HOW AND WHY THE BRAZILIAN ZERO TILLAGE EXPLOSION OCCURRED

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ABSTRACT

A complex institutional framework underpinned the exponential expansion of Zero Tillage (ZT) in Brazil to 8.7 million hectares in 1997/8 (summer- planted area), preponderantly in the medium/large mechanised farm sector. Expansion was predicated on (i) farm-tested and cost-effective technology, (ii) awareness of benefits, (iii) technical training (iv) removal of serious soil physical and chemical constraints and problem weeds, (v) availability of cover crop seeds, (vi) credit or small grants for small farmers and (vii) enabling legislation for community management of micro-catchments. Farmer organisations led the formation of the National Federation for Direct Planting into Crop Residues (FEBRAPDP[2]) in 1992 which has acted as a countrywide facilitator for ZT adoption. Farmer-to-farmer contact with integrated support from private sector, NGO, government and some international agencies were the prime factors in dissemination. Farmer involvement has led to substantial improvements in the delivery of agricultural services. Government support has been essential in the small farm sector. ZT is based on permanent soil cover with crop residues, crop rotations including cover crops, specialized planters/drills, and maximisation of biological activity and enhanced management capabilities of the farmer, leading to environmental responsibility. Besides reducing soil erosion losses by up to 90%, and substantially improving rainfall infiltration rates, ZT generates a series of direct and indirect benefits both to the farmer and society. The gains to society, mostly generated by farmer's own resources, merit greater public investment in dissemination of ZT; recognition of society's co-responsibility for natural resource degradation and the ZT farmer's role in reversing this as crucial and not yet in place**. ZT is the gateway to sustainable integration of natural resources management**.

Key words: zero tillage, farmer-to-farmer contact, crop residues, erosion, institutional framework and crop rotations.

A. INTRODUCTION

Zero Tillage (ZT) in Brazil is a story of farmer-led technological evolution and integration. Farmers and technicians who adopt this technology have consistently resolved all the challenges to its sustainability in the humid sub-tropics and humid wet-dry tropics of Brazil, with promising results in the humid tropics. This paper presents an analysis of the new principles, the impacts, dissemination and adoption mechanisms/motives of this new technology for sustainable intensification of natural resource management (NRM). This is based on the large-scale continuing substitution of Conventional Tillage (CT) by Zero Tillage (ZT) technology, as developed in Brazil,

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[2] Federação Brasileira de Plantio Direto na Palha

attaining 8.7 million ha in 1997/8, over 20% of the area of annual summer crops and more than 11 million hectares of total plantings (all seasons) in 1998/9. The expansion of the Zero Tillage area in Brazil is shown in Figure 1. The reasons behind this growth will be examined.

B. HISTORICAL BACKGROUND

The early development of ZT was spurred by a mixture of necessity and idealism, resulting from excessive erosion losses and credit restrictions, mostly in regions highly susceptible to erosion under CT. Continuous ZT at farm level started in 1972, in Rolândia, Paraná state (PR) and farmer organisation to develop and promote the new system started in 1976 in Ponta Grossa - PR. Here, the Earthworm Club was formed in 1979 and this progressed to the ABC Foundation in 1984 (Borges, 1993), in response to the practical needs of farmers for ready-to-go technology. The Clube Amigos da Terra (CAT or *Friends of the Land Clubs, FLC*) movement started in Rio Grande do Sul State (RS) in 1982 (Borges, 1993) and today there are 43 clubs in, the CONCAT[3]. In 1992 FEBRAPDP and APDC[4] were formed independently, with immediate affiliation of the latter to FEBRAPDP, followed by the formation of state associations and an expansion of CATs into the rest of Brazil.

Although isolated tests began from 1969 onwards in southern Brazil (Borges, 1993), research trials began in PR in 1971, with the support of GTZ[5] (Derpsch, 1998), from which the first publication on MiT derived (Ramos, 1976). . This work, plus interchanges with scientists from the USA and the signing of a 1976 research agreement between ICI[6] do Brazil and IAPAR[7], renewed in 1981, were fundamental in consolidating early research efforts. A state-of-the-art publication followed (IAPAR, 1981) covering all aspects of ZT and the Embrapa Wheat Centre, Passo Fundo – RS, imported planters/drills from the USA in 1975, which formed the basis for the modern Brazilian machines (Herbert Bartz, personal communication, 1999), accompanied by research on cover crops, rotations, plant pathology and other aspects of ZT. This early effort was later complemented by the adaptive research carried out by farmer-owned foundations, of which the two most important were the ABC Foundation, Castro PR and FUNDACEP [8] Foundation, Cruz Alta, RS, followed by many others.

