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EFFECTS OF LAND RECLAMATION PRACTICES ON CHEMICAL PROPERTIES OF AN ACID, INFERTILE OXISOL IN WEST SUMATRA

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Summary

Improper mechanical land clearing has damaged large areas in humid tropical regions. The objective of this study was to evaluate the effects of several soil reclamation treatments on the soil chemical properties of an acid, infertile Oxisol in West Sumatra. All combinations of four lime plus fertilizer (N, P, K, Mg, S, Cu, Zn, Mn) applications (none, low, medium, and high) and six tillage practices (hoeing [H], H + mulching with calopogonium (*Calopogonium mucunoides*), H + green manure, manually turning the upper 30 cm of soil with a digging fork, deep forking in alternate strips, and rototilling) were evaluated. The continuous cropping sequence was rice (*Oryza sativa* L.), soybean (*Glycine max* L. (Merr)), mungbean (*Vigna radiata* L.), rice and soybean. Soil chemical levels were measured initially and after harvesting each crop. The initial high lime application rate (6840 kg ha^{-1}) increased and maintained soil pH > 6.0, increased ECEC by 3.1 $cmol_c$ L^{-1}, and decreased the exchangeable Al and Al saturation percentage below 0.5 $cmol_c$ L^{-1} and 5%, respectively. The initial high P application rate (567 kg P ha^{-1}) increased modified Olsen extractable P to 118 mg P L^{-1} which decreased with time at a faster rate than the decrease in soil pH. Fertilizer K had to be applied after each crop to maintain desired critical levels. Mulching decreased the percentage of Al as a result of basic cations coming from the mulch. The medium level of chemical inputs was sufficient to maintain soil fertility above critical, but below optimum nutrient levels, and is a practice that could be adopted to reclaim highly acid soils in the humid tropics.

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1 Introduction

The use of improper mechanical land clearing procedures often removes topsoil and results in unfavourable soil physical and chemical properties for plant growth (LAL & CUMMINGS 1979, LAL et al. 1986). Much mechanically cleared land in the humid tropics, especially that cleared with bulldozers with straight blades, has limitations for annual crop production (LAL 1981, NYE & GREENLAND 1964, SEUBERT et al. 1977). Prior to clearing,

the topsoil typically is richer in nutrients, has a higher organic matter content, and has a higher CEC compared to the subsoil. Mechanical clearing often removes significant amounts of the topsoil, and in extreme cases, the soil remains devoid or nearly devoid of vegetation. Such bare soil typically has high soil temperatures which may result in further reductions in organic matter, total N and P (CUNNINGHAM 1963).

Simple methods for reclaiming soils damaged in the above manner were developed for Ultisols (ALEGRE et al. 1986) and Alfisols (OPARA-NADI et al. 1986). For those soils unfavorable physical properties resulting from mechanical land clearing operations limited plant growth. Little reclamation work has been done on damaged Oxisols which typically have stronger soil structure and a higher degree of aggregation.

Strategies for reclaiming land damaged or harmed by mechanical land clearing must be designed to alter soil chemical properties, physical properties, or both (ALEGRE et al. 1987). High application rates of lime and P may be needed to overcome low pH and low P levels on acid, infertile soils, respectively, and both chemicals have long lasting residual effects on soil chemical properties (SANCHEZ & UEHARA 1980, YOUNG & PLUCKNETT 1966, SEUBERT et al. 1977). High P and lime application rates decrease the amount of P required for plant growth, decrease the P fixation capacity (SALMON 1973) and increase CEC in soils of variable charge (UEHARA & KENG 1975). Incorporation of green manure may help maintain the levels of soil P, K, N, Ca and Mg (WADE & SANCHEZ 1983).

The objective of this investigation was to evaluate the effects of a wide range of soil reclamation practices on the chemical properties of an Oxisol. The soil had previously been stripped of most of its topsoil during mechanical land clearing and subsequent erosion (MAKARIM et al. 1988).

