

PAPER • OPEN ACCESS

Land Husbandry: Biochar application to reduce land degradation and erosion on cassava production

To cite this article: E.D. Yuniwati 2017 *IOP Conf. Ser.: Earth Environ. Sci.* **97** 012013

View the [article online](#) for updates and enhancements.

Related content

- [Estimating effectiveness of crop management for reduction of soil erosion and runoff](#)
K Hlavcova, Z Studvova, S Kohnova et al.
- [The effect of monoculture peanut and cassava/peanut intercropping on physical and chemical properties in peanut rhizosphere soil under the biochar application and straw mulching](#)
X Chen, Y Tian, X F Guo et al.
- [Effects of ecological and conventional agricultural intensification practices on maize yields in sub-Saharan Africa under potential climate change](#)
Christian Folberth, Hong Yang, Thomas Gaiser et al.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Land Husbandry : Biochar application to reduce land degradation and erosion on cassava production

E.D. Yuniwati

¹ Wisnuwardhana University, Malang, East Java

Telp: +0341-713604, Fax: +0341-719297

E-mail: nieyuniwati @wisnuwardhana.ac.id

Abstract: This field experiment was carried out to examine the effect of increasing crop yield on land degradation and erosion 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.

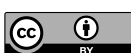
The experiment was done in a farmer's fields in Batu, about 15 km south east of Malang, East Java, Indonesia. The soils are Alfisols with a surface slope of about 8%. There were 8 experimental treatments with two replications. The experiment results show that biochar applications reduce of soil erosion 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, also observed 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, biochar 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, biochar, application, land degradation, soil erosion, cassava production

1.Introduction

Cassava can be considered a super-crop. It can be utilized for many purposes, and it can grow well in very marginal environmental conditions. In Indonesia, although cassava is an important crop and is planted in a very large area, it is still considered a minor crop by both the government and private sectors so it only receives little attention (2). Recently, with the 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 (4). This opinion is considered to be true by most people due to the fact that land planted with cassava is usually in a very poor condition with a very low productivity, or even already in a degraded condition.



Notwithstanding the fact that land planted with cassava is usually in a 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 (2) calculated that with a harvest of 35.7 fresh tubers/ha (equal to 13.53t/ha dry) cassava removes 55kg/ha of N, 13.2kg/ha of P, and 112kg/ha of K. As a comparison, Heckman *et al.* (3) show that nitrogen, phosphorus and potassium removed by 10.3t/ha maize grain yield was 141 kg N, 39 kg P, and 49 kg K. In more recent studies conducted in Thailand, Puttacharoen *et al.* (4) showed that the amounts of N and P removed in the harvested plant areas 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 that of pineapple or cassava grown for forage. In term of concentration of plant nutrient, a good comparison of nutrient removal by cassava and some other crops had been summarized by Howeler (5). Indeed, nutrient removal with harvesting will be influenced by crop management, and hence crop yields. Amanulah *et al.* (6) showed that application of organic manure in cassava growing increased 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 Puttacharoen *et al.* (4) 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). Soil erosion in cassava crops mainly occurs at the early phase of growth in which poor land coverage exists. 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. Therefore, if there is any practice that can speed up and improve coverage of the land surface, it will help to reduce soil erosion. A common management to reduce soil erosion for this purpose is mulching (11; 12), and intercropping the cassava with other short maturity crops such as maize, upland rice, peanut, and soybean. The benefits of the cassava intercropping system in reducing soil erosion has been shown elsewhere (13, 14)

The aim of this study is to demonstrate that planting cassava does not necessarily accelerate soil and land degradation. The study is also aimed at showing that increasing the crop yield does not necessarily speed up land degradation, and at determining a planting management system which could simultaneously increase crop yield and decrease land degradation, or even maintain and increase land productivity.

2. Materials and Methods

The experimental treatments were set up according to the farmer's suggestions and the experiment was carried out on the farmer's field at Batu Village, 10 km south west of Malang, East Java, Indonesia. The soil was Alfisol, developed from volcanic materials with the top soil (up to 25cm depth) properties as given in Table 1. The experiment was carried out from September 2004 through to August 2008.

