Performance of cassava (*Manihot esculenta* Crantz) based cropping systems and associated soil quality changes in the degraded tropical uplands of East Java, Indonesia

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Received 26 January 2011; received in revised form 26 May 2011; accepted 26 May 2011.

Abstract

Field studies were conducted (2005 to 2009) in the degraded uplands (Entisols) of East Java, Indonesia to evolve a sustainable cassava (*Manihot esculenta* Crantz) production technology. Screening of crops and cropping systems for profitability was followed by standardization of soil management techniques to optimize productivity. The screening trials indicated that cassava – either as sole crop or under intercropping systems – is a profitable crop for this region. Application of inorganic fertilizers, however, failed to sustain cassava productivity. Sole cassava yield was 9.9 Mg ha^{-1} during the first year, which decreased to 7.44 Mg ha^{-1} in the fourth year. Supplementing inorganic fertilizers with organic manures, either through farmyard manure or through addition of residues of the intercrops, was beneficial to maintain cassava productivity and soil quality. Intercropping cassava with peanuts (*Arachis hypogaea* L.) and cowpea (*Vigna unguiculata* (L.) Walp) was particularly useful. Sole cassava treated with 7.5 Mg ha^{-1} FYM produced a stable tuber yield of about 13 Mg ha^{-1} and cassava intercropped with peanut and cowpea gave yields of about 16 Mg ha^{-1}, implying complementraty effects of legume intercropping.

Keywords: Agrotechniques, Intercropping; Sustainable production; Soil organic matter.

Introduction

Land degradation due to improper land use management is paramount in many parts of East Java, Indonesia. There are about 271, 000 ha (out of the total of about 1.1 million ha) of degraded uplands in the Brantas watershed, East Java alone (BPDAS Brantas, 2010). Poor soils with low organic matter content, nitrogen, phosphorus, zinc, and iron are a characteristic feature of these sites (Howeler, 2008). Planting agricultural crops on these soils has traditionally been unprofitable; hence, the land is fallowed or whenever crops are planted, they are managed poorly. The main arable crop on such sites is cassava (*Manihot esculenta* Crantz), and, to some extent, maize (*Zea mays* L.), upland rice (*Oryza sativa* L.), and soybean (*Glycine max* (L.) Merr.). Owing to poor management, the cassava crop seldom yields more than 10 Mg ha^{-1}. Poor crop growth has also resulted in accelerated soil erosion leading to sedimentation in downstream areas and siltation of dams along the Brantas River (Sasinggih et al., 2005).

Soil erosion in cassava fields occurs mainly during the early phase of crop growth due to poor land surface coverage. Any practice that can improve land surface coverage, such as intercropping with short duration crops, will help reduce soil erosion. However, the farmers' choice of intercrop is often inappropriate and they also remove the entire plant biomass from the field at harvest. Such practices deplete soil organic matter content and speed up soil deterioration (Makinde et al., 2006). Incorporating organic manure exogenously will be an appropriate land management strategy under such situations (Amanullah et al., 2007).

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Intercropping systems also can restore degraded lands besides ensuring sustainable cassava production (Olasantan, 1988). Although the underlying principle of intercropping is resource sharing which will increase land productivity and biological efficiency (Midmore, 1993) and thereby increase farmers' income, the component crops sometimes compete with one another and depress cassava productivity. Careful selection of intercrops and proper farm management are therefore crucial to maintain optimal levels of productivity (Sullivan, 2003). Leguminous intercrops can increase soil nitrogen and improve productivity of associated crops (Dapaah et al., 2003; Adeniyan and Ayoola, 2006). However, information on the profitability of such cropping systems and the technology for sustained crop production in the degraded uplands of East Java, Indonesia are scarce. Hence field experiments were conducted (1) to screen suitable intercrops for cassava-based production system, and (2) to evaluate the agrotechnologies for optimizing productivity and profitability of cassava-based intercropping systems in the degraded tropical uplands of East Java.

