consisted by inserting one season of improved fallow with a crop cover on four cultural seasons instead of one season on two, as an ordinary relay. During cultural season preceding trial period, plot with system of continuous maize received maize crop (50 000 plants.ha^{-1}), maize–mucuna (*Mucuna pruriens var utilis*) system received mucuna (35 000 plants.ha^{-1}) and maize–pigeon pea (*Cajanus cajan*) system received pigeon pea (42 000 plants.ha^{-1}). All harvest dry residues were incorporated into soil. The maize (*Zea mays* L.), IKENNE variety, has been chosen like plant test because it's able to show soil nutrients deficiencies.

Data collection and analysis

Composite soil was taken in every system at 0-30 cm and 30-60 cm depths at the beginning and the end of the experiment. On these samples, chemical analysis were carried out on organic N, total N, nitric N (NO_3-N), total C, total P and available P. Maize plant samples were collected at maturity harvest according to Witt *et al.* (1999)[32] methods to determine total dry matter then analysed to determine their content of N and P. The nitrogen in form of NO_3-N is chosen because it was more stable in soil than NH_4^+-N which could be nitrified very quickly[10].

Maize grain yield and its components were determined and compared for every cropping system for each cultural season and for the year. Nitrogen (N) and P partial budgets were established in 0-60 m soil layer corresponding to depth of maize roots. This balance was considered in each cropping system in soil-plant-atmosphere system.

Analysis of variance (ANOVA) and Duncan multiple test range (DMT) were done using STATISTICA software version 5.5 at 5% level.

RESULTS

Maize grain yield and yield components

Maize grain yield varied according to all cropping systems and ranged from 3.00±0.37 to 6.83±0.26 Mg.ha^{-1} during the first season (FS), from 3.02±1.28 to 5.85±0.58 Mg.ha^{-1} during the second season (SS) and for the year, varied from 6.02±1.62 to 12.66±0.60 Mg.ha^{-1} (Table 1). In maize-mucuna system, $N_{40}P_{30}$ and $N_{80}P_{30}$ treatments gave the best cumulated yield for the year (12.66±0.60 and 12.53±0.58 Mg.ha^{-1} respectively). Control treatment (N_0P_0) always was the lowest yield (9.89±0.95 Mg.ha^{-1}). In maize-pigeon pea system, the yield was the same between $N_{40}P_0$ and $N_{40}P_{30}$ treatments (11.01±1.11 Mg.ha^{-1} and 11.15±1.26 Mg.ha^{-1} respectively), while treatment $N_{80}P_{30}$ carried out with 11.37±0.59 Mg.ha^{-1}.

The comparison between continuous maize system and maize-mucuna system showed that, whatever the cropping period, mucuna used as cover crop increased maize grain yield from 38 to 57%. Control treatment (N_0P_0) in maize-mucuna system gave a yield statistically superior ($F_{(11;\ 36)}$= 3013.66; p=0.00) to fertilizer use in continuous maize system ($N_{40}P_0$) even for application of $N_{40}P_{30}$ in continuous maize system. Also, maize-pigeon pea system increased maize grain yield from 30 to 49% compared to continuous maize system. Without fertilizer application (N_0P_0), maize-pigeon pea system gave a yield similar to continuous maize system ($N_{40}P_0$ and $N_{40}P_{30}$). However, this remains lower than yield of maize-mucuna system in the same conditions. Comparing the two systems of cover crops, the yield of the first season increased by 12% comparing to maize-pigeon pea system, whereas the second season revealed a mean yield increase by 4% only and a yearly yield growth by 8%. The three cropping system comparison showed the superiority of mucuna cropping system on pigeon pea cropping system and the both on continuous maize cropping system.

