CROPPING SYSTEMS TO PRESERVE FERTILITY OF RED-YELLOW PODZOLIC SOILS IN INDONESIA

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Red-Yellow Podzolic soils in Indonesia

Red-Yellow Podzolic soils are a part of the broad category of Red soils in Indonesia (Soepraptohardjo and Ismangun, 1980). These soils collectively cover much of the land area of Indonesia that is not swampy, alluvial or of recent volcanic origin. They are distinctly different from the Latosols and Mediterranean soils that are also a part of the Red soil group, (Rapat Kerja, 1969 as reported by Buurman, 1980). These general classifications have been adequate in the past since these soils are not widely used for food crops production. Physical characteristics and topography were most important for planning large perennial crops estates. There was little need for more detailed classification because the land was not considered suitable for sustained agriculture involving food crops. Shifting cultivation has been and still is a major management technique for food crops production on these soils.

The "Red Soils" cover about 30% of the land area of Indonesia (Driessen and Soepraptohardjo, 1974). A little more than one half of this area or 32 million hectares consist of Red-Yellow Podzolic soils. Within the Soil Taxonomy Classification System most of these soils would be Udults and would be described as fine loamy to clayey, kaolinitic and isohyperthermic. Within a few square kilometers, however, we may expect to find many differences at the sub-group and family levels of classification. For example, within the Gunung Batin Sugar Cane project area in Central Lampung, Sumatra, eleven different soils are classified even though the land appears quite uniform and reasonably level (SRI, 1975). In the level areas ($<2\%$ slope) where there is poor surface drainage, plinthite is usually present in the subsoils. Well drained soils on rolling land usually contain no plinthite and exhibit the characteristics of Paleudults. The most common soil family found in the transmigration areas of Lampung and South Sumatra where we have worked would be Orthoxic Tropudults or variations thereof.

1 Physiography and physical characteristics

The topography of the Red-Yellow Podzolic soils in Indonesia varies from almost level to gently undulating to hilly. There are outcrops of gravelly material and some stone. But in general these soils have good physical properties for cultivation. If an underlying hard pan exists, it is usually deep enough that cultivation is not affected. The surface horizon, especially on newly opened land, is usually friable and freely permeable to water. Underlying less permeable layers exist and cause drainage problems on level land and accelerate erosion and sloughing of soil on the undulating and hilly land. In some areas, particularly in Lampung, South Sumatra, Jambi and Riau provinces of Sumatra, there are large areas of relatively level land. From 70 – 80% of the land has less than 15% slope (Taslim and Pasaribu, 1978). But commonly, even in hilly areas small level areas of land are present on ridges and are interspersed with sloping lands. There is

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sufficient level or reasonably suitable land for cultivation in most regions where these soils are common.

Table 1 Mean monthly rainfall, number of rainy days and daily maximum rainfall for five Cropping Systems Research Sites

Province Station and Elevation		Crop Year												
West Sumatra		SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	YEAR
Kota Bảru	RF (mm)	173	259	360	346	277	226	288	267	214	117	114	107	2748
(Sitiung I)	RD (no.)	8	13	15	18	16	13	15	15	11	6	5	7	144
77 M	M. max (mm)	54	67	81	58	60	61	61	66	62	46	51	47	114
S. Sumatra														
Baturaja	RF (mm)	152	206	264	363	333	279	327	196	214	129	115	125	2803
(Batumarta)	RD (no.)	8	12	15	18	17	14	16	14	11	8	8	8	149
150 M	M. max (mm)	55	56	65	74	70	71	70	69	61	48	44	47	121
Lampung														
Kota Bumi	RF (mm)	107	146	181	342	364	264	316	228	165	127	100	83	2423
(Way Abung)	RD (no.)	7	10	12	17	17	15	17	13	10	8	7	6	139
32 M	M. max (mm)	41	46	43	64	74	63	59	53	51	42	38	35	106
S. Kalimantan														
Pelaihari	RF (mm)	64	118	242	426	439	311	303	221	167	143	111	78	2623
(Tajau Pecah)	RD (no.)	4	7	13	18	17	14	14	11	10	8	7	4	129
21 M	M. max (mm)	27	40	55	91	86	72	69	64	49	44	44	39	117
S.E. Sulawesi														
Wawotobi	RF (mm)	53	42	65	101	128	107	163	168	277	225	124	107	1560
(Puriala)	RD (no.)	5	4	8	28	14	10	16	15	19	16	11	10	130
35 M	M. max (mm)	18	18	28	26	37	33	40	38	37	54	42	30	80

1. Data taken from Berlage; RF = rainfall, RD = rainy days and M. max = mean maximum rainfall (event) for time periods indicated.
2. Cropping season in S.E. Sulawesi would normally start in December. Data are arranged in this sequence for consistency only.

