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Combating Land Degradation in Cassava Field By Crop Yield Improvement

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ABSTRACT

Field experiments were carried out to examine the effect of increasing the crop yield on land degradation in cassava-based cropping systems. The experiment was also aimed at showing that with proper crop management, the planting of cassava does not result in land degradation, and therefore, a sustainable production system can be obtained. The experiment was done in a farmer's fields in Jatikerto, about 25km south west of Malang, East Java, Indonesia. The soils are Alfisols with a surface slope of about 8%. There were 8 experimental treatments with two replications. The experiment results show that the nutrient uptake and soil erosion rate of the cassava field were not necessarily higher than those of maize in terms of crop yield and crop management. At low-to-medium yield, the nutrient uptake of cassava was lower than that of maize. At high yield, only the K uptake of cassava was higher than that of maize, whereas the N and P uptake was more or less similar. Soil erosion on the cassava field was significantly higher than that on the maize field; however, this only occurred when there was no suitable crop management. Simple crop managements, such as ridging, fertilizer application, or manure application could significantly reduce soil erosion. The results also revealed that proper management could prevent land degradation and increase crop yield. In turn, the increase in crop yield could decrease soil erosion and plant nutrient depletion.
Keywords: land husbandry, land degradation, cassava nutrient uptake, soil erosion

INTRODUCTION

Cassava can be considered as the mighty crop. It can be utilized for multipurpose, and it can grow well in very marginal environmental conditions. In many countries cassava is used as a food crops; in most African and Latin American Countries it is used as the main food crop [1], and in Indonesia it is used as an alternative food crop [2], while in Thailand, it is used for animal feed and industry raw material for plastic, paper, textile, and more recently for bio fuel [3]. Cassava is one of the crops with high tolerance to soil acidity and drought. It is a very efficient in using nutrients, water and other natural resources so it can grow and produce a reasonable yield in marginal areas with adverse climatic, edaphic and topographic conditions, such as steep slopes and forest margins.

In Indonesia, although cassava is an important crop, and is planted in a very large area, it is still considered as a minor crop, by both the government and private sectors, so it only receives little attention [2]. Recently, with food crisis due to the difficulty in increasing cereal crop production, and decreasing oil fuel reserves, cassava has attracted more attention, especially from businessmen. However, the development of cassava still faces many constraints, one of which is the assumption that planting cassava will accelerate soil and land degradation. In addition, some people believe that land degradation accelerates with the increase of cassava yield. The suggestion is usually based on the assumption that cassava removes a lot of plant nutrients from the soil, due to both high plant nutrient uptake and soil erosion. This opinion is considered to be true by most people due to the fact that land planted with cassava is usually in very poor condition, with a very low productivity, or even already in degraded condition.

Not with standing the fact fact that land planted with cassava is usually in degraded or nearly degraded condition, the hypothesis that growing cassava and/or increasing cassava yield causes soil and land Degradation is still questionable. A better interpretation of the fact would probably be that only cassava. Crops can grow and produce a reasonable yield in such a poor soil condition. The common assumption that the nutrient uptake by cassava is higher than other crops is also not entirely correct. Howeler [4] has calculated that with harvest 35.7 fresh tubers/ha (equal to 13.53 t/ha dry) cassava removes 55 kg N/ha, 13.2 P/ha and 112 kg K/ha. In contrast, the production of 6.5 t/ha of grain maize (5.53 t/ha dry) removes as much as 96 kg/ha of N, 17.4 kg/ha of P and 26 kg/ha of K while the production of 4.6 t/ha rice (3.97 t/ha dry) removes 60 kg/ha of N, 7.5 kg/ha of P and 13 kg /ha of K. In more recent studies conducted in Thailand, Puttacaharoen *et al*. [5] showed that the amounts of N

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and P removed in the harvested plant parts were also much lower than those removed by other crops, while the amount of K removed by cassava was similar to other crops but much lower than pineapple or cassava grown for forage. Indeed, nutrient removal with harvesting will be influenced by cropping management, and hence crop yields. Amanulah *et al.*, [6] showed that application of organic manure in cassava growing increase both tuber yields and nutrient uptake. Application of Composted Poultry manure had a positive soil Nitrogen balance, while Farm Yard Manure application had a negative soil Nitrogen balance.

