Cultural practices for soil erosion control in cassava-based cropping systems in Indonesia

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In Indonesia about 1.3 million hectares of cassava are located on marginal sloping uplands, where soil erosion is a serious problem. Alfisols are the dominant soil type for cassava cultivation. Cassava cultivated on sloping land can cause severe erosion if it is not properly managed. A study on the effect of different cultural practices on erosion and yield of cassava was conducted on an Alfisol with about 15% slope in East Java during the rainy season of 1996/97. Twelve cultural practices were tested, using 12-m long and 3-m wide plots for each treatment. A channel was made below each plot and covered by plastic sheet to collect the eroded soil. The eroded soil was weighed every month and the crop yield was recorded at the harvest time. Another trial on the effect of potassium fertilizer on cassava yield was also conducted close to the above trial. Five fertilizer treatments were studied to determine the role of potassium in increasing the yield of cassava.

The results show that the farmers' practice of 'up-and-down ridging' gave the highest cassava yield (18.6 t ha^{-1}), but produced a high level of erosion (11.8 t ha^{-1}) compared to other treatments. Staggered mounds for cassava cultivation, which is practiced by other farmers, also produced high levels of erosion (8.3 t ha^{-1}). When contour ridges were prepared before planting, the soil loss due to erosion was similar to the above system (9.0 t ha^{-1}). Combining contour ridging with hedgerows of elephant grass (Pennisetum purpureum) or vetiver (Vetiveria zizanioides) every 4 m produced the lowest level of soil erosion (7.3 t ha^{-1}) and a good cassava yield (13.4 t ha^{-1}). Lemon grass (Cymbopogon citratus) could be used as an alternative for hedgerows; however, vetiver was the most tolerant to drought compared to the other grasses. On the other hand, Gliricidia (Gliricidia sepium), Flemingia (Flemingia macrophylla), Leucaena (Leucaena leucocephala), or Calliandra (Calliandra calothyrsus) hedgerows produced higher levels of soil erosion (9–10 t ha^{-1}) compared to elephant grass and vetiver grass hedgerows. It can be concluded that contour ridging combined with hedgerows of either elephant grass or vetiver grass could be recommended for planting cassava, since such practice could reduce soil erosion and gave a good cassava yield. Potassium application of up to 200 kg KCl ha^{-1} linearly increased cassava yield, and would indirectly reduce soil loss due to erosion. Alternative materials which are cheaper than KCl and available locally should be identified, since this fertilizer now is too expensive for farmers.

Introduction

Cassava, originally from South America, is an important root crop in Indonesia. It is mostly grown in marginal sloping lands during the rainy season. Farmers in these areas use cassava as the main food. Besides as a staple food, cassava is also utilized as animal feed and as raw material for industry. Young cassava leaves are consumed as vegetable. During the recent food crisis, cassava has become more important as an alternative food for many farmers.

In Asia, Indonesia is the second largest cassava producer after Thailand. During the last three decades the harvested area of cassava decreased from about 1.5 million hectares in 1968 to 1.2 million hectares in 1998. However, the total production increased due to an increase in productivity from 7.5 t ha^{-1} to 12.3 t ha^{-1} during the same period (BPS, 1999).

Java is the main cassava production area, where the crop is grown mainly on Alfisols followed by Entisols, Inceptisols and Ultisols (Howeler, 1992). On these soils, cassava is predominantly cultivated on sloping lands with low fertility.

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Cassava is often blamed for causing severe soil erosion when grown on sloping land, as the crop is planted at a wide spacing and has a slow initial development; thus, it takes a long time for the canopy to protect the soil from raindrop impact. At harvest nothing is left on the soil except the dropped leaves.

Among tropical food crops, cassava does not extract large amounts of N and P, but removes relatively high amounts of K from the soil and has therefore a high K:N ratio in the harvested cassava roots. The amounts of nutrients extracted from the soil per ton of fresh root yield are about 6.22 kg N ha^{-1}, 0.79 kg P ha^{-1}, 5.41 kg K ha^{-1}, 2.83 kg Ca ha^{-1}, and 0.89 kg Mg ha^{-1} if all plant parts are removed from the field. The nutrients in one ton of fresh roots are approximately 2.32 kg N, 0.39 kg P, 3.05 kg K, 0.47 kg Ca and 0.27 kg Mg (Howeler, 2001).