2 Climate

The amount and distribution of rainfall is a dominating factor in determining the potential and management of soil for crop production. The rainfall distribution and number of rainy days per month give a general idea of these important determinants for crop production and soil management. Table 1 shows these data for five different locations in Indonesia where extensive cropping systems research has been conducted. The data show the tremendous natural resource Indonesia possesses in having sufficient rainfall for year round crop production. Even in the drier areas such as S.E. Sulawesi there is enough rainfall, sufficiently well distributed, to grow crops the year round if drought tolerant crops are grown during the dry season.

3 Traditional soil management

The traditional method of land use has involved two basic practices. The first method is a sequence of cutting and burning of the forests, production of food crops such as rice for three to four years and gradual inter-planting of perennial crops such as rubber, fruit trees, spices and coffee. The size of each land unit cleared at one time is dependent upon the food crop needs of the farmer or group of farmers involved. This pattern is followed where the soil is more fertile and where population pressures have encouraged permanent settlement of land. After 15 – 20 years usually the trees are cut and the process started over again for a given piece of land.

The second method simply involves cutting and burning of forest or grassland, production of food crops for 3 – 4 years or until the soil nutrients are lost to cropping, leaching and erosion. It is this practice that has caused the development of large areas of *Imperata cylindrica* (alang-alang) infested lands. The situation is exacerbated by annual burning during the dry season to drive out wild animals and to encourage new growth of vegetation for pasture. These practices are followed in many places where the inherent fertility of the soil is low. Even though clearing new land either from forest or *Imperata* is labor intensive and precludes land development and establishment of individual land rights, shifting cultivation persists. One reason is the rejuvenation of the soil fertility without the need for fertilizers and another is the control of weeds. Land newly opened from forest remains relatively weed-free for 3 years. Even land opened from *Imperata* tends to be free of broad leaf weeds. It is not unusual for farmers in some of the older transmigration area to allow *Imperata* to grow as a kind of cover crop for 3 – 4 years and follow with food crops. The soil fertility gradually builds up and erosion is controlled. In cropping patterns for this situation, cassava is not a main crop. Table 2 shows some test data for the macro-nutrient elements, pH and exchangeable aluminum in Red-Yellow Podzolic soils from West Sumatra to Southeast Sulawesi. Samples 3, 4 and 5 were from land that had been used recently and had received some lime and phosphorus applications. For these soils if the pH (KCl) is higher than 4.0 lime has probably been applied recently. Many times Al extracted with lN KCl exceeds exchangeable bases in unlimed soils. The soil reactivity is mostly contained in the soil organic matter.

Table 2 Analysis of soil samples from some research sites in Indonesia [1]

Sample Site[2]	Truog P	Bray 2 P	pH (H_2O)	pH (KCl)	N. KCl (ext Al)	CEC	Ca	Mg	Na	K
	ppm	ppm					(meq/100 g)			
1. Sitiung, West Sumatra	3.35	1.98	4.31	3.71	2.77	14.02	0.05	0.11	0.02	0.03
2. Baturaja, South Sumatra	5.91	2.05	4.75	3.86	1.75	10.13	0.25	0.34	0.06	0.12
3. BUK, Lampung, Sumatra	13.78	5.58	4.78	4.15	0.18	15.41	2.20	0.84	0.05	0.30
4. BPMD, Lampung, Sumatra	6.69	2.72	5.12	4.55	0.13	14.53	1.64	1.00	0.07	0.26
5. Nakau, Lampung, Sumatra	6.30	2.50	5.36	4.70	<0.01	13.82	1.04	0.07	0.06	0.18
6. Way Abung, Lampung, Sumatra	6.69	4.83	4.71	4.06	0.87	7.64	0.46	0.31	0.05	0.11
7. Puriala, Southeast Sulawesi	4.53	1.76	5.15	3.80	1.66	11.68	0.76	0.96	0.04	0.13

[1] Analyses were made through the courtesy of the Benchmark Soils Project, University of Hawaii.
[2] Samples were taken from the upper 20 cm of the soil profile. The plant nutrient content below this zone is not sufficient to sustain plant growth.

