VEGETATION MANAGEMENT SYSTEMS FOR CROP PRODUCTION IN TROPICAL REGIONS OF CENTRAL AMERICA: THE CASE OF COSTA RICA [1/]

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ABSTRACT

Experiments in two regions of the Atlantic Zone of Costa Rica with diverse weed complexes show that no-tillage vegetation management systems are more appropriate for small farmers in the humid tropics than plowing-disking of fields. No-till systems permit maize yields that are equal to or superior to those obtanined with mechanization, especially in periods of limited rainfall. Soil and water conservation are enhanced under no-till.

Yield loss from insects in maize was significantly reduced with no-till, but slug damage in common beans and lima beans was greater. When lima beans were intercropped with maize, slug damage was reduced.

Cassava yields were equal for the two tillage systems in loam soils. In a clay loam soil, root production was significantly less in no-till.

Energetic and economic efficiency were greater with no-till systems for maize and a maize-bean polycrop with and without the addition of N fertilizer.

INTRODUCCION

In Central America, farming is practiced under extremely varied climatic, topographic and edaphic conditions. Approximately 75% of basic food crops are produced on small farms, many with socio-economic problems common to small farmers around the world (23). As is common in tropical areas, many small farmers have practiced diverse forms of slash and burn weed management for decades. However, population pressure has increased proportions of their land under constant cultivation or resulted in the utilization of increasingly marginal lands. This has increased soil erosion and reduced fertility and productivity (7, 10, 18). Mechanical land clearing and soil preparation have aggravated and accelerated these processes (6,10,11,17,24).

Lal states that mulch farming techniques avoid problems caused by mechanical tillage and offer a potentially viable land use system for the humid tropics (10). Agronomic and socio-economic observations by project personnel (15) indicated that no-till vegetation managements within the project target area were probably more appropriate than weed control systems designed for mechanized farming systems in temperate climates. Thus, research was focused on no-till vegetation management techniques.

BACKGROUND INFORMATION

Results obtained since January 1977 from two areas of the Atlantic Zone of Costa Rica are presented. The lowland area (Cariari, El Bosque, Diamantes, Asbana and Guácimo) is characterized by 4300mm mean annual precipitation, 23.5°C mean annual temperature and 80 to 300m elevation. The intermediate elevation area (Turrialba) is characterized by 2670mm mean annual precipitation, 22.3°C mean annual temperature and 600 to 900m elevation (8).

Predominant weeds in both areas include Paspalum fasciculatum L., Panicum maximum Jacquin, Paspalum paniculatum L., Digitaria spp., Eleusine indica L., Melampodium spp, Melanthera spp, Hemidiodia ocimifolia (Wild.) Schum., Borreria spp, and Bidens spp. Rottboellia exaltata L.f. is rapidly becoming one of the most serious weeds in cultivated fields in the lowland area.

The lowland area has extensive export banana operations with a high sustained labor demand. A government-supported land colonization program has given 20 ha tracts to hundreds of farmers during the past 15 years. Many farmers are occupied in the development of their own holdings. Nearly 100% of all farmers in the area use herbicide to circumvent the labor shortage and related high cost for annual crop production (13). Extensive sugar cane and coffee farming create a similar labor scarcity problem in the Turrialba area. Maize is the primary annual crop in both areas. Cassava is also common. Small quantities of dry beans, mostly for home use, are grown in the drier season on some farms. Vegetables are common at higher elevations in the Turrialba area.

Present no-till systems in the area are varied. Most farmers cut weeds from 5 to 20cm from ground level, wait 12 to 20 days for regrowth, spray with a contact herbicide alone or in mixtures (paraquat + MSMA, paraquat + 2,4-D, paraquat + diuron, and paraquat + MSMA + diuron or 2,4-D) and then plant. Some farmers wait 7 to 10 days after the first herbicide application to plant and follow this immediately with another herbicide application to burn back regrowth. This second application is more common if perennial weeds are abundant.

