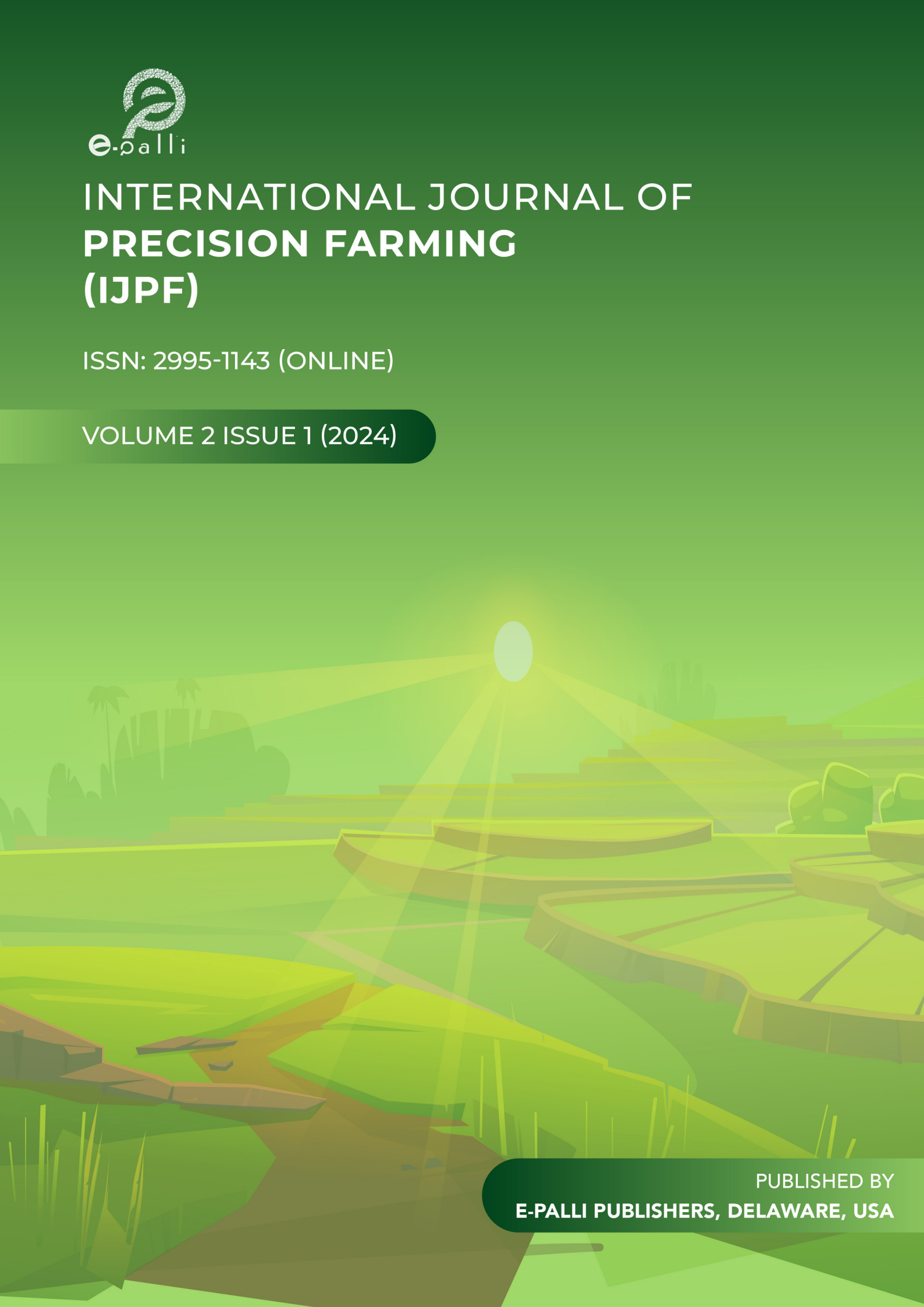

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Modelling Nutrient Flows and Economic Performance in Cotton-Based Farming Systems in Three Regions of Togo: Application of the NUTMON Model

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ABSTRACT

In order to assess the impact of farm management practices on soil fertility, 30 cotton-based farms were randomly selected and monitored in Togo during the growing seasons of the years 2023/2024 in the Savanes, Plateaux-Nord and Maritime regions of Togo. The data collected were analyzed using the "NUtrient MONitoring" (NUTMON) model. The results showed that the mineral Nitrogen balance was positive in 90%, 60% and 33% of farms in the Plateaux-Nord, Maritime and Savanes regions, respectively. The Phosphorus balance was positive in 50%, 11% and 10% in the Maritime, Plateaux-Nord and Savanes regions, whereas the potassium balance was positive in 30%, 20% in the Maritime and Plateaux-Nord. The average partial mineral balance on cotton plots was negative for N (-12.39 kg/ha), P (- 8.78 kg/ha) and K (-17.1 kg/ha) in the Savanes region; positive for N (+10.63 kg/ha) and negative for P (- 4.76 kg/ha) and K (- 2.69 kg/ha) in the Plateaux-Nord; positive for N (+ 2.19 kg/ha) and P (+19.0 kg/ha) but negative for K (-5.2 kg/ha) in the Maritime. Net Operating Income was relatively low in the three regions, denoting a low level of profitability. Knowledge of the flow of each element in the soil that shelters the cotton allowed for suggestions to producers on the order of succession of crops in rotation. It allowed to indicate the site-specific quantities of each nutrient to be provided to the crops that follow the cotton, in order to guarantee the sustainability of cotton-based cropping systems.

