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COMPARATIVE ANALYSIS OF NUTRIENT LOSSES ON EXPERIMENTAL PLOTS UNDER CROPPING SYSTEM

Comparaison des pertes en substances nutritives de parcelles expérimentales sous divers types de cultures

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RESUME

Les pertes en substances nutritives sous différents couverts végétaux ont été mesurées dans des parcelles expérimentales et ont été mises en corrélation avec certaines caractéristiques des précipitations, l'importance du ruissellement et les quantités de sol érodé. Des parcelles expérimentales, trois ont été mises en culture: maïs seul, en culture hâtive et tardive; manioc et maïs puis manioc seul et enfin maïs avec cultures intercalaires traditionnelles (patate douce, okra nain, poivre doux). Des deux parcelles non cultivées, une a été dégagée de son couvert herbeux. Sur une période d'un an, les effets de 43 averses ont été observées. Un ruissellement retardé ne s'est produit que lors de 12 averses particulièrement fortes.

Les pertes en substances nutritives par mise en solution dans les eaux de ruissellement sont peu importantes, contrairement à celles associées à l'érosion des sols. Les pertes par lessivage viennent en second lieu: elles sont entre 4 et 10 fois plus importantes que celles dues au ruissellement proprement dit. Dans tous les cas, l'ordre d'importance décroissant des pertes selon le couvert végétal est le suivant: parcelle nue, mono-culture de maïs, culture combinée de maïs et manioc, maïs et plantes traditionnelles, jachère herbeuse.

Les pertes sur parcelles cultivées sont corrélées significativement avec les quantités ruisselées et surtout les volumes de sol érodé. Ce n'est que dans certains cas que les caractéristiques des précipitations interviennent.

ABSTRACT

Nutrient losses from experimental farm plots are correlated with data on runoff, sediment yield and rainfall characteristics with respect to plant cover and plant growth.

The first farm plot used as a control was kept bare while a second control plot of grass/forb fallow community was left undisturbed throughout. The three remaining plots

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were cropped differently to (a) sole maize (white TZPB variety; Zea maïs *L.) in both early and late growing seasons; (b) cassava/maize intercrop in the early growing season and cassava (*Manihot utilissima*) for the rest of the period; and (c) intercropping of yam (*Dioscorea rotunda*), dwarf okra (*Hibiscus esculentus*) and sweet and mild pepper (*Capsicum annum *L.) reminiscent of the traditional system of cropping. Samples of runoff water and eroded sediments were collected during 43 storm events that occurred during the year. Interflow occurred only during 12 particularly heavy storms.*

Nutrient loss through surface runoff water per se *is the least significant of the three channels of nutrient loss. Most nutrient losses in runoff are associated with the eroded soil. Leaching by percolating rainwater is the second most important mode of nutrient loss, nutrient loss in leachate could be as much as four to ten times greater than losses in runoff water for most nutrient elements. Individual nutrient elements vary in the magnitude of losses sustained. In all cases variation in the magnitude of nutrient losses is of the order : bare fallow plot> sole maize> maize/ cassava> maize/ okra/ pepper> grass/ forb fallow.*

Total nutrient losses on the cultivated plots are most significantly correlated with storm runoff volume and storm sediment yield. But nutrient loss from some of the plots is also significantly correlated with rainfall parameters.

INTRODUCTION

Although there has not been much detailed investigation into soil physical and biochemical processes and characteristics in Nigeria, the few studies that have been carried out seem to indicate rapid losses of soil nutrients and applied fertilizers during crop cultivation (AGBOOLA, 1970; SOBULO & OSINAME, 1985). Whilst this may be partly due to the low buffering capacities of the soils (JONES, 1971; BABALOLA *et al.*, 1978), it also may be due to inadequate protection of the farms against sheet erosion (OSUJI, 1985).There is some concern that nutrient fertilizer losses from farms would increase with time as mono-cropping systems spread and as there are further reductions in fallow periods in those areas still adopting traditional cropping systems. However, more empirical studies are needed before valid conclusions can be reached on the effect of cropping systems on soil fertilizer and nutrient losses such that appropriate management measures can be developed to minimize losses on the farms.

In this study, we have measured and analyzed nutrient losses from experimental farm plots with different cropping systems and which have been treated with artificial chemical fertilizers. This paper presents results of nutrient losses measured in surface runoff, eroded sediments and drainage water (interflow) from the different plots. This should enable a comparison of the relative proportions of nutrient loss due to surface runoff, soil removal and leaching by percolating rainwater in the soil.