High soil erosion in cassava field is believed to be another factor that accelerates soil and land degradation. This suggestion arises because cassava stake is usually planted with wide spacing, and cassava stake has a slow initial canopy development. Study by Puttacaharoen *et al.* [5] showed that soil losses due to erosion were highest in cassava grown for roots, followed by cassava for forage, sugarcane, mungbean, sorghum, peanut, maize and pineapple. Ardjasa *et al.* [7] showed that in wet areas like those in Sumatra with an annual rainfall of about 2,500 mm/year, the amount of eroded soil during the first 4-month period in the rainy season was about 90% of the annual amount. However, the case might be different if in the area the short cycle crops can be planted twice a year. Because of more frequent land preparation and weeding, it is reasonable to suggest that soil losses from that cropping system will increase. Wargiono *et al.* [8] reported that annual soil losses for cassava were similar to those obtained with two successive crops of soybean, slightly higher than the rice-soybean rotation or two crops of maize, and about twice as high as that of two crops of peanut.

The aim of this study was to demonstrate that planting cassava does not necessarily accelerate soil and land degradation. The study is also aimed to show that increasing the crop yield does necessarily speed up land degradation, and to determine the planting management which can simultaneously increase crop yield and decrease land degradation, or even maintaining and increase land productivity.

MATERIALS AND METHODS

The experiment was carried out at farmer's field at Kromengan village, 25 km south west of Malang, East Java, Indonesia. The soil was Alfisols developed from volcanic materials with the top soil (up to 25 cm depth) properties as given in Table 1. The experiment was carried out from September 2004 through August 2008.

Table 1 The properties of soil before experiment and of Manure use for the experiment

Sample	Chemical characteristics						Physical characteristics					
	pH	C	N	P	K	pb	Sand	Silt	Clay	FC	WP	MWD
	H2O	%	%	ppm	Mmol	Mg/m3	%	%	%	%	%	Mm
Soil	6.40	1.14	0.09	11.61	1.61	1.31	28.6	32.6	38.8	36.32	21.25	2.34
Manure	5.68	28.86	1.29	0.68	0.96	-	-	-	-	-	-	-

The experimental treatments were the management practice suggested by the farmers. This approach was done based on Utomo *et al.* [9] finding which show that any technology production will be adopted by farmers if the technology meet the farmers' needs and condition. The treatments are:

1. Cm : Control, cassava was planted on flat land (without ridging) in mono cropping system, no fertilizers applied
2. CmR : Cassava was planted on ridges in mono cropping system, no fertilized applied. The ridges were constructed across the slope with distance of 1.0 m between ridges.
3. CmRF : Cassava was planted on ridges in mono cropping system. The crops ware given 300 kg Urea, 150 kg SP36, and 100 kg KCl/ha
4. MmRF : Maize was planted on ridges in mono cropping system. The crops ware given 300 kg Urea, 150 kg SP36, and 100 kg KCl/ha
5. CmRF+Mnr : Cassava was planted on ridges in mono cropping system. In addition fertilized as the treatments 3 (CmRF), it was added 5 t farm yard manure/ha was added
6. (C+M)RF : Cassava was intercropped with maize and planted on ridges. The crops were given 400 kg Urea, 200 kg SP36 and 150 kg KCl/ha
7. (C+M)RF+Gl :Cassava was intercropped with maize and planted on ridges. The crops were given 400 kg Urea, 200 kg SP36, 150 kg KCl and planted in alley cropping system with *Gliricide sepium* as the hedgerow with a spacing of 4 m between hedgerow and 0,5 m in the hedgerow.
8. (C+M)R+Eg :Cassava was intercropped with maize, and planted on ridges. The crops were given 400 kg Urea, 200kg SP36, 150 kg KCl and were planted in alley cropping system with Elephant grass as the hedgerow with a spacing of 6 m between hedgerow and 0,3 m in the hedgerow

These 8 treatments were arranged in Randomized Block Design with three replications. The crops were planted in field plots with size of each 12 m x 5 m on slope of about 8 %. To collect the run off and eroded soil, a collector made from oil drum was constructed at the lower end of the plots.

Cassava cutting of about 25 cm length was planted at a distance of 1.0 x 1.0 m. For the treatment of maize intercropping, two maize seeds were planted with a 30 cm interval on the sides of the cassava row (± 25 cm from the cassava row). After 2 weeks, the maize was thinned to one plant/hill. For the mono crop maize, maize was planted at a distance of 0.8 x 0.25 m. Cassava, maize and the hedgerow crops were planted at the same time. For the mono crop maize, maize was planted twice/year.

