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Derpsch worked from 1966 to 2001 for GTZ, German Agency for Technical Cooperation. He is now a consultant. He started research in no-tillage in April 1971 in Brazil and was one of the first to research no-tillage in Latin America. He worked closely together with pioneer no-till farmer from Brazil, Herbert Bartz, who started no-tilling in 1972 and now is the President of the Brazilian Federation of No-till Farmers Associations, FEBRAPDP. Derpsch worked at the Research Institute of Paraná, IAPAR, in Brazil from 1977 to 1984 with R & D of the no-tillage system (tillage, cover crops, crop rotations).

From 1993 to 2001, he was senior advisor to the MAG – GTZ Soil Conservation Project, which was a joint venture between the Ministry of Agriculture and Livestock of Paraguay and GTZ. He has working experience in Paraguay, Brazil, Argentina, Bolivia, Chile, Honduras, Colombia, Somalia and Germany. Derpsch has been recognized with several awards by the Ministry of Agriculture of Paraguay and the Paraguayan Federation of No-till Farmers. After the Soil Conservation Project ended in 2001, he left GTZ and decided to stay in Asunción, Paraguay, where he has been based since 1988. Rolf is married to Anke Derpsch, German with one daughter, Susanne - she married in 1999. She finished her studies of Architecture in Germany in 2001 and started working. She and her husband live in Siegen (near Frankfurt) Germany

Economics of No-till farming.
Experiences from Latin America.

Introduction

Before analyzing the economics of No-till we should ask the question, why is No-tillage really booming in Latin America? While in 1987 we would find only 670.000 ha of No-till in the MERCOSUR Countries (Brazil, Argentina, Paraguay and Uruguay), by the year 2002 the technology had grown to over 30 million ha (a 45 fold increase). In the same period No-till grew in the USA from 4 to 22 million ha (only a 5.5 fold increase). While NT has been adopted on 19.7% of total cultivated area in the US, it has been adopted on 45% of total cultivated area in Brazil, 50% in Argentina and about 60% in Paraguay. The reasons for this rapid growth are manifold but the most important aspects are ecological (erosion control, improvement of soil fertility), but mainly economical (less work, higher profits). Farmers would certainly not have adopted the technology so rapidly (if at all) if it would have been only for ecologic and not for economic reasons. According to Sorrenson and Montoya (1984) No-tillage is the most cost effective means of controlling erosion in Brazil and according to King (1983) economic analysis of various conservation practices show that no-till is the most cost effective of any practice commonly used in the USA.

Tebrügge and Böhrnsen (1997) conclude from a long-term tillage field experiments in Germany that:
"No-tillage is a very profitable cultivation system compared to conventional tillage because of the cost savings from lower machinery costs and lower operation costs.
No tillage decreases

- the purchase costs
- the tractor power requirements

- the fuel consumption
- the amount of required labor
- the variable and fixed costs.

At the same time no-tillage increases the campaign performance so that it is a very powerful cultivation system.

On average the same crop yields are possible (in Germany) by no-tillage compared to plow tillage. So the profit will increase. On the other hand lower yields can be accepted without any loss of profit in comparison to the conventional system.

Calculating the total process costs the relative superiority of no-tillage systems would increase further, if we took the positive environmental effects of no-tillage (e.g. less erosion, less pollution by agrochemicals) into account".

What to consider when making economic analysis

When making economic comparisons between Conventional Tillage (CT) and No-tillage (NT) we can not just compare one growing season. We have to compare the whole system over several years and give a monetary value to such things as loss of organic matter and soil fertility in CT compared to gains in organic matter content of the soil and improvement of soil fertility in NT.

If economic analysis of NT is performed the following questions should be asked:

Have all aspects been included that affect economic performance of a system over several years?

Has soil erosion (degradation and loss of productivity) in CT versus soil building (improvement of soil fertility) in a NT system been considered?

How do we rate losses of OM in the soil (and CO_2 emissions) in CT as against build up of OM (and Carbon sequestration) in a NT situation?

Are we considering; yield increases with time in NT as against decreases in CT?

Are we considering the lifespan of a tractor which normally is 8 – 10 years in CT, against 16 – 20 years in NT?

Are we considering the size of the tractor and the horsepower/ha needed in both systems?

Are we considering savings in fuel when practicing NT as compared to fuel costs in CT systems?

Are we considering that cost of building and maintaining mechanical infrastructure (contour banks, terraces, grassed waterways) will be drastically reduced in NT because of higher water infiltration rates and less runoff in this system?