The experimental treatments were:

1. Cm: Control - cassava was planted on flat land (without ridging) in a mono-cropping system with no fertilizers applied.
2. CmR: Cassava was planted on ridges in a mono cropping system with no fertilized applied. The ridges were constructed across the slope with a distance of 1.0m between ridges.
3. CmRF: Cassava was planted on ridges in a mono cropping system. The crops were given 300kg/ha urea, 150kg/ha SP36, and 100kg/ha KCl.
4. MmRF: Maize was planted on ridges in a mono cropping system. The crops were given 300kg/ha urea, 150kg/ha SP36, and 100kg/ha KCl.
5. CmRF+Mnr: Cassava was planted on ridges in a mono cropping system. In addition, it was fertilized with the same treatments as in 3 (CmRF), 5t/ha of farm yard manure was also added.
6. (C+M) RF: Cassava was intercropped with maize and planted on ridges. The crops were given 400kg/ha urea, 200kg/ha SP36, and 150kg/ha KCl.
7. (C+M)RF+B: Cassava was intercropped with maize and planted on ridges. The crops were given 400kg/ha urea, 200kg/ha SP36, and 150kg/ha KCl and planted in an alley cropping system with Biochar
8. (C+M) R+Eg: Cassava was intercropped with maize and planted on ridges. The crops were given 400kg urea, 200kg SP36, and 150kg KCl and were planted in an alley cropping system with Elephant grass as the hedgerow with spacing of 6m between hedgerow and 0.3m as the width of the hedgerow.

These 8 treatments were arranged in Randomized Block Design with three replications. The crops were planted in field plots with the size of each 12m x 5m on a slope of about 8%.

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

Farm yard manure (the properties are given in Table 1) was applied during land preparation. All SP36 (36% P₂O₅), KCl (50% K₂O) and a third of the urea (45% N) fertilizers were given at the planting date, and then a third of the urea fertilizer was given at 60 days after planting. The remaining urea fertilizer was given after harvesting the maize intercrop (105 days after planting). Observations were made for runoff 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 the experiment and after the first and fourth year harvests were also observed.

Laboratory analysis done for the soil includes: soil pH (in H₂O), soil organic matter content by wet digestion method Walkley and Black, total N (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 m of -33kPa and -15MPa. Plant analysis was done (wet destruction) for total N (Kjeldhal), total P (spectrophotometer), and total K (Flame photometer).

3. Results and Discussion

3.1 Nutrient Uptake

Nutrient uptake in the harvested tuber yield of cassava and grain maize is given in Table 1. The amount of nutrients removed by cassava tuber harvesting is not necessarily larger than that by maize grain harvesting. In the Cm treatment, for example, with a yield of 9.12 t/ha, the nutrients removed by tuber harvesting only stood at 14.04 kg N/ha, 2.50 kg P/ha and 24.02 kg K/ha. For maize, with a yield of 6.21 t/ha, the nutrients removed in the grain are 87.08 kg N/ha, 20.53 kg P/ha and 29.86 kg K/ha. While in the CmRF treatment, 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.

Table 1. Nutrient uptake in the harvested tuber yield of cassava and grain maize

Crop Mgmt	Csv Yield (t/ha)	Nutrient uptake			Maize Yield (t/ha)	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	0	0	0
CmR	9.83	14.49	2.58	24.79	0	0	0	0
CmRF	27.33	54.42	9.07	75.28	0	0	0	0
MmRF	0	0	0	0	6.21	87.08	20.53	29.86
CmRF +Mnr	31.70	61.32	10.22	84.83	0	0	0	0
(C+M)RF	23.72	48.72	8.12	67.40	3.54	38.22	9.01	13.10
(C+M)RF+B	26.73	49.68	8.28	68.72	2.78	34.58	8.15	11.86
(C+M)RF+Eg	20.67	37.44	6.24	51.79	2.09	25.90	6.11	8.88

The macro nutrient uptake per unit of yield as given in Table 2 is obtained by dividing the total plant nutrient in the tuber or grain yield and that in the harvested biomass (Table 4) 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, and K removal was similar to that of other crops tested.