Farm yard manure (the properties are given in Table 1) was applied during land preparation. All SP36 (36 % P_2O_5) and KCl (50 % K_2O) and ⅓ Urea (45 % N) fertilizers were given at planting date, then ⅓ Urea fertilizer was given at 60 days after planting, and remaining Urea fertilizer was given after harvesting the maize intercrop (105 days after planting).

In the first year, the first alley crop pruning was done at 3 months after planting, the second 2 months later, and the third 3 months after the second pruning. For the second year and after, the first pruning was done at land preparation (September), then the second, third, and fourth pruning were done at 3 months, 5 months, and 8 months after planting, respectively. The pruned leaves of gliricide were put back to the plots while the pruned stem of gliricide and all pruned elephant grass were taken out from the plots.

Observations were made for run off water, eroded soil, total harvested biomass of cassava and maize, cassava tuber yields, grain maize yield, gliricide stem and leaves, and elephant grass biomass. Soil properties before experiment and after first year and four year harvesting were also observed.

Laboratory analysis done for soil includes : soil pH (in H_2O), soil organic matter content (Walkley and Black), nitrogen (Kjeldhal), available P (Bray II), exchangeable K (NH4OAc) as well as soil physical properties which include soil bulk density, aggregate stability (wet sieving, Yoder 1928) and water content at ψm of 33 kPa and 15 MPa. Plant analysis was done (wet destruction) for total N , total P and total K. Nirogen analysis was done with Keldahl method, total P was measured with spectrophotometer, and total K with AAS (Shimatzu).

RESULTS AND DISCUSSION

Crop Yield

The result given in Figure 1 shows that with no fertilizer application cassava yield of both that planted on surface flat land (CmF) and on the ridges (CmR) decreases markedly from more than 20 t/ha in the first year to less than 10 t/ha in the third year, after which the yield remains constant at about 9 t/ha. In the first year, the yield of cassava planted on ridges is relatively higher than that of planted on flat land. However, in the second year and after the cassava yield of those two treatments is relatively the same, although soil erosion from surface flat land is far beyond that from ridges (see Table 5). These results indicate that at least till four years of planting cassava on the same land, the cassava yield is mainly controlled by the nutrient status of the soil regardless the rate of soil erosion.

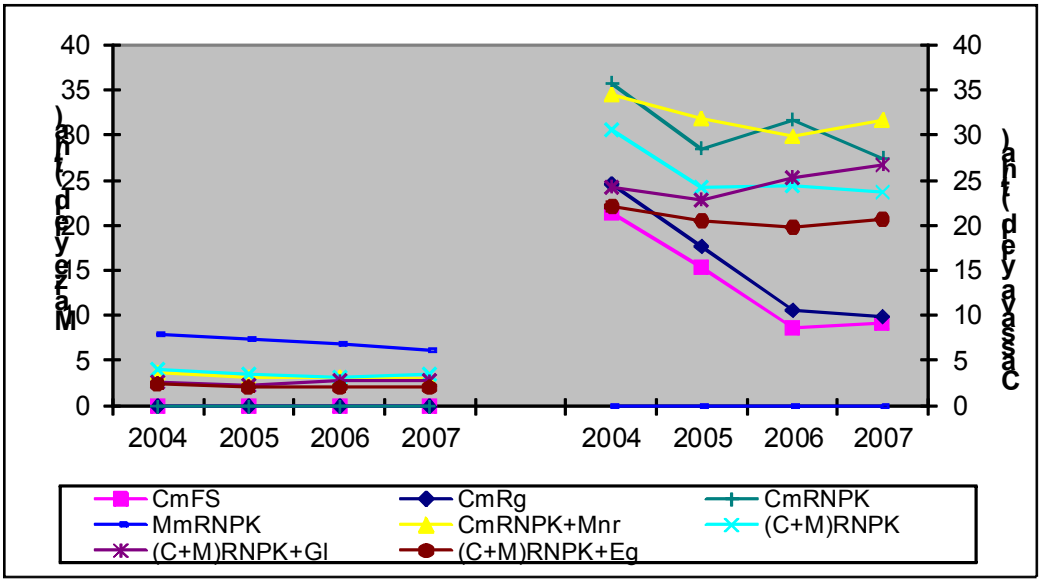

Figure 1 The effect of crop management on the yield of cassava

The decrease in cassava yield with time if there is no fertilizer application has also been found in Columbia [10], in Thailand [11], on acid Utisols in Sumatera, Indonesia [7], and in North Vietnam [12]. This

yield decrease is due to either nutrient extraction in the harvested product leading to soil nutrient depletion (See Table 7), or excessive erosion with a significant loss of nutrients (Table 6).

