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CASSAVA CULTURAL PRACTICES

Proceedings of a workshop held in Salvador, Bahía, Brazil, 18-21 March 1980

Editors:
Edward J. Weber, Julio Cesar Toro M., and Michael Graham

Organized by:
Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA)
Centro Internacional de Agricultura Tropical (CIAT)
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Contents

Soil-Related Intercropping Practices in Cassava Production

Carlos F. Burgos[1]

Simultaneous polyculture has been suggested as a way of reducing soil and nutrient losses and of maintaining the good physical properties of the soil. To prevent soil losses, cassava should be intercropped with a fast-growing crop that can cover the ground rapidly while the cassava develops a good leaf canopy. Soil losses for monocultures vary with soil management practices. Losses of 101–111 t/ha were measured in freshly cultivated cassava plots after a high intensity rainfall. However, maize plots that had not been cultivated for 3 months prior to the rain showed no loss.

Increases in soil resistance in nine cropping systems plots, which included cassava, appear to be related more to human traffic than any other factor.

In cassava monoculture, five times as much phosphorus was lost as was absorbed by the crop. The amount lost in two-crop polycultures ranged from two to three times as much as the amount absorbed by the plants and four-crop polycultures lost less than half the amount of phosphorus removed by the crops. Cropping systems that showed potassium loss absorbed five times as much nutrient as was lost for cassava monocrop, three times the amount lost by the two-crop intercropped, and 10 times the loss in a three-crop intercropped system.

Calcium loss appears to be greatly influenced by the degree of ground cover provided by the cropping pattern. Larger absorption than loss of magnesium from the soil was detected for two- and three-crop polyculture, and larger soil magnesium loss than absorption was observed for cassava monocrop and four-crop polyculture systems that included cassava.

There are several advantages of intercropping cassava with other crops: runoff and soil losses are reduced; the physical properties of the soil are conserved; and the maintenance of soil fertility is aided. When possible, stover of the accompanying plant should be left on, or semi-incorporated into the soil to recycle nutrients.

Intercropping is widely practiced and is common on small cassava farms in Latin America (CIAT 1976). Cassava is frequently intercropped with maize, common bean (CIAT 1975; Krantz et al. 1974; Tobon et al. 1975), yams (CATIE 1978), potatoes, tomatoes, and several other species according to traditional practices based on little-understood agronomic criteria (CIAT 1976).

Yields of cassava intercropped with either maize or common bean are sometimes similar to those of the monocrop (CIAT 1975). In other cases, when intercropped with maize and soybeans, for instance, cassava yields have been about 50% less than those of the monocrop (CIAT 1971). Cassava is commonly associated with maize in the low, humid tropics of Central America. Sometimes both crops are planted simultaneously at the beginning of the rainy season.

At CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) in Turrialba, Costa Rica, several cropping systems that include cassava were studied in an experiment from 1974 to 1978. For the November planting of the 1st year, 1974–75, no significant differences were obtained for treatments that included maize. This crop, maize, competed successfully, lowering the yields of crops associated with it. Only cassava, cultivar Valencia, seemed to have made some competition for maize Tuxpeño-1, especially when they were planted simultaneously. In this case, the maize yielded 2.2 t/ha, which was significantly inferior to the maize yield in monoculture (3.2 t/ha). Cassava yield decreased by 50%, from 23.6 t/ha in monoculture to 11.6 t/ha.

From 1975 to 1976, yields of cassava and maize were evaluated in terms of dry matter. Maize yields were lower in the second planting

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(May) and showed better response to fertilizer applications in this planting, than in the first one. In the first planting, maize intercropped with cassava yielded 3524 kg/ha of dry matter, which was similar to that yielded by the monocrop. Cassava yielded 1570 kg/ha, which represented a decrease of 51% in relation to the monocrop (CATIE 1977). Between 1976 and 1977, the yield range for cassava was 6.5 t/ha at 10 months harvest to 17.3 t/ha for the monocrop harvested at 11.5 months. Yields of cassava intercropped with maize were 9.3 t/ha, which indicates strong competition caused by the maize (CATIE 1978).