Materials and Methods

The experiments were carried out on an upland farmers' field at Wringinrejo, South Blitar, East Java, Indonesia (08º05' S, 112º02' E; 117 m altitude). The soils are Entisols, with an effective depth of less than 25 cm, and a surface stone or gravel content of about 100 g kg^{-1}. Sand and clay content were 246 and 190 g kg^{-1} respectively with pH 7.1, organic C 8.4 g kg^{-1}, total N 0.5 g kg^{-1}, available P 7.61 mg kg^{-1}, and exchangeable K 1.21 cmol kg^{-1}. The site experiences a distinct wet and dry season. Based on the data of the Climatology Station of Karangkates Dam, East Java, Indonesia, the average (1995 to 2005) annual rainfall was about 1500 mm. During the experimental period, the rainy season started around mid-November, and ended in early March of the following year, and the average daily temperature was 28ºC (range: 25ºC at night to 32ºC in the afternoon). The site was under rubber (*Hevea brasiliensis* Müll-Arg.) before food crop cultivation began. In 1970, after the cessation of HGU (Hak Guna Usaha or the right to use the land which was given to the plantation company), the land was utilized by farmers for upland rice and maize cultivation. Poor site fertility due to soil erosion and plant nutrient removal decreased crop yields steadily, which made the farmers shift to cassava cultivation.

Two experiments were conducted to screen crops and/or crop combinations to identify profitable crops, and to explore the soil management technologies for different cassava based-cropping systems. The first experiment was carried out from November 2005 to July 2006, and the second experiment from November 2006 to July 2009. The intercrops were harvested in March and cassava in July.

The crops and cropping systems tested in the first year's experiment were selected based on the existing cropping pattern of the region. These include (1) sole cassava, (2) upland rice, (3) maize, (4) peanuts (*Arachis hypogaea* L.), (5) soybean, (6) mungbean (*Vigna radiata* (L.) R. Wilczek), (7) and cowpea (*Vigna unguiculata* (L) Walp), besides intercropping systems involving (8) cassava +upland rice, (9) cassava + maize, (10) cassava + peanut, (11) cassava + soybean, (12) cassava + mungbean, (13) cassava + cowpea, (14) upland rice + peanut, (15) upland rice + soybean, (16) upland rice + mungbean, (17) upland rice + cowpea, (18) maize + peanut, (19) maize + soybean, (20) maize + mungbean, and (21) maize + cowpea. The treatments were arranged in randomized block design, with four replications. Results of the first year showed that cassava either in monoculture or intercropping was the most profitable cropping system. Hence, the treatments in the second experiment were only cropping systems involving cassava. Since the soil organic matter content was low, a farmyard manure treatment was introduced. The treatments thus consisted of cropping systems: sole cassava; cassava + upland rice, cassava + maize, cassava + peanut, cassava + soybean, cassava + mungbean, cassava + cowpea, and farmyard manure (FYM) application: no FYM and 7.5 Mg ha^{-1} FYM. The FYM used had 302.8 g kg^{-1}organic C, 14.2 g kg^{-1}total N, 5.8 g kg^{-1} total P, and 8.8 g kg^{-1} total K.

The plot size was 8 x 4 m. The cassava cultivar used was 'Faroka', a high yielding bitter variety; and the upland rice, maize, peanut, soybean, mungbean, and cowpea cultivars used were IR-64, Pioneer 2, 'Turangga', 'Willis', 'Perkutut', and KT-1 respectively. Cassava, upland rice, maize, peanut, soybean, mungbean, and cowpea monocultures were planted at 1.0 x 0.8, 0.25 x 0.25, 0.8 x 0.25, 0.25 x 0.25, 0.40 x 0.20, 0.40 x 0.20, and 0.40 x 0.20 respectively. For the intercropping system, cassava was planted at a distance of 1.25 x 1.0 m, and the component crops in between rows of cassava.

