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Research Article

Effect of long of landuse and cropping system on soil fertility and cassava yield

Andy Wijanarko[1*], Benito Heru Purwanto[2]

[1] Indonesian Legumes and Tuber Crops Research Institute. Jl. Raya Kendalpayak km 8, PO Box 66, Malang, East Java, Indonesia
[2] Agriculture Faculty, Gadjah Mada University, Jl. Flora, Bulaksumur, Yogyakarta, Indonesia - 55281

[*]corresponding author: ndy_wijanarko@yahoo.com

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Abstract: A study that was aimed to determine the influence of long of land use and cropping systems on soil fertility and yield of cassava conducted at centre of cassava in Sukadana Subdistrict, East Lampung. Survey was conducted to characterize soil fertility due to the long of landuse and cassava cropping system from February to September 2014. Treatments of cropping system and long of land use observed involving: (1) Cassava monoculture for more than 30 years, (2) Cassava monoculture for 10- 30 years, (3) Cassava monoculture for less than 10 years, (4) Intercropping cassava and maize, (5) Intercropping cassava and groundnut, (6) Crop rotation of cassava and maize, and (7) Crop rotation of cassava and groundnut. The results showed that concentration of all macro nutrients of cassava monoculture for more than 30 years was lower than cassava monoculture for less than 10 years including the decrease of 11% of soil pH, 49% of total N , 66% of organic C, 57% of available P, 64% of K, 70% of Ca, 55% of Mg and 37% of CEC. Intercropping or crop rotation of cassava with legume or non-legume increased the soil pH, organic C, total N, K, Ca and Mg and decreased exchangeable Al. The changes in soil chemical and physical properties due to different cropping system affected the yield of cassava. The highest yield of cassava was obtained by crop rotation of cassava and maize, while the lowest was monoculture for more than 30 years. Cassava monoculture grown for 10-30 years or more than 30 years had low soil fertility so that the yield of cassava was also low. The yield of cassava in the rotation system was higher than the intercropping.

***Keywords** : cassava yield, cropping system, land use, soil fertility*

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Introduction

Cassava is generally cultivated on marginal lands with minimal management level, especially fertilization (Sarno et al., 2004). Cassava can grow well under certain conditions covering temperature of 22-28^{o}C, rainfall of 1000-2000 mm per year, good drainage, very low erosion,on less than 8% slope, and crumbly soil texture. Soil depth of more than 100 cm, with base saturation of more than 20%, soil pH of 5.2-7.0 and organic C of more 0.8% are suitable for cassava growth (Wargiono et al., 2006). Good management on cassava cultivation can increase the yield up to 30-40 t/ha (Wargiono et al., 2006) higher than productivity of cassava in some centres of cassava production in Indonesia reaching 23 t/ha (BPS, 2016). One of the causes of the yield gap is improper management and continuous monoculture cassava cultivation that can decrease soil fertility. Nutrients absorbed and carried during cassava harvest were 6.54 kg N, 2.24 kg P_2O_5 and 9.32 kg K_2O per ton yield (Wargiono et al., 2006). The result of study in Vietnam showed that every 15 ton of cassava, nutrients transported were 74 kg N, 16 kg P, 87 kg K, 27 kg Ca and 12 kg Mg (Howeler and Phien, 2001). Cong Doan

Sat and Deturch (1998) compared soil physical and chemical properties of area planted with cassava, wood, rubber and sugar cane. Area with continuous cassava monoculture showed low aggregate stability and water holding capacity and high of bulk density. Chemically, content of organic C, total N, cation exchange capacity (CEC), as well as available P, K and Mg were much lower than other commodities cultivation system. Cassava planting for 2 years lowered 0.1-0.4 units of soil pH and soil organic matter content about 59-72% (Phien and Vinh, 1998). Nguyen Tu Siem (1992) reported that cassava planting for 10 years decreased soil organic matter content from 1.72% to 0.55%. Cassava yield on continuous monoculture cultivation for 20-30 years decreased from 26-30 t/ha to 10-12 t/ha. In Malaysia, cassava continuous cultivation for 9 years decreased cassava yield from 50 t/ha to 20 t/ha (Howeler, 1992).