2 Materials and methods

A 0.23-ha field was selected in an area that had been cleared in 1977 using a bulldozer with a straight blade. The field, located in an area of undulating topography, had a 10% slope, and most of its topsoil had been removed during the 1977 land clearing operation. The soil was a clayey, kaolinitic, isohypothermic, Typic Haplorthox. Several attempts by local farmers to grow crops on this soil had failed.

The site was located in the humid tropics at Sitiung, West Sumatra, Indonesia (2°S, 102°E, 60 m above sea level). Daily air temperature ranges from 20 to 33°C and there is a wet season of 6 months duration (> 200 mm month^{-1}) and less than 2 months of dry season (rainfall < 100 mm month^{-1}). The reclamation study was conducted from September 1983 through May 1985.

Soil physical and chemical properties of the field site were measured intensively prior to formulating reclamation treatments. Selected chemical properties in the 0- to 15-cm depth and methods of measurement follow: 12 mg organic C g^{-1} soil (WALKLEY & BLACK 1934); 1.0 mg total N g^{-1} soil, determined by Kjeldahl (BREMNER 1960); 0.4 mg extractable P L^{-1} soil, Modified Olsen (HUNTER 1974), 0.12 cmol$_c$ extractable K L^{-1} soil, Modified Olsen (HUNTER 1974); 0.73 cmol$_c$ exchangeable Ca + Mg $^{-1}$ soil, 1 N KCl extraction (THOMAS 1982); and 2.22, 7.7, 4.2, and 69 mg ex-

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changeable Mn, Zn, Cu, and Fe L^{-1} soil, Modified Olsen (HUNTER 1974). pH was measured in a 1:2.5 (g/g) soil to water suspension. Summation of K, Ca, Mg, Al, and H gave an effective cation exchange capacity (ECEC) of 4.61 $cmol_c$ L^{-1} soil. Soil physical property measurements in the 0- to 15-cm depth showed the soil was 74% clay, had a low bulk density of 1.09 g cm^{-3}, and an infiltration rate of 0.20 m hr^{-1}.

Based on the above information, we concluded that unfavorable chemical properties were the major constraints to crop production. Consequently, three fertility treatments (tab.1) were designed: treatment F0, no lime or fertilizers; F1, the addition of lime to maintain Al saturation near 40% and fertilizers to maintain nutrients just above their critical levels (HUNTER 1974); and F2, lime and fertilizers added to neutralize all exchangeable Al in the soil, to satisfy the P fixation capacity of the soil, and to maintain the other nutrients at their lowest optimum levels. Because soil acidity and P levels of the F0 treatment were so low, plant growth was negligible. Consequently, treatment F0 was terminated after the third crop and was replaced by treatment F1–2, for which lime was applied in amounts to attempt to maintain the Al saturation at 20%, while other nutrients were kept above critical, but below optimum levels (HUNTER 1974).

All fertilizers and lime were broadcast except Cu, Zn, and Mn which were foliar applied to each crop 30 days after planting. Broadcast applications were applied one day before planting, except that lime and P were applied 7 days before planting. Rates of lime and P were doubled for the forking tillage treatment (described later) prior to planting each rice crop; these chemicals were incorporated into a volume of soil two times greater than for the other five tillage treatments. Lime and fertilizers were applied to the strip forked plots on a whole plot basis, but were concentrated in the forked strips. Two additional N applications were applied 30 and 60 days after planting.

Six tillage treatments were formulated in an attempt to optimize chemical incorporation and promote deep rooting. Tillage treatments were:

1. hand hoeing to the 15-cm depth (the accepted tillage practice in the area);
2. hoeing followed by mulching with calopogonium (*Calopogonium mucunoides*) at 12.5 Mg fresh weight ha^{-1} for the rice crop, or 8.0 Mg dry matter of rice straw ha^{-1} for the soybean and mungbean crops;
3. green manuring by incorporation with hoeing of calopogonium at the rate of 12.5 Mg fresh weight ha^{-1} prior to planting the first, fourth, and fifth crops;
4. forking, i.e., uniformly mixing the soil to the 30-cm depth with a 4-or 5-pronged digging fork;
5. strip forking by tilling the soil to the 30-cm depth in alternate 20-cm wide strips spaced at 40-cm centers; and
6. rototilling, an operation that uniformly mixed soil to the 10-cm depth.