Sole cassava was fertilized with 300 kg urea ha^{-1}, 100 kg SP36 ha^{-1}, and 100 kg KCl ha^{-1}. Upland rice and maize were fertilized with 200 kg urea ha^{-1}, 100 kg SP36 ha^{-1}, and 100 kg KCl ha^{-1}; peanut, soybean, mungbean, and cowpea were fertilized with 50 kg urea ha^{-1}, 50 kg SP36 ha^{-1}, and 50 kg KCl ha^{-1}. For cassava intercropped with upland rice and maize, the fertilizers applied were 400 kg urea ha^{-1}, 100 kg SP36 ha^{-1}, and 100 kg KCl ha^{-1}. For cassava intercropped with legume and the upland rice or maize intercropped with legume crops, the fertilizers applied were the same as that of sole cassava, upland rice, or maize. SP36 is a commercial product of PT Petrokimia, Gresik, Indonesia with chemical formula $Ca(H_2PO_4)_2$. All P and K were applied at planting and N fertilizers for cassava, upland rice, and maize monoculture, were applied twice (at planting and 30 days after planting). For peanut, soybean, mungbean, and cowpea, all fertilizers were applied at planting. For intercropping systems, N was applied three times i.e., one third each at planting, 30 days after planting, and after harvesting intercrops.

The data on soil properties were collected before the experiment (November 2005) and at final harvest (July 2009). Two soil samples (0 to 20 cm depth) of about 0.5 kg each were randomly collected from each plot and then mixed. To reduce cost of analysis, the soil samples from replicate 1 was mixed with that of replicate 2; likewise replicate 3 was mixed with replicate 4. Then a composite 0.5 kg sample of each was processed for laboratory analysis. Crop yield was obtained by weighing the harvested produce from all except the outer rows of plants. Upland rice, maize, soybean, peanuts, cowpea yields were expressed on sun dried basis (moisture content: 14 to 18%), and that of cassava on fresh tuber yield basis.

The soil parameters analyzed were pH (H_2O), organic C, total N, available P, exchangeable K, bulk density (ρb), percentage sand and clay content, soil aggregate stability, and soil moisture content. Soil pH was measured with a pH meter (Jenway 3305), organic C by Walkley and Black method (Soil Survey Laboratory Staff, 1992), and total N by Kjeldahl method (Bremner and Mulyaeny, 1982). Available P was extracted with Bray II solution and the concentration determined using a spectrophotometer (Vitatron Scientific Instruments Dieren, the Netherlands). Exchangeable K was extracted with I N neutral CH_3COONH_4 and the concentration measured with AAS (Shimatzu *AA* 6800, Schimazu Crop., Kyoto, Japan). An undisturbed soil sample was used to determine soil bulk density (Blake and Hartge, 1986), sand and clay content (pipette method). Aggregate water stability was measured by wet sieving as described by Kemper and Rosenau (1986), and the result was expressed as the mean weight diameter (MWD), calculated as follows:

$MWD = \sum (w \times d)$ .... (1)

where d is the diameter (in mm) of the soil aggregate left on the sieve, w is dry weight of the soil aggregate (d) expressed as percentage of its initial weight.

Gravimetric soil moisture content was determined at a potential matrix, ψm, of –33 kPa (field capacity, FC) and –15 MPa (wilting point, WP) using a pressure plate apparatus. The soil had negligible swelling characteristics; hence the volumetric soil water content (θ) was calculated by multiplying the gravimetric soil water content with soil bulk density.

Economic Analysis

To evaluate the profitability of different crop combinations and cassava based-cropping system, a simple economic analysis was carried out by subtracting the cost of inputs (sum of price of the planting materials, fertilizers, and pesticides and labour for land preparation, crop husbandry, and harvesting) from the revenue generated (harvested yield multiplied by the price of the commodity). The unit cost used for the analysis was that of 2005, although it is acknowledged that there would be fluctuations in the unit cost from year to year.

Statistical analysis

ANOVA was used to determine the differences between treatments. Significant differences among the treatments were tested using LSD 5% test. To measure land use efficiency land equivalent ratio, LER, as calculated by equation (2) was used.

$LER = Yc_1(IC)/Yc_1(MC) + Yc_2(IC)/Yc_2(MC)$ .... (2)

where Yc_1 is the yield of crop 1, Yc_2 is the yield of crop 2, *IC* is the intercropping system, *MC* is the monoculture system (sole crop).