Intercropping or crop rotation in cassava cultivation system can improve soil fertility. Intercropping of cassava with maize and cassava with groundnut increase organic C 12% and 56%, respectively (Ispandi, 2002). Nnadi and Haque (2008) showed that legumes might contribute about 30% N from N fixation process to other crops in intercropping and crop rotation. Legumes such as groundnut were able to fix N about 40 kg/ha in Ulltisol (Okito et al., 2004) in addition to additional residue at legumes root of about 5-15 kg N/ha. Bundy and Andraski (2005) reported that the residues of corn returned to the field can contribute 50-100 kg N/ha where 5-20% of N residue can still be used by the next crop (Marthens et al., 2006). Some studies showed that another benefit of intercropping system was the reduced surface erosion (Wargiono et al., 2006).

Based on those problems, the research aimed to determine the influence of long of land use and cropping systems on soil fertility and yield of cassava.

Material and Method

Survey was conducted to characterize soil fertility due to the long of land use and cassava cropping system at centre of cassava in Sukadana Subdistrict, East Lampung. This research was conducted from February to September 2014. Treatments of cropping system and long of land use observed involving (1) Cassava monoculture for more than 30 years, (2) Cassava monoculture for 10- 30 years, (3) Cassava monoculture for less than 10 years, (4) Intercropping cassava and maize, (5) Intercropping cassava and groundnut, (6) crop rotation of cassava and maize, and (7) crop rotation of cassava and groundnut. Soil samples were taken to determine soil fertility representing every treatment above. Soil samples were taken five times as replicates at 0-20 cm depth. Every soil sample then put in a labeled plastic for analysis in laboratory. Soil analysis included (1) Soil chemical properties: pH of H_2O, exchangeable Ca, Mg and K, exchangeable Al, organic C (OC), total N (TN), available P and Fe as well as Cation Exchange Capacity (CEC), the soil properties was determined using methods as described by Eviati and Sulaeman (2009), (2) Soil physical properties: bulk density and aggregate stability, and (3) Cassava yield as the main parameter of this research. Analysis of variance and mean comparison with Duncan Multiple Range Test (DMRT) at 5% of probability were processed using Mstat-C. Linear regression and correlation as well as graphical presentation were performed using Microsoft Excel program.

Results and Discussions

Effect of long of land use and cropping system on soil chemical properties

The chemical analysis results of soil in Sukadana, East Lampung at 0-20 cm depth for some cropping systems of cassava (monoculture, intercropping, and crop rotation) are presented in Table 1. This study showed that the cassava monoculture decreased almost all of macro nutrients (N, P, K, Ca, Mg, and organic C) as well as CEC and increased exchangeable Al and Al saturation.

Concentration of all macro nutrients of cassava monoculture for more than 30 years was lower than cassava monoculture for less than 10 years including the decrease of 11% of soil pH, 49% of total N , 66% of organic C, 57% of available P, 64% of K, 70% of Ca, 55% of Mg and 37% of CEC. The decrease of macro nutrients is caused by: 1) cassava is generally planted in a wide spacing at the beginning of rainy season when the soil has not been covered by a canopy and thus susceptible to erosion, (2) the upper plant is timber that rarely returned to the soil, (3) there are no roots left behind, (4) Time of soil recovery is very short, and (5) farmers fertilize the crops in small quantities (Wargiono *et al.*, 2006). All above reflected cassava monoculture cropping system that if applied continueously for long term may deplete the soil nutrient. On the other hand, exchangeable Al (Al-exch) and Al saturation increased by 79% and 57% for cassava monoculture for than 30 years when compared to cassava monoculture for less than 10 years.

Table 1. Soil chemical properties at 0-20 cm depth for some cassava cropping systems in Ultisol of Sukadana, East Lampung.