Maize plant productivity varied according to cropping system from 51 to 141 g.plant^{-1} during the first (FS) and 35 to 128 g.plant^{-1} during the second season (SS). Maize productivity statistical variability was identical to maize grain yield variability according to cropping systems and fertilizer treatments (Table 2). Maize grains 1000 weight remained invariable ($F_{(11;\ 36)}$ = 3.71 and p = 0.0556) whatever treatments or cropping systems. Maize grains 1000 weight mean value was 282±23 g. It showed that the maize grain yield was more influenced by the grain number formed on the ears than by the specific grain mass. Dry straw yield averaged at 7.3±1.67 $Mg.ha^{-1}$ for the FS and 7.7±1.85 $Mg.ha^{-1}$ for the SS. Grain-straw ratio (GSR) was in average 0.71±0.15 for the FS and 0.65±0.19 for the SS while harvest index (HI) was in average 0.40±0.052 for the FS and 0.37±0.049 for the SS. GSR was statistically identic during the two cultural seasons (0.71 and 0.65 respectively for FS and SS). HI presented a higher variability during SS (0.17 – 0.72) than during FS (0.24 – 0.58) but in average, it was no difference between HI at FS (0.40) and HI at SS (0.37). Fertilizer treatments and cropping systems had no influence on grain-straw ratio ($F_{(11; 36)}$=1.75 and p=0.214) and harvest index ($F_{(11; 36)}$ =1.091 and p =0.367). Positive relationship (p≤0.000234) was found between HI and maize plant productivity.

Resources Use Efficiencies

Water use efficiency (WUE) in continuous maize system varied around 0.8±0.22 $kg.m^{-3}$ for FS and 2.98±0.54 $kg.m^{-3}$ for SS (Table 3). In maize-mucuna system, it was 1.03±0.15 $kg.m^{-3}$ for FS and 4.20±0.40 $kg.m^{-3}$ for SS. For maize-pigeon pea system, it ranged around 0.90±0.14 $kg.m^{-3}$ for FS and 4.08±0.05 $kg.m^{-3}$ for SS. Water was better used in SS (3.8±0.65 $kg.m^{-3}$) than in FS (0.9±0.17 $kg.m^{-3}$). This study revealed dissimilarity between water use efficiencies for FS and SS. It could be explained by rains regime which was raised in FS (504 mm) than in SS (115 mm). Water availability was restricted in SS, and then maize plant used this resource better than in FS. Otherwise, mucuna improved water use as well as in FS than in SS comparing to others two cropping systems.

Nitrogen agronomic efficiency (AE-N) in continuous maize system varied around 62.3±15.3 $Mg.ha^{-1}$ for FS and 30.7±12.1 $Mg.ha^{-1}$ for SS. For maize-mucuna system, AE-N was 33.0±16.5 $Mg.ha^{-1}$ for FS and was 25.0±0.0 $Mg.ha^{-1}$ for SS. For maize-pigeon pea system, AE-N varied around 36.3±3.5 $Mg.ha^{-1}$ for FS and 4.0±1.0 $Mg.ha^{-1}$ for SS. P agronomic efficiency (AE-P) in continuous maize system was 91.5±19.1 $Mg.ha^{-1}$ for FS and 50.0±4.2 $Mg.ha^{-1}$ for SS. For maize-pigeon pea system, AE-P averaged at 51.0±4.2 $Mg.ha^{-1}$ for FS and was 5.5±0.7 $Mg.ha^{-1}$ for SS. For maize-mucuna system, AE-P was 56.5±3.5 $Mg.ha^{-1}$ for FS and 33.5±0.7 $Mg.ha^{-1}$ for SS. It was a better AE-P in FS (66±20.44 $Mg.ha^{-1}$) than in SS (30±20.84$Mg.ha^{-1}$) and the same for AE-N (44±16.79 $Mg.ha^{-1}$ for FS and 20±13.05 $Mg.ha^{-1}$ for SS).

N and P nutrient partial budget

Nitrogen and phosphorus nutrient partial budget was based on evaluation of nutrient inputs and outputs in soil layer of 0-60 cm depth during the first season (FS).

