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CONSERVATION TILLAGE IN THE HUMID TROPICS OF PERU

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PURPOSE

The potential for soil erosion is high in continuously cultivated Ultisols of the humid tropics because much of the rainfall occurs during brief, intense rainfall events. Even though total annual rainfall is high in many areas of the tropics, crops often suffer from severe moisture stress when rainless periods extend for two weeks or longer. Conservation tillage systems such as stubble mulching, minimum or reduced tillage, and no-till, are currently in use in many parts of the world (Lal, 1975; McCown, 1980; Wilson, 1982; and Tawonmas, 1984). Benefits of conservation tillage management are reduced soil erosion (Triplett and Van Doren 1977), improved soil fertility (Lal et al., 1980), better soil water relations (Hargrove, 1985; Ne Smith et al., 1987), increased soil biological activity (Doran, 1980ab), improved soil physical conditions including increased aggregate stability and macroporosity (Allison, 1968; Hargrove, 1988), reduced fossil fuel use (Neeley et al., 1987), and increased crop yields (Hargrove, 1985; Beale and Langdale 1967; Ne Smith et al., 1987; and Van Doren et al., 1976). It may be desirable to adopt these or similar management practices for the Amazon to reduce compaction, conserve water for crop use and reduce runoff and soil erosion. In fact, we believe conservation tillage practices will be necessary to sustain continuous crop production in some areas of the Amazon.

The objectives of this study were: 1) to determine the feasibility of introducing minimum tillage and no-tillage practices into continuous crop production systems in the humid tropics, and 2) to determine the effects of each tillage system, with and without in-row-subsoiling, on soil physical and chemical properties and crop yields.

METHODS

The study was conducted from October 1986 to January 1989 in the humid tropics at Yurimaguas, Peru (5° 45' S, 76.5' W, 184 m sea level) on a isohyperthermic Typic Paleudult with slope ranging from 1 to 2%. The site was cleared by traditional slash and burn in 1972 and was continuously cropped until September 1986. During this period 31 continuous crops were grown; lime and fertilizers based on soil tests were applied for these crops.

The six tillage treatments described in Table 1 were imposed in 1986. A five crop rotation of corn (*Zea mays*)-soybean (*Glycine max* (L.) Merr)-corn-soybean-corn was employed. The dates of planting and harvesting and the rates of liming and fertilization are given in Table 2.

Table 1. Tillage treatments imposed in 1986 in Yurimaguas, Peru.

Treatment	Subsoiling	Description
Conventional till (CT)	No	Cultural operations in order of use were: bush-hog, disk plow, S-tyne field cultivator, disk bedder, bed shaper, and planter. Dual herbicide applied.
Conventional till (CTS)	Yes	Same as CT, but with subsoiling 0.3 m deep at the time of disk bedding.
Minimum till (MT)	No	Bush-hog, Dual Paraquat herbicide applied, no-till planting (coulter opening). Lime and P incorporated every 2 years with disk harrow.
Minimum till (MTS)	Yes	Same as MT, but subsoiler used ahead of coulters on the planter.
No-till (NT)	No	Bush-hog, Dual & Paraquat hervicide applied; no-till planting (coulter opening).
No-till (NTS)	Yes	Same as NT, but with subsoiler used ahead of coulter on planter.

Table 2. Planting and harvesting dates and the liming and fertilization regime for five successive crops in Yurimaguas, Peru.

Crop No.	Date		Fertilization				
	Planted	Harvested	N	P	K	Mn	Lime
			- - - kg/ha - - -				
Corn (1)	Oct. 17, 86	Feb. 1, 87	100	45	67		
Soybean (2)	June 17, 87	Sept. 25, 87		45			3000
Corn (3)	Nov. 11, 87	March 16, 88	120				
Soybean (4)	May 23, 88	Sept. 1, 88					
Corn (5)	Sept. 13, 88	Jan. 5, 89	120	45	67	10	

The first corn (cv. Marginal 28) crop was planted at 0.80 m x 0.20 m spacings and P was banded at planting. Dual and Paraquat, each at a rate of 2 L/ha, were applied before planting in the minimum (MT, MTS) and no till (NT, NTS) treatments.