Soil and crop management research

A long-term soil and crop management experiment was begun in 1973 in Central Lampung by the Central Research Institute for Agriculture in Indonesia. This research was conducted in a farmer's field on land that had been opened for about 20 years. The objective was to study the effects of fertilizer, lime and crop residues on production of crops grown in traditional systems of mixed cropping and in monoculture. The results of this research have been reported by McIntosh and Surjatna (1978) and some data are shown in Table 3. Other long-term studies have been conducted by the Soil Research Institute and the Benchmark Soils Project of the University of Hawaii in collaboration with the Soil Research Institute. These studies all show the potential for crop production on these soils if properly managed.

The first two studies were basically cropping systems research involving a limited number of different cropping patterns. The management treatments were based on the premise that these were fragile soils and research was needed to evaluate management practices that would slow down or prevent the loss of soil productivity with continuous cropping. Results in Table 3 indicate that crop yield levels could be maintained. In the short term the data indicate that applications of inorganic sources of N, P, K and lime to replace nutrient removal would be sufficient to maintain production. On the other hand, without these applications the yields decreased yearly. Year to year rainfall fluctuations make it difficult to detect definite trends in loss of production where fertilizers have been used. Two factors other than crop yield, however, give an indication of potential production problems. Firstly, soil analysis data in Table 4 show changes that occurred

Table 3 Comparisons of crop yields and net returns for three management practices in long-term cropping systems study from 1973 – 78. Cropping Systems Research, Banjarjaya, Central Lampung [a]

Fertility	Dry grain				Cassava wet root	Net returns	Food calories	Padi rice equivalent
	Corn	Upland rice	Peanut	Ricebean				
	(ton/ha)				(ton/ha)	(Rp/ha)	(KCal/ha)	(ton/ha)
No lime + no NPK + no mulch								
1973 – 74	0.46	0.77	0.22	0.09	14.6	91,000	22,287	9.3
1974 – 75	0.21	0.86	0.47	0.05	6.1	–	12,391	5.2
1975 – 76[b]	0.22	0.65	0.23	–	6.0	21,667	10,590	4.4
1976 – 77	0.05	0.54	–	0.07	3.7[c]	–	5,908	2.5
1977 – 78	0.13	0.15	0.22	–	3.9	27,137	6,520	2.7
Lime + NPK + no mulch								
1973 – 74	1.35	1.61	0.43	0.54	22.2	–	39,044	16.3
1974 – 75	1.90	3.11	0.74	0.38	20.6	–	43,536	18.2
1975 – 76[b]	1.98	1.89	0.35	–	19.9	212,784	37,024	15.5
1976 – 77	1.84	1.45	–	0.04	14.2[c]	–	27,161	11.3
1977 – 78	2.06	2.06	0.58	–	21.0	344,765	40,083	16.7
Lime + NPK + mulch								
1973 – 74	1.35	2.72	0.57	0.63	23.2	265,000	43,791	18.3
1974 – 75	2.44	3.22	0.76	0.49	20.1	–	45,558	19.0
1975 – 76[b]	2.21	1.82	0.49	–	36.8	397,344	58,588	24.5
1976 – 77	1.90	1.49	–	0.04	15.9[c]	–	29,523	12.3
1977 – 78	2.26	2.15	0.58	–	22.7	369,540	43,043	18.0

[a] Taken from Laporan Kemajuan Penelitian, Seri Pola Bertanam (No. 4, 5 and 6), from 1974 – 77.
[b] Exceptionally dry year – almost no rain in May, June, and July.
[c] First planting of cassava failed because of bad cuttings and had to be replanted late.

Table 4 Changes in some chemical measurements of soil from plots treated or managed differently for 5 years

Treatment	pH	Extract Al.	Exchangeable bases			Bray 2	Organic	
	(KCl)	(KCl) (meq/100 g)	Ca	Mg (meq/100 g)	K	P (ppm)	C (%)	N (%)
Check (not tilled)	4.8	Nil	2.8	0.4	0.1	4.2	1.23	0.1
No treatment (continuous crop)	4.1	0.21	0.98	0.51	0.1	4.6	0.96	0.08
Full treatment (continuous crop)	5.5	Nil	3.8	0.3	0.1	50.0	1.15	0.09

Source: McIntosh and Effendi, 1978.