Until recently, most cassava farmers only applied N fertilizer and they were not very concerned about soil erosion. Farmers felt that during the last three decades cassava yields did not decrease, but tended to increase due to the application of improved technologies. Utomo (1994) stated that farmers are actually well aware of the problem of soil erosion, soil degradation and how to overcome the problem. However, technology adoption is very slow since it takes time to observe the effect of soil conservation technologies on crop yields.

Potassium deficiency often becomes a problem when cassava is planted continuously on marginal soils. The reasons for this are: the crop extracts a large amount of K, many cassava soils have a low K content, and farmers rarely apply K fertilizers.

The objective of the trials described in this paper is mainly to identify effective crop/soil management practices to reduce soil erosion and to increase cassava productivity on sloping lands.

Methodology

Two trials were conducted on an Alfisol of south Malang, East Java, Indonesia, during the rainy season of 1996/1997 (November 1996–September 1997).

Soil erosion control experiment

A study on the effect of different cultural practices on soil erosion and cassava productivity was conducted on an Alfisol with about 15% slope. Twelve treatments were tested using 12 m long and 3 m wide plots for each treatment (**Table 1**). There were two replications. A channel was made below each plot and covered with plastic sheet to collect eroded soil, which was weighed every month. A sample of wet eroded soil was taken for moisture determination in the laboratory. Then, dry soil loss due to erosion was calculated. Every plot was bordered by a partially dug-in sheet of zinc to avoid water entering from adjacent plots. All plots were fertilized with 200 kg ha^{-1} of urea, 100 kg ha^{-1} of SP-36, and 100 kg ha^{-1} of KCl except treatment one, which received only 200 kg ha^{-1} urea. The yield of crops was determined at the harvest time. The local variety (Menyok) of cassava was used in this experiment.

Table 1. Treatments of soil erosion control experiment, Malang, Indonesia, 1996/97.

No.	Treatments[†]
1.	C+M: Farmers' practices; up-and-down ridging
2.	C+M: Recom. practices; contour ridging; vetiver grass *(Vetiveria zizanioides)* hedgerows
3.	C+M: Recom. practices; staggered mounds
4.	C+M: Recom. practices; contour ridging; lemon grass *(Cymbopogon citratus)* hedgerows
5.	C+M: Recom. practices; in-line mounds, then changed to contour ridging during weeding
6.	C+M+P+Cp: Recom. practices
7.	C+M: Recom. practices; contour ridging
8.	C+M: Recom. practices; contour ridging; Gliricidia *(Gliricidia sepium)* hedgerows
9.	C+M: Recom. practices; contour ridging; Flemingia *(Flemingia macrophylla)* hedgerows
10.	C+M: Recom. practices; contour ridging; Leucaena *(Leucaena leucocephala)* hedgerows
11.	C+M: Recom. practices; contour ridging; Callandra *(Callandra calothyrsus)* hedgerows
12.	C+M: Recom. practices; contour ridging; elephant grass *(Pennisetum purpureum)* hedgerows

[†] C = cassava, M = maize, P = peanut, Cp = cowpea; contour hedgerows are planted every 4 m.

Potassium fertilization experiment

This trial was also conducted on an Alfisol close to the first trial where cassava showed symptoms of K deficiency during the previous rainy season. Five treatments were tested on 6 x 6 m plots, replicated three times, with a plant spacing of 1 x 1 m (**Table 2**). The local variety (Menyok) of cassava was used in this experiment. This trial was conducted to complement the first trial, and only cassava yields were recorded at the harvest time.

Table 2. Treatments in potassium fertilization experiment, Malang, Indonesia, 1996/97.

Treatment codes	Rates, kg ha^{-1}			Fym, t ha^{-1}
	Urea[†]	SP-36	KC1	
NP	200	100	-	-
NPK1	200	100	50	-
NPK2	200	100	100	-
NPK3	200	100	200	-
NPK3F	200	100	200	10

[†] Urea: Source of N (46% N); SP-36: Source of P (36% P_2O_5); KCL: Source of K (60% K_2O); Fym: Farmyard manure.

Soil analysis before planting

A composite soil sample was taken before planting, and analyzed in the laboratory. Most of the nutrients in the soil were low to very low, especially potassium and phosphorus (**Table 3**).

Table 3. Results of soil analysis before planting.

Item	Value	Criteria[†]
pH (H_2O)	5.2	Slightly acid
Organic matter	1.1%	Low
N total	0.1%	Low
P Bray II	1.56 ppm	Very low
K	0.07 me/100 g	Very low
Ca	9.7 me/100 g	High
Mg	2.6 me/100 g	High
Al	0.52 me/100 g	Normal
B	0.38 ppm	Low
Zn	1.48 ppm	Medium
Mn	57.0 ppm	Medium
Cu	2.74 ppm	High
Fe	29.6 ppm	Medium
Texture	clay	
Sand	32.0%	
Silt	23.5%	
Clay	44.5%	

[†] Howeler (1996b).