Results and Discussion

Crop yield and land use efficiency

From an economic point of view, cassava-based cropping system was the most profitable on this degraded site, as exemplified by higher net incomes (Table 1). Cassava growing was less expensive in view of the lower cost of planting materials (only the labour cost for cutting the cassava stem), and the crop did not require intensive management. Moreover, yield reduction in cassava was of a lower magnitude compared to that of upland rice and maize. The high cost for growing leguminous intercrops may be due to the high price of seeds and the additional costs involved in pest control.

Table 1. Crop yield, cost, gross income and benefit of different cropping system in degraded land of South Blitar, East Java, Indonesia.

Cropping systems	Mean crop yield ($Mg\ ha^{-1}$)		Input cost (Rp)			Gross income (Rp)	Benefit/cost (Rp)
	Main crop	Intercrop	Material	Labor	Total		
Cassava	9.90	none	1,030	1,540	2,570	2,970	400
Upland rice	1.20	none	1,150	1,940	3,090	3,000	–90
Maize	1.50	none	1,080	2,040	3,120	2,250	–870
Peanuts	0.80	none	1,050	2,060	3,110	3,200	90
Soybean	0.68	none	1,150	2,060	3,210	2,720	–490
Mungbean	0.60	none	950	1,960	2,910	2,100	–810
Cowpea	0.53	none	965	1,960	2,925	1,855	–1,070
Cassava+upland rice	7.46	0.72	1,410	2,240	3,650	4,092	442
Cassava+maize	7.40	1.05	1,415	2,280	3,695	3,995	300
Cassava+peanuts	8.45	0.60	1,500	2,220	3,720	4,935	1,215
Cassava+ soybean	7.90	0.45	1,420	2,240	3,660	4,170	270
Cassava+mungbean	8.00	0.40	1,460	2,120	3,580	3,850	770
Cassava+cowpea	7.95	0.40	1,480	2,140	3,620	3,785	165
Upland rice+peanuts	0.76	0.60	1,600	2,380	3,980	4,300	320
Upland rice+soybean	0.79	0.52	1,690	2,380	4,070	4,055	–15
Uplandrice+mungbean	0.75	0.40	1,510	2,320	3,830	3,475	–355
Upland rice +cowpea	0.80	0.42	1,500	2,320	3,820	3,470	70
Maize+peanuts	1.16	0.67	1.520	2,380	3,900	4,420	520
Maize+soybean	1.09	0.49	1.405	2,360	3,765	3,495	–270
Maize+mungbean	1.10	0.40	1.385	2,360	3,745	3,250	–495
Maize+cowpea	1.15	0.45	1.395	2,360	3,755	3,525	–230

Rp (rupiah) is the Indonesian currency; 1 US$ = Rp 9,500; Labor wages: Rp 20,000 day^{-1}; Fertilizer price: urea Rp 1,500; SP36 Rp 2,500; KCl Rp 3,500 kg^{-1}; Crop yield price: cassava Rp 300; rice Rp. 2,500 kg; maize Rp 1,500 kg; peanut Rp 4,000; soybean Rp 4,000; mungbean Rp 3,500; cowpea Rp 3,500 kg^{-1}.

As can be seen from Table 2, all intercropping systems on this degraded site had an LER greater than 1.0, which varied between 1.35 (cassava + upland rice) and 1.60 (cassava + peanut and maize + peanut). Thus, in terms of land use efficiency, intercropping is profitable and in particular, intercropping leguminous crops like peanut, gave the top LER. High LER with legume intercropping may be due to the lower competition for soil N in such systems (Dapaah et al., 2003). There is also less competition for sunlight because cassava and the legume crops possess divergent architectural patterns (Fukai and Trenbath, 1993). Overall, cassava intercropped with leguminous crops showed higher yield compared to cassava intercropped with upland rice or maize. Better weed suppression by legume intercrops may also contribute to the higher yield in cassava intercropped with legume crops (Chikoye et al., 2001); however, we do not have data to support this contention.

A comparison of the data in Tables 1 and 2 also indicates that LER can only be used to compare the agronomic advantage but is less suitable for evaluating the economic advantage of cropping systems. For instance, maize with cowpea had an LER of 1.56, but the net income was negative (Rp. 230,000/- or about US $ 25/-).