INTRODUCTION

In sub-Saharan Africa, cultivated soils are in permanent degradation (Sanchez *et al.,* 1997; Amonmidé *et al.,* 2021). This degradation is manifested through the decline in C and mineral stocks and soil acidification (Hien, 2004; Deen & Kataki, 2003; Kintche, 2011) and is one of the causes of declining field yields.

In Togo, Kintche (2011) demonstrated that the degradation of cultivated soils, particularly those used in cotton cultivation, is primarily attributed to various inappropriate cultivation practices. These practices are characterized by continuous cultivation without fallow, with zero or low input of mineral fertilizer and removal of harvest residues (Kintche, 2011). Even the input of only high doses of mineral fertilizer in continuous cultivation also contributes to soil degradation (Kintche, 2011). The consequences of these practices are the decline in field yields and the quality of agricultural products.

A quantitative assessment of the flow of key plant nutrients is valuable for designing sustainable nutrient management strategies (Roy *et al.,* 2005). In Togo, no study has yet been conducted to assess nutrient flows on farms, including cotton farms, using the NUTMON model. The objective of this study was to establish the partial and economic mineral balance of cotton-based farms in order to formulate better recommendations to producers.

MATERIAL AND METHODS

Study area

The study was conducted in the Savannah, Plateaux-Nord and Maritime regions on 30 farms, ten per region (Figure 1). These three regions were characterized by different agro-climatic conditions. In the Savannah region, there is a tropical Sudanian climate with a single rainy season (1000 to 1100 mm/year) from May to October and a dry season from November to April. In the Plateaux-Nord and Maritime regions, there is a subequatorial regime with two rainy seasons (1200 to 1700 mm per year) whose duration is very variable (March to mid-July for the main rainy season and from mid-September to November for the short rainy season).

Choice of Sites And Producers

The study was conducted in the Savanes, Plateaux-Nord and Maritime regions in 30 farms, ten farms per region chosen randomly using the method of Zuo-Rui *et al.* (1986). These three regions were chosen because of their very contrasting pedoclimatic conditions and for the observation of several symptoms of cotton deficiency.

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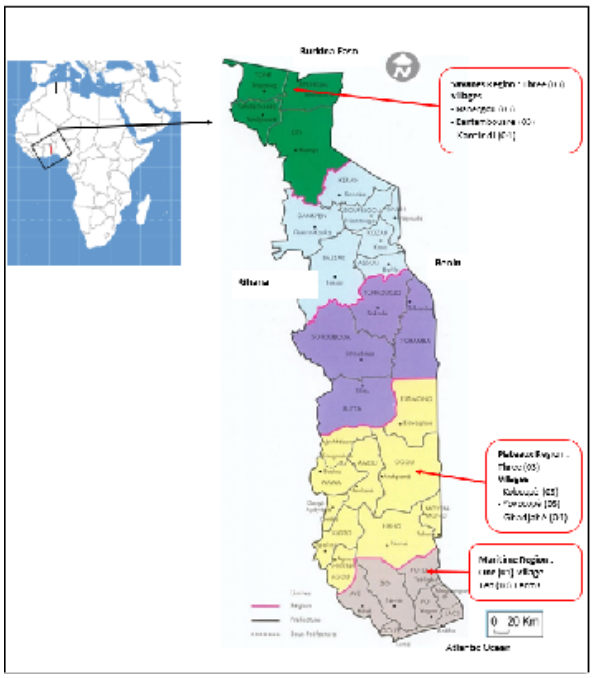

Figure 1: Map of Togo showing the study areas

In each region, ten (10) producers were selected in consultation with the supervision department of the New Cotton Society of Togo (NSCT). The selection criteria were as follows: (i) be cotton growers and (ii) respect good agricultural production practices.

Inventory and Monitoring of Farms

Once the producers were selected, an inventory questionnaire was administered to them for a general characterization of their operation. These surveys made it possible to determine, according to the methodology of the model, NUTMON Toolbox version 3.6, the Farm Division Units (FDUs), the Primary Production Units (PPUs), the Secondary Production Units (SPUs) and the Redistribution Units (RUs) of each farm (De Jager *et al.,* 1998; Roy *et al.,* 2005).

The inventory survey was carried out from October 2023 to January 2024. The follow-up survey followed the inventory survey. It focused on collecting data on incoming flows (fertilizer, manure, incorporated crop residues, etc.) and outgoing flows (exported crop residues, cotton sold, etc.) from the different blocks of farms during the same period. Two (02) follow-ups were carried out per farm and carried out in the middle and end of the agricultural season.

Statistical Analysis of Data

The data were entered and analyzed using the NUTMON model. The parameters analyzed were the partial balance of macronutrients such as Nitrogen (N), Phosphorus (P) and Potassium (K) and the Net Operating Income (NOI) or Cash flow.