Deep tillage in the forked and strip forked treatments was performed one time each year, before planting rice. Crops were planted in the tilled soil for the strip forked treatment. All six treatments were hand hoed before planting the second, third, and fifth crops.

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Lime fertilizer	Nutrient unit	F0	F1-2	F1	F2
		kg ha^{-1}			
Rice (1)					
Lime*	$CaCO_3$	0		1500	6840
Urea	N	0		120	150
TSP**	P	0		39	567
KCl	K	0		73	146
$MgSO_4 \cdot H_2O$	Mg	0		70	140
$MgSO_4 \cdot H_2O$	S	0		93	187
$CuSO_4 \cdot 5H_2O$	Cu	0		1	2
$ZnSO_4 \cdot H_2O$	Zn	0		4.5	9
$MnSO_4 \cdot 3H_2O$	Mn	0		0	0
Soybean (2)					
Lime*	$CaCO_3$	0		0	0
Urea	N	0		0	0
TSP**	P	0		0	0
KCl	K	0		50	149
$MgSO_4 \cdot H_2O$	Mg	0		0	0
$MgSO_4 \cdot H_2O$	S	0		0	0
$CuSO_4 \cdot 5H_2O$	Cu	0		0	0
$ZnSO_4 \cdot H_2O$	Zn	0		0	0
$MnSO_4 \cdot 3H_2O$	Mn	0		1	2
Mungbean (3)					
Lime*	$CaCO_3$	0		313	0
Urea	N	0		0	0
TSP**	P	0		39	0
KCl	K	0			0
$MgSO_4 \cdot H_2O$	Mg	0		0	0
$MgSO_4 \cdot H_2O$	S	0		0	0
$CuSO_4 \cdot 5H_2O$	Cu	0		0	0
$ZnSO_4 \cdot H_2O$	Zn	0		0	0
$MnSO_4 \cdot 3H_2O$	Mn	0		0	2

Tab. 1: *Rates of lime and fertilizers applied, based on nutrient units, for each level of chemical inputs and for each crop.*

Treatments were arranged in a split plot with fertility as the whole plot and tillage as subplots. The experimental design was a randomized complete block with four replications. Subplot size was 4 m × 8 m and the field was terraced to control surface water removal. The cropping sequence was rice (crop 1), soybean (crop 2), mungbean (crop 3), rice (crop 4), and soybean (crop 5). Rive cv. 'Sentani' was planted with a dibble stick at 25 cm by 25 cm spacing, except for the strip forking treatment which required a 40 cm by 15 cm spacing because of the 20-cm wide untilled strips. A granular insecticide, carbofuran [2,3-dihydro-2, 2-dimethyl-7-benzofuranylmethyl-carbonate (3G)], was mixed with the seeds as the rate of 30 g insecticide per kg seed. Soybean cv. 'Orba' was planted with the dibble stick at 40 cm by 20 cm spacings. All details concerning plant response to the reclamation treatments will be presented in a separate paper.

Effects of the imposed reclamation

Lime/fertilizer	Nutrient unit	F0	F1-2	F1	F2
		kg ha^{-1}			
Rice (4)					
Lime*	$CaCO_3$		2200	100	0
Urea	N		135	120	150
TSP**	P		150	22	
KCl	K		152	46	140
$MgSO_4 \cdot H_2O$	Mg		105	0	0
$MgSO_4 \cdot H_2O$	S		140	0	0
$CuSO_4 \cdot 5H_2O$	Cu		1	0	0
$ZnSO_4 \cdot H_2O$	Zn		1.7	1.7	1.7
$MnSO_4 \cdot 3H_2O$	Mn		0.8	0.8	0.8
Soybean (5)					
Lime*	$CaCO_3$		0	0	0
Urea	N		0	0	0
TSP**	P		0	0	0
KCl	K		93	46	140
$MgSO_4 \cdot H_2O$	Mg		0	0	0
$MgSO_4 \cdot H_2O$	S		0	0	0
$CuSO_4 \cdot 5H_2O$	Cu		0	0	0
$ZnSO_4 \cdot H_2O$	Zn		0	0	0
$MnSO_4 \cdot 3H_2O$	Mn		0	0	0
Total					
Lime*	$CaCO_3$	0	2200	1913	6840
Urea	N	0	135	240	300
TSP**	P	0	150	100	567
KCl	K	0	245	224	576
$MgSO_4 \cdot H_2O$	Mg	0	105	70	140
$MgSO_4 \cdot H_2O$	S	0	140	93	187
$CuSO_4 \cdot 5H_2O$	Cu	0	1	1	2
$ZnSO_4 \cdot H_2O$	Zn	0	1.7	6.2	10.7
$MnSO_4 \cdot 3H_2O$	Mn	0	0.8	1.8	4.8