Lime and P were broadcast before the second crop (soybean, cv. Jupiter) was planted. These materials were incorporated with a disk plow and disk harrow in the CT and CTS treatments and with a disk harrow only in the MT and MTS treatments; the chemicals were left on the soil surface in the NT and NTS treatments. No N or K was applied. Soybean inoculated with the appropriate Rhizobium strain was planted at 0.50 m x 0.05 m spacings.

The third crop (corn) was managed similarly to the first corn crop. Nitrogen at a rate of 120 kg N/ha was applied. No P or K was added. The fourth crop (soybean) was planted similarly to the second soybean crop, but no lime or fertilizer was applied because pH and soil nutrient levels as determined by soil tests were adequate, with the exception of Mn. The fifth crop (corn) was fertilized with N, P, K, and Mn (Table 2).

Selected chemical properties (P, Ca, Mg, and K) and physical properties (bulk density and mechanical resistance) were measured before planting and after harvest of each crop. Six runoff plots, 10 m long by 3.2 m wide, were installed on a 2% slope in October 1987. Each runoff plot had wooden borders on three sides to prevent water from the surrounding area from running onto the plot. A collection system of small channels and serially connected containers to catch water and sediment was installed on the remaining side of each runoff plot. The first container for each plot had a multislot divisor with eleven slots. Water and suspended soil solids flowed from the central slot into a second container, thus accumulating one-eleventh of the water and solids that overflowed the first container. Daily rainfall was measured with a recording rain gauge. The amount of runoff water from each plot was measured the day following a rain event. Grain and biomass yield was measured by hand harvesting.

RESULTS

Monthly rainfall for the first crop generally exceeded the 35-year average (Fig. 1). Rainfall was below average for the third crop and average to slightly above for remaining crops.

Bulk density at the 0-10 cm depth after harvest for each of the three tillage treatments with subsoiling were similar to the initial bulk density of 1.40 Mg/m^3 (Table 3). Likewise, bulk density at the 10-20 cm depth after harvesting the fifth crop was similar to the initial 1.45 Mg/m^3 value. Bulk densities at both depths increased for the non-subsoiled