SITE AND SOIL

The experiment was set up downslope of the weather station of the Department of Geography on the University of Ibadan campus on a smooth middle slope, at an elevation of about 180 m above sea level. The site has only a 3% slope. It had been under cultivation by folks adopting traditional farming systems but by the time of this experiment the land was under a dense thicket mainly of forbs and grasses.

The soil is an alfisol; it has a dark grey sandy-loam surface layer and a reddish brown more clayey and compact subsoil. It is developed on a thick regolith derived essentially from gneissic rocks. Table I provides the mean analytical data on the topsoils on all the five experimental plots used in this study (DAURA, 1995).

Tab.I.- Initial Topsoil Characteristics on the Experimental Plots (Value averaged over the five plots)

Soil property	Mean Value
pH (H_2O)	7.5
Electrical Conductivity S m^{-1}	0.024
Organic Carbon g kg^{-1}	14.2
Organic matter g kg^{-1}	24.5
Total N g kg^{-1}	0.12
Av. P mg kg^{-1}	143.07
Calcium mol_c kg^{-1}	6.00
Magnesium mol_c kg^{-1}	1.38
Sodium mol_c kg^{-1}	0.37
Potassium mol_c kg^{-1}	1.00
Exchange activity mol_c kg^{-1}	0.08
C.E.C. mol_c kg^{-1}	8.83
Base saturation %	99.09
Manganese mg kg^{-1}	241.00
Iron mg kg^{-1}	21.70
Copper mg kg^{-1}	1.00
Zinc mg kg^{-1}	15.40
Sand %	85.20
Silt %	8.80
Clay %	6.12

mol_c = moles in ion charge per kg

TREATMENTS

The experimental farm plots were located within five standard runoff plots (LAL, 1975, IMOROA, 1984, DAURA, 1995). All the plots were of the same size measuring 22 m x 5 m. Runoff and associated eroded soil materials were collected in sedimentation tanks through aprons while PVC drain pipes, installed at 0.5m, 1.0m and 1.5m depths, were used to collect subsurface water flow (LAL, 1975).

The vegetation on the runoff plots was cleared manually and burnt at the beginning of the raining season in 1992 and then the farm plots were established. The first plot, used as a control, was kept bare throughout by the use of a follar contact herbicide (round-up chemical). Herbicide was used to avoid possible disturbance of the soil. The second plot, also a control plot, was left undisturbed to allow the vegetation to regenerate. The vegetation grew into a grass-cum-forb fallow.

The three remaining plots were cropped differently. The first was cropped to sole maize (*Zea maïs* L.) during both the early and late maize growing seasons. The white TZPB variety of maize was planted in both seasons at a rate equivalent to 55,500 plants per hectare. The second plot was planted to cassava (*Manihot utilissima*) and maize mixture during the early growing season and cassava was left as the sole crop after the early maize had been harvested. The third cropped plot was devoted to intercropping of yam (*Dioscorea rotunda*); dwarf okra (*Hibiscus esculentus*) and sweet and mild pepper (*Capsicum annum* L.). Weeding on all three cropped plots was done manually throughout.

A pre-project soil test indicated that nitrogen was the only limiting soil nutrient hence it was decided to apply a nitrogen fertilizer, urea, to all the planted crops at the rate of 2.41 kg ha^{-1}. A single dose was applied on a side band application three weeks after planting on the maize and cassava/maize plots and six weeks after planting on the yam/okra/pepper plot.

NUTRIENT LOSS MEASUREMENTS

Samples of runoff water and eroded soil from each plot were collected after each runoff producing storm. There were 43 storm events altogether for the duration of our measurements. Interflow occurred only during heavy storms or in storms following high antecedent soil moisture conditions; thus, collection of samples was possible only on 12 such episodic occurrences. The water samples were stored in 1.5 1 plastic bottles and preserved in the refrigerator until they were analyzed in the laboratory.

The water samples were analyzed for: (i) pH by the potentiometric method (ii) calcium, potassium and sodium by flame photometry; (iii) magnesium, zinc, iron by atomic absorption spectrophotometry; (iv) nitrate (NO_3-N) determined colorimetrically by the Brucine method; and (v) phosphate (PO_4-P) also determined colorimetrically by the ascorbic acid molybdate blue method of MURPHEY & RILEY(1962).