Nitrogen exports exceeded extensively inorganic fertilizer amount applied in all cropping systems (table 4). Nitrogen balance was influenced considerably by soil initial available N content. Soil initial available N contents were in average 45.2 kg N ha^{-1}, 91.5 kg N ha^{-1} and 83.5 kg N ha^{-1} respectively in continuous maize system, maize-mucuna system and maize-pigeon pea system. Nitrogen balance was negative in all systems. In relation to soil NO_3-N content, continuous maize system lost 93% NO_3-N while maize-mucuna system and maize-pigeon pea system lost just 26% and 28% respectively. It was an N luxurious consumption in maize-pigeon pea and maize-mucuna systems because maize grains yield in these treatments (40 $kg.ha^{-1}$ and 80 $kg.ha^{-1}$ of N) were statistically identic. Otherwise, N exports exceeded soil N initial content and N dose applied. Nitrogen amount to satisfy required yields were not available in soil. In fact, mineral N balance was negative in most of cropping systems. N complements to reach required yields in every system, would come from N atmospheric depositions and organic N (organic matter) mineralization. Nitrogen atmospheric depositions (13.9 $kg.ha^{-1}$) were not negligible in front of organic matter mineralization (N sold). On average, these N gains coming from organic N mineralization were heavy and highly variable in continuous maize system (56±56.61 kg N ha^{-1}), intermediate in maize-pigeon pea system (31±30.62 kg N ha^{-1}) and in weak maize-mucuna system (38±11.19 kg N ha^{-1}).

Continuous maize system impoverished soil more than others cropping systems because it encouraged a high soil organic matter mineralization dragging down its rate in soil. This situation explained how tropical soil became a mining soil. Cover crops used (mucuna and pigeon pea) permitted to increase not only soil organic matter content but also to temporize its mineralization and to rise its N content, while producing better maize grains.

P exports were more than P applied doses in the trial. But P balance is influenced considerably by soil initial available P content which averaged at 262 kg P ha^{-1}, 278 kg P $ha^{-1}$and 280 kg P ha^{-1} respectively in continuous maize system, maize-mucuna system and maize-pigeon pea system (Table 4). On average, P balance was negative in continuous maize system (-5±33.81kg P ha^{-1}) and maize-pigeon pea system (-31±36.18kg P ha^{-1}) but was positive in maize-mucuna system (5±22.14 kg.ha^{-1}). Loss of available P was medium in continuous maize system and maize-pigeon pea system (10% and 11% respectively) and low in maize-mucuna system (7%). In maize-mucuna system, P was always present in soil layer and represented available P fraction derived from mineralization which remained in soil after its chemical precipitation by soil iron and aluminium oxides. In others systems, organic complex had to mineralize to provide P needed for maize production. Results revealed that pigeon pea required more P to grow or pigeon pea biomass was not rich in P to improve its soil level. It required organic matter mineralization to provide P and in this case, soil was more and more depleted in available P.

In all systems, N exports evolution was not proportional to N doses brought but seems to follow P availability. In continuous maize and maize-pigeon pea systems, when N dose increased by 40 kg N ha^{-1}, N and P exports decreased. With application of 30 kg P ha^{-1}, P exports were stagnant while N exports more decreased. Supplementary addition of 40 kg N ha^{-1} increased N exports as well as P exports. In maize-mucuna system, when N dose increased by 40 kg N ha^{-1}, N and P exports were intensified and, with application of 30 kg P ha^{-1}, P and N exports decreased but were superior to initial level. In these situation, supplementary application of 40 kg N ha^{-1} increased more N exports as well as P exports.

The nutrients dynamic in soil as affected by cropping system and mineral fertilizers showed that cover crops were able to sustain maize production, and to protect soils from nitrogen and phosphorus depletion.

Table 1: Maize grains yields (Mg.ha^{-1})