Postplant weed control varies according to weed severity. Weeds are often cut 5 to 10cm above the soil surface 20 to 30 days after planting (DAP), permiting a paraquat application 40 to 50 DAP without excessive damage to maize. Others apply paraquat 35 to 50 DAP without cutting weeds but, as spray shields are not used in the area, considerable damage to the maize foliage is common. If perennial weeds predominate, postplant weed control may include an additional application of herbicide.

When maize reaches physiological maturity it is doubled over to hasten drying, for storage in the field and to reduce bird damage. Just prior to doubling of the maize, weeds are cut at a height of 5 to 10cm to reduce excessive growth which accompanies the extra light entering the field after doubling. This final cutting is optional when annual weeds predominate.

An alternative for perennial weed control is to cut them 40 to 60cm high, wait 15 to 20 days, and apply the previously mentioned herbicides on the regrowth. Planting follows when the vegetation is desiccated. A second herbicide application may be made prior to planting. Two or three postplant weed control measures are applied as described earlier.

The wide use of herbicide in both areas reflects, in part, technology transfer from the banana, sugar and coffee plantations.

RESEARCH RESULTS AND DISCUSSION

Much of the research has emphasized a more rational use of herbicides and improved timing of postplant weed control. Weed control alternatives that enable the farmer to choose between manual, chemical, or combinations of these two methods, according to particular socio-economic conditions are also emphasized.

Experiments have been conducted in farmers fields as well as on the CATIE Experiment Station in Turrialba and the Ministry of Agriculture Experiment Station in Guápiles during the past four years, permitting evaluation of various alternatives under varied conditions.

Table 1 presents results for two plantings, August 1977 and January 1978, with eight weed management systems (21). Annual weeds predominated. The most prevalent annual weeds were Digitaria sanguinales, Eleusine indica, Alternanthera sessilis, Solanum nodiflorum and Physalis sp. The perennial weed, Paspalum paniculatum, also was abundant.

No-tillage systems 4, 5, 6 and 8, were less costly and permitted yields equal to or greater than those obtained with plowing. Costs include three man-days extra to plant in no-till systems. Planting was done with a dibble in all cases. MSMA did not perform well in 1977 because of rainfall immediately after the application. It is also known that this herbicide is not highly effective on Eleusine indica, Paspalum paniculatum, and large Digitaria.

The importance of properly timed postplant weed control and the proper dosage of paraquat was demonstrated in the farmer's treatment in the remainder of the field. He applied 0.35 kg/ha of paraquat 42 DAP, in contrast to treatment 3 where 0.5 kg/ha of paraquat was applied 25 DAP. The farmer's field was overgrown by Paspalum paniculatum, a species that becomes progressively more tolerant to paraquat as it becomes larger.

The -weed complex in the mulch treatment, created by cutting weeds at ground level the day of planting, shifted from a predominance of grasses to a predominance of Alternanthera sessilis (L) R. Br., Solanun sp., and Paspalum paniculatum. Two postplant hand weedings may have become necessary in this treatment if the experiment had continued for one or two cycles longer. Weed populations in plowed plots with paraquat applied 25 DAP were 60 to 70% less than in the plowed treatments with manual weeding or atrazine preemergence. Grass species predominated in these two treatments.

Table 1. Yield of maize, labor and costs/ha and cost as percent of farmers practice for eight weed control systems with predominance of annual weeds. Cariari, Costa Rica. September 1977 and January 1978 (21).