The soil samples were fully analyzed also. The parameters analyzed include (i) particle size distribution by the hydrometer method; (ii) pH in water by the potentiometric method in a soil to water ratio of 1:2 ; (iii) electrical conductivity by the Wheatstone bridge arrangement; (iv) % organic carbon by the Walkley-Black wet oxidation method; (v) total nitrogen by the micro-Kjeldahl method; (vi) available phosphorus by Bray-1 method; (vii) exchangeable calcium, sodium and potassium by flame photometry; (viii) exchangeable magnesium and manganese, copper, zinc and iron by atomic absorption spectrophotometry; (ix) exchange acidity by the KCL extraction method and (x) cation-exchange capacity by the summation method.

The results of the laboratory analysis of the soil and water samples are all expressed in kg ha^{-1}.

STATISTICAL TREATMENT OF RESULTS

The main hypothesis of this study was that variations in nutrient losses could be explained by differences in cropping system. But, cropping system is important through its influence on runoff and sediment generation from storm events. Hence, in our analyses the nutrient losses are correlated with data on runoff, sediment yield, and rainfall characteristics in addition to the elements of plant growth and plant cover on the farm plots.

Analysis of variance is applied in comparing nutrient losses between the experimental plots while the multiple regression technique is used to identify the explanatory variables.

RESULTS AND DISCUSSION

PATTERNS OF RUNOFF AND SOIL LOSS

Table II summarizes the data on runoff and soil loss from the five experimental plots for the duration of this study.

The first two plots represent the two extreme conditions of plant cover; the bare plot predictably generated the highest amounts of runoff and soil loss while the well-protected grass/forb fallow generated the least. Among the three cropping systems, runoff and soil loss are highest with sole maize cropping.

Tab.II.- Total runoff and soil loss from experimental farm plots.

Cropping Type	Runoff (mm)	As Bare plot %	Soil loss t ha^{-1}	As Bare Plot %
Bare Plot	279.34		2.099	
Grass Fallow	26.27	9.4	0.188	9.0
Sole Maize	92.77	33.2	1.112	53.0
Maize/Cassava	49.69	17.4	0.956	45.5
Yam/okra/pepper	40.48	14.5	0.872	41.5

Followed, in decreasing order, by maize/cassava and yam/okra/pepper intercropping. Analysis of variance confirms the differences between the plots in terms of runoff and sediment yield associated with storm events; the differences are significant at the 0.1% confidence level for runoff and at the 1% confidence level for soil loss. Expressing runoff and soil losses in the other plots as percentages of the values obtained on the bare plot provides a measure of the relative effectiveness of the crop cover associated with the different cropping systems. In this regard, the results clearly vindicate the traditional system of intercropping as being more protective of the soil than modern systems of sole cropping without mulching.

PATTERNS OF INTERFLOW

It was not considered meaningful to measure the amount of interflow given the difficulty of isolating interflow from the plots from that from outside. KAMUKONDIWA & BERGSTROM (1994) solved this problem by planting his crops inside lysimeters such that interflow from each container could be isolated. This was not possible in the open field. Furthermore, interflow from the plots sometimes continued for days after the rainfall event.

NUTRIENT LOSS IN RUNOFF

As can be judged from Table III, nutrient loss through surface runoff water is the least significant of the three channels of nutrient loss from the farm plots investigated; it is only in a handful of cases that loss by surface runoff is more than 5% of total loss of each nutrient element from each plot. The total nutrient losses from the various experimental plots due to runoff water are, in decreasing order: bare fallow plot, 0.180 kg ha^{-1}; sole maize, 0.068 kg ha^{-1}; yam/okra/pepper, 0.036 kg ha^{-1}; maize/cassava, 0.031 kg ha^{-1}; and grass/forb fallow, 0.015 kg ha^{-1}.

The pattern of nutrient losses conforms to the pattern of runoff in accord with the observations of LAL (1975) based on his studies in this same region.