Results and discussion

Effect of cultural practices on erosion

From the soil analysis result, it can be concluded that the fertility of the soil in this experiment was low. Terracing of sloping lands is a good way to control erosion, but it requires a lot of labor, time and capital, so farmers in this area do not apply this system. Farmers commented that there was no reduction in cassava yield during the last three decades, but that they have to apply more fertilizer to obtain the same yield. It can be said that the capacity of this soil to produce cassava tends to decrease year by year.

Results of the erosion control experiment indicate that the amount of dry soil loss due to erosion ranged from 5.45 to 19.4 t ha^{-1}. The lowest soil loss was obtained from a plot with contour ridging plus elephant grass hedgerows, while the highest soil loss was found on intercropping cassava + maize + peanut + cowpea without any contour ridging or hedgerows (**Table 4**).

Table 4. Effect of cultural practices on soil loss due to erosion and yield of cassava, Malang, Indonesia, 1996/97.

No.	Treatments†	Dry soil loss, t ha^{-1}	Yield, t ha^{-1}	
			Fresh cassava roots	Dry grain maize
1.	C+M: Farmers' practices; up-and-down ridging	11.82	18.63	1.33
2.	C+M: RP‡; contour ridging; vetiver grass hedgerows	7.31	13.46	1.21
3.	C+M: RP; staggered mounds	13.43	12.56	1.17
4.	C+M: RP; contour ridging; lemon grass hedgerows	9.03	11.53	1.16
5.	C+M: RP; in-line mounds, then contour ridging when weeding	8.34	15.51	1.09
6.	C+M+P+Cp§: RP	19.40	4.71	1.21
7.	C+M: RP; contour ridging	9.04	10.92	1.09
8.	C+M: RP; contour ridging; Gliricidia hedgerows	9.43	14.33	1.25
9.	C+M: RP; contour ridging; Flemingia hedgerows	10.32	13.73	1.13
10.	C+M: RP; contour ridging; Leucaena hedgerows	10.26	12.38	1.09
11.	C+M: RP; contour ridging; Callandra hedgerows	8.10	7.59	1.01
12.	C+M: RP; contour ridging; elephant grass hedgerows	5.45	13.41	1.05

† C = cassava, M = maize, P = peanut, Cp = cowpea; contour hedgerows are planted every 4 m.
‡ RP = Recommended practices
§Yield of peanut in dry pods = 340 kg ha^{-1}; cowpea in dry grain = 300 kg ha^{-1}.

Table 4 shows that the farmers' practice of 'up-and-down ridging' gave the highest cassava yields (18.6 t ha^{-1}). Farmers apply this system to drain rainwater quickly from the heavy clay soil.

Another system introduced in this experiment was staggered mounds, which is usually practiced by farmers in other areas, but this still produced a high level of erosion (13.4 t ha^{-1}) with low cassava yield (12.5 t ha^{-1}) compared to the up-and-down ridging.

A modified system was to use 'in-line mounds' at the beginning of the crop's cycle followed by contour ridging during weeding; this produced higher cassava yields (15.5 t ha^{-1}) and lower soil losses (8.3 t ha^{-1}). When contour ridges were made before planting, the soil loss due to erosion was similar to the above system (9.0 t ha^{-1}). On the other hand, the mound system should require less labor and time compared to contour ridging. The mound system is also a good way to drain water, so that soil moisture is favorable for cassava root development.

The plot with a combination of contour ridging and elephant grass hedgerows every 4 m not only gave the lowest soil loss, but also produced a good cassava yield (13.5 t ha^{-1}). When vetiver grass was used as hedgerows instead of elephant grass, soil erosion and cassava yield were similar to the above combination. Lemon grass hedgerows produced similar results as vetiver grass hedgerows. However, vetiver would be preferable as this grass is highly tolerant to drought. Elephant grass and vetiver grass were more effective as hedgerows than Gliricidia, Flemingia, Leucaena, and Calliandra, since the last four hedgerows produced higher soil losses (9–10 t ha^{-1}). Farmers preferred to grow elephant grass because it can be used for animal feed.