* Rates of lime and P only were doubled for the forking tillage treatment as described in the text.
** TSP = Triple super phosphate

Tab. 1: *Continuation.*

treatments on the following soil chemical properties were measured periodically: pH, exchangeable Al, Al saturation percentage, extractable P, exchangeable K, exchangeable Ca + Mg, ECEC, and extractable Mn. Soil samples for the strip forked treatment were taken from those soil strips where lime and fertilizers had been incorporated. The lime and fertilizer application rates for each fertility level for each crop are shown in tab.1.

3 Results and discussion

3.1 Soil Acidity : pH

The effects of chemical inputs and tillage on soil acidity (pH) for five successive crops are shown in tab.2. Soil pH increased with increasing lime and fertility levels. After the first crop was harvested, i.e., 19 wk after the initial lime application was made, soil pH had increased 0.03 and 0.02 pH units per 100 kg lime

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Treatment	Rice (1)	Soybean (2)	Mungbean (3)	Rice (4)	Soybean (5)
F0	4.2*	4.1	3.9	—	—
F1	4.8	4.6	4.6	4.6	4.4
F1-2	—	—	—	4.9	4.8
F2	6.6	6.3	6.1	5.9	6.1
$LSD_{0.05}$	0.2	0.3	0.2	0.3	0.2
Hoe	5.2	5.0	4.9	4.9	5.2
Mulch	5.2	5.0	4.9	5.0	5.0
Green Manure	5.1	5.0	4.8	5.0	5.0
Fork	5.4	5.2	4.9	5.6	5.6
Strip Fork	5.0	4.9	4.8	4.9	4.9
Rototill	5.2	5.0	4.8	5.3	5.1
$LSD_{0.05}$	0.2	0.2	0.2	0.3	0.4

* Initial pH was 3.7

Tab. 2: *Soil acidity (pH) as affected by chemical inputs and tillage for five successive crops on an Haplorthox soil.*

ha^{-1} for treatments F1 and F2, respectively. For each chemical input level, pH at harvest of the second crop was similar to the corresponding values at harvest of the first crop. The 313 kg lime ha^{-1} application prior to planting mungbean maintained the pH level at 4.6 for treatment F1. Soil pH for treatment F2 was still >6.0 one year after the initial lime application although pH gradually decreased with time.

Before planting the fourth crop (rice), lime and fertilizers were applied to create main plot treatment F1-2, thus terminating treatment F0 (tab.1). When rice was harvested 17 wk later, soil pH for treatment F1-2 had increased from 3.9 to 4.9, or 0.05 pH unit per 100 kg lime ha^{-1} applied. Treatment F1, which received only 100 kg lime ha^{-1} before planting the fourth crop, maintained its pH at 4.6. For treatment F2, although no lime was added for the fourth crop, the soil pH after rice harvet was still high (5.9). Only a 0.5 unit decrease in pH occurred for treatment F2 during the 61 wk period between the harvest of the first and fifth crops.