Fertilizer application, does not only increases the cassava yield, but also inhibits the yield decrease such as found in the treatment of CmRF. With NPK application, cassava yield obtained in the first year was 35.7 t/ha; this is much higher than that of 24.5 t/ha obtained by no fertilizer application treatment, CmR. After four years of planting cassava, the yield decreases to a level of about 27 t/ha. This decrease is about 30%, and is much lower than that of no fertilizer treatment, CmR. At the same period, the yield decrease in this treatment is about 170 % (from 24.5 t/ha to 9 t/ha). The addition of 5 t/ha farm yard manure (CmRF+Mnr), in addition to fertilizer application, could maintain the stability of cassava yield at a level of about 30 t/ha. With low soil organic matter on the experimental sites (see Table 1), the application of farm yard manure increases the ability of soil to maintain its productivity. This is partly due to the addition of plant nutrient and the improvement of soil properties, such as soil organic matter content, soil bulk density, soil aggregation, and soil water availability (see Table 8). The beneficial effect of manure, either farm yard manure or composted manure has been shown elsewhere [6]

Nutrient Uptake

Nutrient uptake in harvested tuber yield of cassava and grain maize is given in Table 2, and shows that the nutrients removed by cassava tuber harvesting are not necessarily higher than that by maize grain harvesting. In the Cm treatment, for example, with a yield of 21.42 t/ha, the nutrients removed by tuber harvesting are only stand at 32.94 kg N/ha, 5.86 kg P/ha and 56.36 kg K/ha. For maize, with a yield of 7.82 t/ha, the nutrients removed in the grain are 95.76 kg N/ha, 22.57 kg P/ha and 32.83 kg K/ha. At the CmRF treatment, for example, only the absorption of potassium at the high yield of cassava was higher than that of maize. Nitrogen and Phosphorus absorption at this yield level is still lower by cassava compared to that by maize. A similar figure is found in the harvested leaves and stems (Table 3). The absorption of plant nutrient by cassava is not much different from that by maize, especially in terms of the low to medium yield of cassava. For 5.27 t of cassava stem and leaves biomass for example (C+M)RF treatment, the removal of N, and P was 74.76, and 7.85 kg respectively, whereas to produce 5.02 t of maize stem and leaves biomass required 71.49 kg N and 16.87 kg P (MmRF treatment).

Table 2 Macro nutrient content in the harvested tuber yield of cassava and/or grain yield of maize with different crop management

Planting year 2004/2005

Crop management	Yield t/ha	Cassava Nutrient Uptake			Yield t/ha	Maize Nutrient Uptake		
		N (kg.ha)	P(kg.ha)	K(kg.ha)		N(kg.ha)	P(kg.ha)	K(kg.ha)
Cm	21.42	32.94	5.86	56.36	0.00	0.00	0.00	0.00
CmR	24.55	38.16	6.78	65.30	0.00	0.00	0.00	0.00
CmRF	35.73	66.84	11.14	92.46	0.00	0.00	0.00	0.00
MmRF	0.00	0.00	0.00	0.00	7.82	95.76	22.57	32.83
CmRF+Mnr	34.44	71.70	11.95	99.19	0.00	0.00	0.00	0.00
(C+M)RF	30.62	56.28	9.38	77.85	3.94	43.96	10.36	15.07
(C+M)RF+Gl	24.30	49.20	8.20	68.06	2.52	31.50	7.43	10.80
(C+M)RF+Eg	22.12	47.88	7.98	66.23	2.44	30.24	7.13	10.37