SYSTEM	Yield shelled maize 13% moisture (kg/ha)		Labor (man-days/ha)	Cost of weed control (₡/ha	Cost as % of conventional
	1977	1978			
1. Plow + hand weeding 25 DAP	2277	4280	9.0	770	107
2. Plow + atrazine Pre (2.0 kg/ha)	2414	-	2.5	729	101
3. Plow + paraquat Post (.5 kg/ha) 25 DAP	2626	4431	3.5	719	100
4. Mulch + hand weeding 25 DAP	2613	4302	21.0	630	88
5. Glyphosate Preplant (1.3 kg/ha)	3177	4769	5.5	645	90
6. Paraquat Preplant (0.75 kg/ha)	2487	4381	5.5	342	48
7. MSMA Preplant (5.0 kg/ha)	1831	4117	5.5	378	53
8. Paraquat Preplant + Post (0.5 kg/ha) 25 DAP	-	4653	9.0	561	78
CV (%)	19.0	10.0			
LSD (kg/ha)	702	ns			

Preplant application (PP) of glyphosate (System 5) over existing vegetation or a preplant application of paraquat over the existing vegetation followed by a directed application 25 DAP using a spray shield, both gave season-long control. After three years of research, these two treatments were considered the most reliable for this area. Thus, in 1980 several farmers agreed to compare the two treatments with their practices. One farmer with a field heavily infested with Digitaria sp., Eleusine indica and 15% Paspalum paniculatum employed his usual practice of slash and burn followed by an application of paraquat just prior to planting, 15 days after burning. Combinations of burning three days prior to planting were also included with the two selected treatments (Table 2).

The benefits of timely postplant weeding and the benefits of a mulch cover on the soil are demonstrated by the data. The principle difference between systems 1 and 2 was that postplant weed control was done 22 DAP in the treatment with the higher yield. Yields also increased significantly when the mulch remained on the soil surface (system 5 compared with 4). With burning in system 4, germination of annual weeds was greater than in system 5. Glyphosate eliminated the perennial grass Paspalum paniculatum, but paraquat did not. Even though, system 4 was burned five days after applying glyphosate, there was sufficient translocation to control the perennial root system.

Both no-till alternatives compared favorably with the farmer practice of tillage in a field infested with Imperata sp., Digitaria sp., Paspalum paniculatum, Hyptis sp., and Rottboellia exaltata (Table 3).

Glyphosate reduced the population of Imperata sp., by 90% at harvest. Despite the repeated application of paraquat in the other two treatments the regrowth of this rhizomatous perennial weed was 50 to 60cm at harvest. Although the difference in yield was not significant, the trend suggests that the glyphosate treatment would be superior over time, especially where Imperata sp. or other perennials predominate.

Table 2. Maize yields, costs, and labor for five weed control systems with a predominance of annual weeds. Cariari, Costa Rica, 1980 (20).

SYSTEMS	Yield shelled maize - 13% moisture (kg/ha)	Cost of weed control (¢/ha)	Labor (man-days/ha)
1. Slash-burn + paraquat (0.2 kg) PP + paraquat 42 DAP	1368	1104	21
2. Paraquat - (0.4 kg) - burn PP + paraquat (0.2 kg/ha) 22 DAP	2066	396	6
3. Paraquat (0.4 kg) PP + paraquat (0.2 kg) 22 DAP	2024	516	9
4. Glyphosate (1.3 kg) PP + burn	2008	890	2.5
5. Glyphosate (1.3 kg) PP	2822	1010	5.5
CV (%)	11		
$LSD_{.05}$ (kg/ha)	434		

Table 3. Yield of maize, labor and costs/ha for three weed control systems with a predominance of perennial weeds. El Bosque, Costa Rica, 1980 (20).

SYSTEMS	Yield shelled maize 13% moisture (kg/ha)	Labor (man-days/ha)	Cost of weed control (₡/ha)
1. Plow-disk + paraquat (0.2 kg) 25+40 DAP	2174	7.0	1084
2. Paraquat PP (0.4 kg/ha) + paraquat directed (0.2 kg/ha) 25 - 40 DAP	2291	12.5	708
3. Glyphosate PP (1.5 kg kg/ha)	2861	5.5	1128
CV (%) =	18		
$LSD_{.05}$ (kg/ha)	954		

Special management problems of perennial grasses

If tall perennial grasses predominate it is advisable to cut them from 0 to 50cm high and apply herbicides when sufficient regrowth (15 to 25 days) has occured to insure proper functioning of systemic or contact herbicides. Planting follows as soon as the vegetation begins to desiccate. Slashing rank perennial weeds prior to applying herbicides forms a thick mulch that retards establishment of annual weeds. Maize and beans planted with a dibble have consistantly emerged through thick mulch.