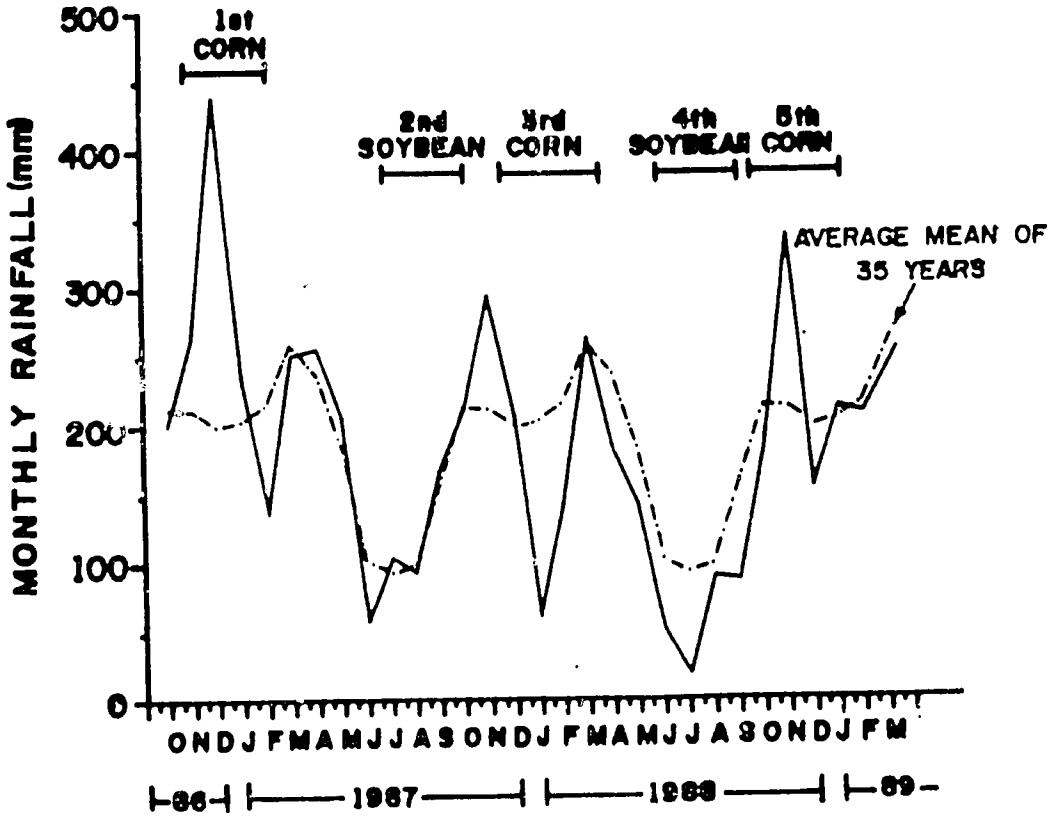

Figure 1. Monthly rainfall from October 1986 through March 1989 at Yurimaguas, Peru.

Table 3. Bulk density in the crop row at the 0-10 to 20-40 cm depths before planting the first crop and after harvested the fifth consecutive row crop for six tillage systems.

Tillage	0 - 10 cm		10 - 20 cm	
	Before	After	Before	After
	- - - - - - - - Mg/m³ - - - - - - - -			
Conventional	1.40	1.44	1.45	1.55
Conventional, subsoil	1.40	1.41	1.45	1.44
Minimum	1.40	1.51	1.45	1.55
Minimum, subsoil	1.40	1.43	1.45	1.50
No-till	1.40	1.55	1.45	1.56
No-till, subsoil	1.40	1.45	1.45	1.47
LSD .05 (Tillage x Time)	0.05		0.07	

treatments. For the non-subsoiled treatments, bulk density at the 0-10 cm depth was highest for treatment NT. No differences in bulk density among non-subsoiled treatments occurred at the 10-20 cm depth.

Cone penetrometer resistance (PR) followed the same trend as bulk density (Table 4). Subsoiling reduced PR in the 0-10 cm depth for the minimim and no-till treatments but not for the conventional treatment because the soil at this dept in the conventional treatment was mixed by plowing and disking before each crop was planted. However, at the 10-20 cm depth, subsoiling effectively reduced PR to values more favorable to root penetration.

Table 4. Cone penetrometer resistance in the crop row at the 0-10 and 10-20.cm depths before planting the first crop and after harvesting the fifth consecutive row crop for six tillage systems.

Tillage	0 - 10 cm		10 - 20 cm	
	Before	After	Before	After
	- - - - - - - - (MPa) - - - - - - -			
Conventional	0.30	0.50	0.51	1.75
Conventional, subsoil	0.30	0.40	0.51	0.65
Minimum	0.30	1.50	0.51	1.40
Minimum, subsoil	0.30	0.48	0.51	0.83
No-till	0.30	1.60	0.51	1.81
No-till, subsoil	0.30	0.52	0.51	0.88
LSD .05 (Tillage x Time)	0.30	0.35		

Table 5. Grain and stover yields for corn as affected by tillage.

Tillage	1st crop		2nd crop		3rd crop	
	Grain	Stover	Grain	Stover	Grain	Stover
	- - - - - - - - - Mg/ha - - - - - - - -					
Conventional	1.90	2.40	2.35	1.94	2.91	3.99
Conventional, subsoil	2.00	2.50	3.39	3.89	2.68	4.53
Minimum	1.44	1.94	2.66	2.32	2.58	4.07
Minimum, subsoil	2.20	2.70	2.41	2.90	3.40	4.36
No-till	1.39	1.89	2.58	2.21	2.90	3.53
No-till, subsoil	1.90	2.40	2.83	3.27	3.27	3.26
LSD .05	0.63	NS	0.96	0.39	NS	NS

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Subsoiling increased grain yield for the NTS and MTS treatments for the first crop (Table 5). In general, yields were low for the first crop due to abnormally high rainfall. Rainfall in December 1986 was 418 mm (Fig. 1); the highest rainfall intensity was 50.8 mm/h. Treatment NT was waterlogged during heavy rains, but drainage in NTS was better thus preventing waterlogged conditions. Leaching losses of NH_4 and NO_3 may be important at this site as indicated by the data in Table 6.