Tab.III.- Comparative data on nutrient losses (in kg ha^{-1}) and % of each value in runoff and eroded sediments, from experimental farm plot

Element		1		2		3		4		5	
		Kg ha^{-1}	%	Kg ha^{-1}	%	Kg ha^{-1}	%	Kg ha^{-1}	%	Kg ha^{-1}	%
Org.C	Sediment	30.85		2.20		17.48		12.31		14.94	
Total N	Runoff	0.042	2	0.002	1	0.010	1	0.005	*	0.003	*
	Sediment	1.881	98	0.157	99	1.576	99	1.461	100	1.504	100
	Total	1.923		0.159		1.586		1.466		1.507	
Av. P	Runoff	0.005	26	0.000	*	0.002	20	0.000	*	0.000	*
	Sediment	0.014	73	0.001	100	0.008	80	0.007	100	0.007	100
	Total	0.019		0.001		0.010		0.007		0.007	
Ca	Runoff	0.047	3	0.004	3	0.013	3	0.008	2	0.008	2
	Sediment	1.790	97	0.145	97	0.450	97	0.447	98	0.395	98
	Total	1.837		0.149		0.463		0.455		0.403	
Mg	Runoff	0.027	8	0.004	14	0.007	4	0.008	5	0.004	4
	Sediment	0.300	92	0.024	86	0.174	96	0.143	95	0.044	96
	Total	0.327		0.028		0.181		0.151		0.048	
Na	Runoff	0.011	6	0.001	8	0.008	9	0.004	6	0.003	5
	Sediment	0.300	94	0.011	92	0.079	91	0.058	94	0.060	95
	Total	0.311		0.012		0.087		0.062		0.063	
K	Runoff	0.015	3	0.001	3	0.013	4	0.004	1	0.009	3
	Sediment	0.567	97	0.035	97	0.292	96	0.287	99	0.269	97
	Total	0.582		0.036		0.305		0.291		0.278	
Mn	Sediment	0.271		0.025		0.162		0.161		0.163	
Cu	Sediment	0.005		0.000		0.002		0.003		0.003	
Fe	Runoff	0.029	19	0.002	17	0.013	24	0.001	2	0.008	10
	Sediment	0.124	81	0.010	83	0.041	76	0.061	98	0.069	90
	Total	0.153		0.012		0.054		0.063		0.077	
Zn	Runoff	0.004	50	0.000		0.001	50	0.001	50	0.001	50
	Sediment	0.004	50	0.000		0.001	50	0.001	50	0.001	50
	Total	0.008		0.000		0.002		0.002		0.002	

1 = bare surface plot; 2 = grasse/forb fallow; 3 = sole maize; 4 = maize/cassava; 5 = yam/okra/pepper. * = proportion not up to 1 %

It would appear that, to a large extent, runoff volume alone can explain the differences in nutrient loss; it is conceivable that the mixed cropping systems were more efficient than the sole cropping system in taking up applied fertilizers thereby reducing the proportion available for removal by surface runoff.

The results of analysis of variance indicate significant differences in nutrient elements lost in runoff from the various plots. The magnitude of the losses through this medium varies from one nutrient element to another. Exchangeable calcium, magnesium and potassium suffered the greatest losses from surface runoff on all the surfaces; losses of $P0_4$-P, exchangeable Na and extractable Zn are comparatively small.

NUTRIENT LOSS IN ERODED SOIL MATERIAL

Table III confirms the findings of previous workers that most nutrient losses in runoff are associated with the eroded sediments (LAL, 1976; ALBERTS *et al.*, 1978; OSUJI & BABALOLA, 1983). Total nutrient losses from the plots vary in accordance with the pattern of runoff and soil losses. The greatest total nutrient loss occurs on the bare fallow plot, while the grass/forb fallow plot suffered the least total nutrient loss. However, individual nutrient elements vary in the magnitude of the losses sustained. Between 90 and 99 per cent of the nitrogen and over 70 per cent of the phosphorus lost are through the eroded sediments. The nutrient losses, especially of nitrogen (1.881 kg ha^{-1}), and phosphorus (0.014 kg ha^{-1}), are greatest from the bare fallow plot. The results indicate that nitrogen losses are higher than phosphorus losses on all the plots.

Losses of the exchangeable bases also vary among the plots but in the same general order; in all cases variations in the magnitude of nutrient losses is of the order: bare fallow plot> sole maize> maize/cassava> yam/okra/pepper> grass/forb fallow. However, losses of extractable micro-nutrients are higher on the yam/okra/pepper plot than on the other cropped plots, hence the order of variation is: bare fallow> yam/okra/pepper> maize cassava and/or sole maize> grass/forb fallow.