From the reports available, it can be stated that the associations of cassava and other crops, mainly maize, are widely practiced in Central America and that the degree of competition between cassava and maize depends on the morphology of both crops and plant density.

Management Practices

Reduced soil and nutrient losses as well as maintenance of good physical properties have been suggested as reasons for increased yields in simultaneous intercropping.

Reduced Soil Losses

It has been proposed that, in regions of high rainfall intensity, the soil surface be kept covered for as long as possible. Cassava grown on an inceptisol of Turrialba showed highest increments of total biomass between 4 and 8 months after planting (Gallegos 1976). Cassava in monoculture reached its peak of leaf area production before any of the five cropping systems under study, namely:[2] cassava → sweet potato → sweet potato; cassava → maize → maize; cassava + common bean → maize; and cassava + common bean + maize → sweet potato; however, it shed leaves sooner than in the other systems.

The highest leaf area index measured for cassava was 1.44 for the monocrop at age 6 months and 1.51 at 8 months for cassava + common bean intercropping (Gallegos 1976). These values are low when compared with values obtained elsewhere: Colombia 2.0; Nigeria 5.6 and 7.5. Experimental results reported of leaf area index curves and reserve roots (Gallegos 1976) showed for cassava monoculture a progressive leaf area increase up to age 6 months when the leaf area began to diminish. However, the biomass of the roots increased rapidly, starting at the 6th month. Therefore, as a protection against soil losses, cassava should be simultaneously intercropped with a fast-growing crop that can cover the ground rapidly. The intercropped plant should be harvested when the cassava canopy and roots provide protection against erosion of the soil.

In a forest receiving 2000 mm rainfall per year, annual soil losses of 900 kg/ha have been reported from small plots with slopes of 2–15%. A plot of 7–8% slope under bare fallow lost 100 t/ha-year (Greenland and Nye). On moderate slopes planted very closely, soil losses may not be so important. It has been reported (Greenland and Nye) that plots with a 25% slope, which had been cleared in a forest with a rainfall of about 2500 mm a year and planted to upland rice with little disturbance of the soil, lost 4050 kg/ha in the 1st year and less than 900 kg in the second.

Mounding or ridging of the soil for root crops such as yams, sweet potato, and cassava accelerates erosion in forest environments (Greenland and Nye). Rotation experiments (2 years of rice followed by sweet potato on ridges or by cassava planted on the flat) showed a loss of 4 t/ha from the ridged plot but only small losses from the undisturbed plot. Soil losses vary in magnitude depending on rainfall intensity, percent of slope, soil type, and soil and crop management. Amounts of soil losses range from 2.7 to 4.9 t/ha a year (Greenland and Nye). Traditional systems used by small farmers in forest regions seem to protect the soil well from erosion even on steep slopes and under heavy rainfall.

Soil erosion problems have also been studied in Nigeria (Lal 1976) for different soil management practices and four cropping systems: maize → maize with mulch; maize → maize with tillage; maize → cowpea with no tillage; and cowpea → maize tilled. The study was carried out on an alfisol; average rainfall was 1100–1300 mm bimodally distributed. Soil losses for a 10% slope were: bare fallow 153 t/ha; maize → maize with mulch 0.1 t/ha; maize → maize tilled 4.4 t/ha; maize → cowpea untilled 0.1 t/ha; and cowpea → maize tilled 3.3 t/ha. The same trend was found for 1.5 and 15% slopes (Lal 1976). These results show that mulching and no tillage treatments are very effective in preventing soil losses on land with slopes ranging from 1 to 15%.

Crops and soil management systems that provided early ground cover controlled runoff and erosion better than those that did not (Lal 1977). The number of days required for 50%

[2]The symbol → means rotation; + means association.

canopy to form was approximately 38, 48, and 63 for respective cultivars of soybeans, pigeon peas, and cassava grown at Ibadan, Nigeria (Lal 1977).