Soil quality

As can be seen from Table 3, soil quality declined when continuously planted with sole cassava. After four years of cassava monocropping, the soil organic matter content declined to 8.4 g kg^{-1} from the pre-treatment value of 11.4 g kg^{-1}. This may be due to the high plant biomass removal (tubers and stems) associated with cassava harvest. Low soil organic matter content also impeded soil aggregation and reduced soil water availability (Table 3), which is consistent with the observations of Shepherd et al. (2006). Continuous sole cropping of cassava also decreased available soil P levels. Although cassava is known as a soil exhausting crop that removes profound quantities of K (Howeler, 1991), planting cassava on this land did not substantially alter the exchangeable K levels. This is not surprising because the site has high K levels (Howeler, 2008).

Data presented in Table 3 also show that intercropping and FYM application reduced the decline in soil quality

Table 2. Crops yields and land equivalent ratio in intercropping systems in degraded land of South Blitar, East Java, Indonesia.

Cropping System	Yield (Mg ha^{-1})		Land equivalent ratio (LER)		
	Main crop	Intercrop	Main crop	Intercrop	Total
Cassava+upland rice	7.46	0.72	0.75^{abc}	0.60^{a}	1.35^{a}
Cassava+maize	7.40	1.05	0.74^{abc}	0.70^{abc}	1.44^{a}
Cassava+peanuts	8.45	0.60	0.85^{c}	0.75^{bc}	1.60^{c}
Cassava+soybean	7.90	0.45	0.79^{bc}	0.66^{ab}	1.45^{ab}
Cassava+mungbean	8.00	0.40	0.81^{bc}	0.77^{bc}	1.59^{c}
Cassava+cowpea	7.95	0.40	0.80^{bc}	0.70^{abc}	1.50^{bc}
Upland rice+peanuts	0.76	0.60	0.63^{a}	0.75^{bc}	1.38^{ab}
Upland rice+soybean	0.79	0.52	0.66^{ab}	0.76^{bc}	1.44^{ab}
Upland rice+mungbean	0.75	0.40	0.63^{a}	0.76^{bc}	1.39^{ab}
Upland rice+cowpea	0.80	0.42	0.67^{ab}	0.73^{abc}	1.40^{ab}
Maize+peanuts	1.16	0.67	0.77^{abc}	0.83^{c}	1.60^{c}
Maize+soybean	1.09	0.49	0.72^{abc}	0.72^{bc}	1.44^{ab}
Maize+mungbean	1.10	0.40	0.73^{abc}	0.77^{bc}	1.50^{bc}
Maize+cowpea	1.15	0.45	0.77^{abc}	0.79^{bc}	1.56^{c}

Means followed by the same superscripts in the same column are not significantly different (p=0.05); cassava yield was in the form of fresh tubers; rice, maize and legume were at sun dry condition (11–14 % moisture content); main crop refers to the principal crop, and the intercrop refers to the subsidiary crops.

Table 3. Soil properties before and after harvesting the experimental crop in the degraded lands of South Blitar, East Java, Indonesia.