Cropping systems	**Parameters**										
	pH	**TN**	**OC**	**P-Bray 1**	**K**	**Ca**	**Mg**	**Al-exch**	**H-exch**	**CEC**	**Al saturation**
		%	**%**	**mg/kgP_2O_5**	**………………..….cmol (+) /kg…………………………**						**%**
Monoculture (M) > 30 th	4.6 g	0.037 e	0.70 f	6.8 f	0.05 c	0.50 g	0.15 d	2.50 a	1.46	4.12 d	52.14 a
Monoculture (M)10-30 th	4.8 e	0.047 d	1.44 e	10.4 e	0.08 c	1.04 f	0.32 c	1.99 b	0.90	6.00 c	42.79 b
Monoculture (M) < 10 th	5.1 c	0.073 b	2.06 a	15.9 d	0.14 b	1.68 d	0.33 c	1.40 c	0.54	6.54 c	33.28 c
Crop rotation with maize (TS-J)	4.9 d	0.060 c	1.80 d	20.2 b	0.25 a	1.82 c	0.34 c	1.27 d	0.73	7.27 d	27.97 d
Crop rotation with groundnut (TS-Kc)	5.2 b	0.077 b	1.96 b	18.2 bc	0.16 b	1.92 b	0.40 b	1.14 e	0.53	8.28 a	26.63 d
Intercropping with maize (TG-J)	5.3 a	0.070 b	1.88 c	35.8 a	0.24 a	1.53 e	0.43 ab	1.06 e	0.57	7.66 b	27.95 d
Intercropping with groundnut (TG-Kc)	5.3 a	0.093 a	2.03 a	17.6 cd	0.16 b	2.27 a	0.48 a	0.28 f	0.59	7.45 b	18.46 e

Note: the numbers in columns followed by the same letter showed no different according to DMRT at 5% of probability

Nutrients absorbed and carried during cassava harvest was 6.54 kg N, 2.24 kg P_2O_5 and 9.32 kg K_2O per ton of yield (Wargiono et al., 2006). The survey in Sukadana Subdistrict resulted farmers' habbit in cassava fertilization were 150 kg of Urea/ha (equal to 67.5 kg of N/ha) and 100 kg of SP36/ha or (equal to 36 kg of P_2O_5/ha); or 200 kg of Phonska fertilizer (15% N, 15% K_20 and 15% P_2O_5) /ha (equal to 30 kg of N/ha, 30 kg of P_2O_5/ha, and 30 kg of K_2O/ha). Nutrient balance of N, P and K was negative if farmers used only Urea and SP36 assuming cassava yield was 15 t/ha. The nutrient balance of N was positive while P and K were negative if farmers used Urea and Phonska fertilizer (Table 2).

Table 2. Nutrient balance of cassava as a result of usual fertilizer used by farmers in East Lampung (Assuming cassava yield was 15 t/ha).

	Fertilizer	**Nutrient absorption equivalent to 15 t/ha**	**Nutrient balance**
Urea and SP 36			
N	150 kg of Urea/ 67.5 kg of N	74 kg of N	-6,5 kg
P	100 kg SP 36/ 36 kg of P_2O_5	37 kg of P_2O_5	-1 kg
K	-	87 kg of K_2O	-87kg
Urea and Phonska			
N	150 kg Urea/ 67.5 of kg N + 200 kg of Phonska*/ 30 kg N	74 kg N	+ 23.5 kg
P	200 kg of Phonska/ 30 kg P_2O_5	37 kg of P_2O_5	-7 kg
K	200 kg of Phonska/ 30 kg K_2O	87 kg of K_2O	-57 kg

Note : * Phonska fertilizer (15% N, 15% K_2O and 15% P_2O_5)