Both grain and strover yields for the second crop were greater for the CTS treatment than for CT. No yield differences were found for the third crop. In general, corn grain yields tended to be greater for each pair of tillage practices when in-row subsoiling was performed at planting.

Table 6. Concentrations of NO_3 and NH_4 in the soil solution at the 1 m depth after 79 mm of rain on December 12, 1986 for six tillage treatments at Yurimaguas, Peru.

Treatment	NO_3	NH_4
	- - - - - ppm	- - - -
Conventional	2.40	23
Conventional, subsoil	2.64	13
Minimum	1.62	29
Minimum, subsoil	3.20	40
No-till	1.81	28
No-till, subsoil	1.39	53

Table 7. Grain and stover yield for soybean as affected by tillage.

	1st crop		2nd crop		Mean	
Tillage	Grain	Stover	Grain	Stover	Grain	Stover
	- - - - - -		Mg/ha	- - - - - - - -		
Conventional	1.80	1.32	0.80	1.05	1.30	1.19
Conventional, subsoil	1.99	1.42	1.18	1.50	1.59	1.46
Minimum	1.79	1.27	1.20	1.00	1.50	1.14
Minimum, subsoil	1.63	1.22	1.40	1.10	1.52	1.16
No-tillage	2.18	1.20	0.90	1.15	1.54	1.18
No-tillage, subsoil	2.25	1.37	1.25	1.40	1.75	1.39
LSD .05	0.52	NS	NS	NS		

Soybean yields tended to be higher for the no-till treatments (Table 7). Considering that the first soybean crop was planted later than desirable, it produced a good crop due to low rainfall (110 mm) during November 1986 which permitted a late harvest of grain without moisture damage. Yields for the second soybean crop were lower and no differences among treatments occurred. These plants displayed symptoms of Mn deficiency. Soil Mn levels were found to be less than 1 ppm.

Considering that the small slope of the soil, the amounts of runoff and soil loss are considered to be high (Table 8). Compared to CTS, water and soil loss were significantly smaller for the MTS and NTS treatments. The amounts of soil lost from all three treatments were unacceptable high for a slightly sloping soil.

Soil samples collected after the harvest of the first corn crop and after harvest of the fourth corn crop indicated that P and Ca accumulated in the surface 5 cm of soil in the NTS treatment, whereas Mg accumulated in the CTS, MTS, and NTS treatments (Table 9).

Table 8. Runoff and soil loss for various tillage practices for row crops from November 1987 through January 1989.

Treatment	Runoff	Percent runoff†	Soil loss
	(mm)	(%)	Mg/ha
Conventional, subsoil	249	14.0	22.4
Minimum, subsoil	120	6.8	19.4
No-tillage, subsoil	165	9.4	14.9
LDS .05	43		5.5

†Total precipitation = 1757 mm.

Table 9. Nutrient contents in the 0 to 5 cm depth before planting soybean (B) and (A) after growing the three crops (soybean-corn-soybean) in different tillage systems.

Tillage	P		K		Ca		Mg	
	B	A	B	A	B	A	B	A
	- μg/L -		- - - -		cmol/L - - - - - -			
Conventional, subsoil	26	22	0.29	0.31	1.9	2.0	0.47	1.1
Minimum, subsoil	32	29	0.35	0.27	2.4	1.7	0.46	1.2
No-till, subsoil	28	36	0.30	0.31	1.5	2.5	0.41	1.2

CONCLUSIONS

Based on this study the following conclusions are drawn: 1) in-row subsoiling maintains lower bulk density and mechanical impedance in the crop row compared to non-subsoiled treatments, 2) surface water runoff and soil loss were greatest for conventional tillage, 3) crop yields for no-tillage, minimum tillage, and conventional tillage treatments were not different when accompanied by in-row subsoiling, and 4) P, Ca, and Mg accumulated in the topsoil under the no-tillage regime.

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