The tillage effects on soil pH were not as great as those for the chemical inputs. Compared to hoeing, no significant differences in soil pH were found for tillage except for the fourth and fifth crops. In general, compared to hoeing, pH in the forked treatment tended to be higher, whereas it tended to be lower in the strip forked treatment. Recall that lime was applied at twice the rate on a plot basis for the forked treatment compared to the other five tillage treatments (tab.1). Although an effort was made to uniformly mix the chemicals throughout the 0- to 30-cm depth of the forked treatment, a greater proportion of lime apparently remained in the 0- to 15-cm depth as compared to the amount incorporated in the 15- to 30-cm depth. The lower pH in the strip forked treatment, on the other hand, probably resulted from unintentional mixing of soil from the 20-cm wide strip to which the lime was applied with soil from the adjacent

Treatment	Rice (1)	Soybean (2)	Mungbean (3)	Rice (4)	Soybean (5)
			($cmol_c$ L^{-1})		
F0	4.3	3.6	3.7	—	—
F1	1.8	1.8	1.6	1.7	2.0
F1-2	—	—	—	0.5	1.0
F2	0.4	0.1	0.2	0.2	0.2
$LSD_{0.05}$	0.4	0.6	0.3	0.2	0.3
Hoe	2.3	2.0	2.0	1.2	1.2
Mulch	2.0	1.8	1.7	0.8	1.1
Green Manure	2.1	1.8	1.8	0.8	1.1
Fork	1.9	1.5	1.6	0.3	0.6
Strip Fork	2.4	2.1	2.0	0.9	1.4
Rototill	2.1	1.9	1.8	0.7	1.1
$LSD_{0.05}$	0.3	0.3	1.3	0.3	0.3

Tab. 3: *Exchangeable Al as affected by chemical inputs and tillage for five successive crops on an Haplorthox soil.*

20-cm wide untilled strip which received no lime. In general soil pH decreased between successive lime applications for all tillage treatments. No significant interaction between chemical input level and tillage was found.

3.2 Exchangeable aluminum and aluminum saturation

The effects of chemical inputs and tillage on exchangeable soil Al after harvest of all five crops are shown in tab.3. Exchangeable Al levels varied inversely with soil pH. The initial 6.84 Mg ha^{-1} lime application rate for treatment F2 was based on the presence of 4.56 $cmol_c$ L^{-1} of exchangeable Al and the assumption that 1500 kg ha^{-1} of lime would be required to neutralize each $cmol_c$ of exchangeable Al L^{-1}.

The effects of tillage on exchangeable Al were less than those for chemical inputs (tab.3). Compared to hoeing, mulching resulted in significantly lower soil levels of exchangeable Al following harvest of the first, second and fourth crops. Although the difference was not significant, the trend was for exchangeable Al level in the green manured treatment to be less than for hoeing. It is possible where mulches or green manures were applied, that temporary complexing of Al by organic acids occurred. Deep forking consistently decreased the amount of exchangeable Al, the reason being attributed to non-uniform incorporation of lime throughout the 30-cm deep soil volume as discussed above. Difficulties associated with uniformly incorporating lime below the plow layer in Oxisols have been reported by GONZALEZ et al. (1979). Incorporation of the second lime application prior to planting the fourth crop resulted in a significant reduction in exchangeable Al for all tillage treatments compared to hoeing.

The effect of chemical input on Al saturation for each crop was significant (tab.4). The initial lime application reduced the Al saturation value in treatment F1 to about 40% and maintained it near that value for each crop except

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Treatment	Rice (1)	Soybean (2)	Mungbean (3)	Rice (4)	Soybean (5)
			%		
F0	90	80	79	—	—
F1	39	46	38	38	55
F1-2	—	—	—	10	27
F2	5	2	2	3	4
$LSD_{0.05}$	8	8	7	6	6
Hoe	47	47	44	25	30
Mulch	41	41	36	18	32
Green Manure	45	43	39	19	31
Fork	40	36	35	7	15
Strip Fork	51	47	43	20	28
Rototill	44	43	40	15	28
$LSD_{0.05}$	5	5	6	6	6

Tab. 4: *Aluminum saturation as affected by chemical inputs and tillage for five successive crops on an Haplorthox soil.*