The most nutrient depleted due to cassava monoculture was K. The highest lost of K due to harvesting, while farmers did not apply K fertilizer or apply in low dosage that was 200 kg Phonska/ha (equal to 30 kg K_2O/ha). It can be seen from soil analysis, that the concentration of K in monoculture was the lowest compared to intercropping or crop rotation (Table 5). Polthanee et al. (2012) suggested that in Thailand, K and N had negative nutrient balances; while P was positive. Other nutrients depleted from soil were Ca and Mg. The depletion of K, Ca and Mg causes the soil becomes more acidic. The data is consistent with the results of analysis of this study that the longer the cassava cultivation increasingly acid of soil. The results of soil analysis showed that the availability of N, P, K, Ca and Mg in intercropping or crop rotation were higher than the monoculture. Biomass in the intercropping or crop rotation with groundnut or maize are mostly returned to the soil or burned. The return of organic matters into the soil increases mineralization of organic matter into inorganic forms. This led to the availability of nutrients in the intercropping or crop rotation that are higher than the monoculture. Intercropping or crop rotation of cassava with legume or non-legume increases the pH, organic C, total N, K, Ca and Mg and decreases exchangeable Al. In acidic soil, soil pH increases due to organic acids from decomposition process bind Al to form a complex compound (chelate). as well as due to organic matter that has been mineralized releases base cations (Azeez and van Averbeke, 2010). The results of this study indicate that there was a positive correlation between pH with organic C (0.85**), pH with Ca (0.82**) and Mg (0.83**) (Table 3). The role of organic matter on the availability of nutrients in the soil cannot be separated with the mineralization process as the final stage of the reform of organic matter process. During mineralization, some nutrient minerals will be released (N, P, K, Ca, Mg and S, as well as micronutrients) in an unspecified and relatively small amount. Organic matters are the major source of N in the soil. The influence of organic matter to the availability of P can be directly through the mineralization process or indirectly by helping the release of fixed P. The availability of P in the soil is also strongly affected by soil pH. Soil pH to approximately 7 increases P availability.. In the intercropping or crop rotation, soil pH was higher than the monoculture for 30 years. Correlation analysis result showed that the pH and the availability of P was positively correlated (0.63**), meaning that the higher soil pH, the greater the availability of P. Intercropping or crop rotation increased soil CEC compared to the monoculture especially for 30 years. Return of crop residues in intercropping or crop rotation system increases the content of organic matter in the soil that can increase the negative charge thereby increasing CEC. Approximately 20-70% of soil CEC is generally based on colloid humus, so there is a positive correlation between soil organic matter with CEC (0,57). The main source of negative charge of humus derived from the carboxyl group (-COOH) and phenolic (-OH) (Jiang et al., 2010). Rivero et al. (2004) reported that the application of straw 10 t/ha in Ultisol was able to increase 15.18% of CEC from 17.44 to 20.08 cmol$^{(+)}$/kg. The benefit of returning organic matter in the intercropping or crop rotation system on acid soil such as Ultisol is lowering the concentration of Al in the soil. The presence of Al is often be linked to the decrease of crop yield on acid soils and to be a limiting factor in crop production (Zheng et al., 2007; Schuch et al,. 2010; Silva, 2010).

Soil analysis result showed that concentration of exchangeable Al in the intercropping or crop rotation was lower than the monoculture. Al concentration in the soil will decrease when organic matter content increases because it will form a very strong complex with Al. Research of Jansen et al. (2003) showed that the addition of organic matter to Oxisol from Burundi and Ultisol from Cameroon decreased Al activity from 38 mM to 11 mM in the Oxisol andfrom 11 mM to 2 mM in Ultisol. Oburger et al. (2009) suggested that the addition of organic matter to the fine-clay soil is very important in controlling Al^{3+}. The application of organic matter on acid soil could decrease the excess micro nutrient by forming the complexes with humic compounds. Between crop rotation and intercropping also showed differences in soil pH and CEC. The soil pH and CEC in intercropping was higher than crop rotation (Table 1). Types of crops used for crop rotation and intercropping also affect the chemical properties of soil. Intercropping or crop rotation cultivation with groundnut increased the availability of N, organic C, Ca and Mg however decreased of exchangeable Al and Al saturation. Intercropping or crop rotation cultivation with maize increased the availability of P and K. The role of legumes on soil fertility is associated with its N fixation ability. Legumes may contribute about 30%N. Besides, there was additional residue from the roots of legumes around 5-15 kg N/ha (Nnadi and Haque, 2008). Legumes are also able of provide of alkali in the soil. Legumes incubated in Ultisol were able to increase the base cations in the soil between 116-135% compared to the soil without legumes (Mao et al., 2010).