after five years of continuous cropping compared to an adjacent plot that had not been cultivated in the farmer's field. Without fertilizer and return of residues, pH and organic carbon decreased and KCl extractable Al increased. On the other hand, with fertilizer and return of residues these values were about the same as the check even though the soil had been cropped and considerable food products removed. The return of the residues is needed to maintain the level of soil organic matter and provide buffering and exchange capacity to the soil. Secondly, the direct effect on the physical properties of the soil is probably equally as important. After four years of continuous cropping there were noticeable differences in the appearances of corn depending on whether residues had been returned to the plots. Without the residues the corn growth was uneven. The soil was hard in spots over the plots and there were differences in germination as well as growth rate of the corn.

The productivity of these soils has also been established through the Benchmark Soils Project (Manuelpillai *et al.*, 1980). In their study of Typic Paleudult soils on a worldwide basis, three sites were located in Southern Sumatra. Their work was designed to study the response of corn to P and N applications and determine the contribution of residual P to grain yield. The remarkable aspect of their research was the 5 to 6 ton/ha yields of corn they were able to grow rather consistently on these soils. These yields were obtained with initial rates of 80 to 120 kg P and 80 kg N/ha. They also used 50 kg K, 1,000 kg lime and 50 kg Mg/ha as well as minor element applications of Zn and B. But likely, their most effective management practice was the use of drip irrigation as needed. These yields are about double those obtained from other experiments on these soils with comparable management practices but where drip irrigation was not used.

Cropping systems research

The initial results from research on Red-Yellow Podzolic soils in Central Lampung showed the potential for crop production. However, there were some apprehensions that the soil in the plot area was unique and that the results would not be representative of many other Red-Yellow Podzolic soils. The research was expanded to include three new sites. One site was in a partially irrigated area where farmers were growing only one paddy rice crop per year even though in their adjacent land, without any irrigation, they were growing crops throughout the year. The other two sites were on land newly opened from secondary forest and land previously cultivated within the last 3 – 4 years. These studies were designed primarily to evaluate different cropping patterns for productivity and acceptability to farmers in terms of economics, labor, markets and need for capital. Introduced patterns were compared to the farmers' existing patterns wherever possible. This research gave similar results to the previous work in Central Lampung. Furthermore, because of the larger plot size and greater visibility, the research results were more convincing to farmers, extension staff, donors and visiting colleagues. Additional support was obtained from Transmigration authorities to expand the research into other provinces in Sumatra and to South Kalimantan and Southeast Sulawesi.

Tables 5, 6 and 7 show the results of year round cropping systems studies on Red-Yellow Podzolic soils in different regions of Indonesia. The components of each pattern; such as, varieties, fertilizer response and pest management were studied simultaneously. The performances of the Introduced Cropping Patterns compared to the Farmer's Cropping Patterns are quite impressive, either in terms of net returns or gabah rice equivalent (rough rice). The variations in yields of crops among the different locations indicate the need for further studies on component technology. For example, blast (*Pyricularia oryzae*) is still a major problem for upland rice. This disease problem is accentuated by the uncertain rate of release of nitrogen from decomposing organic matter on newly opened land. At the same time the soils are extremely deficient in P and have low pH's. Consequently, after continuous cropping and use of P and return of crop residues, yield fluctuations tend to decrease.

Table 5 Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns for second year's results from different locations in Lampung, 1976 – 79

Cropping Patterns	Yields and net returns/location[1]		
	Komering Putih	Way Abung	Bandar Agung
	1976 – 77	1977 – 78	1976 – 77
		(ton/ha)	
Farmers' C.P.:			
Corn +	0.34	0.92	0.76
Upland Rice	1.56	1.90	2.02
Cassava	18.33	9.79	–
Peanut	–	–	(Corn) 0.81
Net Returns	Rp.159,237	Rp.125,763	Rp.110,859
Gabah Rice Equiv.[1] (ton/ha/yr)	11.23	8.16	4.33
Introduced C.P.:			
Corn +	2.08	2.55	1.98
Upland Rice	1.02	3.69	1.69
Cassava	26.11	19.89	21.12
Peanut –	0.38	0.58	(Corn) 1.74
Ricebean	–	0.28	(Cowpea) 0.33
Net Returns	Rp.201,878	Rp.409,743	Rp.216,594
Gabah Rice Equiv.[1] (ton/ha/yr)	17.88	18.89	18.22

Source: Cropping Systems Research Annual Reports.