Cropping System	Organic-C (%)	N (%)	P (ppm)	K (cmol kg^{-1})	Pb (Mg m^{-3})	MWD (mm)	Available water (%)
Before experiment	1.14 (±0.08)	0.09 (±0.02)	11.61 (±1.35)	1.61 (±0.22)	1.31 (±0.15)	2.04 (±0.14)	11.07 (±0.45)
Cassava	0.84 (±0.04)	0.08 (±0.02)	7.61 (±0.95)	1.59 (±0.17)	1.29 (±0.12)	1.25 (±0.13)	9.45 (±0.37)
Cassava+upland rice	1.87 (±0.13)	0.07 (±0.02)	9.25 (±0.75)	1.75 (±0.21)	1.09 (±0.16)	2.57 (±0.21)	13.62 (±0.87)
Cassava+maize	1.96 (±0.17)	0.05 (±0.02)	8.24 (±0.64)	2.23 (±0.19)	1.23 (±0.08)	2.19 (±0.18)	12.36 (±1.04)
Cassava+peanuts	1.17 (±0.09)	0.13 (±0.02)	7.98 (±0.87)	1.07 (±0.15)	1.30 (±0.17)	2.45 (±0.22)	11.32 (±1.22)
Cassava+soybean	0.95 (±0.07)	0.11 (±0.03)	6.60 (±0.55)	1.45 (±0.12)	1.32 (±0.15)	1.18 (±0.09)	10.85 (±0.67)
Cassava+mungbean	1.02 (±0.07)	0.10 (±0.02)	7.75 (±0.87)	1.78 (±0.11)	1.24 (±0.09)	2.05 (±0.18)	10.34 (±0.97)
Cassava+cowpea	1.06 (±0.08)	0.11 (±0.02)	8.05 (±0.92)	1.34 (±0.12)	1.16 (±0.11)	1.95 (±0.15)	12.24 (±1.15)
Cassava (+FYM)	1.27 (±0.07)	0.12 (±0.02)	9.34 (±0.88)	1.26 (±0.14)	1.05 (±0.08)	2.05 (±0.14)	13.23 (±1.04)
Cassava+upland rice (+FYM)	2.34 (±0.14)	0.14 (±0.03)	11.31 (±1.04)	2.37 (±0.16)	1.06 (±0.09)	2.45 (±0.16)	14.56 (±1.34)
Cassava+maize (+FYM)	1.97 (±0.15)	0.12 (±0.02)	9.98 (±0.82)	1.96 (±0.20)	1.11 (±0.07)	1.98 (±0.12)	13.90 (±0.97)
Cassava+peanuts (+FYM)	1.22 (±0.18)	0.19 (±0.03)	9.47 (±0.90)	2.05 (±0.18)	1.15 (±0.08)	2.08 (±0.11)	12.15 (±1.12)
Cassava+soybean (+FYM)	1.02 (±0.09)	0.09 (±0.02)	9.40 (±0.87)	1.85 (±0.17)	1.20 (±1.10)	1.90 (±0.13)	10.25 (±0.87)
Cassava +mungbean (+FYM)	1.12 (±0.08)	0.14 (±0.03)	8.97 (±0.78)	1.95 (±0.18)	1.19 (±0.07)	1.88 (±0.14)	11.10 (±1.05)
Cassava+cowpea (+FYM)	1.25 (±0.08)	0.20 (±0.04)	9.40 (±0.92)	1.80 (±0.19)	1.15 (±0.09)	2.10 (±0.18)	12.05 (±1.16)

The data presented here are means of two measurements; ρb=soil bulk density MWD= mean weight diameter.

of continuously cropped cassava plots. Indeed, intercropping cassava with upland rice and maize increased soil organic matter content, both with and without FYM application. However, a divergent trend was obtained when cassava was intercropped with legumes. Even with FYM application, the leguminous intercrops did not influence the soil organic matter content much. Soil organic matter before the experiment was 11.4 g kg^{-1}, whereas soil organic matter content for the legume intercrops without manure varied from 9.5 g kg^{-1} (cassava + soybean) to 11.7 g kg^{-1} (cassava + peanuts), and those with FYM application varied from 10.2 g kg^{-1} (cassava + soybean + FYM) to 12.5 g kg^{-1} (cassava + cowpea + FYM). This phenomenon can be explained based on the recalcitrance characteristics of the organic matter inputs (von Lutzow et al., 2006). Soil organic matter derived from leguminous crops has a lower C/N ratio, signifying faster turnover in the soil, compared to cereal crops. Conversely, both upland rice and maize had a relatively higher C/N ratio. In addition, the organic matter originated from upland rice and maize also may have high levels of complex organic compounds, such as lignin and cellulose (von Lutzow et al., 2006).

The higher soil organic matter content in the upland rice and maize intercrop plots, led to an increase in soil aggregation and available soil water content, and a decrease in soil bulk density. The persistent humic substances may act as the binding agents and would promote soil aggregation (Shepherd et al., 2006). Although the addition of FYM to cassava intercropped with peanut and cowpea did not increase soil organic matter, it increased the soil N content (Table 3). This indicates that N fixed by the legume intercrops was not only used by itself but also contributed to the nitrogen balance of the soil.