Effect of long of land use and cropping system on soil physical properties

The physical properties of soil as measured by soil aggregate stability (DMR, average mass diameter) showed that maize cultivation provided higher aggregate stability than groundnut cultivation. Land use for cassava decreased soil aggregate stability, the longer its use decreased its aggregate stability (Figure 1). Groundnut is a legume having low C:N ratio, which rapidly mineralizes so that nutrients are readily available, while maize has higher C:N ratio that plays more importance to soil physical properties. Organic matter derived from legumes and non legumes play an important role in maintaining soil fertility. Soil organic matter derived from plant decomposition process contains the elements of C, N, P and S which are necessary for the crops.

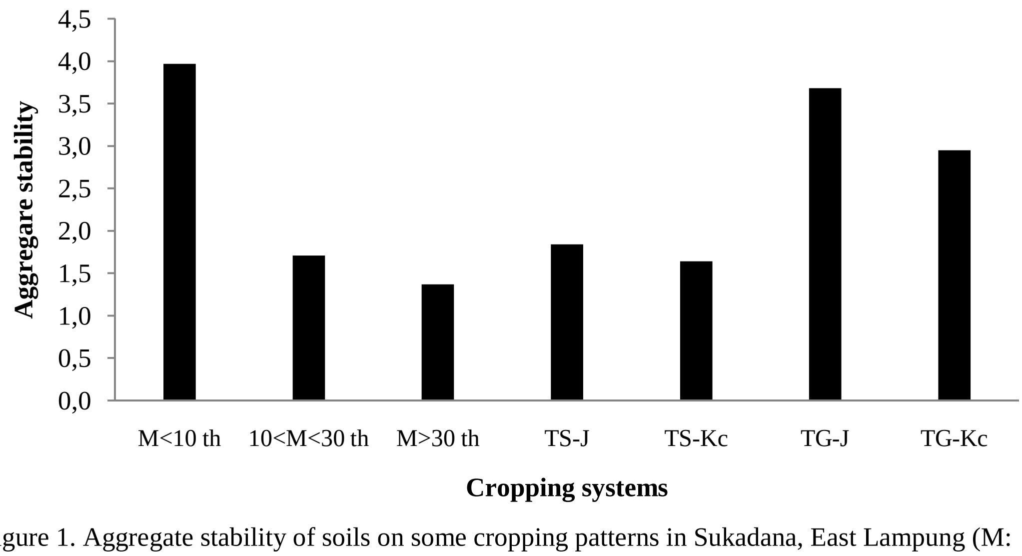

Figure 1. Aggregate stability of soils on some cropping patterns in Sukadana, East Lampung (M: monoculture, TS: intercropping, TG: crop rotation, J: Maize, Kc: Groundnut)

In term of soil physic, organic matter is able to increase soil aggregation, amount of soil pores, and water infiltration into soil. On the other hand, it is able to decrease weight of soil content and soil erosion. In relation to nutrient release, organic matter which releases nutrients rapidly will immediately provide nutrients. The speed of nutrient release or mineralization process is strongly influenced by the quality of organic matter. High quality organic matter such as low C:N ratio is quickly mineralized. That characteristic is often owned by legumes, whereas low quality of organic matter with high C:N ratio is owned by non-legumes.

Effect of long of land use and cropping system on cassava yield

The changes in soil chemical and physical properties due to different cropping system affect the yield of cassava. The highest yield of cassava was obtained by crop rotation of cassava and maize, while the lowest was monoculture for more than 30 years (Figure 2). Cassava monoculture grown for 10-30 years or more than 30 years had low soil fertility so that the yield of cassava was also low. The yield of cassava in the rotation system is higher than the intercropping. In the intercropping, two crops are cultivated simultaneously in same area so that there will be competition in nutrient and water uptake in the soil as well as sunlight and CO_2 interception by the leaves (Prayitno, 1992).

Cassava performance in crop rotation system is similar to the monoculture. The difference is on the cultivation system which is in rotation cassava is planted after maize or groundnut. The highest yield of cassava was obtained from crop rotation system of cassava and maize followed by a rotation of cassava with groundnut.