Table 2. Nutrient uptake per unit of yield of cassava or maize with different crop managements

Crop Mgmt	Csw Dry tuber (t/ha)	Nutrient uptake			Maize Dry tuber (t/ha)	Nutrient uptake		
		N (kg/t)of tuber	P (kg/ha) of tuber	K (kg/t) of tuber		N (kg/t) of tuber	P (kg/t) of tuber	K (kg/t) of tuber
CM	3.48	4.15	0.73	7.1	0	0	0	
CmR	3.82	3.79	0.67	6.48	0	0	0	
CmRF	10.96	4.96	0.82	6.86	0	0	0	
MmRF	0	0	0	0	5.46	15.9	3.76	
CmRF +Mnr	11.32	5.41	0.9	7.49	0	0	0	
(C+M)RF	9.89	5.02	0.83	6.94	3.11	12.28	2.89	
(C+M)RF+B	8.78	4.26	0.71	5.89	2.52	13.72	3.23	
(C+M)RF+Eg	6.34	5.91	0.98	8.17	1.88	13.77	3.25	

3.2 Runoff, soil erosion and nutrient lost

The measurement results given in Table 3 and Figure 1 show that runoff and soil erosion from cassava planted on surface land without fertilizers throughout the time were higher compared to those from the other crop management systems. Simple management by planting cassava on ridges has significantly reduced both runoff and soil erosion. However, care should be taken with making ridges because it can increase the erosion rate. Odemerho and Auwunudiogba (13) showed that erosion from flat surface land is lower than that from ridging, and erosion from contour ridging is lower than that from ridging following the contour. The reason for these phenomena is that ridges can accumulate surface runoff water, and if the ridges fail to function, the erosive energy of this concentrated surface runoff is much higher.

Table 3. Nutrient removal by erosion from different crop managements

Crop Mgmt	The removal of plant nutrient					
	2015/2016			2016/2017		
	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+B	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

Figure 1: Effects of crop managements on soil loss and runoff

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

Compared to maize (treatment CmRF and MmRF), it can be concluded that the amount of surface runoff and soil loss from a cassava plot is not larger than that from a maize plot. Indeed, in the early growth phase, cassava has a lower speed of covering the land surface. However, with two times of planting maize, there are two times of land preparation, in which the conditions are very susceptible to erosion. Thus, it is not surprising that the amount of surface runoff and soil loss from maize plots is larger than that from cassava plots.

The removal of the macro nutrients by erosion is given in Table 3. It is interesting to notice that a high level of surface runoff and soil loss are not followed by a high nutrient removal. In the Cm treatment, for example, with a surface runoff of more than 400m³/ha and a soil loss of more than 45t/ha per 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 2015/16 planting season, and 49.6 kg N/ha, 5.6 kg P/ha and 23.2 kg K/ha in the 2016/2017

planting season. For a lower level of surface runoff and soil loss, such as in the treatment of CmRF, the amount of removal of nutrients in both planting seasons was much lower. This phenomenon is merely due to the higher concentration of nutrients in the eroded soil of the fertilized plot. The nutrient contents in eroded soil of CmRF, for example, were 1.88% N, 0.57% P, and 1.01% K, whereas the concentrations of N, P, and K in the eroded soil of CmR treatment were 1.20%, 0.12%, and 0.59% respectively.

4. Conclusion

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 tubers 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 the 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 crop management system such as the addition of farm yard manure or the use of alley cropping systems can minimize this negative effect, notwithstanding the fact that it increases the level of plant nutrients in the soil (see Table 3 for treatment of alley cropping with Biochar). In addition, increasing the yield is usually associated with the improvement of crop growth; hence, there will be a better land management, addition organic of matter from biochar, and improvement of soil properties, leading to the decrease of soil erosion. In terms of production sustainability, the addition of either organic materials such as farm yard manure (treatment CmRF+Mnr) or fresh biomass (treatment (C+M) RF+B) has proven able to maintain soil productivity. If it is only added with organic fertilizers, the cassava yield decreases by 30% (see Figure 1). With the addition of 5t/ha of manure, the yield is relatively constant at about 30t/ha.