Planting year 2007/2008

Crop management	Yield t/ha	Cassava Nutrient Uptake			Yield t/ha	Maize Nutrient Uptake		
		N (kg.ha)	P(kg.ha)	K(kg.ha)		N(kg.ha)	P(kg.ha)	K(kg.ha)
Cm	9.12	14.04	2.50	24.02	0.00	0.00	0.00	0.00
CmR	9.83	14.49	2.58	24.79	0.00	0.00	0.00	0.00
CmRF	27.33	54.42	9.07	75.28	0.00	0.00	0.00	0.00
MmRF	0.00	0.00	0.00	0.00	6.21	87.08	20.53	29.86
CmRF+Mnr	31.70	61.32	10.22	84.83	0.00	0.00	0.00	0.00
(C+M)RF	23.72	48.72	8.12	67.40	3.94	38.22	9.01	13.10
(C+M)RF+Gl	26.73	49.68	8.28	68.72	2.52	34.58	8.15	11.86
(C+M)RF+Eg	20.67	37.44	6.24	51.79	2.44	25.90	6.11	8.88

The results in Table 2 and Table 3 also show that the addition of fertilizers and farm yard manure not only the yield but also the total nutrient uptake by the cassava tuber and the maize grain as well as the leave and stem yield.

Table 3 Nutrient removal in stem + leaves and in total biomass of cassava and maize for planting year 2007/2008

Crop management	Stem+leaves biomass t/ha	Cassava			Stem+leaves biomass t/ha	Maize		
		N(kg.ha)	P(kg.ha)	K(kg.ha)		N(kg.ha)	P(kg.ha)	K(kg.ha)
Cm	2.05	24.90	3.29	18.91	0.00	0.00	0.00	0.00
CmR	2.27	27.80	23.65	20.95	0.00	0.00	0.00	0.00
CmRF	6.26	96.69	12.04	74.01	0.00	0.00	0.00	0.00
MmRF	0.00	0.00	0.00	0.00	5.02	71.49	16.07	28.31
CmRF+Mnr	6.94	94.72	10.42	76.10	0.00	0.00	0.00	0.00
(C+M)RF	5.27	74.76	7.85	67.92	2.70	37.57	9.58	15.37
(C+M)RF+Gl	4.41	55.66	6.49	52.14	2.13	28.70	7.58	12.20
(C+M)RF+Eg	4.13	59.88	7.92	48.80	1.58	22.66	5.60	8.88

A different phenomenon could be seen if nutrient uptake is calculated per unit of yield. The result presented in Table 4 show that the increase in yield is not always followed by that in nutrient uptake per unit of yield. The macro nutrient uptake per unit of yield as given in Table 4 is obtained by dividing the total plant nutrient in the tuber or grain yield and that in the harvested biomass with the respective yields. Again, except Potassium, the removal of macro nutrients of cassava is lower than that of maize. Howeler *et al.* [1] have summarized the previous research results and found that N and P removal in the harvested part of the cassava plant was actually lower than, and K removal was similar to that of other crops tested.

Table 4 Total nutrient removed by cassava and maize, planting year of 2007/008

Crop management	Total biomass	Nutrient removed by cassava			Total biomass	Nutrient removed by maize			Total Nutrient removed from soil		
		N	P	K		N	P	K	N	P	K
	t/ha	Kg/ha			t/ha	Kg/ha			Kg/ha		
Cm	5.43	38.94	5.79	42.93	0.00	0.00	0.00	0.00	38.94	5.79	42.93
CmR	6.09	42.38	6.23	45.74	0.00	0.00	0.00	0.00	42.38	6.23	45.74
CmRF	17.22	151.11	21.11	149.29	0.00	0.00	0.00	0.00	151.11	21.11	149.29
MmRF	0.00	0.00	0.00	0.00	10.48	71.49	16.07	28.31	158.57	36.60	58.17
CmRF+Mnr	18.26	156.57	36.60	160.43	0.00	0.00	0.00	0.00	156.04	20.64	160.43
(C+M)RF	15.16	123.48	15.97	135.32	5.81	75.59	18.59	28.47	199.27	34.56	163.79
(C+M)RF+Gl	13.19	105.34	14.77	120.86	4.65	63.28	15.73	24.06	168.62	30.50	144.92
(C+M)RF+Eg	10.47	97.32	14.16	100.29	3.46	48.56	11.71	17.76	145.88	25.87	118.05

Run off, Soil erosion and Nutrient loss

The measurement results given in Table 5 show that run off and soil erosion from cassava planted on surface land without fertilizers throughout the time are higher compared to the other crop management. A simple management by planting cassava on ridges has significantly reduced both run off and soil erosion. However, it should be careful in making ridges because it can increase even the erosion rate. Odemerho and Auwunudiogba [13] show that erosion from flat surface land is lower than that from ridging; erosion from contour ridging is lower than that from ridging following the contour. The reason for this phenomenon is that ridges can accumulate surface run off water, and if the ridges fail to function, the erosive energy of this concentrated surface run off is much higher.