RESULTS AND DISCUSSION

Results

Monitoring of agricultural holdings (NUTMON)

Chemical characteristics of soils before sowing and at harvest

Soil analysis results show that at sowing, the average pH of the different cotton plots was lower in Nanergou than at the other sites (Table 1). This low pH is explained by the presence of H+ ions in these soils. The organic carbon level was very low at all sites at the time of sowing (0.4% to 0.8%). The total nitrogen content was higher on the Kolokopé plots and lower on the Kantidi plots. However, the highest total phosphorus content was observed on the Kantidi plots. In terms of particle size, the analysis results show that the soils at the different sites were sandy with low proportions of clay.

Furthermore, the results of soil analysis taken after the cotton harvest showed an increase in organic carbon content in the cotton plots of Gbadjahè and Yovokopé

Table 1: Average chemical characteristics of soils in non-cultivated plots of study sites after harvest

Characteristics		Gbadjahe	Kantindi			Kolokope		Nanergou		Yovokope	
Granulometry		**P1**	**P1**	**P2**	**P3**	**P3**	**P6**	**P1**	**P2**	**P5**	**P7**
Coarse sand (2000- 200µm)	%	40,24	29,28	34,99	34,00	28,11	26,12	41,66	46,48	21,56	46,55
Fine sand (200-50µm)		40,45	46,46	29,97	25,81	48,42	56,84	37,59	33,59	57,18	36,85
Coarse silt (<50µm)		5,25	7,91	6,21	7,63	6,57	6,44	10,58	13,73	11,68	4,11
Fine silt (<20µm)		4,6	7,39	6,18	7,63	5,59	3,79	5,21	19,37	2,96	3,80
Clay (<2µm)		9,46	8,85	22,66	7,63	11,30	6,81	4,96	14,29	6,63	8,69
N-total	mg/kg	498,75	405,00	545,45	443,18	825,00	517,50	348,75	886,36	375,00	562,50
P-total		322,65	469,97	333,60	523,54	421,27	373,78	301,95	390,83	312,91	332,39
P-Brayl		3,12	3,57	2,65	3,02	8,64	4,91	4,91	4,68	3,31	3,12
K-total	%	0,10	0,28	0,25	0,35	0,17	0,09	0,10	0,13	0,06	0,09

Organic-Carbon	%	0,65	0,37	0,49	0,47	1,13	À?55	0,38	0,72	0,54	0,64
Na^+	cmol /kg	0,05	0,07	0,14	0,12	0,05	0,05	0,10	0,05	0,21	0,05
K^+		0,12	0,15	0,14	0,09	0,38	0,14	0,14	0,10	0,10	0,10
Ca^{2+}		4,12	4,38	5,96	5,73	8,04	3,12	2,83	5,46	2,90	2,82
Mg^{2+}		1,87	1,65	1,69	1,90	1,92	1,51	0,38	1,73	1,84	1,55
CEC-Ag		7,16	5,86	8,70	8,84	8,37	4,39	2,63	6,10	6,47	3,95
H^+	cmol/kg	0,03	0,03	0,04	0,05	0,04	0,04	0,08	0,05	0,03	0,06
$A1^{3+}$		=	ff	If	.	If	If	If	=	=	If
pH-H_2O		6,25	6,14	6,35	6,40	6,77	5,57	5,50	5,93	6,55	5,65
pH-KCl		5,42	5,01	5,05	4,81	5,94	4,87	4,74	5,29	5,32	4,90

(Northern Plateau) and a decrease in this element in the other sites (Table 2). The mineral N balance was positive in the cotton plots of Gbadjahè and Yovokopé, and negative in the other sites. The mineral P balance was positive in the cotton plots of Gbadjahè Kantidi and Yovokopé, and negative in the other sites.

Table 2: Average chemical characteristics of soils in non-cultivated plots of study sites after harvest

Characteristics		**Gbadjahe**	**Kantindi**			**Kolokope**		**Nanergou**		**Yovokope**	
Granulometry		**P1**	**P1**	**P2**	**P3**	**P3**	**P6**	**P1**	**P2**	**P5**	**P7**
Coarse sand (2000- 200µm)	%	39,67	47,59	45,97	27,06	31,18	50,78	46,46	39,65	23,82	41,50
Fine sand (200-50µm)		38,55	33,01	32,84	53,55	54,45	33,23	35,85	37,28	45,75	40,58
Coarse silt (<50µm)		5,61	3,94	5,14	7,42	6,08	7,85	9,21	12,66	8,27	4,47
Fine silt (<20µm)		5,28	6,02	6,01	4,27	2,84	4,04	4,14	5,33	6,59	3,54
Clay (<2µm)		10,89	9,44	10,04	7,70	5,45	4,10	4,34	5,07	15,57	9,92
N-total	mg/kg	780,00	292,50	375,00	517,50	386,25	367,50	306,82	375,00	480,00	498,75
P-total		362,83	282,47	653,81	413,96	342,13	314,12	295,86	338,47	343,34	328,73
P-Brayl		4,82	3,97	12,56	22,01	8,74	6,42	9,16	5,20	3,02	3,45
K-total	%	0,11	0,30	0,57	0,11	0,09	0,09	0,08	0,09	0,08	0,12
Organic-Carbon	%	0,98	0,31	0,33	0,71	0,38	0,37	0,16	0,41	0,68	0,69
Na^+	cmol"/kg	0,06	0,08	0,09	0,05	0,04	0,06	0,05	0,06	0,11	0,10
K^+		0,30	0,12	0,09	0,32	0,20	0,16	0,09	0,14	0,08	0,22
Ca^{2+}		6,36	5,00	1,47	5,80	1,51	1,09	1,65	1,37	6,16	3,33
Mg^{2+}		2,11	2,14	2,31	1,73	0,98	0,46	0,49	1,21	3,13	1,62
CEC-Ag		8,14	6,75	6,95	6,73	2,69	2,17	3,02	2,35	8,66	4,60
H+	cmol/kg	0,04	0,05	0,08	0,03	0,06	0,04	0,07	0,03	0,03	0,04
$A1^{3+}$		ff	ff	0,03	.	If	If	If	If	=	=
pH-H_2O		6,43	5,84	5,88	6,34	5,37	6,11	5,47	6,08	6,41	6,01
pH-KCl		5,56	4,70	4,42	5,65	4,70	5,43	4,86	5,40	5,30	5,20