Weeds up to one meter tall may be treated with glyphosate (1.5 kg acid equivalent/ha has given consistant results) without slashing first. Vegetation begins to die and fall to the ground after 8 to 12 days, facilitating planting with a dibble. Postplant weed control is not necessary when sufficient mulch is present.

Differences in form and weight of weed species complicates determination of the quantity of vegetation needed to create an adequate mulch. Thick annual grasses, especially Digitaria spp, from 50 to 70cm tall are very good. Paspalum fasciculatum sprayed with glyphosate when 50 to 100cm tall falls flat on the soil surface and forms an especially effective barrier against germinating weeds.

Some Panicum and Paspalum species grow in dispersed bunches and have strong erect stems that do not fall to the soil surface for several weeks after desiccation. Other vegetation between clumps may not form an effective barrier to weed germination, necessitating postplant weed control.

Data from early experiments at three lowland sites (21) indicate that perennial weed control is more costly and that yields from no-till and mechanized treatments were equivalent (Table 4). In two cases the glyphosate application reduced perennial weed populations enough to allow the less costly preplant plus a postplant application of paraquat in subsecuent plantings.

Table 4. Yield of maize and cost/ha for five weed management systems at three locations: Asbana, Diamantes, and Guácimo, Costa Rica, 1978 (19).

	Kg/ha shelled maize 13% moisture				Cost[3/] ₡/ha
Systems [1/]	**ASBANA**[2/]	**DIAMANTES**	**GUACIMO**	**AVE.**	
1. Plow + hand weedings (15 + 30 DAP)	3959	2149	3551	3220	1040
2. C50 + farmers Mix PP + paraquat 15 and 30 DAP	3387	187	1787	1787	839
3. Co + glyphosate PP	3426	2574	4092	3364	985
4. C50 + glyphosate PP	4184	2136	3657	3326	870
5. Co + paraquat PP + paraquat	3709	2549	4098	3452	840
CV (5)	13	23	10		
LSD (kg/ha)	ns	ns	611		
Replicación	2	9	2		
Predominant weeds:	*Paspalum fasciculatum*, *Panicum maximum*, *Paspalum paniculatum*, *Cynodon dactylon*				

[1/] C50 = Weeds cut at 50cm height 15 days before applying herbicide
Co = Weeds cut at ground level 15 days before applying herbicide
Farmer mixture = paraquat + MSMA + diuron (0.5 + 4.0 - 1.0 kg/ha)

[2/] Predominant weeds at ASBANA site: *Digitaria* sp, *Hemidiodia ocimifolia* and *Panicum maximum*. Farmer mix performed well here, but it failed in Diamantes where an extremely heavy stand of *P. fasciculatum* prevailed.

[3/] Costs include three extra man-days/ha to plant into mulch.
$1.00 US = ₡8.54.

Other advantages of no-tillage systems are increased soil moisture, greater energetic and economic efficiency, increased soil organic matter content, increased availability of phosphorus and calcium, improved soil structure and reduced losses from insects. Fertilizer use efficiency has also been greater in most cases studied during the past four years.

No-till systems had greater soil moisture during the dry season in three different years with various cropping systems (4, 5, 14). Soil moisture was 50% in no-till treatments and 36% in the plowed treatment 40 DAP cassava intercropped with beans (4). Rainfall was 62.6mm during this period.

Crissien (5) studied the effect of different phosphorus sources and two tillage systems on maize production. Soil moisture was greater in the no-till treatments 30 and 60 DAP and yields were higher in the no-till treatments (Table 5).

Maldonado (14) reported greater soil moisture at reduced force of retention in no-till treatments. The correlation coefficient between yield and soil moisture was $r = 0.98$, demonstrating the critical role of moisture conservation during periods of limited rainfall. Rainfall during the first 45 days after planting was 80mm with a water deficit of -54.8mm (Figure 1).