Surface run off water and soil loss can be decreased further by improving crop management, such as by fertilizer application, intercrop cassava with maize, applying farm yard manure and practicing alley cropping system (Table 5). Fertilizer application will improve crop development, and hence speed up land coverage. Similarly, in intercropping system, the addition of other crops will speed up the coverage of the surface land. This will reduce both erosive energy of rain fall and surface run off. A decrease of erosion on a cassava a plot with intercropping of upland rice and maize has also been shown by Ardjasa *et al.* [7].

Table 5 Nutrient uptake per unit of yield of cassava or maize with different crop management

1. If only the tuber or grain yield is removed.

Crop management	dry tuber t/ha	2007/08			dry tuber t/ha	2007/08		
		Cassava Nutrient Uptake				Maize Nutrient Uptake		
		N (kg.ha)	P(kg.ha)	K(kg.ha)		N(kg.ha)	P(kg.ha)	K(kg.ha)
Cm	3.38	4.15	0.73	7.10	0.00	0.00	0.00	0.00
CmR	3.82	3.79	0.67	6.48	0.00	0.00	0.00	0.00
CmRF	10.96	4.96	0.82	6.86	0.00	0.00	0.00	0.00
MmRF	0.00	0.00	0.00	0.00	5.46	15.90	3.76	5.46
CmRF+Mnr	11.32	5.41	0.90	7.49	0.00	0.00	0.00	0.00
(C+M)RF	9.89	5.02	0.83	6.94	3.11	12.28	2.89	4.21
(C+M)RF+Gl	8.78	4.26	0.71	5.89	2.52	13.72	3.23	4.70
(C+M)RF+Eg	6.34	5.91	0.98	8.17	1.88	13.77	3.25	4.72

2. If total biomass is remove

Crop management	total biomass t/ha	2007/08 Cassava Nutrient Uptake (of tuber)			total biomass t/ha	2007/08 Maize Nutrient Uptake (of grain)		
		N (kg/t)	P(kg/t)	K(kg/t)		N(kg/t)	P(kg/t)	K(kg/t)
Cm	5.43	7.16	1.05	7.89	0.00	0.00	0.00	0.00
CmR	6.09	6.96	1.01	7.50	0.00	0.00	0.00	0.00
CmRF	17.22	8.76	1.29	9.33	0.00	0.00	0.00	0.00
MmRF	0.00	0.00	0.00	0.00	10.48	15.13	4.11	5.98
CmRF+Mnr	18.26	8.54	1.13	8.80	0.00	0.00	0.00	0.00
(C+M)RF	15.16	8.13	1.59	7.90	5.81	13.04	3.19	4.90
(C+M)RF+Gl	13.19	7.98	1.11	9.15	4.60	13.75	3.42	5.23
(C+M)RF+Eg	10.47	7.32	1.35	9.60	3.44	14.11	3.40	5.15

Compared to maize (treatment CmRF and MmRF), it can be concluded that surface run off and soil loss from cassava plot is not higher than that from maize plot. Indeed, in the early growth phase, cassava has a lower speed for covering the land surface. However, with two times planting maize, there are two time land preparations, in which the condition is very susceptible to erosion. Thus, it is not surprising that surface run off and soil loss from maize plot is higher than that from cassava plot.

The removal of the macro nutrient by erosion is given in Table 6. It is interesting to notice that a high surface run off and soil loss is not followed by a high nutrient removal. In the Cm treatment, for example, with a surface run off of more than 400 m3/ha and a soil loss of more than 45 t/ha/year, the removal of nutrients is less than 65.7 kg N/ha, 6.7 kg P/ha, 34.6 kg K/ha in the 2004/05 planting season, and 49.6 kg N/ha, 5.6 kg P/ha and 23.2 kg K/ha in the 2006/2008 planting season. For a lower surface run off and soil loss, such as in the treatment of CmRF, the removal of plant nutrients in both planting season is much lower. This phenomenon is merely due to the higher concentrations of plant nutrient in the eroded soil of fertilized plot. The plant nutrient contents in eroded soil of CmFR, for example, are 1.88 % N, 0.57 % P, 1.01 %K, whereas the concentration of N, P, and K in eroded soil of CmR treatment are 1.20, 0.12, and 0.59 respectively.