Soil-conserving crops are those with quick growth; soil-depleting crops take longer to cover the ground. Practices such as mixed cropping also affect ground cover. It took cassava as a monocrop 63 days to cover 50% of the ground, whereas intercropped maize and cassava took only 51 days (Lal 1977).

Soil erosion and runoff losses were less with mixed crops than with monocrops in an alfisol in Nigeria (Lal 1977). Other cultural practices that affect erosion control are plant density, planting time, and soil fertility. More important than the growth habit is the soil management practice. Soil-depleting crops grown with proper soil-conserving techniques could result in less runoff and soil losses than a soil-conserving crop grown without conservation practices (Lal 1977). This was the case when maize (considered a soil-depleting crop) was grown in untilled plots and compared with cowpea (soil-conserving crop) grown with no conservation practices. Runoff and soil losses were less for maize than for cowpea, especially on slopes greater than 5% (Lal 1977).

Soil losses for rotations in tropical regions of Africa and Madagascar have also been studied (CIDIAT 1977). Rotations that included cassava showed higher soil losses and mean annual runoff. This finding was probably due to cassava's delay in developing an effective ground cover. Soil losses in the system peanuts → green manure cowpea → cassava → forages (soybeans + maize) were higher, 15.80 t/ha-year, in unfertilized plots than plots receiving manure plus potash, which lost 11.73 t/ha-year. Plots that received potash alone had a slightly lower soil loss (15.67 t/ha-year). Soil losses for cassava in the 1st year were 19.60 t/ha and in the 2nd year, 17.46 t/ha. These losses were less appreciable on plots fertilized with manure and potash, namely: the 1st year 15.28 t/ha, and the 2nd year, 2.90 t/ha (CIDIAT 1977).

At Turrialba on 6 December 1949, a heavy rain fell (410 mm, of which about 250 mm fell in fewer than 10 h) on plots utilized for studies of soil and water runoff from grass, bare soil, and rotation of molasses grass, tropical kudzu, potatoes, peanuts, grain sorghum, and cassava. Soil losses from plots planted with cassava were 101 and 111 t/ha for the 16 and 45% sloped plots, respectively. Plots covered with grass showed zero loss. The high losses reported for cassava plots were due to the early growth stage of cassava and to the fact that they had been freshly cultivated just before the storm (Ives 1951). Plots covered with corn had not been touched since September, and crops and weeds provided a good cover for the ground. No soil losses were observed from these plots. These results give support to the suggestion that intercropping and mixed cropping reduce soil losses and in this way help to maintain the soil in good condition; in addition they sometimes increase yields.

Table 1. Calculated soil losses for cassava monocrop grown in two soil series of Turrialba (ultisol-inceptisol CATIE 1975).

Slope (%)	Length (m)	Soil series	Soil loss (t/ha-year)
5	15	Colorado	1.61
5	30	Colorado	3.21
10	30	Colorado	5.97
5	15	Instituto	2.42
5	30	Instituto	4.83
10	30	Instituto	8.98

Soil losses in cassava monoculture were calculated by the Universal Soil Loss Equation in two soil series, Colorado and Instituto, at CATIE, Turrialba, Costa Rica (Table 1). The data indicate rather low soil losses, mainly due to the low-intensity rains in Turrialba.

Physical Properties

The effect of various cropping systems on the mechanical resistance of soils was studied at CATIE, and in a complementary study (Tafur 1976). Criteria for interpreting resistance to penetration were 0–6 bars, excellent; 7–12 bars, acceptable; 13–25 bars, unacceptable; 25 and higher restricts root growth. Variations measured for all 48 treatments, 24 cropping systems at two levels of technology, were not significant. Values obtained ranged from 13.64 to 8.74 bars. At the time of measurement, correspondence between resistance and number of crops grown on the soil was not detected. Lowest resistance values were found on the soil surface, 6.46 bars; at 30 cm deep, values increased significantly to 13.20 bars. When the common beans were harvested, resistance to penetration values (adjusted to 40% of soil moisture) were, on average, higher for plots not intercropped with cassava than on those that were. Plots that included maize without cassava gave lower resistance readings, 16.4 bars, than those intercropped with cassava, 17.78 bars. Subtracting the resistance just before harvesting from the resistance before the experiment was started suggested that increase of soil resistance to penetration is more related to human traffic than any other activity (Tafur 1976).