According to Tebrügge and Böhrnsen, (1997) the following economic advantages have been found when comparing CT with the plow to NT in long-term soil tillage field experiments in Germany:

Investments for machines are 39% lower in NT

Power requirements are 75% lower in NT

Working time is 80% lower in NT

Fuel consumption is 84% lower in NT

Variable costs: wages are 84%, fuel is 85% and repair costs are 65% lower in NT

Fixed costs: tractor is 86% lower, stubble cultivation is 100% lower, soil tillage and sowing are 27% lower in NT

These values will certainly change from one country to the other and also from one region to the other, but probably in most parts of the world the trend will be the same.

It is important not to forget the offsite costs that occur when using conventional agriculture and the offsite benefits of using the No-tillage technology as for instance (Sorrenson et al., 1997):

Lower water treatment cost through reduced sedimentation in rivers (for domestic and industrial use)

Longer life of reservoirs used for electricity generation through reduced siltation.

Reduced dredging cost at ports due to reduced river siltation.

Reduced road maintenance costs through largely eliminating soil deposited on roads and road damage caused by severe water runoff, erosion of road sides and surfaces.
Normally these offsite costs which occur when using CT are paid by the government and society, that means by you as a taxpayer.

For the reasons enumerated here we have to be extremely skeptical if somebody tells us that he or she has found out that conventional tillage has economic advantages over No-tillage. Of course the whole picture might change if conventional tillage or agriculture as a whole is heavily subsidized.

The Paraguay case

Economic studies in Paraguay (Sorrenson et al., 1997)

Eighteen farmers in two departments of south-eastern Paraguay (Itapua and San Pedro) were selected for in-depth study on the basis of their representativity and availability of farm records[1]. Following recommended practice, no-tillage (NT) and crop rotations were being introduced gradually by most of these farmers, normally over four to five years. The time series data collected for the study enabled a valid comparison of NT and conventional cultivation (CT) under roughly the same physical and management conditions over several seasons. Other farmers were also interviewed during the course of the study to canvas their attitudes towards soil erosion and the NT/crop rotation technologies.

The study has shown that there are additional benefits from adopting NT and crop rotations in place of CT cropping systems. These include: (i) reduced tractor hours and lowered permanent farm labor and machinery costs; (ii) savings in fertilizer, insecticide, fungicide and herbicide usage per crop over time in NT compared to CT; and (iii) cost savings in NT through eliminating contour terracing and the replanting of crops following heavy rain which is often needed under CT. However, the study does draw attention to the fact that the use of NT and crop rotations call for new management skills, particularly needed to cost-effectively control weeds. Farmers require a number of years to master these skills, the key ones being: (i) type and quantity of herbicide used; (ii) regulation of sprayer pressure, output, speed and timing of herbicide application; (iii) the choice and sequencing of cash and green manure crops in rotations; (iv) minimizing the time between harvesting and the sowing of a subsequent crop; (v) managing ground cover and crop residues; and (vi) using spot spraying with weed-specific herbicides or manual labor, where cost-effective, to control sporadic patches of weeds as opposed to blanket spraying with broad-spectrum herbicides. If these skills are not mastered, inevitably weed infestation increases, production costs rise, and crop yields may fall, which combine to significantly erode farm profits. Farmers then revert back to CT methods as they attempt to survive for some more time before reaching the inevitable point of having to abandon their land when it is no longer productive and economic to cultivate[2].

The farm models developed during the study enable comprehensive evaluation of the financial benefits and economic impacts of NT/crop rotations compared to CT cropping practices over 10 years. NT can be introduced over a number of years with the rate of adoption being specified by the user. The recommended practice is to introduce NT over 4 years; normally 10% of the farm in the first year, 40% in the second, 70% in the third and over the whole farm from the fourth year onwards.

Differences in crop yields, as well as crop fertilizer and herbicide usage (the most significant items of farm costs) were observed on the farms studied under both CT and NT. In general, depending on the crop, yields under CT were following a declining trend[3], while the reverse was occurring under NT when used in combination with green manure cover crops and crop rotations. Based on detailed analysis of the case study

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1 Farms were selected on the basis of representativity in terms of the 2 main agro-ecological zones, farm size and soil tillage/cropping systems.

2 In the San Pedro region, land can be abandoned in as few as 5-7 years after having been cleared of virgin forest for cropping. In Itapua, the period before abandonment may be as short as 8-10 years.

3 According to Kelly (1983), it is estimated that if soil erosion continues unchecked, yield declines of 15% in Africa, and 19% and 41% in southeast and southwest Asia respectively, are expected in the period 1980-2000.

farms, as well as published research data from Paraná (analyzed by Sorrenson and Montoya, 1984 and 1989), crop yields under CT decline over a period of about 10 years by between 5%-15% (depending on the crop), while over approximately the same time period under NT, they increase between 5%-20% (again depending on the crop). These trends in crop yields were found to impact strongly on farm incomes. Savings in herbicide and fertilizer inputs, per crop, under NT compared to CT, which are partially dependent on the crop rotation being followed, range from 30% to 50%, respectively, over approximately the same period and significantly affect farm variable costs and profits[4].