Table 6 Run off and Soil loss from different cropping management

Crop management	Run off				Soil loss			
	2004/05	2005/06	2006/07	2007/08	2004/05	2005/06	2006/07	2007/08
	M3/ha				t/ha			
Cm	425	496	483	508	64.5	46.5	51.4	49.3
CmR	364	401	426	409	49.5	30.8	35.6	34.7
CmRF	347	296	287	297	38.2	29.4	30.8	24.2
MmRF	375	325	295	307	37.5	34.4	32.4	36.7
CmRF+Mnr	365	259	234	227	34.5	26.4	21.6	22.6
(C+M)RF	357	264	249	246	32.1	28.3	25.5	24.3
(C+M)RF+Gl	352	298	204	218	35.2	26.6	19.4	20.4
(C+M)RF+Eg	315	216	207	224	34.5	22.8	20.6	19.5

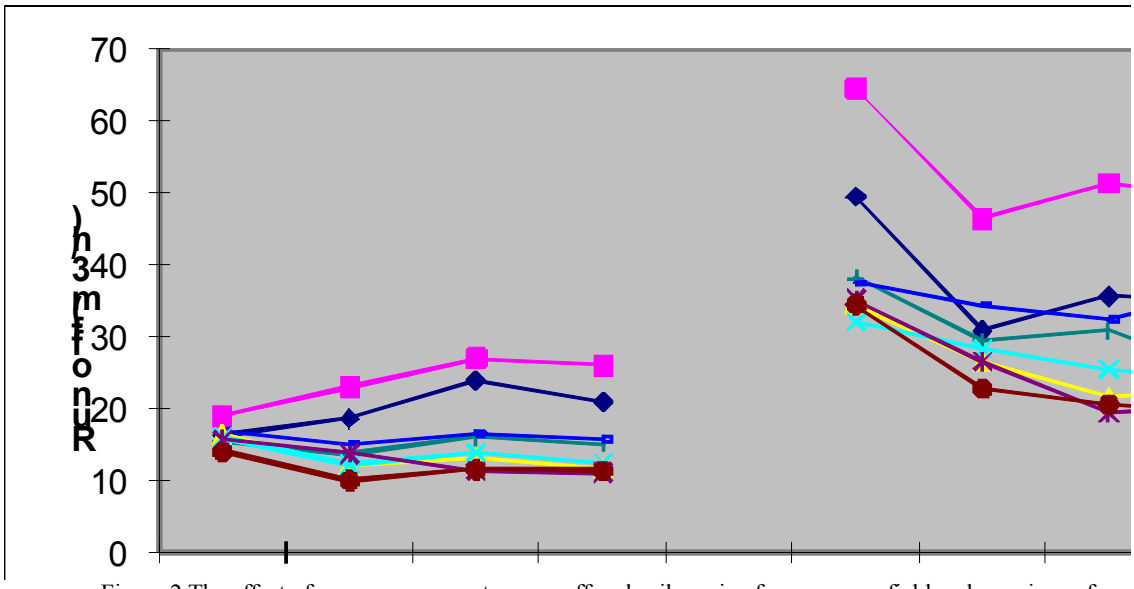

Figure 2 The effect of crop management on run off and soil erosion from cassava field under various of crop managements

Nutrient Balance

The data nutrient balance data given in Table 7 are obtained by subtracting the nutrient input by nutrient removal. Nutrient input comes from fertilizer and manure application. In addition, for the treatment of alley cropping with gliricide (C+M)RF+Gl), the input is added with the nutrient content in the pruned material put back to the land. The nutrient removal is the sum up of total plant nutrient uptake and nutrient loss in eroded soil.

The data given in Table 7 show that except in the treatment of alley cropping with gliricide (C+M)RF+Gl), the removal of Nitrogen is higher than the input. This means that there is Nitrogen deficiency in the soil. A similar result is found for the potassium balance. This phenomenon might be the reason why, even in fertilized soil the yield of cassava decreases if the land is continuously planted with cassava. Unlike Nitrogen and Potassium, the removal of Phosphorus from the land is lower than the input. As shown in Tables 3 and 4, the uptake of phosphorus by plants is relatively low compared to that of Nitrogen or Potassium.