Characteristics of the Farms

In the Plateaux-Nord and Maritime regions, the producers' working tools are 100% rudimentary (hoe, daba and machete) (Figure 2). However, in the Savanes where livestock farming is often practiced, we noted that 40% of farms practice animal traction compared to 60% that practice traditional agriculture characterized by the use of rudimentary tools.

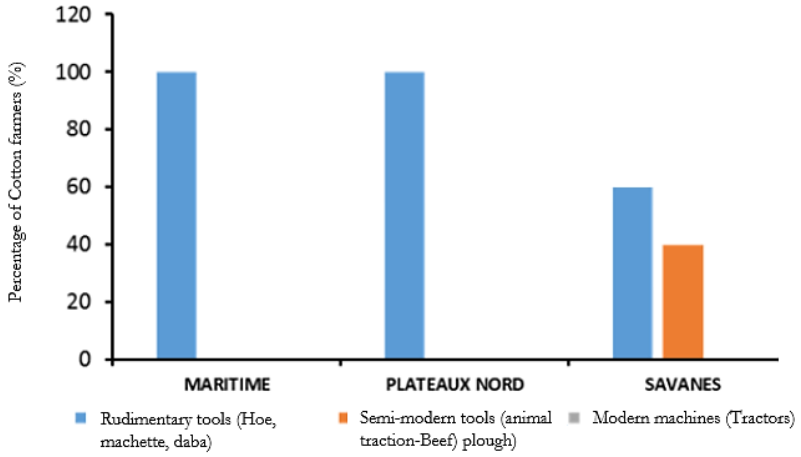

Figure 2: Level of equipment of farms according to the different study regions

Household Structure and Cultivated Area

The demographic structure of households and the cultivated area vary from one region to another. In the Maritime region, farms have an average number of active workers equal to 5 ± 2, of which 55 ± 9.7% are women, and farm an average area of 3.95 ± 1.46 ha (Table 3).

Table 3: Total areas, number of active workers, active rate and rate of active women per farm in the Maritime region

Producers	Total area (ha)	Number of assets	Asset rate (%)	Rate of active women (%)
TGPM01	4.00	10	77	40
TGPM02	2.50	5	63	40
TGPM03	3.00	3	50	67
TGPM04	5.25	4	44	75
TGPM05	4.50	3	50	67
TGPM06	3.75	4	50	75
TGPM07	6.75	6	60	67
TGPM08	5.00	5	56	20
TGPM09	2.75	5	45	60
TGPM10	2.00	5	56	40
Average	3.95± 1.46	5.00 ± 2.00	55.04 ± 9.66	55.00 ± 18.66

In the Plateaux region, farms have an average number of active workers equal to 5.20 ± 1.87, of which 56.00 ± 16.31% are women, and operate on average an area of 4.50 ± 1.32 ha (table 4).

In the Savanes region, farms have an average number of active workers equal to 7.20 ± 2.66 (i.e. 69.23% of the household size) of which 47.58 ± 15.9% are women and operate on average an area of 5.16 ± 3.84 ha (Table 5).

Level of Education of The Head of Household

In the Plateaux Nord region, 70%, 20% and 10% of respondents had a primary, post-primary and secondary education level respectively (Figure 3a).

In the Plateaux Nord region, 50% of respondents were uneducated while 30% and 20% had primary and secondary education respectively (Figure 3b).

In the Northern Plateaux region, 10% were uneducated; 50%, 30% and 10% of respondents had primary, secondary and post-primary education respectively (Figure 3c).

Livestock Per Household

In the Maritime region, the farms surveyed do not raise animals (Table 6). In the Plateaux region, we counted an average of 5 goats and 32 poultry per household. In the Savanes region, we counted an average of 10 cattle, 15 sheep, 7 goats and 43 poultry per household.

Nutrient Balance (N, P, K)

Cotton Plots

The results show that the mineral balance and the method of managing soil fertility in cotton plots vary from one

Table 4: Total areas, number of active workers, active rate and rate of active women per farm in the Plateau/Nord region

Producers	Total area (ha)	Number of assets	Asset rate (%)	Rate of active women (%)
TGPN01	5.50	5	83	60
TGPN02	4.38	5	56	60
TGPN03	3.94	4	57	50
TGPN04	6.75	4	57	50
TGPN05	4.13	5	71	80
TGPN06	4.00	3	60	67
TGPN07	4.88	6	86	33
TGPN08	2.50	10	71	40
TGPN09	2.89	5	83	40
TGPN10	6.00	5	71	80
Average	4.50 ± 1.32	5.20 ± 1.87	69.65 ± 11.77	56.00 ± 16.31

Table 5: Total areas, number of active people, active rate and rate of active women per farm in the Savanes region.