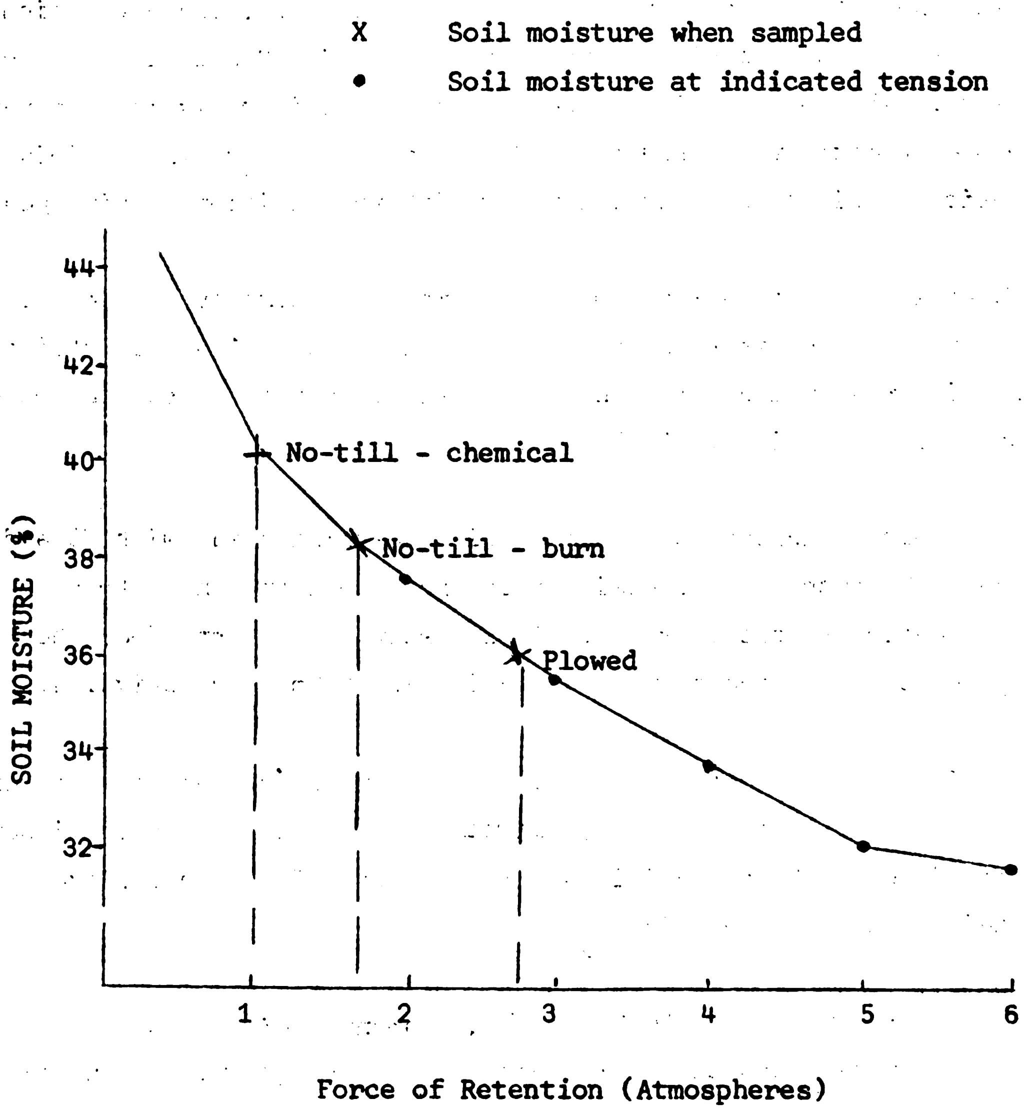
Leach (12) described the relation between agricultural productivity and energy consumption. More intense production systems consume greater quantities of energy and decrease the efficiency ratio for agricultural production to energy input. Inorganic fertilizers, machinery and fuels represent a large portion of total energy inputs in modern agricultural systems (1,2,12,16). As these inputs become increasingly more expensive, energy considrations will become increasingly important in the decision making process at the individual farm level (2).