Table 7 Nutrient removal by erosion from different crop management

Crop management	The removal of plant nutrient					
	2004/05			2007/08		
	N (kg/ha)	P(kg/ha)	K(kg/ha)	N(kg/ha)	P(kg/ha)	K(kg/ha)
Cm	65.7	6.7	34.6	49.6	5.6	23.2
CmR	45.6	5.6	23.3	42.8	4.2	20.7
CmRF	75.5	16.7	38.5	45.5	13.8	24.6
MmRF	74.7	17.6	36.6	48.2	19.2	26.3
CmRF+Mnr	70.5	16.4	31.5	34.6	11.4	22.9
(C+M)RF	72.7	14.7	28.7	39.7	11.2	18.4
(C+M)RF+Gl	75.8	14.2	32.4	46.4	12.6	22.3
(C+M)RF+Eg	70.6	16.3	29.4	47.3	13.4	20.6

The nutrient removal from the soil is much higher than the input. However, there is only a minor decrease in plant nutrient in the soil continuously planted with cassava (Table 8). It seems that after reaching a certain level, plant nutrient in the soil occurs at an equilibrium value. The data in Table 8 also show that, in the treatment added with farm yard manure (CFR+Mnr) and alley cropping system, there is a building up of soil organic mater content. The building up of soil organic matter content improves some soil properties, such us increasing CEC of the soil, decreasing soil bulk density, and improving soil aggregation and soil water availability.

Table 8 Nutrient balance in different crop management

Crop management	Nutrient input			2007/08			2007/08		
	N	P	K	N	P	K	N	P	K
	kg/ha			kg/ha			kg/ha		
Cm	0	0	0	89	12	66	-89	-12	-66
CmR	0	0	0	85	10	67	-85	-10	-67
CmRF	135	24	41	197	35	174	-62	-11	-133
MmRF	135	24	41	207	56	85	-72	-32	-44
CmRF+Mnr	199	58	89	191	32	183	+8	+26	-94
(C+M)RF	180	31	62	239	46	180	-59	-15	-118
(C+M)RF+Gl	236	37	87	235	43	189	+1	-6	+46
(C+M)RF+Eg	180	31	62	193	39	139	-13	-8	-131

Crop Yield, Land Degradation and Crop Production Sustainability

Looking at the experimental results discussed above, it can be concluded that planting cassava does not necessarily speed up land degradation, either by plant nutrient uptake or soil erosion. Except for potassium, the nutrient uptake by cassava is not higher than that by maize. In terms of nutrient utilization for biomass production, cassava is more efficient than maize. To produce one ton of dry tuber in treatment (CmRF), for example, only requires 5.94 kg N, 0.99 kg P and 8.21 kg K. On the other hand, the production of one ton of grain maize requires 15,90 kg N, 3.76 kg P, and 5.46 kg K.

Another important result to point out is that increasing crop yield does not necessarily increase the rate of land degradation. It is true, however, that increasing the yield will increase the nutrient uptake. A proper cropping management, such as the addition of farm yard manure or the use of alley cropping system can minimize this negative effect, notwithstanding the fact that it increases the plant nutrient in the soil (see Table 8 for treatment of Alley cropping with *gliricide*). In addition, increasing yield is usually associated with the improvement of crop growth. Hence, there will be a better land coverage, higher biomass, improvement of soil properties, leading to the decrease soil erosion.

In terms of production sustainability, the addition of either organic materials, either as farm yard manure (treatment CmRF+Mnr) or fresh biomass (treatment (C+M) RF+Gl) has proven able to maintain soil productivity. If it is there was only added with organic fertilizers, at the four year of planting, cassava yield decreases by 30% (see Figure 1). With the addition of 5 t/ha manure the yield is relatively constant at about 30 t/ha.

CONCLUSION

The experiment results presented here demonstrated the nutrient uptake and soil erosion rate of the cassava field were not necessarily higher than those of maize in terms of crop yield and crop management. At low-to-medium yield, the nutrient uptake of cassava was lower than that of maize. At high yield, only the K uptake of cassava was higher than that of maize, whereas the N and P uptake was more or less similar. Soil erosion on the cassava field was significantly higher than that on the maize field; however, this only occurred when there was no suitable crop management. Simple crop managements, such as ridging, fertilizer application, or manure application could significantly reduce soil erosion. The results also revealed that proper management could prevent land degradation and increase crop yield. In turn, the increase in crop yield could decrease soil erosion and plant nutrient depletion.

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