Producers (P)	Total area (ha)	Number of assets	Asset rate (%)	Rate of active women (%)
TGPM01	2.25	7	58	71
TGPM02	2.00	2	40	50
TGPM03	1.88	6	67	50
TGPM04	6.20	12	80	50
TGPM05	7.75	7	64	57
TGPM06	8.75	5	50	20
TGPM07	0.50	9	90	44
TGPM08	12.50	7	64	29
TGPM09	2.98	9	100	67
TGPM10	6.75	8	80	38
Average	5,16 ± 3,84	7,20 ± 2,66	69,23 ± 18,33	47,6±15,90

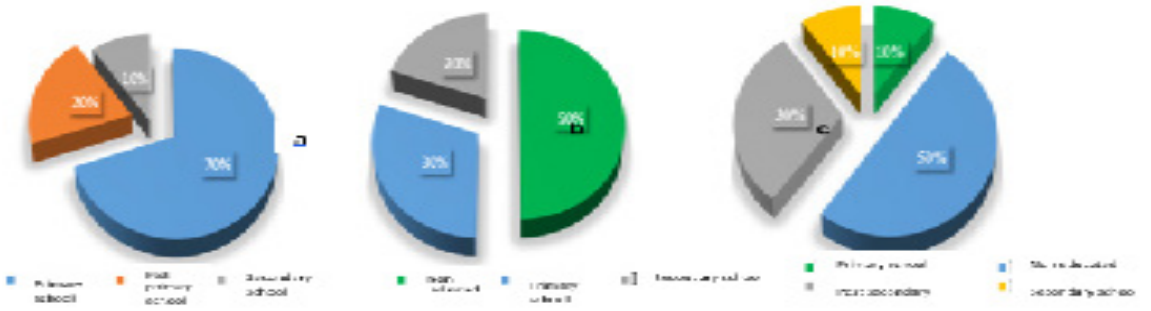

Figure 3: Levels of education of heads of households on farms studied in the Plateaux Nord (a), Maritime (b) and Savanes (c) regions.

region to another.

In the Maritime region, the area cultivated with cotton was 2.3 ha on average, for an average yield of 1110.75 kg/ha (Table 7). The mineral balance on the cotton plots was positive for NP and negative for K (Figure 4). The NPK SB fertilizer and urea applications were made at the respective average doses of 147.83 kg/ha and 42.39 kg/ha (Table 7). Cotton stalk residues were not exported from the plot.

In the Plateaux region, the area cultivated with cotton was 1.35 ha on average, for an average yield of 937.42 kg/ha (Table 8). The mineral balance on the cotton plots was positive for N, and negative for the PK (Figure 4). The contributions of NPKSB fertilizers and urea were applied at the respective average doses of 125.26 kg/ha and 45 kg/ha (Table 8). Cotton stalk residues were not removed from the plot.

In the Savannah region, the average area cultivated with cotton was 1.02 ha on average, for an average yield of 957.15 kg/ha (Table 9). The mineral balance on the cotton plots was negative for the NPK (Figure 4). The NPKSB fertilizer and urea were applied at the respective

Table 6: Number of types of animals on the farm

Region	Bovine	Sheep	Goat	Poultry
Maritime	0	0	0	0
Plateaux-Nord	0	0	5	32
Savanes	10	15	7	43
Average	3	5	4	25

Table 7: Area, cotton seed yield, partial N, P and K balance of plots, quantity of fertilizer applied and method of residue management on cotton plots in the Maritime region.

Producers (P)	Area (ha)	Cotton seed yield (kg/ha)	Partial balance (kg/ha)			Fertilization (kg/ha)		
			N	P	K	NPKSB	Urea	OF
P 1	2,50	600,00	3,60	48,30	0,40	100,00	40	0
P 2	1,00	1831,00	-32,20	-16,30	-15,20	150,00	50	0
P 3	1?50	1066,67	-19,10	-12,60	-12,40	200,00	17	0
P 4	3,00	1411,67	6,90	-12,30	-11,40	150,00	50	0
P 5	2,00	802,50	-6,40	25,60	-2,10	150,00	50	0
P 6	1,50	1207,33	30,20	53,90	-0,60	200,00	0	0
P 7	5,00	1599,80	-9,90	-15,40	-14,60	150,00	50	0
P 8	3,50	476,86	1,30	-6,70	-6,80	128,57	43	0
P 9	2,00	789,50	31,90	33,50	3,40	150,00	50	0
P 10	1,00	1716,00	12,60	92	3,60	150,00	50	0
Average	2,30	1110,65	2,19	10,00	-5,57	147,83	42,39	0,00
Standard deviation	1,19	455,13	18,81	35,38	7,02	18,07	17,00	0,00

Table 8: Area, cotton seed yield, partial N, P and K balance of plots, quantity of fertilizer applied and method of residues management on cotton plots in the Plateaux/Nord region