Jiménez (9) studied six cropping systems; maize, common beans (Phaseolus vulgaris L.), and lima beans (Phaseolus lunatus L.) in monocrops, and common bean-maize, lima bean-maize, and common bean-lima beans intercropped in the

Table 5. Yields of intercropped maize and common beans. Yields of intercropped maize and common beans and available soil moisture 30 and 60 days after planting under two tillage systems with five levels of phosphorous.

Tillage systems	**Phosphorus kg/ha**	**Grain yield - kg/ha maize**	**beans**	**% soil moisture 30 DAP**	**60 DAP**
Plowed	0	1645	902	36	38
	100	2727	801		
	200	2293	1076		
	300	2676	973		
	400	2944	883		
No-till	0	4143	386	40	41
	100	4368	306		
	200	4366	380		
	300	5194	506		
	400	5451	384		

Figure 1. Percent soil moisture and force of retention for three vegetation management systems in a clay loam soil 45 DAP maize intercropped with beans. Turrialba. 1980. Adapted from Maldonado (14).



first cycle, followed by monocrop maize in the second cycle. Each cropping system was repeated under plowed and no-till conditions, with 0 and 120 kg N/ha. Energy efficiency coeffieients (energy produced/energy spent in grain production) and grain yields are given for the 12 most efficient systems (Table 6). Eight of the 12 most efficient systems were no-till. Only four of the 12 included the application of nitrogen.

Maldonado (14) also reported that energetic efficiency was highest for no-till systems by calculating the energy input/$100 net income produced (Table 7). The two no-till systems required considerably less energy than the plowed treatment to produce $100 net income. As shown by Jiménez (9), energetic efficiency decreased notably with the addition of nitrogen.

No-till vegetation management systems are generally less costly than the mechanized systems (Tables 1, 3, 4). Maldonado (14) reported significantly higher economic efficiency for no-till systems, based on the cost of producing $100 net income (Table 8).

Economic efficiency was greater with no-tillage and with 75 and 150 kg of N/ha. The increased economic efficiency for nitrogen contrasts sharply with energetic efficiency for N. This resulted, in part, from the relative high price of maize and beans ($200 and $572.60/Tm, respectively).

Jiménez (9) and Zaffaroni (25) also reported greater economic efficiency in no-till systems for maize production and Jiménez reported higher economic efficiency with the addition of 120 kg N/ha, for both tillage systems, when maize and beans were intercropped.

In experiments of 12 to 18 months, aparent soil density was lower and total porosity and capilarlly pore space were greater for no-till systems (3, 4, 5). Burity (4), Crissien (5), Maldonado (14) and Zaffaroni (26) reported tendencies towards increased organic matter content with no-till.

Table 6. Energy efficiency coefficients for different cropping systems with two levels of nitrogen and two tillage systems. Adapted from Jiménez (9).

	Cropping system 1/	Tillage system 2/	N kg/ha	Energy efficiency coefficients	Grain yields (kg/ha) Common Bean	Lima Bean	Maize 3/
1.	M_1 - M_2	N.T.	0	8.65			6137
2.	M + B_1 - M_2	N.T.	0	6.8	620		5353
3.	B_1 - M_2	N.T.	0	5.96	1685		3027
4.	B + L_1 - M_2	N.T.	0	5.51	1442	657	4795
5.	M + L_1 - M_2	N.T.	0	5.43		655	1901
6.	B_1 - M_2	CON	0	5.05	1678		4901
7.	M_1 - M_2	N.T.	120	5.03			7169
8.	M + B_1 - M_2	CON	0	4.98	442		5386
9.	M_1 - M_2	CON	0	4.8			5065
10.	M + B_1 - M_2	N.T.	120	4.69	1488		6434
11.	M + L_1 - M_2	N.T.	120	4.26		692	6935
12.	M + B_1 - M_2	CON	120	4.19	1329		7131

1/ M_1, B_1, L_1 = Maize or common beans or lima beans, respectively, as monocrop in first cycle
M + B_1 = maize intercropped with common beans in first cycle
M + L_1 = maize intercropped with lima beans first cycle
B + L_1 = common beans intercropped with lima beans first cycle
- M_2 = maize monocrop in second cycle.