[1] Amount of rough rice calculated to provide food calories equivalent to the total produced by all the crops in the cropping pattern.

In general the yields increased with succeeding years of cultivation due to amelioration of soil problems and improvement of management and technology. The lower total yields from Kalimantan and Southeast Sulawesi (Table 7) were due mostly to lower yields of cassava. The local varieties that were used in these locations had lower yield potentials. Also the cassava was planted late. These are examples of management and logistic problems that may occur which affect production.

Table 6 **Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns for second years' results from different locations in South Sumatra, 1977 – 78**

Cropping Patterns	Yields and net returns/location	
	Batu Raja 1977 – 78	Lahat Tebing Tinggi 1977 – 78
	(kg/ha)	
Farmers' C.P.:		
Corn +	0.40	None
Upland Rice –	1.88	None
Peanut	0.52	None
Net Returns	Rp.132,500	
Gabah Rice Equiv. (ton/ha/yr)	3.46	
Introduced C.P.:		
Corn +	1.63	2.44
Upland Rice	1.08	2.82
Cassava	14.71	14.87
Peanut –	0.57	0.55
Ricebean	0.54	0.28
Net Returns	Rp.176,540	Rp.377,825
Gabah Rice Equiv. (ton/ha/yr)	12.67	15.29

Source: Cropping Systems Research Annual Reports

Table 7 **Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns for second years' results from different locations in Tajau Pecah, S. Kalimantan and Puriala, Southeast Sulawesi, 1978 – 80**

Cropping Patterns	Yields and net returns/location	
	Tajau Pecah S. Kalimantan	Puriala S.E. Sulawesi
	(ton/ha)	
Farmers' C.P.:		
Corn +	0.25	1.32
Upland Rice	1.48	–
Soybean	0.31	0.42
Net Returns		Rp. 58,597
Gabah Rice Equiv. (ton/ha/yr)	2.31	2.54
Introduced C.P.:		
Corn +	0.66	0.40
Upland Rice	1.18	1.42
Cassava	7.83	6.26
Peanut –	0.12	0.83
Cowpea +	0.26	0.52
Pigeonpea	–	0.22
Net Returns		Rp.289,723
Gabah Rice Equiv. (ton/ha/yr)	6.70	7.77

Source: Cropping Systems Research Annual Reports.

Cultural practices and crop management

1 Land preparation

For newly opened *Imperata* fields, the vegetation must be cut close to the ground and the soil worked with a hoe, before the start of the rainy season. Then the land is left fallow for at least one month to allow the *Imperata* roots to dry and decompose. The cropping pattern found to be appropriate for Red-Yellow Podzolic soils in most regions of Indonesia is shown in Fig. 1. The management practices that follow are based on this pattern.

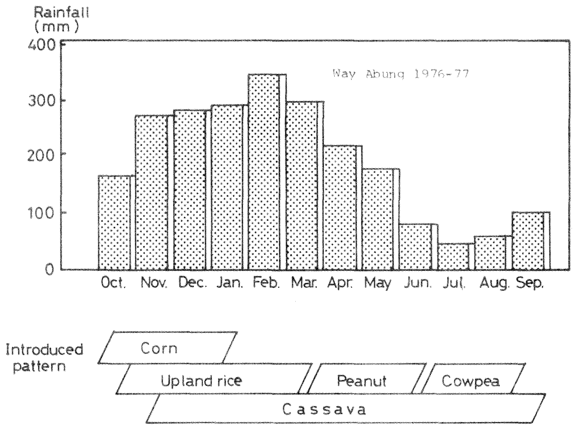

Fig. 1 Monthly rainfall distribution and year around cropping pattern commonly tested on Red-Yellow Podzolic soils.

When the rains begin to fall, strips are made by hoe two meters apart for planting corn. Land preparation for the rice to be planted between the corn rows is made after the corn germinates. This tillage system may provide a more even demand for labor. However, if the farmer hires labor or uses a plow to prepare the land, then all of the land is usually prepared at one time. No cultivation is necessary for the cassava. The sticks are directly slipped into the soil between the corn hills.

Minimum tillage is recommended for the peanuts that are planted immediately after rice harvest. First, furrows are made along the rice stubble rows. Next, fertilizer and peanut seeds are dibbled into the opening and covered with soil.

After the peanut harvest, one light hoeing is made to control weeds and loosen the soil for planting ricebeans or cowpeas – the last crop in the cropping sequence.