Yield trends

Each cropping pattern was analyzed individually employing year of planting as a factor (Fig. 1 on cassava and Fig. 2 on intercrops). The data in Fig. 1 show that although enough fertilizer was applied to the crops, planting cassava continuously on degraded lands progressively decreased crop yields: 9.90 Mg ha^{-1} in the first year of planting, 8.27 Mg ha^{-1} in the second year, and 7.44 Mg ha^{-1} in the fourth year. This decrease in cassava yield when it was continuously planted on the same field, however, is not a new phenomenon and was reported earlier too (e.g., Howeler, 1991). It seems that although there are enough plant nutrients from the applied fertilizers, the yield of cassava is limited by other physical or biological factors. This is consistent with the data (Table 3) on declining soil quality of continuously cassava cropped plots. Such yield declines, however, can be minimized by adopting intercropping with cassava (Fig. 1). Leguminous intercrops (e.g., cassava + peanuts and cassava + cowpea) are particularly useful in this respect. For instance, during 2006/07, sole cassava with FYM yielded 11.56 Mg ha^{-1}, which increased to 13.34 Mg ha^{-1} in 2008/09, as against 7.44 Mg ha^{-1} for plots receiving no FYM. Furthermore, application of FYM in intercropping systems, especially with peanut and cowpea had an additional positive effect on cassava yield. In 2008/09, the yield of cassava intercropped with peanut and cowpea was 15.84 Mg ha^{-1} and 15.30 Mg ha^{-1} respectively. In addition to supplementing plant nutrients, FYM can also improve the soil physical (Table 3) and biological attributes. The beneficial effect of manure to maintain stability in cassava yield has been shown by many workers (e.g., Amanullah et al., 2007).

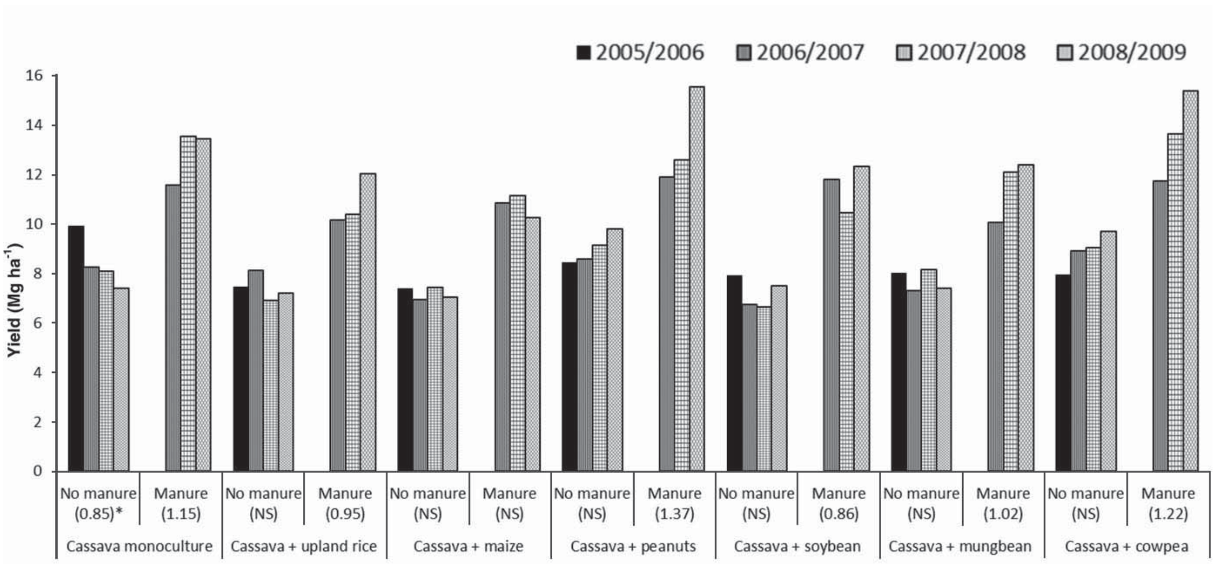

Figure 1. Yield trend of cassava with different cropping system and manure application in the degraded lands of South Blitar, East Java, Indonesia. (*LSD (5%); NS: Not significant)

As regards to intercrop yields, there was no yield decrease with advancing crop cycles. Indeed, there was a tendency of increased yield for the leguminous crops (Fig. 2). The intercrop yield without manure, except peanut, was relatively constant. Peanut yield increased from 0.6 Mg ha^{-1} in the first year to 0.9 Mg ha^{-1} in the fourth year. In cassava with FYM, the yield of all intercrops increased with time of planting.