The loss of organic on is substantial on all plots; values range from as high as 30.85 kg ha^{-1} on the bare plot to as low as 2.2 kg ha^{-1} on the grass/forb fallow plot. However, these values are much less than those reported by OSUJI & BABALOLA (1983) and LAL (1975). The higher losses (ranging from 71 to 99%) of all nutrient elements associated with eroded sediments, compared with other sources, confirm the view that eroded sediments are the single most important pollutants of surface water; they enter streams and lakes from both point and non-point sources.

The differences between the plots in total nutrient losses through eroded sediments, with few exceptions, are statistically significant at the 0.1% confidence limit.

NUTRIENT LOSS IN INTERFLOW

Leaching by percolating rainwater is the second most important mode of nutrient loss from the experimental farm plots. Although total nutrient losses in leachate have not been quantified because of the difficulty in determining the volumes of interflow from the different plots, the measured concentration levels of nutrients, shown in Table IV, indicate that nutrient losses in leachate could be as much as four to ten times greater than losses in runoff water for most nutrient elements. However, leaching losses are several times less than losses through eroded sediments. Leaching of phosphorus is negligible, perhaps, due to the high phosphorus fixing capacity of the soil in this environment which limits the downward movement of the nutrient as reported by UZU & UDO (1972) and by JUO & MADUAKOR (1974). Loss of NO_3-N through leaching could be about four times greater than that by runoff water on the bare fallow plot and six to ten times greater on the other plots. Losses of Ca and Mg could be about three times higher than in surface runoff water.

Nutrient losses through leaching vary with depth (Table IV). A high proportion of the nutrients leached were measured in the interflow collected at 0.5m depth; over 40% of NO_3-N and K; 35% of Ca, Mg, Na and Fe; and between 50% and 100% of phosphorus losses were recorded at this depth. Thus, it would appear that nutrients are not carried deep into the soil but only a little distance below the surface soil. KHAKURAL, ROBERT & KOSKINEN (1994), also found that alachlor, a pesticide applied to the soil, was not detected in soil samples obtained from depths greater than 15cm. in any soil or treatment after the first sampling.

The pattern of nutrient losses through leaching just described are similar to those found by LAL (1975, 1976); BAKER & JOHNSON (1976); OSJUI & BABALOLA (1983) and BOTTCHER *et al* (1985). The results of analysis of variance indicate that the differences between the plots in leaching losses are more significant at 0.5m depth for NO_3-N, Na, K, Fe and Zn; at the 1.0 m depth for NO_3-N, Ca, Na and K and at the 1.5m depth for NO_3-N, Ca, Mg, Na and K. Differences between the plots in the leaching losses of other nutrient elements are not statistically significant.

FERTILIZER NUTRIENT LOSSES ON CROPPED FARM PLOTS

Since the total nitrogen loss from the bare fallow plot (1.923kg ha^{-1}) is higher total nitrogen losses from the cultivated plots, it is not possible to determine the nitrogen fertilizer losses sustained on the plots where urea was applied. As shown in Table III, total nitrogen losses amounted to 1.586 kg ha^{-1} on the sole maize plot; 1.507 kg ha^{-1} on the yam/okra/pepper plot; and 1.466 kg ha^{-1} on the maize/cassava plot. The higher losses of total nitrogen and other nutrients from the bare fallow plot may be due to the much greater volumes of runoff and eroded sediments than on the cultivated plots with applied fertilizers. Also, the insignificant losses of nitrogen on the cultivated plots may have been due to the

Tab.IV.- Nutrient elements leached from the experimental plots by percolating rainwater (Interflow). Concentration of Nutrients in mg l^{-1}