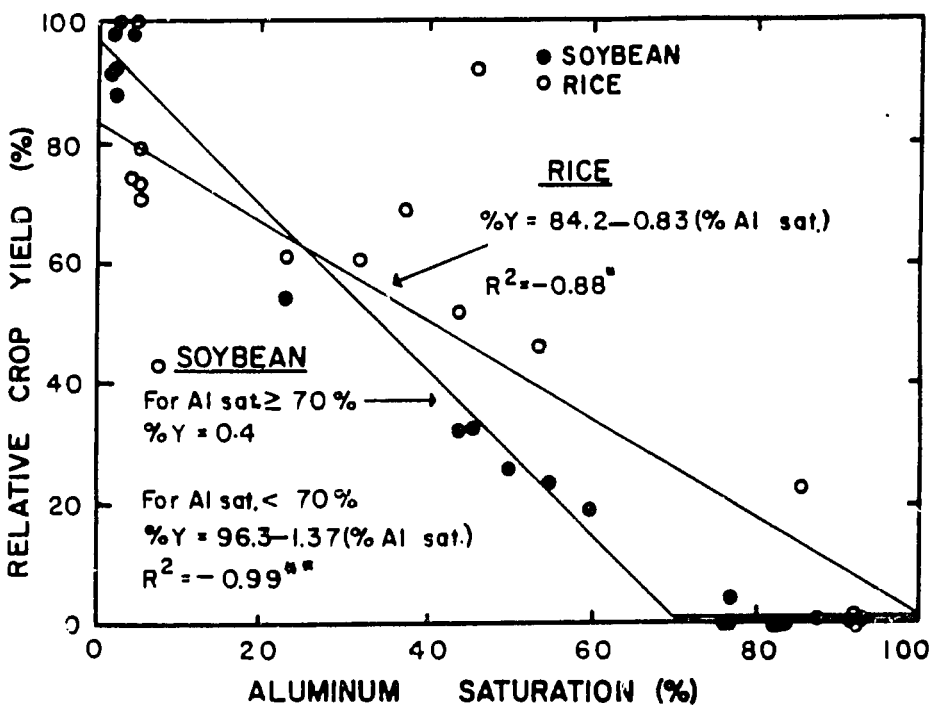

Fig. 1: *Relative rice and soybean yields as functions of Al saturation at harvest time.*

Treatment	Rice (1)	Soybean (2)	Mungbean (3) ($cmol_c\ L^{-1}$)	Rice (4)	Soybean (5)
F0	0.4	0.9	1.0	—	—
F1	2.7	1.9	2.5	2.6	1.4
F1-2	—	—	—	4.0	2.3
F2	7.2	5.6	6.5	5.3	5.1
$LSD_{0.05}$	0.5	0.3	0.2	1.3	0.4
Hoe	3.2	2.7	3.1	3.6	2.9
Mulch	3.6	2.8	3.4	3.7	2.6
Green Manure	3.3	2.7	3.1	3.8	2.6
Fork	4.0	3.4	3.9	5.0	3.9
Strip Fork	2.6	2.3	2.8	3.4	2.4
Rototill	3.8	3.0	3.6	4.3	3.2
$LSD_{0.05}$	0.5	0.4	0.5	0.6	0.5

Tab. 5: *Exchangeable Ca + Mg of soil as affected by chemical inputs and tillage for five successive crops on an Haplorthox soil.*

the last one. Likewise, Al saturation for treatment F2 remained ≤5.0& for all five crops. These results suggest that soil tests can be used to help maintain a low Al saturation for very acid soils. The effects of tillage on Al saturation, also shown in tab.4, are similar to those reported in tab.3, i.e., mulching and forking consistently decreased Al saturation compared to hoeing. No significant interaction between chemical input level and tillage was found for either exchangeable aluminum or aluminum saturation.