This continuous cropping pattern is labor intensive. It requires from 500 – 600 manday/ha/year. The most labor is required for land preparation, planting and weeding. The use of animal power and development of appropriate hand tools to ease the burden is strongly recommended.

2 Planting

The first corn crop is planted in rows 200 cm apart. Two seeds are dibbled by hand in small holes made by a wooden stick and spaced every 50 cm. The seed should be of good quality (90% germination). This planting arrangement will give a population of about 20,000 plant/ha.

Two weeks later, rice seed is dibbled every 10 cm within rows which are spaced 40 cm apart between the corn rows. We try to drop about five seeds per hill. The rice population is not reduced because of the corn. There will be five rows of rice between two rows of corn. Planting rice two weeks after the corn reduces the shading effects of the corn on the rice. By the time the rice plants flower (the most critical stage), the corn is ready for harvest. If early maturing corn varieties (<90 days) are used, the corn and rice should be planted at the same time.

One and a half months after planting the corn (one month after rice), cassava sticks are inserted between the corn hills in every other row, giving a cassava spacing of 400 x 500 cm. The population of cassava will be 5,000 plant/ha.

After harvesting the rice, the straw is cut close to the ground and pushed aside into the cassava rows. Peanut seed is dibbled beside each hill of rice stubble (one seed/hill) at a spacing of 50 x 10 cm. The rice straw is then spread out on the field surface as mulch. This is very important to suppress weed growth, conserve both soil moisture and organic matter and prevent erosion.

After peanut harvest either cowpea or ricebean may be planted as the last crop in the sequence. The seeds are planted at a spacing of 40 x 20 cm with two seed/hill.

3 Fertilizing

For these soils fertilizer should be put as close as possible to the root zone so that the plant roots can easily and efficiently reach the nutrients. For P this can be done by evenly distributing the fertilizer at the bottom of the furrows made for the plant rows of each crop. For N and K the fertilizer should be banded in a row beside and below the seed. Soils with pH's (KCl) below 4 and low levels of exchangeable Ca (<1.0 meq/100 gm) must be limed to sustain crop production*. The amounts of fertilizer needed for each crop in the pattern and time of application are shown in Table 8.

Table 8 Kind, amount and timing of fertilizer applications in the cropping pattern

Crop	0 DAP[a]		14 DAP	30 DAP	42 DAP	Total/crop[b]	
	Urea	TSP	Urea	Urea	Urea	Urea	TSP
				(kg/ha)			
Corn +	25	50	0	50	0	75	50
Upland Rice	0	100	100	0	50	150	100
Cassava	0	0	0	0	0	0	0
Peanut –	25	50	0	0	0	25	50
Ricebean/cowpea	25	50	0	0	0	25	50
				Total/year		275	250

[a] DAP = Days After Planting

[b] The amount of P may be reduced over time as this nutrient builds up in the soil.

4 Weeding

Normally one or two weedings are enough. The time for the first weeding depends on the weed situation. Make sure that the rice crop is free of weeds during the early vegetative stages. Weeding can be done by hand or with any appropriate tools that may be available.

5 Pest mangement

During the early growth stages, corn, rice and legumes can be well protected by seed treatment with the granular insecticide, Furadan 3G (or any other similar material**). For rice, 30 gram of Furadan 3G/kg of rice seed is effective. Mix the insecticide with the seed and add sufficient water to just cover the mixture. Allow the seed (and Furadan) to soak for about 12 hours.

For corn and legumes Furadan 3G may be applied with the seeds at planting at a rate of 7.9 kg/ha. The amount of Furadan 3G that can be easily held between two finger tips is about

* A rate of one metric ton/ha burned limestone has been adequate for crop production over a period of five years. Work is being done to determine lime rates and develop sources of ground limestone.

** Mention of Trade names does not constitute a recommendation but is used for clarity.

the right amount per hill. If Furadan is not available we recommend at least two sprayings of Diazinon, Sevin, Surecide or Azodrine at ten-day intervals. The first spraying should be made 7 – 10 days after planting and the second when necessary.

6 Harvest and crop residue management

This cropping pattern provides five well distributed harvests throughout the year. One important thing to keep in mind is that all crop residues should be returned to the soil after harvest in order to conserve soil fertility.