On the soil surface, soil resistance adjusted to 40% soil moisture increased from 4.2 to 8.8 bars after 10 months of cropping; at 10 cm depth, the changes of adjusted resistance were very small; at a depth of 20–30 cm, variations of the resistance depended greatly on soil moisture changes, whereas on the soil surface the changes were attributed to human traffic (Tafur 1976).

Compared with bare and covered soils, sweet potato intercropped with cassava and maize significantly increased the adjusted resistance from the surface to 20-cm depth. On plots planted with maize, a large part of the area was walked or stepped on twice, whereas on plots with sweet potato intercropped with cassava the entire area was stepped on twice and in some places three times (Tafur 1976).

The soil with cassava and sweet potato simultaneously intercropped had an air space of 8.1%; the value for maize monocrop was 10.8%. This difference was not significant. The lower average aeration of the intercropped plot was probably due to compaction caused by human traffic.

The effect of ridging or hilling on the performance of cassava intercropped with maize, string bean plus maize, and string beans was assessed at CATIE (Gerodetti and Holle 1980). At the beginning of the experiment, bulk density was 0.75 g/cm^3 on the ridge and 0.89 g/cm^3 on flat soil. At harvest, average bulk density was 0.86 g/cm^3 for both, the differences between soil management systems having disappeared.

Soil resistance to penetration was 2.15 bars for the flat soil and 1.12 bars for the ridged soil; both values are within the 0–6 range considered excellent. At harvest, the values were 5.27 bars for flat and 2.92 for ridged soil; this difference was significant (p = 0.01), although they were both still within the range of values considered excellent for root penetration and development. The soil from which cassava was harvested was moist, and manual harvest was not difficult.

Cassava planted on flat soil yielded more total roots (24.8 t/ha for monoculture; 14.4 t/ha for intercropped plots) and commercial roots (17 t/ha and 9 t/ha, respectively) than did the cassava on ridged soil where average yields of total roots for cassava monoculture and intercropped maize–cassava were 21.6 and 12.4 t/ha, respectively. Commercial root yields on ridged soil were 12.3 and 6.2 t/ha for cassava monocrop and intercropped maize–cassava, respectively. For both cassava monocrop and cassava–maize planted on flat soil, more roots of commercial quality were obtained in relation to yields on ridged soil. No differences were found among management systems, flat and ridged land, for number of total and noncommercial roots.

More broken roots were obtained from flat than from ridged plots: average 9.4 roots per plot compared with 5.9 for the ridged soil. The area harvested for each plot was 30 m^2. Planting without ridging increased cassava and bean yields, but maize yields were similar for flat and ridged plots (Gerodetti and Holle 1980).

Nutrient Losses

The reduction of nutrient losses has been proposed as one of the reasons for increased yeilds from intercropped plots. However, reduced soil losses may not affect yields of crops in the same growing season, but will conserve soil fertility in the long run. There are few studies that measure the effects of intercropping on soil nutrients (Kass 1976).