5. Acknowledgments

Thanks to the Directorate of Research and Dedication to the community, the research ministry, and higher education who have funded the research of Superior University (PUPT) on DIPA Kopertis Nomor 042.06.1.401516/2017, tanggal 07 Desember 2016.

6. References

- [1] Howeler, R.H., Oates, C.G., and Allen, A.C., 2001, *Strategic Environmental Assessment: An Assessment of the Impact of Cassava Production and Processing on the Environment and Biodiversity* FAO, Rome.
- [2] Howeler, R.H. 1991. *Long Term Effect of Cassava Cultivation on Soil Productivity*. Field Crops Research 26, pp. 1-18.
- [3] Heckman, J.R., Sims, J.T., Beegle, D.B., Coale, F.J., Herbert, S.J., Bruulsema, T.W., and Bamka, W.J. 2003. *Nutrient Removal by Corn Grain Harvest*. Agron. J. 95, pp. 587-591
- [4] Putthacharoen, S., Howeler, R.H., Jantawat, S., and Vichukit, V., 1998. Field Crops Research 57, pp. 113–126
- [5] Howeler, R.H., 2002. "Cassava Mineral Nutrition and Fertilization." In Hilloks, R.J., Thresh, J.M., and Belloti, A.C. (Eds.). *Cassava: Biology, Production and Utilization* CAB International. New York. pp 115-147
- [6] Amanullah, M.M., Vaiyapuri, K., Sathyamuorthi, K., Pashanivelan, S., and Alagesan, A., 2007, "Nutrient Uptake, Tuber Yield of Cassava (*Manihot Esculenta* Crantz.) and Soil Fertility as Influenced by Organic Manures," *Journal of Agronomy* 6, pp. 183-187.
- [7] Ardjasa, W. S., Ando, H., and Kimura, M., 2001, "Yield and Soil Erosion among Cassava-Based Cropping Patterns in South Sumatra," *Soil Sci. Plant Nutr.* 47, pp. 101 -112
- [8] Lal, R., 1984, "Soil Erosion from Tropical Arable Lands and its Control," *Advances in Agronomy* 37, pp. 183–248.
- [9] Bhatt, R., and Khera, K.L., 2006, "Effect of Tillage and Mode of Straw Mulch Application on Soil Erosion in the Submountainous Tract of Punjab, India," *Soil & Tillage Research* 88, pp. 107–115.
- [10] Howeler, R.H., Tongglum, A., Jantawat, S., and Utomo, WH., 1998, "The Use of Forage for Soil Fertility Maintenance and Erosion Control in Cassava in Asia," In Sturr EW. (Ed). *Proc. Third Regional Meeting of the Forages for Smallholder Project (FSP)*, held in Samarinda, Indonesia. March 23-26, 1998. CIAT Working Document No. 188. pp. 196-211
- [11] Iijima, M., Izumi, Y., Yuliadi, E., Sunyoto, Arjasa, S.B., 2004, "Cassava Based Cropping System in Sumatra in Indonesia: Productivity, Soil Erosion and Rooting Zone," *Plant Prod. Sci.* 7, pp. 347 – 355.
- [12] Odemero, F.O., and Avwunudiogba, A., 1993, "The Effect of the Changing of Management Practices on Soil Loss: A Nigeria Example," *The Geographical Journal* 159, pp. 63 – 68.
- [13] Yuniwati, E.D., N. Basuki, E.W. Wisnubroto, and W.H. Utomo. 2012. "Combating land degradation in cassava field by crop yield improvement.. *Basic. Appl. Sci. Res.*, 2: 4975-4982,
- [14] Yuniwati E.D., W.H. Utomo, and R.H. Howeler. 2015. Farmers' Based Technology Development for Sustainable Cassava Production System. *International Journal Agriculture Research*. ISSN 1816-4897 Vol 10 (No 02): <http://scialert.net/archivedetails.php?issn=1816-4897&issueno=84>