Producers (P)	Area (ha)	Cotton seed yield (kg/ha)	Partial balance (kg/ha)			Fertilization (kg/ha)		
			N	P	K	NPKSB	Urea	OF
P 1	0,75	1000,00	30,7	0	0	133,33	50	0
P 2	1,88	800,00	24	7	10	80,00	50	0
P 3	1,25	426,40	11,2	-3,7	-3,5	120,00	50	0
P 4	2,00	572,50	1,9	-5	-4,6	75,00	50	0
P 5	1,00	1000,00	10,1	-7,9	-2,6	150,00	50	0
P 6	1,25	768,00	0,7	-5,6	-5,2	120,00	50	0
P 7	0,75	1397,33	18,9	-6,1	-5,7	200,00	50	0
P 8	0,50	2224,00	8,6	-19,4	-18	200,00	50	0
P 9	2,04	461,27	7,4	-2	-1,9	49,02	50	0
P 10	2,13	724,71	-7,2	-4,9	,6		0	0
Average	1,35	937,42	10,63	-4,76	-2,69	125,26	45,00	0,00
Standard deviation	0,58	508,77	10,76	6,30	6,90	49,77	15,00	0,00

average doses of 151.48 kg/ha and 29.32 kg/ha (Table 9). Cotton stalk residues were removed from the plot.

Corn plots

The partial mineral balance on corn plots in the Maritime region was positive for NP and negative for K (Table 10). The NPK and urea application rates averaged 26.32 kg/ha and 10.44 kg/ha, respectively. The average corn area sown was 3.63 ha for an average yield of 499.7 kg/ha. Cotton stalk residues were not removed from the plot.

Table 9: Area, cotton seed yield, partial N, P and K balance of plots, quantity of fertilizer applied and method of residue management on cotton plots in the Savanes region

Producers (P)	Area (ha)	Cotton seed yield (kg/ha)	Partial balance (kg/ha)			Fertilization (kg/ha)			Waste management
			N	P	K	NPKSB	Urea	OF	
P 1	0,25	1172,00	-19	75,8	-2,1	0,00	0	0	Export
P 2	0,17	4729,41	-11,9	-41,3	-38,3	441,18	147	0	Export
P 3	0,50	2010,00	-33,8	-17,5	È16,3	200,00	0	0	Export
P 4	2,75	545,45	24,5	-8,4	-15,9	118,18	45	0	Export
P 5	0,75	1233,33	9,9	-10,8	-10	133,33	67	0	Export
P 6	5,00	840,00	-3	-6,7	-6,2	150,00	10	0	Export
P 7	0,06	6400,00	-108	-55,9	-51,8	180,00	0	0	Export
P 8									
P 9	0,75	889,33	15,7	-7,8	-7,2	200,00	67	0	Export
P 10	0,88	734,09	13,8	-6,4	-5,9	170,45	57	0	Export
Average	1,02	957,14	-12,39	-8,78	-17,08	141,48	29,32	0,00	
Standard deviation	1,53	1953,53	38,02	34,19	15,89	224,53	46,00	0,00	

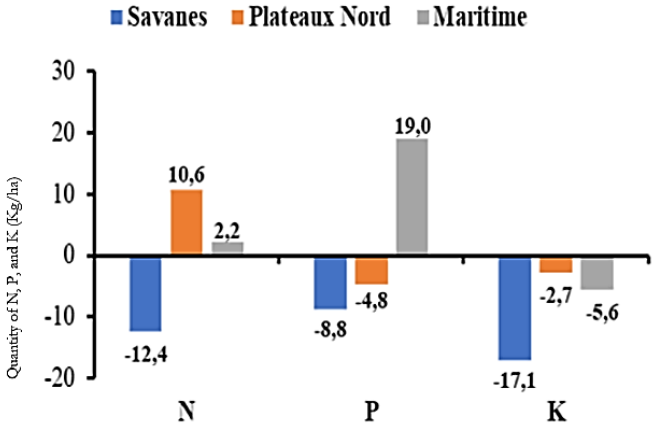

Figure 4: Average partial balance in N, P and K of cotton plots in the Savanes, Plateaux Nord and Maritime regions

Table 10: Area, cotton seed yield, partial N, P and K balance of plots quantity of fertilizer applied and method of residue management on cotton plots in the Maritime region

Producers (P)	Area (ha)	Cotton seed yield (kg/ha)	Partial balance (kg/ha)			Fertilization (kg/ha)		
			N	P	K	NPK	Urea	OF
P1	3,50	1161,60	3,60	48,3	0,40	57,14	29	0
P2	2,50	92,40	-12,20	-5,70	5,67	0,00	0	0
P3	3,00	924,00	9,20	-5,30	-6,80	16,67	8	0
P4	5,00	0,00	1,95	-6,70	-6,10	0,00	0	0
P5	4,25	195,67	-1,85	29,45	1,60	47,06	12	0
P6	3,25	540,18	21,73	60,47	5,47	92,31	31	0
P7	6,75	410,67	21,07	-10	-10,80	0,00	0	0
P8	5,00	702,24	-5,15	-4,90	-5	0,00	0,00	0,00
P9	2,00	693,00	31, 90	33,50	3,40	50,00	25,00	0,00

P10	1,00	277,20	12,60	92	3,60	0,00	0	0
Average	3,63	499,70	8,29	23,11	-0,86	26,32	10,44	0,00
Standard deviation	1,59	355,48	12,99	33,66	5,55	31,39	12,00	0,00

In the Northern Plateaux region, the area cultivated with maize was 1.8 ha on average, for an average yield of 846.24 kg/ha (Table 11). The mineral balance on the maize plots was negative for N, P and K (Figure 11). NPK and urea fertilizer inputs were zero. Cotton stalk residues were not exported from the plot.