Treatments	First season		Second season		Year	
	Means	SD	Means	SD	Means	SD
MaN_0P_0	3.00 e	0.37	3.02 e	1.28	6.02 e	1.62
$MaN_{40}P_0$	4.98 cd	0.75	3.72 de	0.49	8.70 d	0.94
$MaN_{40}P_{30}$	5.35 cd	0.34	4.61 bcd	0.70	9.97 bcd	0.49
$MaN_{80}P_{30}$	6.16 abc	0.27	4.42 cd	0.67	10.58 abc	0.63
Mu N_0P_0	5.06 cd	1.00	4.84abcd	0.69	9.89 bcd	0.95
Mu $N_{40}P_0$	5.61 bc	0.90	5.83 ab	0.27	11.43 ab	1.04
Mu $N_{40}P_{30}$	6.83 a	0.26	5.83 ab	0.57	12.66 a	0.60
Mu $N_{80}P_{30}$	6.68 ab	0.34	5,85 a	0.58	12.53 a	0.58
Ca N_0P_0	4.31 d	0.25	5.26 abc	0.64	9.57 cd	0.57
Ca $N_{40}P_0$	5.64 bc	0.69	5.38 abc	0.44	11.01 abc	1.11
Ca $N_{40}P_{30}$	5.73 abc	1.05	5.42 abc	0.28	11.15 abc	1.26
Ca $N_{80}P_{30}$	5.92 abc	0.51	5.45 abc	0.38	11.37 ab	0.59

SD: Standard Deviation;

a, b, c, d, e indicated class of means values as segregated by statistical analysis with α = 5%.
MaNxPy = continuous maize system with application of x N quantity and y P quantity
MuNxPy = maize-mucuna system with application of x N quantity and y P quantity
CaNxPy = maize-pigeon pea system with application of x N quantity and y P quantity

Table 2: Components of maize grains yields

Treatments	**First season**				**Second season**				**1000 grains weight**
	Prodty 14%	**Straw yield**	**HI**	**GSR**	**Prodty 14%**	**Straw yield**	**HI**	**GSR**	
Units	*g.plt^{-1}*	*Mg.ha^{-1}*			*g.plt^{-1}*	*Mg.ha^{-1}*			g
MaN_0P_0	60.0 e	4.60	0.32	0.47	60.0 e	5.30	0.34	0.57	250.0
$MaN_{40}P_0$	100.0 cd	5.20	0.48	0.93	74.0 de	6.00	0.35	0.55	279.0
$MaN_{40}P_{30}$	107.0 cd	6.70	0.39	0.75	92.0bcd	5.30	0.48	1.23	267.0
$MaN_{80}P_{30}$	123.0abc	6.80	0.44	0.82	88.0 cd	6.70	0.38	0.63	281.0
Means	97.5	5.83	0.41	0.74	78.50	5.83	0.39	0.75	269.3
SD	26.8	1.10	0.07	0.20	14.55	0.67	0.06	0.33	14.2
Mu N_0P_0	101.0 cd	6.50	0.46	0.88	97.0abcd	11.10	0.27	0.38	262.0
Mu $N_{40}P_0$	112.0 bc	10.60	0.30	0.43	117.0 ab	9.00	0.36	0.56	286.0
Mu $N_{40}P_{30}$	137.0 a	6.10	0.42	0.79	117.0 ab	9.70	0.37	0.62	300.0
Mu $N_{80}P_{30}$	134,0 ab	8.90	0.37	0.59	117.0 a	9.70	0.34	0.52	299.0
Means	121.0	8.03	0.39	0.67	112.0	9.88	0.34	0.52	286.8
SD	17.4	2.12	0.07	0.20	10.0	0.88	0.05	0.10	17.7
Ca N_0P_0	86.0 d	6.20	0.35	0.54	105.0 abc	7.00	0.43	0.84	271.0
Ca $N_{40}P_0$	113.0 bc	8.50	0.32	0.47	108.0 abc	8.40	0.36	0.55	299.0
Ca $N_{40}P_{30}$	115.0abc	8.00	0.32	0.59	108.0 abc	7.40	0.39	0.63	293.0
Ca $N_{80}P_{30}$	118.0abc	9.50	0.40	0.66	109.0 abc	6.50	0.42	0.73	299.0
Means	108.0	8.05	0.35	0.57	107.5	7.33	0.40	0.69	290.5
SD	14.8	1.38	0.04	0.08	1.73	0.81	0.03	0.13	13.3
Means	108.8	7.30	0.38	0.66	99.33	7.68	0.37	0.65	282.2
SD	20.9	1.80	0.06	0.17	18.06	1.89	0.05	0.21	16.8

SD: Standard Deviation; Prodty: productivity, HI: harvest index, GSR: grain - straw ratio
a, b, c, d, e indicated class of means values as segregated by statistical analysis with α = 5%.