The cropping system did not have a significant effect on the exchangeable Ca, Mg, or K content in soil where maize and pigeon peas had been planted (16 weeks before) in monoculture and intercropped plots. This study was carried out in soil with an exchange capacity of 12 meq/100 g and in an environment with monthly rainfall less than 10 mm; under these circumstances leaching of nutrients would probably be small (Kass 1976). Sandy soils (dystrophic red and yellow quartz sands) of the Tracuateua Experiment Station (UEPAE), Pará, Brazil, where rainfall for 8 months was more than 100 mm but less for the remainder of the year, lost about five times as much magnesium, 85 kg/ha, as was recovered in the plants, 18 kg/ha, in cassava monoculture, cassava + maize, and cassava + maize + rice plots. About four times as much was lost, 58 kg/ha, in the rice → cowpea sequence, and less than three times, 33 kg/ha, as much in the rice + cassava combination (Kass 1976). These findings indicated that losses of magnesium at a depth of 0–40 cm were considerably less for simultaneous intercropping of rice and cassava than for the other cropping systems tested. A similar but less marked pattern was observed for potassium. Potassium soil losses were 113, 100, 112, 103, and 143 kg/ha for cassava monocrop; rice → cowpeas; cassava + maize; cassava + rice; and cassava + maize mixed cropped with rice, respectively.

In experiments with polycultures at CATIE, Turrialba, it was found that cassava had higher nutrient uptake when intercropped than when grown alone. Intercropped with maize, cassava had a total nutrient uptake of 417, 51, and 357 kg/ha of N, P, and K, respectively. These amounts were higher than the amounts added as chemical fertilizer (Jimenez 1976). This study suggests that cassava as a monocrop absorbs larger amounts of K and N than of any other nutrient.

At CATIE (Soria et al. 1975), several cropping systems that included maize, beans, sweet potato, and cassava were studied. The spatial and chronological arrangements that were tested consisted of association, sequences, and relay of crops. In some cases, the cropping systems were managed at two levels of fertilizer application.

Nutrient Changes

Studies were conducted at CATIE in an inceptisol from 1974 to 1978 to ascertain nutrient changes in the soil with systems that included cassava. The nutrients measured were phosphorus, calcium, potassium, and magnesium.

Extractable P in the soil where cassava was grown alone had a marked decline in 1975, but it increased in 1976 to a level higher than its initial value. At harvest in 1978, P was 1 ppm higher than the 1974 level. The same pattern was observed for polycultures such as cassava + green maize; cassava + maize; cassava + maize → green maize; cassava + sweet potato; and cassava + maize + beans → sweet potato. The cropping system of beans intercropped with maize gave lower values than cassava monoculture.

Exchangeable potassium in the 0–30 cm soil layer of the cassava monoculture decreased during the experimental period from 0.29 to 0.22 meq/100 g. The cassava monoculture to which a higher dose of fertilizer was applied had a larger decrease in the soil exchangeable potassium (0.29 to 0.14 meq/100 g). A decrease in the level of exchangeable potassium was the trend in every system.

Soil exchangeable magnesium diminished with time for all systems, but a sharper decline was measured for the more intensive systems.

In 1976 a marked drop of the calcium level was also observed for most treatments, but for 1978 calcium levels increased to about the level of 1974. The mechanisms that may explain this phenomenon are excessive leaching in 1974 and 1975 and calcium removal by both cassava and the accompanying crop. In 1978, the calcium level measured was higher than expected, probably because the soil-extracting solution employed (ammonium acetate pH 7.0) was different from the one used previously.

Nutrient Balance Sheet

Table 2 indicates that phosphorus losses were highest for the cassava monocrop system. The other systems in descending order with regard to phosphorus losses were simultaneous intercropping of cassava plus beans (T 52 B+C); beans + cassava followed by green maize (T 16-2 B+C→Me), fertilized at a higher dose than T 16-1 (B+C→Me); maize + cassava (T 6-2 M+C); beans + cassava followed by maize (T 16-1 B+C → Me); beans + maize + cassava followed by sweet potatoes (24-2 B+M+C+→SP), fertilized with a high dose of fertilizer; and, in last place, beans + maize + cassava followed by sweet potatoes (24-1 B+M+C+→SP). It is evident that soil phosphorus losses were less in systems that included maize and much less in three-crop polycultures. Another interesting fact is that phosphorus removal by aerial parts of cassava was higher in four-crop polycultures than in two- or three-crop intercropping. Phosphorus loss was influenced

Table 2. Phosphorus balance sheet for five selected cassava intercropped systems tested on an inceptisol at CATIE (1975–78).