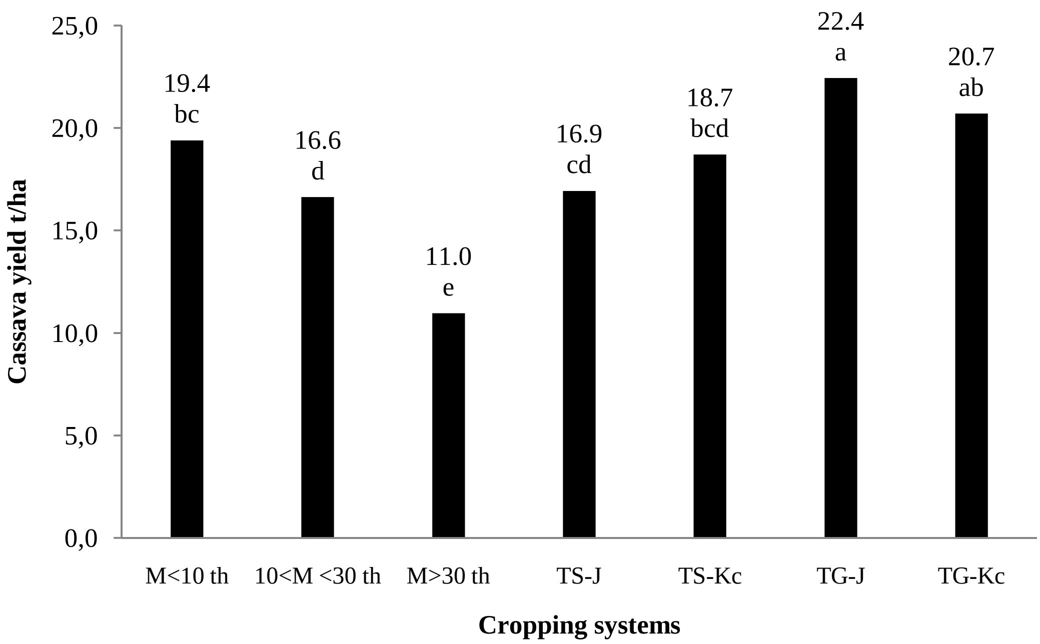

Figure 2. Cassava yields on some cropping patterns in Sukadana, East Lampung (M: monoculture, TS: intercropping, TG: crop rotation, J: Maize, Kc: Groundnut)

The intercropping system of cassava and maize produced the lower yield compared to the rotation. Dapaan et al. (2002) and Daellenbach et al. (2005) suggested that intercropping of cassava with maize decreased 13% of cassava yield compared to the monoculture. The result of correlation analysis showed that some soil chemical properties affected cassava yield (Table 3). The soil chemical properties of pH, organic C, total N, P, K, Ca, Mg, CEC and saturation alkali were positively and significantly correlated with cassava yield. It indicated that the increase of those nutrients availability will increase cassava yield. The concentration of Al-exch, Fe, Mn, Cu and Al saturation is negatively correlated with cassava yield indicated that the increase concentration of these elements in the soil will decrease, cassava yield. Cassava crop is resistant to Al, however if the high concentration will certainly affect the growth of cassava.

Table 3. Correlation of cassava yield with soil chemical properties at 0-20 cm depth in Ultisol of Sukadana, East Lampung

Parameters	**pH**	**OC**	**TN**	**P**	**K**	**Ca**	**Mg**
Yield	0.83**	0.85**	0,725**	0,700**	0,513*	0,707**	0,838**
Parameters	Fe	Mn	Cu	Al-exch	CEC	Al Saturation	Bases saturation
Yield	-0,148	-0,133	-0,043	-0,84**	0,745**	-0,80**	0,631**

Note : * significant at 0,05, ** significant at 0,01

Conclusion

Cassava monoculture decreased almost all of macro nutrients (N, P, K, Ca, Mg, and organic C) as well as CEC and increased exchangeable Al and Al saturation. Concentration of all macro nutrients of cassava monoculture for more than 30 years was lower than cassava monoculture for less than 10 years. Intercropping or crop rotation of cassava with legume or non-legume increased the pH, organic C, total N, K, Ca and Mg and decreased exchangeable Al. The changes in soil chemical and physical properties due to different cropping system affected the yield of cassava. The highest yield of cassava was obtained by crop rotation of cassava and maize, while the lowest was monoculture for more than 30 years

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