The phenomenon of high yield in legume intercropping, especially peanut and cowpea with manure addition (Fig. 1) can be understood, because in this treatment, in addition to plant nutrients from fertilizers and nitrogen fixation, there was additional source of energy from FYM, which is very important for microbial activity. Soybean and mungbean plots might also have N inputs from these crops; however, the amount of additional N is lower compared to that of peanut and cowpea.

Our results showed that in the degraded upland tropical conditions of East Java, Indonesia, the only profitable crop is cassava either planted in a monoculture or with intercrops. Planting cassava continuously, without proper management, however, depleted soil fertility. This negative effect can be reduced by simple management techniques such as intercropping and/or the use of FYM. Use of leguminous cover crops not only increased cassava yield in the first year, but also improved soil quality. Chemical fertilizers in monoculture cassava were inadequate to maintain sustained yields. Application of FYM in conjunction with chemical fertilizers, however, increased soil fertility and crop productivity. Intercropping of cassava with legume crops, especially peanuts and cowpea further increased crop productivity. With the FYM treatments, the yield of monoculture cassava was about 13 Mg ha^{-1} whereas the yield of cassava intercropped with peanut and cowpea increased to about 16 Mg ha^{-1}.

Acknowledgements

This article was written with the support of the Indonesian Department of National Education under PAR Scheme. We thank the Massey University for providing the facilities during finishing the manuscript. Many thanks to the reviewers for their useful and inspiring comments.

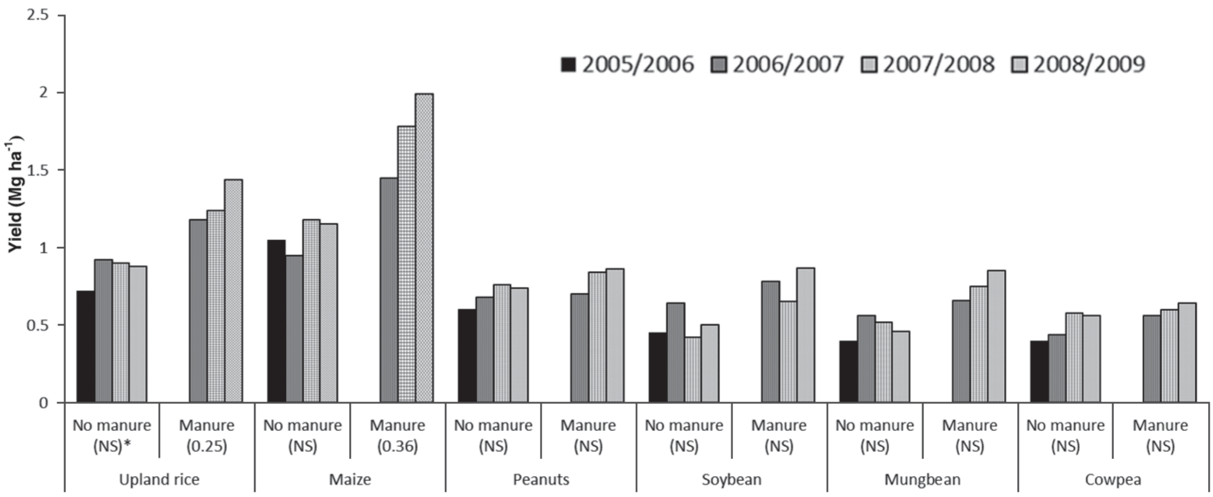

Figure 2. Yield of intercrops in cassava-based cropping system with different manure application in the degraded lands of South Blitar, East Java, Indonesia. (*LSD (5%); NS: Not significant)

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