Relative grain yields for rice (first crop) and soybean (second crop) for all chemical input-tillage combinations versus percent Al saturation at harvest time are shown in fig.1. A relative grain yield of 100% corresponds to 2.94 and 2.44 Mg ha^{-1} for rice and soybean, respectively. (A complete discussion of yields as affected by tillage and chemical amendments for all five crops will be presented in a separate paper.) Although the data are scattered, it is apparent that soybean yield decreased linearly until no grain yield was produced at 70% Al saturation. Rice yield also decreased linearly as percentage Al saturation increased, but the effect was not nearly as great as for soybean and no threshold value was observed. Exchangeable Ca + Mg data are presented in tab.5 for completeness.

The addition of lime and fertilizers to treatment F2 increased ECEC (data not shown) at harvest of the first crop to 7.8 $cmol_c\ L^{-1}$ as compared with the 4.7 $cmol_c\ L^{-1}$ for treatment F0. At harvest of the third crop, the ECEC of treatment F2 was still 2.2 $cmol_c\ L^{-1}$ greater than the 4.7 $cmol_c\ L^{-1}$ value for treatment F0.

3.3 Available P

The effects of chemical inputs and tillage on soil extractable P after harvest of each crop are shown in tab.6. The soil P level for treatment F0 was initially below and remained below the critical level of 12 mg P L^{-1} (HUNTER 1974). Treatment F1, designed to maintain P near the critical level, received P fertilizer three times during the study (tab.1). The P level for

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Treatment	Rice (1)	Soybean (2)	Mungbean (3)	Rice (4)	Soybean (5)
			mg P L^{-1}		
F0	2	1	1	—	—
F1	10	4	8	8	6
F1-2	—	—	—	15	17
F2	118	57	47	38	35
$LSD_{0.05}$	13	18	8	6	11
Hoe	38	18	15	16	17
Mulch	48	17	17	19	18
Green Manure	35	14	13	14	13
Fork	56	37	33	36	38
Strip Fork	30	12	12	16	18
Rototill	55	24	22	22	18
$LSD_{0.05}$	14	13	13	8	9

Tab. 6: *Soil extractable P as affected by chemical inputs and tillage for five successive crops on an Haplorthox soil.*

F1 for each of the five crops at harvest had been drawn below the critical level. Phosphorus fertilizer was added to treatment F1 after harvesting the second crop in an attempt to increase its level. After the third crop was harvested, residual soil P had increased to 8.0 mg L^{-1} which was still below the critical level. Further applications of P to treatment F1 maintained the P level slightly below the critical level. The P fertilizer regime for treatment F1-2 successfully maintained P above the critical level. For treatment F2, P underwent an abrupt initial decrease and then a slower rate of decrease but remained in the high range of availability. We anticipate the maintenance levels of P fertilizer will be required 3 to 5 yr after the initial P application for this treatment.

With regard to tillage effects on soil P, the largest extractable P values were found for forking and are atributed to the higher P rates applied to this treatment in conjunction with incomplete mixing throughout the 30-cm depth. However, there was no significant interaction between chemical input level and tillage.

3.4 Soil Exchangeable K

The soil exchangeable K level for treatment F0 (tab.7) was far below the critical level of 0.20 $cmol_c$ L^{-1} (HUNTER 1974). Increasing the initial K level and maintaining it near the critical level (treatment F1) and at a high level of 0.40 $cmol_c$ L^{-1} (treatment F2) required a total of 224 and 576 kg ha^{-1}, respectively, for the duration of the study. Although the target soil K level for treatment F2 was only two times greater than for treatment F1, 2.6 times more K fertilizer was required to maintain it. Soil K was maintained near 0.3 $cmol_c$ L^{-1} for treatment F1-2.