Table 3: Agronomic Efficiency and Water Use Efficiency

Treatments	First season			Second season		
	WUE	AE-N	AE-P	WUE	AE-N	AE-P
Units	*kg.m^{-3}*	*Mg.ha^{-1}*	*Mg.ha^{-1}*	*kg.m^{-3}*	*Mg.ha^{-1}*	*Mg.ha^{-1}*
MaN_0P_0	0.50			2.30		
$MaN_{40}P_0$	0.80	49.0		2.80	17.0	
$MaN_{40}P_{30}$	0.90	59.0	78.0	3.50	40.0	53.0
$MaN_{80}P_{30}$	1.00	79.0	105.0	3.30	35.0	47.0
Means	0.80	62.3	91.5	2.98	30.7	50.0
SD	0.22	15.3	19.1	0.54	12.1	4.2
Mu N_0P_0	0.90			3.60		
Mu $N_{40}P_0$	0.90	14.0		4.40	25.0	
Mu $N_{40}P_{30}$	1.20	44.0	59.0	4.40	25.0	33.0
Mu $N_{80}P_{30}$	1.10	41.0	54.0	4.40	25.0	34.0
Means	1.03	33.0	56.5	4.20	25.0	33.5
SD	0.15	16.5	3.5	0.40	0.0	0.7
Ca N_0P_0	0.70			4.00		
Ca $N_{40}P_0$	0.90	33.0		4.10	3.0	
Ca $N_{40}P_{30}$	1.00	36.0	48.0	4.10	4.0	5.0
Ca $N_{80}P_{30}$	1.00	40.0	54.0	4.10	5.0	6.0
Means	0.90	36.3	51.0	4.08	4.0	5.5
SD	0.14	3.5	4.2	0.05	1.0	0.7

Means	0.91	43.9	66.3	3.75	19,9	29.7
SD	0.18	17.9	21.6	0.67	13.6	20.2

WUE: water use efficiency, AE-N (P): agronomic efficiency of N (of P),
a, b, c, d, e indicated class of means values as segregated by statistical analysis with α = 5%.

Table 4: N and P partial balances at 0-60cm soil depths during the first season

		Nitrogen (N)					Phosphorus (P)			
Parameters		N_0P_0	$N_{40}P_0$	$N_{40}P_{30}$	$N_{80}P_{30}$		N_0P_0	$N_{40}P_0$	$N_{40}P_{30}$	$N_{80}P_{30}$
		$Kg.ha^{-1}$								
Continuous maize system										
Initial soil content (+)		45.2	45.2	45.2	45.2		262.1	262.1	262.1	262.1
Applied fertilizer (+)		0.0	40.0	40.0	80.0		0.0	0.0	30.0	30.0
N atmospheric deposition (+)		13.9	13.9	13.9	13.9		0.0	0.0	0.0	0.0
Final soil content (-)		59.9	19.5	20.3	26.0		251.1	218.6	221.4	254.8
Exportations (-)		112.2	85.1	78.0	108.4		55.9	36.8	35.8	52.7
Sold		*-140.7*	*-33.3*	*-27.0*	*-23.1*		*-44.9*	*6.7*	*34.9*	*-15.4*
Loss related to initial content		*93%*					*10%*			
Maize-mucuna system										
Initial soil content (+)		91.5	91.5	91.5	91.5		278.0	278.0	278.0	278.0
Applied fertilizer (+)		0.0	40.0	40.0	80.0		0.0	0.0	30.0	30.0
N atmospheric deposition (+)		13.9	13.9	13.9	13.9		0.0	0.0	0.0	0.0
Final soil content (-)		13.3	4.8	16.2	20.6		247.4	196.0	266.4	208.5
Exportations (-)		115.2	142.7	128.5	179.8		45.2	65.1	53.9	69.1
Sold		*-51.0*	*-30.0*	*-27.1*	*-42.9*		*-14.6*	*16.9*	*-12.3*	*30.4*
Loss related to initial content		*26%*					*7%*			
Maize-pigeon pea system										
Initial soil content (+)		83.5	83.5	83.5	83.5		279.9	279.9	279.9	279.9
Applied fertilizer (+)		0.0	40.0	40.0	80.0		0.0	0.0	30.0	30.0
N atmospheric deposition (+)		13.9	13.9	13.9	13.9		0.0	0.0	0.0	0.0
Final soil content (-)		12.2	12.0	9.4	27.8		233.9	310.5	306.8	256.0
Exportations (-)		128.0	97.6	136.9	137.1		47.8	39.8	56.7	53.2
Sold		*-70.6*	*0.1*	*-36.6*	*-15.3*		*-1.9*	*-70.5*	*-53.7*	*0.7*
Loss related to initial content		*28%*					*11%*			