Farm-level Financial Analysis Results (Sorrenson et al., 1997)

For illustrative purposes, financial performance simulated for a typical large-scale farm (135 hectares = 335 acres) in San Pedro is shown in Table 1. Results for the first and tenth years simulated are shown[5]. Annual income (by crop), variable and fixed costs (by major categories), net farm income, return on capital and annual tractor hours, are calculated. All revenues and costs are expressed in United States dollars (US$). The prices used were those prevailing in 1995/96[6]. The same set of prices was used in all years, so that financial performance figures reflect the dynamic effects of soil tillage/cropping system on crop productivity, quantities of farm inputs used and other farm costs devoid of price changes. Comparing the results of the first and tenth years, farm income decreases under CT in response to declining crop yields built into the model, while it increases under NT. Changes in income and variable costs, under NT between the first and tenth years, reflect increasing crop yields, a higher cropping intensity and savings per crop in fertilizer, herbicide and insecticide.

Highlighted below are the changes in net farm income, return on capital and tractor hours, calculated for San Pedro and Itapua.

Farm Models (135 ha = 335 acres) - Net Farm Income US$				
	San Pedro		Itapua	
	First Year	Tenth Year	First Year	Tenth Year
CT	4,900	-3,000	7,300	1,100
NT	8,600	31,000	9,800	33,700

Farm Models (135 ha = 335 acres) - Return on Capital (%)				
	San Pedro		Itapua	
	First Year	Tenth Year	First Year	Tenth Year
CT	1.8	-1.1	1.8	0.3
NT	3.2	13.3	2.4	8.3

Farm Models (135 ha = acres) - Annual Tractor Hours				
	San Pedro		Itapua	
	First Year	Tenth Year	First Year	Tenth Year
CT	1,228	1,210	1,179	1,179
NT	1,177	776	981	786

All three performance criteria exhibit significant improvements under NT compared to CT in both regions. The net farm income figures for NT do not include the purchase cost of a no-tillage drill and auxiliary equipment. These costs can vary largely depending on the type of machinery purchased and whether a

4 Over 17 years (1977-1995) yield increases have been reported in Parana in NT of 86% in maize and 56% in soybeans, at the same time fertilizer inputs have been reduced 30% and 50% in maize and soybeans respectively (F. Djkstra, pers. comm.).

5 The results presented in this paper, while simulated, are fully indicative of what are actually being realised on farms in Paraguay. Financial results of individual crops (per hectare) in any year (from year 1 to year 10), for individual crop rotations, and the overall farm in any year, can also be outputed from the models.

6 A separate set of prices was used for Itapua.

farmer opts to buy new or used equipment. Should new machinery be purchased, costs average about US$ 15,000 per farm. Net farm income increases in both regions are expected to be sufficient to pay for the NT equipment within 2 years (see Table 2). Often farmers lower their set-up costs in NT by initially hiring a no-tillage drill, through adapting their conventional drills for no-till, or by purchasing used machinery.

The changes in the returns on capital of NT compared to CT are quite impressive. In these calculations allowance is made for the additional investment in NT machinery, costed as new machinery. NT and crop rotations are shown to substantially improve the financial performance of cropping farms in the regions studied, whilst under CT, financial viability becomes seriously threatened.

In both regions, despite increased cropping intensities, total annual tractor hours fall quite sharply by the tenth year in NT compared to CT, with consequential savings in tractor costs and permanent farm labor (see Table 1).

In all 10 years simulated, net farm income was higher under NT than CT in both regions (see Table 2). Sorrenson et al. (1997) concluded that risks (defined as the probability of the net farm income falling below zero in any year) are considerably lowered under NT/crop rotations compared to CT cropping systems.

Country-level Economic Analysis Results (Sorrenson et al., 1997)
Farm models of representative medium and large farms for Itapua and San Pedro were used as the building blocks for an ex-ante economic evaluation of a soil conservation training and extension project proposed by Sorrenson et al. (1997). The project, designed to speed-up the rate of successful adoption of NT/crop rotations in south-eastern Paraguay, would support on-farm trials, farmer workshops and seminars, study tours, up to 50 additional extensionists who would be specially trained and dedicated to the project, as well as a project management facility. The main output of the project would be a higher rate of adoption of no-tillage in combination with financially attractive crop rotations estimated to increase from the present about 20% of farmers to 60%, 75% and 80% by the 5th, 10th and 20th years respectively with the project. Without the project it is estimated that the rate of adoption would increase to 40%, 50% and 55% respectively by the 5th, 10th and 20th years. The direct costs that would be associated with the project over 10 years are estimated at about US$ 20 million. The expected Economic Rate of Return (ERR) over a 20 year period is estimated at 57%. Past research and development costs on NT/crop rotations have been treated as sunk costs and therefore ignored. In economic prices, the **annual incremental** crop output valued at farm gate is estimated to rise from US$ 15 million (m), to US$ 32 m and US$ 38 m respectively in the 5th, 10th and 20th years.