System[a]	Applied P (kg/ha)	Soil P (kg/ha)		Plant P uptake[b] (kg/ha)			Loss of P from soil (kg/ha)	Loss of P from system (kg/ha)
		Start	End	S+L	R	Acc		
1-2 C	128	6	12	15	4	—	-6	103
6-2 M+C	128	4	6	15	2	32	-2	77
5-2 B+C	128	4	8	13	4	13	-4	94
16-1 B+C→Me	99	8	16	13	3	34	-8	41
16-2 B+C→Me	139	6	6	12	4	37	0	86
24-1 B+M+C+→SP	99	6	8	18	2	60	-2	17
24-2 B+M+C+→SP	139	4	12	22	2	66	-8	41

[a]C = cassava; B = beans; SP = sweet potato; Me = green maize; M = maize; → = double cropping; + = association of crops; +→ = double cropping of crop association.

[b]S+L = stem plus leaves; R = roots; Acc = accompanying crop.

Table 3. Potassium balance sheet for five selected cassava intercropped systems tested on an inceptisol at CATIE (1975–78).

System[a]	Applied K (kg/ha)	Soil K (kg/ha)		Plant K uptake[b] (kg/ha)			Loss of K from soil (kg/ha)	Loss of K from system (kg/ha)
				S+L	R	Acc		
1-2 C	166	140	109	96	68	—	31	33
6-2 M+C	311	109	109	62	39	246	0	No loss
5-2 B+C	311	117	94	56	59	143	23	76
16-1 B+C→Me	187	109	117	55	51	277	-8	No loss
16-2 B+C→Me	336	140	101	52	57	311	39	45
24-1 B+M+C+→SP	166	101	125	78	34	450	-24	No loss
24-2 B+M+C+→SP	332	101	86	129	29	521	15	No loss

[a]C = cassava; M = maize; B = beans; Me = green maize; SP = sweet potato; → = double cropping; + = association of crops; and +→ = double cropping of crop association.

[b]S+L = stem plus leaves; R = roots; and Acc = accompanying crop.

Table 4. Calcium balance sheet of five selected cassava intercropped systems tested on an inceptisol at CATIE (1975–78).

System[a]	Soil Ca (kg/ha)		Plant Ca uptake[b] (kg/ha)			Loss of Ca from soil (kg/ha)	Loss of Ca from system (kg/ha)
	Initial	Final	S+L	R	Acc		
1-2 C	2080	2040	120	12	—	40	-92 No loss
6-2 M+C	2160	1760	99	7	84	400	210
5-2 B+C	2160	2000	92	10	301	160	-243 No loss
16-1 B+C→Me	2400	1920	94	9	165	480	212
16-2 B+C→Me	1520	2000	81	10	180	-480	-209 No loss
24-1 B+M+C+→SP	2160	2200	107	7	81	- 40	-235 No loss
24-2 B+M+C+→SP	2240	1960	129	9	82	280	60

[a]C = cassava; B = beans; SP = sweet potato; Me = green maize; M = maize; → = double cropping; + = association of crops; and +→ = double cropping of crop association.

[2]S+L = stem plus leaves; R = roots; and Acc = accompanying crop.

more by the number of crops in the system than by the rate of phosphorus application.

The potassium balance sheet (Table 3) shows that potassium losses did not occur from systems that contained maize harvested for grain, regardless of the amount of applied potassium. Also, no loss was detected for the cropping system that included maize to be harvested as green corn and received a relative low application of potassium in the form of chemical fertilizer. Table 3 indicates that cassava in monoculture removes higher amounts of potassium from the soil than when associated with one, two, or three crops. However, at a high rate of fertilization and in association with three other crops, one of which is maize to be harvested for grain, cassava is responsible for higher potassium removal than when it is grown alone.