2/ N.T. = No till (glyphosate 1.5 kg/ha a.e. applied 8 days before planting)
CON = conventional tillage (plowing + disking + pendimetalin 1.2 kg/ha preemergence followed by paraquat 0.2 kg/ha 25 DAP).

3/ Includes maize yields from both cycles.

Table 7. Energy (Mega Joules) required to produce $100 net with three vegetation management systems, and four nitrogen levels, during three cropping cycles: maize followed by maize intercropped with beans, followed by maize. Turrialba, 1980. Adapted from Maldonado (14).

	Mega Joules/$100 net income [1/]		
Nitrogen kg/ha	Plowed	No-till burn	No-till glyphosate
0	818	164	79
75	1072	660	776
150	1556	1277	1142
225	2263	1736	1623

[1/] Total cultural energy includes human labor and energy represented in fertilizers, pesticides, machinery and fuels. It does not include photosynthetic energy. 1 Mega Joule = 238.83 Kcal.

Table 8. Total cost for producing $100 net income with three vegetation management systems and four nitrogen levels, during three cropping cycles; maize, followed by maize intercropped with beans, followed by maize. Turrialba, 1980. Adapted from Maldonado (14)

Tillage System	Nitrogen levels (kg/ha) 0	75	150	225	$\bar{X}$
Plowed	105	63	61	69	74
No-till, burn	74	42	47	47	52
No-till, glyphosate	77	50	43	46	54
$\bar{X}$	85	52	50	54	

Jiménez (9) presented data from tillage treatments that were maintained for more than three years (seven cropping cycles). Organiocmatter was greater in no-till treatments. Apparent density, and pore space were equal for the two tillage systems.

Burgos and Meneses (3), Burity (4), Crissien (5) and Jiménez (9) all reported increased available P, Ca and Mg with no-till. Potassium was equal, and pH was lower in two cases (3, 4), while Crissien reported less acidity with no-till (9).

Burity (4), Jiménez (9), and Maldonado (14) reported that total soil N from 0 to 20cm tends to be greater in no-till. Crissien (5) showed equal N values for both tillage systems.

Insect pest damage is reduced and production increased in no-till systems in contrast to plowed fields. Spodoptera frugiperda (J. E. Smith) and Diabrotica balteata Leconte colonization incidence was significantly greater in plowed fields. Soil inhabiting pests reduced plant population and plant vigor more in plowed plots than in no-till plots. Uncontrolled insects reduced maize yields up to 44.4% in plowed fields and 24.1% in no-till. For a more complete summary see Shenk and Saunders (23).

Fertilizer use efficiency was higher for no-till in most cases, especially during periods of limited rainfall. Jiménez (9) reported that during the dry season maize yield was higher in the no-till treatment without N than in the plowed treatment with 120 kg N/ha. During the wet season, the no-till plots also had slightly higher yields without N, but plowed fields produced higher yields with 120 kg N/ha (Table 9).

Table 5 presents yield data for different phosphorus levels and percent soil moisture. Average yield was 4704 kg/ha with no-till and 2457 in plowed treatments. Percent soil moisture was also greater in no-till. Phillips et al (16) suggest that increased moisture under a mulch improves the diffusion rate of phosphorus and results in increased uptake by plants. The data in

Table 9. Yield of unshelled maize for two tillage systems with 0 and 80 kg N/ha in rainy season. Guácimo, 1980. Adapted from Shenk (20).