Nutrient	Depth	Bare plot	Grass/Forb	Maize	Cassava/Maize	Yam/ Okra/Pepper
NO_3-N	0.5m	1.75	1.85	2.65	2.64	2.13
	1.0m	1.58	1.50	2.40	2.30	1.87
	1.5m	0.95	1.00	1.45	1.30	1.19
	Total	*4.28*	*4.35*	*6.50*	*6.24*	*5.19*
PO_4-P	0.5m	0.01	0.02	0.02	0.04	0.03
	1.0m	tr	tr	0.01	0.01	0.01
	1.5m	tr	tr	tr	tr	tr
	Total	*0.01*	*0.02*	*0.03*	*0.05*	*0.04*
Ca	0.5m	3.01	3.37	4.00	4.05	3.30
	1.0m	2.75	2.74	3.50	3.64	3.31
	1.5m	2.25	1.97	3.09	2.95	2.77
	Total	*8.01*	*8.08*	*10.59*	*10.64*	*9.38*
Mg	0.5m	1.17	1.39	1.23	1.45	1.36
	1.0m	1.01	1.45	1.25	1.47	1.34
	1.5m	0.65	0.88	1.00	1.07	1.01
	Total	*2.83*	*3.72*	*3.48*	*3.99*	*3.71*
Na	0.5m	0.84	0.91	1.54	1.28	1.54
	1.0m	0.79	0.82	1.76	1.45	1.49
	1.5m	0.32	0.48	0.88	0.97	0.94
	Total	*1.95*	*2.21*	*4.18*	*3.70*	*3.97*
K	0.5m	2.65	2.57	1.70	3.75	3.30
	1.0m	2.05	2.14	1.46	3.45	2.77
	1.5m	1.21	1.46	1.09	2.41	2.18
	Total	*5.91*	*6.17*	*4.25*	*9.61*	*8.25*
Fe	0.5m	1.66	1.85	2.11	2.20	2.45
	1.0m	1.77	1.50	2.17	1.97	2.04
	1.5m	1.00	1.00	1.75	1.51	1.47
	Total	*4.43*	*4.35*	*6.03*	*5.68*	*5.96*
Zn	0.5m	0.29	0.70	0.19	0.16	0.18
	1.0m	0.36	0.47	0.31	0.22	0.18
	1.5m	0.28	0.25	0.16	0.12	0.09
	Total	*0.93*	*1.42*	*0.66*	*0.50*	*0.45*

tr = trace (values less than 0.01 mg l^{-1})

application of the fertilizer at the recommended rate and time. LAL (1975) and CONWAY & PRETTY (1991) reported low losses of applied fertilizers on farm plots under optimal rates of application. Comparative proportions of nutrient loss reported by LAL (1975) ranged between 2.40% and 12.7% of applied fertilizers;

while the optimal average fertilizer nutrient loss under optimal rates of application reported by CONWAY & PRETTY (1991) was 10%.

Tab.V.- Simple correlation analysis between total nutrient loss from experimental plots and factors of rainfall erosivity, runoff, sediment yield and site

Variables	Bare plot	Grass/forb	Sole maïze	Maïze/Cassava	Yam/Okra/ Pepper
RAM	0.71***	0.18	0.49*	0.49*	0.32
SKE	0.75***	0.10	0.55**	0.57*	0.34
SPI	0.55***	0.16	0.38	0.25	0.13
KE> 25	0.68***	0.15	0.59**	0.64*	0.37
I_{15}	0.13	0.12	0.10	0.07	0.12
EI_{15}	0.37*	0.14	0.17	0.19	0.12
AI_{15}	0.35*	0.16	0.15	0.15	0.12
I_{30}	0.38*	0.15	0.22	0.31	0.09
EI_{30}	0.49***	0.02	0.33	0.39	0.10
AI_{30}	0.48***	0.01	0.31	0.37	0.11
API	0.06	0.02	0.24	0.28	0.30
RNF	0.66***	0.15	0.55**	0.63***	0.69***
SDY	0.91***	0.96***	0.87***	0.82***	0.92***
GCO		-0.47*	-0.17	-0.36	-0.29
INC	0.06	0.29	0.21	0.06	0.15
SOT	0.10	0.23	0.12	0.29	0.17

r significant:* at 0.05 level; ** at 0.01; *** at 0.001 level.
RAM = rainfall amount; SKE = storm kinetic energy; SPI = storm peak intensity; KE> 25 = total kinetic energy of rainfall equal or greater than 25 mm hour^{-1}; I_{15} = 15 minutes maximum peak intensity; EI_{15} = storm kinetic energy and 15 minutes maximum peak intensity; AI_{15} = rainfall amount and 15 minutes maximum peak intensity; I_{30} = 30 minutes maximum storm intensity; EI_{30} = storm kinetic energy and 30 minutes maximum intensity; AI_{30} = rainfall amount and 30 minutes maximum storm intensity; API = antecedent precipitation index; RNF = storm runoff volume; SDY = storm sediment yield; GCO = ground cover; INC = infiltration capacity; SOT = soil temperature.