In general terms, the calculations presented in Table 2 show that in cassava monoculture five times as much phosphorus is lost than is absorbed by the crop. However, the amount lost in two-crop polycultures ranged from two to three times as much as the amount absorbed by the plants, and soils in four-crop polycultures lost less than half the amount of phosphorus removed by the crops.

In the case of potassium, cropping systems that showed some loss absorbed five times as much nutrient as was lost for the cassava monocrop system, three times the amount lost by the two-crop intercropped, and 10 times the losses in a three-crop intercropped system.

Calcium losses (kg/ha) in three systems namely, maize associated with cassava (M+C), beans associated with cassava followed by green maize (B+C→Me), and beans associated with maize and cassava followed by sweet potato (B+M+C+→SP), were 210, 212, and 60, respectively (Table 4). Calcium losses for maize plus cassava (M+C) were higher than for cassava monoculture perhaps because of the reduced

Table 5. Magnesium balance sheet of five selected cassava intercropped systems tested on an inceptisol at CATIE (1975–78).

System[a]	Applied Mg (kg/ha)	Soil Mg (kg/ha)		Plant Mg uptake[b] (kg/ha)			Loss of Mg from soil (kg/ha)	Loss of Mg from system (kg/ha)
		Initial	Final	S+L	R	Acc		
1-2 C	47	384	312	44	6	—	72	69
6-2 M+C	50	312	288	41	3	58	24	-28 No loss
5-2 B+C	50	384	312	40	5	59	72	18
16-1 B+C→Me	11	384	336	33	4	46	48	-24 No loss
16-2 B+C→Me	47	312	336	35	5	54	-24	-71 No loss
24-1 B+M+C+→SP	11	456	192	38	3	32	264	202
24-2 B+M+C+→SP	47	384	192	48	4	33	192	154

[a]C = cassava; B = beans; SP = sweet potato; Me = green maize; M = maize; → = double cropping; + = association of crops; and +→ = double cropping of crop association.

[b]S+L = stem plus leaves; R = roots; and Acc = accompanying crop.

ground cover provided by bent corn stalks. This system (6-2 M+C) received a rate of fertilizer application (Table 3) that resulted in a vigorous corn growth and a slow growth of cassava in competition with maize. The amounts of calcium removed from the soil when cassava was planted in monoculture were similar to those removed when it was associated with one, two, or three crops, regardless of the fertilization rate employed. It appears that calcium loss from the system was greatly influenced by the ground cover provided by the cropping patterns.

Magnesium absorbed by cassava monoculture was about half the amount taken up by two-, three-, and four-crop systems (Table 5). Magnesium losses detected for cassava monoculture, cassava associated with beans, and for two four-crop polycultural systems were 72, 72, 264, and 192 kg/ha, respectively. As in the case of calcium, it appears that magnesium loss is greater in systems that do not cover the soil properly. In the four-crop polycultures, the chronological sequence of harvesting and the establishment of the last crop (sweet potato) influenced the magnesium losses from the soil. In general, plants in two- and three-crop polycultures had larger absorption of magnesium than was lost from the soil, whereas the four-crop polycultures and cassava as a monocrop had larger soil magnesium losses than absorption.

All things considered, the advantages of intercropping cassava with other crops are many: it reduces runoff and soil losses, helps to conserve good soil physical properties, and helps maintain soil fertility. When possible, stover of the accompanying plants should be left on, or semi-incorporated into the soil, so that nutrients are recycled in the system.

Future Research

Studies on the performance of cassava in intercropping systems and the effects of various environments deserve attention because of the possibilities presented by these systems for the recycling of soil nutrients. More information is also needed about soil losses in various situations of rainfall intensity, slope, and coverage by plant canopy. The role of weeds in the protection of soil against soil and nutrient losses should also be studied as should the effect of cassava intercropping systems on the physical properties of the soil, especially soil compaction caused by excessive human traffic, which is closely related to the amount of care required by the plant intercropped with cassava. Human traffic causes changes of the physical properties of the soil depending on ground cover and soil moisture content.