	Kg/ha unshelled maize	
	N (kg/ha)	
Tillage	0	80
Plowed	2760	3395
No-till	4215	4640

Table 10. Maize yields for two tillage systems with 0 and 120 kg N/ha in a wet and a dry season. Turrialba, 1981. Adapted from Jiménez (9).

	Kg/ha shelled maize - 14% moisture	
	N (kg/ha)	
Tillage	0	120
Wet season		
Plowed	2572	3804
No-till	2943	3218
Dry season		
Plowed	2493	2808
No-till	3194	3951

table 5 suggest that moisture was important in maize response to P in this experiment.

Maldonado (14) reported equal maize yields at all N levels during the 1978 wet season. In the 78-79' dry season, maize yields were superior in the no-till treatments at N rates above 75 kg/ha. In the third cycle (1979 wet season), yields were greater in the plowed tretaments (Table 10). Nitrogen was not applied in the third cycle. The author suggests that N leaching was greater in no-till than in plowed treatments. Blevins et al (2) suggest that greater macro-pore space and drainage in no-till conditions increase leaching.

In an experiment conducted during the 1980 rainy period (20), yields were significantly higher at 0 and 80 kg N/ha for no-till (Table 11).

Limited research indicates that no-till could be used for cassava and bean production under some conditions. Yield of total cassava roots was 42.2 Tm/ha in plowed treatments and 33.5 Tm/ha with no-till in a clay loam soil (4). In a loam soil cassava yields were equal for both tillage systems (19).

Burity (4) reported that when beans were intercropped with cassava, dry bean yields were 774 kg/ha in the no-till treatment and 623 kg/ha in plowed treatments. Shenk et al (22) reported yields of 1384 kg/ha in no-till and 1169 kg/ha in plowed plots, with beans in monocrop.

Crissien (5) reports average bean yields of 927 kg/ha in plowed plots and 392 kg/ha in no-till treatments (Table 5). Maldonado (14) reported average dry bean yields of 1.450 kg/ha in plowed treatments and 1000 kg/ha with no-till. However, in both cases, beans were intercropped with maize, and the maize plants were more vigorus with higher grain yields in the no-till plots, thus competing more with beans. In addition, increased slug attack to beans was reported in the no-till treatments in both cases.

Table 11. Yields of maize for two tillage systems with four N levels for three cycles. Turrialba. 1980. Adapted from Maldonado (14).

Season and Tillage 1/	Kg/ha shelled maize - 14% moisture N (kg/ha) 0	75	150	225
Wet season 1978				
Plowed	4100	5190	5820	6410
No-Till	4250	5570	5810	5860
$LSD_{.05}$ (kg/ha) - Tillage =	450			
- Nitrogen =	480			
Dry season 1978-79 2/				
Plowed	1240	1630	1760	1690
No-Till	1120	2820	3780	3170
$LSD_{.05}$ (kg/ha) - Tillage =	480			
- Nitrogen =	560			
Wet season 1979 3/				
Plowed	2600	3940	4350	4270
No-Till	2210	2270	3110	3630
$LSD_{.05}$ (kg/ha) - Tillage =	380			
- Nitrogen =	440			

1/ Rainfall during first 45 DAP = 296.1mm, 90 and 278.2, for the three cycles, respectively.

2/ Maize intercropped with beans: average dry bean yield of 1450 kg/ha and 1000 kg/ha for the plowed and no-till treatments, respectively.

3/ N applied only in first two cycles.

CONCLUSIONS

No-tillage vegetation management systems for small farmers in the tropics are more ecologically sound than mechanized systems and have shown agronomic and economic advantages.

No-till systems utilize the available resources of crop and weed residues to form a mulch. This enhances soil and water conservation and retards weed growth.

Economic and energetic efficiency are greater with no-till systems for maize production.

Insect damage has been less in no-till maize production but has increased slug damage to beans.

Production of cassava roots is reduced with no-till systems in heavy clay soils, but not in loam soils.

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