Tillage had little influence on soil exchangeable K level (tab.7). For each chemical input level, each tillage treatment except forking, received the same amount of fertilizer K. Mulching significantly increased the soil K levels measured after the harvest of the third,

Treatment	Rice (1)	Soybean (2)	Mungbean (3)	Rice (4)	Soybean (5)
			(cmol$_c$ L^{-1})		
F0	0.05	0.05	0.04	—	—
F1	0.10	0.18	0.15	0.12	0.20
F1-2	—	—	—	0.25	0.29
F2	0.23	0.30	0.21	0.25	0.38
$LSD_{0.05}$	0.13	0.04	0.02	0.07	0.12
Hoe	0.12	0.16	0.13	0.19	0.27
Mulch	0.14	0.18	0.16	0.25	0.37
Green Manure	0.16	0.19	0.14	0.22	0.31
Fork	0.12	0.16	0.10	0.19	0.24
Strip Fork	0.10	0.18	0.14	0.21	0.27
Rototill	0.11	0.18	0.12	0.17	0.27
$LSD_{0.05}$	0.06	0.10	0.02	0.04	0.05

Tab. 7: *Soil exchangeable K as affected by chemical inputs and tillage for five successive crops on an Haplorthox soil.*

fourth, and fifth crops. K was released from the applied mulch and contributed to a significantly higher K level for later crops. Green manuring did not significantly increase K although the trend was for this treatment to have more K than for hoeing. The greater effect on soil K of mulching as compared to green manure is probably due to the fact that mulch was applied to each crop whereas green manure was incorporated only prior to planting the first, fourth and fifth crops. No significant interaction between chemical inputs and tillage was found.

4 Practical implications

Successful reclamation of this Oxisol resulted by correcting the severe soil acidity problem and applying sufficient P and K at appropriate time intervals. Hoeing was a sufficient low input, but labor intensive, tillage operation to incorporate these materials into the soil. Based on our results and observations at other locations in the vicinity, we believe similar acid, infertile Oxisols cleared by improper mechanical clearing operations can be rapidly reclaimed by judicious applications of lime and chemical fertilizers. We found it technically feasible to use soil tests to monitor changes in soil chemical properties after each crop. This information was used to formulate and maintain plant nutrient levels within prescribed limits for as many as three crops per year by periodic applications of lime and fertilizers. Treatment F2 utilized high input levels of chemicals to successfully maintain a desirable pH and optimum soil level of P, Ca and Mg for a time span long enough to grow five consecutive crops; however, the more mobile K had to be added for each crop.

Subsistence farmers in the area rarely have sufficient capital to purchase the large amounts of lime and fertilizers utilized in treatment F2. It is more likely that farmers would adopt a system that uses lower levels of chemical inputs (treatment F1), and which maintains lower soil levels of P, K, Ca –

Mg, and pH by more frequent, but smaller, additions of lime and fertilizers. Although more research is needed, the medium chemical input system (treatment F1–2) utilized smaller amounts of lime and fertilizers compared to treatment F2, but maintained the levels of P, K, Ca + Mg and pH above critical levels. Long term research for both systems needs to be conducted.

The results of this study differ dramatically from those reported for the reclamation study on an Ultisol in the Amazon (ALEGRE et al. 1986). The Ultisol, a fine loamy, siliceous, isohyperthermic Typic Paleudult, had been severely compacted during land clearing with a bulldozer with a straight blade. Even though the pH was 4.4 to 4.5 to a depth of 45 cm and percent Al saturation ranged from 63 to 90%, the major limitation to plant growth was physical rather than chemical. Its successful reclamation was effected only when the soil, compacted during mechanical clearing, was alleviated by deep tillage, i.e., chisel plowing to 25 cm or subsoiling to 30 cm. The two deep tillage treatments in the Oxisol for the current study presented an advantage over hoeing to 15 cm.

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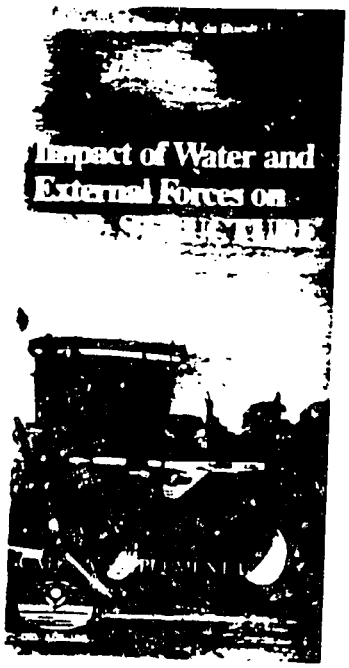

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