Similiar experiments conducted in other Asian countries show the effectiveness of cultural practices, such as fertilizer application, contour ridging, minimum or zero tillage, intercropping, and planting of hedgerows in reducing soil loss due to erosion (Howeler 1996a, 1998; Utomo *et al.*, 1998). Fujisaka (1998) also reported the effectiveness of contour hedgerows for control of soil erosion, and that it was adopted by farmers in the Philippines. In Thailand, using sugarcane as contour hedgerows for cassava gave the highest net return, while growing vetiver grass barrier was the most effective in reducing soil erosion. In Farmer Participatory Research (FPR) trials conducted by farmers on their own fields, average soil loss with vetiver grass hedgerows was only 8.5 t ha^{-1} compared to 24.8 t ha^{-1} from the plot with up-and-down ridging (Vongkasem *et al.*, 1998). Soil loss due to erosion, of course, is also dependent on the amount and intensity of rainfall, the slope, and the characteristics of the soil. However, the data indicate that appropriate cultural practices, mostly contour ridging and contour hedgerows, can reduce erosion.

Effect of K on cassava yields

Low cassava yields obtained by most farmers resulted from the following factors: 1) cassava is grown mostly on low fertility soil, and 2) farmers do not apply enough fertilizers (usually only N and/or farmyard manure). Hartojo (1993 and 1997) stated that fertilization is the dominant factor in increasing cassava yields. He reported yield increases ranging from 4 to 24 t ha^{-1} fresh roots when 200 kg of urea and 100 kg of TSP were applied, compared to that without fertilizer.

Results of this experiment show that application of NP-only fertilizer resulted in the lowest yield of cassava (11.88 t ha^{-1} fresh roots), the lowest plant height (109 cm), and the lowest number of roots/plant (7.5). In this area, the K content of the soil is very low and therefore K was the main limiting factor for cassava production. At the same rate of N and P fertilizer, the application of 50 kg of KCl ha^{-1} increased the cassava yield by 55%, from 11.88 to 18.42 t ha^{-1} fresh roots, compared to the application of N and P fertilizer only (**Table 5**). Increasing the rate of KCl up to 200 kg KCl ha^{-1} increased the cassava yield almost linearly. The highest yield (29.84 ha^{-1} of fresh roots) was obtained from the combination of 200 kg of urea + 100 kg of SP-36 + 200 kg of KCl ha^{-1} and 10 t of farmyard manure ha^{-1}. It was reported that FYM has a valuable effect in increasing cassava yields. Phien and Vinh (1998) reported that application of NPK fertilizers increased cassava yields by 71–112% compared to that of the control without fertilizer. The highest response was found to K fertilizer, followed by P and N fertilizers. A high response of other food crops (rice and maize) to K fertilizer application was also found on Vertisols (Suyamto *et al.*, 1991; Suyamto and Sumarno, 1993).

Table 5. Effect of potassium and farmyard manure on cassava yield, Malang, Indonesia, 1996/97.

Treatment codes	Yield†, t ha^{-1}	Plant height, cm	No. of roots $plant^{-1}$
NP	11.88	109	7.5
NPK1	18.42	116	9.2
NPK2	22.80	138	9.5
NPK3	23.46	147	8.9
NPK3F	29.84	184	10.1
LSD 0.05	9.1	NS‡	0.97
CV (%)	25.1	26.0	6.3

† Fresh roots.

Soil losses due to erosion were not determined in this experiment, but it can be assumed that potassium fertilizers increased crop growth and would therefore indirectly reduce soil loss due to erosion. Previous research has indicated that fertilizer application was an effective way to reduce soil erosion (Howeler, 1996a, 1998). Since the monetary crisis in Indonesia recently, the price of K fertilizer is too high for farmers. Therefore, alternative materials to substitute K fertilizer, which are cheap and locally available, should be identified and then applied.

Conclusions

Based on these experiments, the following four conclusions can be drawn:

1. Cassava cultivation on sloping uplands can result in severe soil erosion if the crop is not properly managed.

2. Several cultural practices, which are cheaper and less time consuming than terracing, were identified to be effective in reducing soil losses due to erosion.

3. Contour ridging and its modification were effective methods to control erosion, and the combination with elephant grass or vetiver grass hedgerows could be recommended, since they reduce soil erosion and gave a good cassava yield. Vetiver grass was the most tolerant to drought, compared to other grass species tested.

4. Potassium was needed to increase cassava yields on these marginal Alfisols, and application of 50–100 kg ha^{-1} of KCl could be recommended. Alternative materials for K fertilizers that are cheaper than KCl and available locally should be identified because the price of KCl now is too expensive for farmers.

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