Table 11: Area, cotton seed yield, partial N, P and K balance of plots quantity of fertilizer applied and method of residue management on cotton plots in the Plateaux Nord region

Producers (P)	**Area (ha)**	**Cotton seed yield (kg/ha)**	**Partial balance (kg/ha)**			**Fertilization (kg/ha)**		
			N	**P**	**K**	**NPK**	**Urea**	**OF**
P1	3,00	1355,20	520	-5,80	-6,80	0,00	0	0
P2	1,25	308,00	-6,90	-2	-1,90	0,00	0	0
P3	2,00	1232,00	-8,70	-5,90	-2,77	0,00	0	0
P4	1,50	1440,00	-15,8	-3,85	‘4,40	0,00	0	0
P5	2,75	862,40	-9,50	-2,50	1,80	0,00	0	0
P6	2,38	492,80	-14,9	-3,60	-4,48	0,00	0	0
P7	1,50	492,80	-40	-1,50	-1	0,00	0	0
P8	2,25	862,40	-5,43	-1,50	-1,70	0,00	0	0
P9	0,09	184,80	-15	-5,45	-4,38	0,00	0	0
P10	1,25	1232,00	-8,70	-5,9	-2,77	0,00	0	0
Average	1,80	846,24	8,36	-3,80	-2,84	0,00	0,00	0,00
Standard deviation	0,81	434,37	0,97	1,76	2,24	0,00	0,00	0,00

In the Savannah region, the average area cultivated with maize was 2.32 ha, for an average yield of 1366.35 kg/ha (Table 12). The mineral balance on the maize plots was positive for N, P and K (Figure 8). NPK fertilizer and urea were applied with average doses of 227.51 kg/ha and 78.57 kg/ha, respectively. Maize stalk residues were not removed from the plot.

Table 12: Area, cotton seed yield, partial N, P and K balance of plots quantity of fertilizer applied and method of residue management on cotton plots in the Savanes region

Producers (P)	**Area (ha)**	**Cotton seed yield (kg/ha)**	**Partial balance (kg/ha)**			**Fertilization (kg/ha)**		
			N	**P**	**K**	**NPK**	**Urea**	**OF**
P1	1,25	1108,80	4,55	92,25	12,70	180,00	60	0
P2	1,75	369,60	27,3	91,3	14,80	114,29	57	0
P3	0,75	1971,20	-35,7	-9,6	-9,80	0,00	0	0
P4	0,50	2772,00	54,08	92,2	36,10	400,00	100	0
P5	2,50	628,32	52,03	89,6	28	70,00	40	0
P6	3,00	462,00	17,5	71	20,33	133,33	50	0
P7	0,13	2956,80	77,5	188,6	88,60	600,00	200	0
P8	10,50	1012,00	48,7	116,2	27,96	200,00	100	2000
P9	-	-	-	-	-	-	-	-
P10	0,50	1016,40	91,6	145	63,9	350,00	100	0
Average	2,32	1366,35	37,54	77,39	31,40	227,51	78,57	222,22
Standard deviation	3,03	915,40	36,66	50,81	27,53	177,88	53,00	628,54

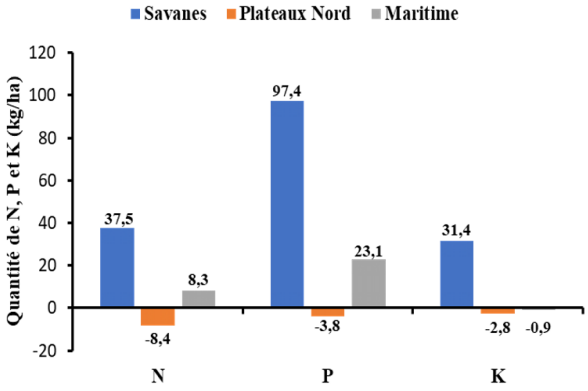

Figure 5: Average partial balance of N, P and K of corn plots in the Savanes, Plateaux Nord and Maritime regions.

Economic Performance of Farms

Average net farm incomes were positive in all regions (Table 13). On average, net incomes were 120,323 CFA francs, 67,575 CFA francs and 753,861 CFA francs respectively in the Maritime, Plateaux Nord and Savanes regions.