EXPLANATORY FACTORS

Table V shows the results of the simple correlation analysis between total nutrient loss on each of the five experimental plots and 16 explanatory variables including those of rainfall, runoff, eroded sediments and site factors. With regard to total nutrient losses on the cultivated plots, the most significant correlations (0.01% and 0.001% significance levels) are with storm runoff volume (RNF) and storm sediment yield (SDY). This means that as the volumes of runoff and sediment yield increase, total nutrient losses also increase. This relationship is not unexpected since the bulk of the nutrient loss from agricultural lands is associated with the eroded sediments which in turn is related to runoff. But nutrient loss from some of the cultivated plots is also significantly correlated with some rainfall parameters such as total kinetic energy of rainfall equal or greater than 25mm $hour^{-1}$, storm kinetic energy and rainfall amount. It is worth noting that although not statistically significant, the correlation between ground cover and total nutrient loss is negative on all the plots. As to be expected, the most direct positive relationships between nutrient loss and the rainfall erosivity parameters are found on the bare fallow plot. The impact of the erosivity factors declines as ground cover increases judging by the pattern of significant correlations with nutrient loss on the cultivated plots described earlier.

Multiple regression analysis is employed to explore the joint contributions of the 16 independent variables to the total nutrient losses in the different experimental plots. The results indicate highly significant joint contributions of all 16 variables to the explanation of total nutrient loss in each of the experimental plots. Multiple R values range from 0.91 to 0.99; thus, the variables explain between 82 and 98 percent of the variance in nutrient losses on the various plots. The five regression equations shown below give the parameters which are statistically important in explaining total nutrient loss from the individual experiment plots:

Bare fallow plot:	$\log N_1 = 4.297 + \log 1.067\, S_1$	(1)
Grass/forb fallow	$\log N_2 = 1.650 + \log 1.740\, S_2$	(2)
Sole Maize	$\log N_3 = -3.793 + \log 1.181\, S_3 + \log 5.659\, SOT_3$	(3)
Maize/Cassava	$\log N_4 = 4.103 + \log 0.704\, S_4 - \log 0.351\, I_{15}$	(4)
Yam/Okra/Pepper	$\log N_5 = 0.161 + \log 1.098\, S_5 + \log 2.920\, SOT_5$	(5)

where, N_1-N_5 = predicted total nutrient loss(g ha^{-1}) on the individual plots respectively; S_1-S_5 = soil loss(kg ha^{-1}) on individual plots; $SOT_{3,5}$ = soil temperature in the relevant Plots; I_{15} = 15 minutes maximum rainfall intensity.

Nutrient loss on the bare fallow plot and on the grass/forb fallow plot is best explained by soil loss (sediment yield) parameter which is the sole statistically significant variable explaining about 90 percent of the variance in nutrient loss on the bare surface and 79 percent on the grass/forb surface. The two significant explanatory parameters on the sole maize plot are soil loss which explains 77 percent of the variance and soil temperature which accounts for 13 percent of the variance. The two parameters jointly explain about 90 percent of the variance. Soil loss also accounts for 69 percent of the variance in total nutrient loss on the maize/cassava plot while the 15 minutes maximum intensity rainfall explains about 19 percent, making a total of 88 percent of the variance explained by the two parameters. Finally, about 97 percent of the variance in total nutrient loss from the yam/okra/pepper plot is explained by soil loss (91 percent) and soil temperature (6 percent).

CONCLUSION

The experimental from which this paper derives was carried out over only one growing season. Furthermore, it was not feasible to accurately measure the volume of interflow from the experimental plots. However, in spite of these limitations, the results of our analyses clearly point to the importance of crop cover in determining runoff, sediment yield and nutrient losses from farm plots. The traditional system of intercropping clearly is superior to the modern system of sole cropping in this regard. Our findings also highlight the serious danger posed by sheet erosion on farmlands in the tropical environment as the bulk of the nutrient losses from the experimental farm plots were through the eroded sediments (AREOLA, 1979). Soil loss is the common element in all the five nutrient loss models arrived at in the study. Soil nitrogen, phosphorus and organic carbon are the worst affected by sheet erosion. A possible comparable medium of nutrient loss from the experimental farm plots is drainage water but this has not been proved conclusively in this study because of inability to isolate and determine the volume of interflow from the individual plots.

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