(+) inputs; (-) outputs

DISCUSSION

The maize grain yield decreased in second season was due to rainfall difference between FS (504 mm) and SS (115 mm). It confirmed the potential yields difference between the big rains season and the small one observed by Sogbedji (1986)[23]. The low yield obtained in FS (5.06 $Mg.ha^{-1}$) and in SS (4.84 $Mg.ha^{-1}$) in maize-mucuna system was distinctly superior to maize grain yield obtained in Malawi (1.2 $Mg.ha^{-1}$) in maize-mucuna relay system[14,20]. Maize grain yield increase (38-57%) generated by mucuna use as a cover crop in this study confirmed the general tendency to yield rise by mucuna observed by some authors as Hulugalle and Lal, (1986)[11], IFDC (1993)[12] and Breman and van Reuler (2000)[4] which communicated 50% increased; IFDC (2002)[13] gave 16-67%, Lamboni (2000)[17] talked about 25% and Sogbedji *et al*. (2006a)[24] revealed 32.1-37.5%.The dry straw yield obtained in this study represented an important dry biomass for a various non-food uses such as energy production and others. It represented also a lot of mulch for soil amendment as suggested Franzluebbers *et al.* (1998)[8]. Concerning GSR, the same values observed in the two cropping season was in contradiction with Hay (1995) results which showed that, vegetation length during FS and during SS influenced cereals GSR such as maize and rice. HI values obtained in this study confirmed IFDC (2002)[13] findings which gave a value ranged from 0.37 to 0.50 for maize. The positive correlation observed between HI and maize plant productivity indicated that HI and maize plant productivity had an expressive influence on maize grain yield formation.

Nitrogen agronomic efficiency (AE-N) in continuous maize system data were superior to those published by IFDC (2002)[13] where AE-N varied from 4 to 17 $Mg.ha^{-1}$ for maize-mucuna ordinary relay. The FS climatic conditions encouraged N and P better use than the SS. The variance between water use efficiencies then N and P agronomic efficiencies confirmed the potential production dissimilarities of rainfall in the two rainy seasons with bimodal character in sub-humid Africa described by Sogbedji *et al.* (2006a)[24].

The influence of the three cropping system on N balance in the soil was in agree with Sogbedji *et al.* (2006a)[24] findings in Togolese ferralitic soil, who stipulated that mucuna and pigeon pea increased soil NO_3-N rate by 39% and 3.6% respectively while maize monoculture made system lost 57.8% NO_3-N after some years. Mucuna cover crop seems to be more favourable for soil P status improvement. It also agrees with Sogbedji *et al.* (2006a)[24] who indicated that maize-mucuna system encouraged vestigial available P rate increase at least by 50% and 53% respectively compared with continuous maize system and maize-pigeon pea system.

CONCLUSION

The three cropping systems tested had different effects on maize grain production. In the overall system, the maize-mucuna cropping system allowed to produce the best maize grain yield and permitted a better resource use (water use; N and P agronomic efficiencies). Using mucuna cover crop alone instead of mineral fertilizer alone could be benefit for maize grain production and for environmental sustainability. The three cropping systems had no influence on maize harvest index, grain straw ratio and 1000 grains weight. Mucuna contributed to enhance soil N and P content more than pigeon pea whereas maize monoculture destroyed soil reserves as showed the nutrient partial budget established. Therefore, maize-mucuna atypical relay (maize-mucuna system) seems to be the best approach to produce high maize grain yield and to reduce soil nutrients depletion.

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