Corn will be harvested first. The stalks are cut and laid down in the original rows. Next, rice is harvested. The straw is used as mulch for the following peanut crop. In order to avoid disease problems, the peanut straw is usually taken from the field. The straw from the following legume crop (ricebeans or cowpeas) should be incorporated into the soil during land preparation for the next season. Cassava is the last crop harvested in this pattern. The leaves should be left in the field, but the stems removed. All diseased plant parts should be burned.

7 Varieties and crop arrangement

Varieties that may be used for each crop along with the spacing, plants per hill and seed requirements are shown in Table 9.

Table 9 Recommended varieties, spacing and amounts of seed required

Crop	Variety/Selection	Spacing	Plants per hill	Seed required
		cm	no.	kg/ha
Corn +	Harapan Baru/DMR-5/Arjuna Bogor DMR-4	200 x 50	2	12
Upland rice	C22/Seratus Malam/Cartuna	40 x 10	5	30
Cassava	No.528/Gading/Local (non branching)	400 x 50	1	5,000 sticks
Peanut –	Gajah/Kidang	40 x 10	1	120
Ricebean	Local	40 x 20	2	20
or				
Cowpea	No.191 No.126/Local	40 x 20	2	20

Conclusions

(1) Crops growing on these soils respond dramatically to fertilizer treatments of phosphorus and nitrogen. Without use of fertilizer and incorporation of crop residues (directly or as animal manure) production from continuous cropping declined rapidly.

(2) With proper management total production of food calories per hectare from a cropping pattern of corn plus upland rice intercropped with cassava and followed by peanut and then cowpea in one year usually exceeds that from fifteen ton of padi rice. Data from six years of continuous cropping show that yield levels can be maintained and even increased.

(3) In transmigration areas where good infrastructure exists, along with alternative sources of markets such as, starch factories, pelleting plants and demand from local population, improved management practices including use of fertilizers and incorporation of residues are not only agronomically feasible but highly profitable.

(4) These soils must be considered fragile compared to Latosol soils found on Java. In comparison they are poorly aggregated and shallow to impervious layers. They are susceptible to erosion and sloughing on all but level land. Continuous cover by cropping and mulching and terracing are management practices that must be followed to protect the soil and maintain its productivity.

(5) In hilly areas where erosion problems can be expected and in remote areas where marketing of food crops may be difficult, cropping systems strategies should be designed to provide food but only enough for subsistence. Rather the cropping systems should contain a high proportion of pasture crops for animal feed and green manure and perennial crops for stability and cash.

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Discussion

Somasiri, S. (Sri Lanka): You seem to obtain high returns from these cropping patterns. What is the cost of production?

Answer: What I showed you were the net returns, thus the cost of production has been subtracted.

Hew, C.K. (Malaysia): For the transmigration schemes there must be high government subsidies, for example in the case of fertilizer application. How about the cost of infrastructure and development?

Answer: The cost is somehow compensated by food production.

Kyuma, K. (Japan): Favorable temperature and rainfall pattern for the crops may be conducive to biological hazards such as weeds, pests and diseases. What is your experience in this regard? Are the measures controlling these hazards available to the farmers?

Answer: The cropping patterns suggested are designed to minimize these problems. The worst problems we have encountered are "neck blast" for rice and pod borers on legumes such as soybeans, mungbean and cowpea. We have rice varieties which are less susceptible to blast but these are not yet available to the farmers. We have corn varieties resistant to downy mildew while pod borers can be controlled by insecticides. However the cost and availability of insecticides and fertilizers are still problems due to the low level of development of the infrastructure.

Watanabe, I. (IRRI): Did you observe soil sickness due to the continuous cropping of a single crop? May I understand that mixed cropping can eliminate soil sickness?

Answer: There are problems, particularly from diseases that arise from continuous cropping with the same or similar crop species. In the cropping patterns we suggest that the farmers use, continuous cropping with similar kinds of crops is avoided and we have not encountered any soil sickness. The real problem is not soil fertility but soil erosion. If residues are properly returned to the soil and if the topsoil and organic matter are well preserved, soil sickness is unlikely to appear.

Somasiri, S. (Sri Lanka): How is the weed control problem for upland rice?

Answer: Weeds are a problem if the farmers do not use an intensive year-round cropping pattern. Sometimes farmers find "off-farm" jobs and under these circumstances weeds do become a problem. But usually, Indonesian farmers are diligent in hand-weeding their fields. A good stand of upland rice is the key crop for prevention of weeds.