Conclusions
Benefits to farmers from the adoption of no-tillage, in combination with sensible crop rotations, could be substantial. However, to reap these benefits, besides converting to NT, farmers concomitantly need to markedly change their cropping systems, switching from monocropping practices to diversified crop rotations, which calls for learning an array of new crop management skills.

The study indicates that investment in public goods over a 10 year period, in the form of specialist training and extension programmes in no-tillage and crop rotations, would increase the rate of adoption of these technologies and be an economically and environmentally attractive investment for Paraguay. The proposed programmes should facilitate farmer-led development and private sector extension initiatives. This could be achieved by supporting self-organized groups of no-till farmers either directly, or indirectly through the technical departments of farmer co-operatives. The proposed training and awareness activities, in combination with substantially increased farm profits, are expected to provide sufficient incentives to encourage most Paraguayan cropping farmers to adopt NT and more diverse crop rotations. These changes in farm production methods are expected to reverse the current trend of declining crop productivity and lead to an economically, ecologically and socially sustainable form of commercial cropping in Paraguay.

In Paraguay as in the rest of South America no subsidies are paid to farmers. Either you No-till or you end up selling your farm to your neighbor, for economic and ecological reasons.

Table 1. Farm Model - San Pedro

	YEAR 1		YEAR 10	
	CT	NT	CT	NT
INCOME (US$)				
Conventional Cultivation				
Soybeans	30,458	27,412	27,412	
Sunflower	13,911	12,519	12,519	
Maize	18,752	16,877	16,877	
Wheat	13,911	12,519	11,824	
No-Tillage				
Soybeans (main season)		5,682		40,913
Maize				20,457
Maize (off-season after sunflower)				7,645
Maize (off-season after soybeans)				11,468
Wheat				13,278
TOTAL INCOME	77,031	75,010	68,632	93,762

Table 2. Farm Models - Simulated Net Farm Income

	US$ per Year			
	San Pedro		Itapua	
YEAR	**CT**	**NT**	**CT**	**NT**
1	4,929	8,569	7,304	9,771
2	3,371	13,973	5,550	17,704
3	2,489	13,002	4,815	23,520
4	1,607	18,337	4,081	25,273
5	724	30,209	3,347	36,282
6	-158	20,043	2,613	32,429

VARIABLE COSTS (US$)				
Tractor	7,507	7,219	7,394	5,035
Harvesting	2,828	2,684	2,828	2,684
Freight	2,878	2,762	2,564	2,519
Seeds	8,164	7,771	8,164	7,442
Fertiliser	15,800	14,606	15,800	14,586
Insecticide	3,491	3,388	3,491	3,345
Fungicide	1,210	1,089	1,210	1,089
Herbicide	6,169	6,790	6,169	6,419
Hired Labour	1,550	1,446	1,550	1,395
Interest	3,886	3,711	3,850	3,652
TOTAL VARIABLE COSTS	53,484	51,467	53,026	48,166
FIXED COSTS (US$)				
Machinery	13,720	10,076	13,720	12,005
Permanent Labour	4,898	4,898	4,848	2,449
TOTAL FIXED COSTS	18,618	14,974	18,618	14,454
NET FARM INCOME (US$)	4,929	8,569	-3,013	31,142
RETURN ON CAPITAL (%)	1.8	3.2	-1.1	13.3
TRACTOR TIME (HOURS)	1,228	1,177	1,210	776

7	-1,040	14,122	1,878	28,917
8	-1,923	44,081	1,144	39,628
9	-2,803	26,658	410	34,800
10	-3,013	31,142	1,095	33,703

Sorrenson et al., (1998) also studied the economics of NT compared to CT on small farmers in Paraguay. The authors conclude that „no-till and crop rotations constitute a technological revolution for small farmers. Never before has the senior author analysed such an impressive technology for small farmers in more than twenty years of extensive experience analysing small farm systems in South America, Africa and Asia. To the authors' knowledge, no other farming techniques have been shown to have such a high impact on farmers' incomes, reduce their production costs and risks, and at the same time be environmentally sustainable and generate very considerable net social gains to society. To realise these private and social benefits will be a major challenge that will call for considerable effort and dedicated support".

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