Table 13: Net income from ten farms in the Savanes, Plateaux Nord and Maritime regions

Producer (P)/Operation	Farm net cash-flow		
	Savanes	Plateaux-Nord	Maritime
P1	-101008	60198	865500
P2	150220	-144611	332730
P3	183500	-	724650
P4	70575	300945	1106000
P5	-1868	-97830	456719
P6	255150	32586	570530
P7	9650	41116	2199770
P8	1029575	250306	771670
P9	44210	-24835	252070
P10	-436770	190300	257980
Average	120323,40	67575,00	753861,90

Discussion

The results showed that the mineral balance of the cotton plots varied from one region to another. The nitrogen mineral balance was positive in 90%, 60% and 33% of the farms in the Plateaux-Nord, Maritime and Savanes regions respectively. Then, the phosphorus mineral balance was positive in 50%, 11% and 10% of the farms in the Maritime, Plateaux-Nord and Savanes regions respectively. Finally, the potassium mineral balance was positive in 30%, 20% and 0% of the farms in the Maritime, Plateaux-Nord and Savanes regions respectively.

In the Maritime region, nitrogen, phosphorus and potassium gains ranged from +1.3 kg/ha to 31 kg/ha, from +26 kg/ha to +92 kg/ha and from +0.4 kg/ha to +3.6 kg/ha, respectively. On the other hand, nitrogen, phosphorus and potassium losses ranged from -32 kg/ha to -7 kg/ha, from -16 kg/ha to -7 kg/ha and from -15 kg/ha to -0.6 kg/ha, respectively. NPKSB and urea fertilizers were applied at the respective average doses of 147.83 kg/ha and 42.39 kg/ha. Cotton stalk residues were not removed from the plot.

In the Plateaux region, gains in nitrogen, phosphorus and potassium varied respectively from +0.7 kg/ha to 30.7 kg/ha, from 0 kg/ha to +7 kg/ha and from 0 kg/ha to +10 kg/ha. On the other hand, losses in nitrogen, phosphorus and potassium were respectively -7,2 kg/ha, from -19.4 kg/ha to -2 kg/ha and from -18 kg/ha to -1.9 kg/ha. NPK SB fertilizer inputs, and urea were applied at the respective average doses of 125.26 kg/ha and 45 kg/ha. Cotton stalk residues were not removed from the plot.

In the Savannah region, nitrogen, phosphorus and potassium gains ranged from +9.9 kg/ha to 24.5 kg/ha, from +0 kg/ha to +75.8 kg/ha and from +0 kg/ha respectively. On the other hand, nitrogen, phosphorus and potassium losses ranged from -107.7 kg/ha to -3 kg/ha, from -155.9 kg/ha to -6.4 kg/ha and from -51.8 kg/ha to -2.1 kg/ha respectively. NPKSB and urea fertilizers were applied at the respective average doses of 151.48 kg/ha and 29.32 kg/ha. Cotton stalk residues were removed from the plot.

Nutrient losses from cotton plots were higher on farms in the Savannah region than on farms in the Maritime and

Plateaux-Nord regions. These high losses are largely due to the export of crop residues. Djagni (2007) reported that in the Savannah region of Togo, crop residues are systematically exported from plots to be used as livestock feed, firewood, and also in house roof repairs (especially for sorghum canes). Piéri (1989) showed that for 1000 kg/ha of seed cotton, the amounts of N, P, and K contained in the biomass are 36.5 kg/ha, 11.1 kg/ha, and 34.4 kg/ha, respectively. Other authors have also shown that the quantity of nutrients contained in cotton harvest residues is significant, hence the need to return them to the soil in order to limit its degradation (Carvalho *et al.,* 2011). Kintche (2011) showed that one of the causes of soil degradation in cotton cultivation in Togo and particularly in the Savannah region is the export of harvest residues.

The negative nutrient balance in some farms in the Maritime and Plateaux-Nord regions is due to the under-dosage of base and maintenance fertilizers. Indeed, 150 kg/ha of NPKSB (12-18-20-5-1) and 50 kg/ha of urea (46% N) are recommended for these regions, but the quantity provided by the producers surveyed is lower than that recommended by research and extension in Togo.

The positive nitrogen balance obtained in certain farms in different regions is explained by the symbiotic fixation of nitrogen by legumes (Danso, 1992; Roy *et al.,* 2005; Chikowo *et al.,* 2007) used as cotton crop predecessors (Maritime and Plateaux-Nord regions), nutrient residues from the application of fertilizer under the maize having preceded the cotton in the same year (Maritime) and by the application of manure (Savanes).

Knowledge of the mineral balance in cotton cultivation allows us to make recommendations to producers. For producers in the Savanes region, crop residues must be returned either directly or through composting. In other regions, the recommended fertilizer dose must be respected. For all regions, a legume must be sown on the cotton plot to improve the sustainability of the production system.

CONCLUSION

The objective of our study was to assess the health of cotton-growing soils in terms of essential nutrients and to establish the related economic benefits. At the end of this study, we found that on average the mineral balance in N, P and K was negative on farms in the Savanes region. In the Plateaux-Nord region, the average mineral balance was positive for N (+10.63 kg/ha) and negative for P (-4.76 kg/ha) and K (-2.69 kg/ha). Furthermore, in the Maritime region the average mineral balance was positive for N (+2.19 kg/ha) and P (+19.0 kg/ha) and negative for K (-5.2 kg/ha). The economic income or cash flows recorded at the farm level were relatively low in the three regions. These results confirm the current state of soil fertility in the savannah region characterized by continued poverty of fertility, and continuous loss of potassium in the Plateaux and Maritime regions of Togo. The popularization and compliance by producers of the proposed sustainable nutrient management strategies are becoming urgent to ensure sustainable intensification of cotton-based farming systems in Togo.

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