In 1977 the Embrapa Soybean Centre promoted the first research meeting on ZT in Londrina-PR (IAPAR, 1981) and farmer- and agronomist-organised technical meetings, with private sector and increasing official support, proliferated from 1981 onwards, starting with three national events in Ponta Grossa, PR (1981, 1983 and 1985), continued in 1994 (Cruz Alta, RS, in 1996 (Goiânia, Goiás state (GO) and 1998 (Brasilia, Federal District, (DF), promoted by FEBRAPDP and organised by member NGOs. A number of ZT scientific events were also held in South Brazil in the 90's. These were the most important among many events, stimulating adoption, research and on-farm development by farmers.

In the 1970's, private sector support began providing technology for pioneer ZT farmers on the use of desiccant herbicides and early-specialized planters and drills. Later, in the 1980's, more private sector R&D was carried out in ZT and most hybrid corn and other seed firms had converted to ZT for variety selection by 1995.

From 1981 onwards, there was an inter-regional technology transfer of the basic principles of ZT through migrating farmers and technical interchanges, from sub-tropical to tropical Brazil, but the agronomics of a warm, dry tropical winter versus a cold wet sub-

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[3] Confederation of CATs for Rio Grande do Sul
[4] Associação de Plantio Direto no Cerrado
[5] Gesellschaft Für Zuscemmungarbeit
[6] Imperial Chemicals Industries UK - Brazil subsidiary
[7] The Paraná State Agricultural Institute
[8] Fundação Centro de Pesquisas/ Federacao das Cooperativas Triticolas do Rio Grande do Sul

tropical winter, with frost, had to be worked out(Landers Ed. 1994). A notable contribution to development of ZT technology in the tropics has been from a CIRAD–CA[9] on-farm program and its various collaborators (Séguy et al. 1998b)and others.

By about 1992, there was enough small farmer technology proven on-farm for extension services in RS, SC, PR to begin technology transfer to the small farm sector, as evidenced by the first and third Latin American meetings on ZT in small farms ((IAPAR, 1993 and IAPAR, 1998). A FEBRAPDP/IAPAR/EMATER–PR[10] initiative in 1992 distributed 30 animal traction planters to small farmers; the results were so good that between 1993 and 1996 nearly 2000 animal traction planters were sold by 7 different manufacturers in PR, Santa Catarina state (SC) and RS (Darolt, 1998). Although often lagging on farmers' initiatives, the official research and development effort on ZT, comprising Embrapa[11] centres, universities and state research organisations has been steadily increasing. The major desiccant herbicide firms, Monsanto, Zeneca, Dow Agrosciences, BASF and others carried out extensive field trials and demonstrations, accelerating these in the 90's and in 1992 the Zero Tillage Group was formed, now with ten major input and machinery firms, specifically to promote ZT. Private sector support has recently shown a preference for farmer organisations, with foundations, co-operatives and CATs increasingly involved in on-farm R&D and technology transfer.

Zero Tillage development in Brazil can be divided into four phases, reviewed in Box 1.

Box 1. The phases of Zero Tillage development.

PIONEER PHASE	**Sub-tropical (mechanized)**	**Sub-tropic. Small**	**Tropics (mechanized)**
On-farm technology development by few farmers Little expansion. Beginnings of research. No extension. Private sector support. Testing of cover crops. Beginning of ZT farmer organization and dissemination events.	1972-1984	1985-1991	1981-1986
CONSOLIDATION PHASE			
Improvements in technology, better planters, more weed control and cover crop options. Early fertilizer/lime recommendation under ZT. Costs approaching CT. Expansion slow, little extension and formal teaching. Private sector support increasing.	1985-1990	1992-1996	1987-1992
MASS ACTION PHASE			
Costs below CT. Increasing adoption by extension in teaching curricula. Technology refinements and wide range of research recommendations. Incentives limited to small/medium farmers. Significant private sector support. Rapid expansion – NGO network with private and public sector.	1991-2000	1997-2010	1993-2000
DOMINANT PHASE			
ZT as the norm. Full research priority to avoid	2001 - 2100	2010 – 2100	2001 - 2100

[9] Centre de Cooperacin Internacional Reserche Agronomy per le Developpament – Cultures Annulles
[10] Empresa de Assistência Técnica e Extensão Rural do Paraná
[11] Empresa Brasileira de Pesquisa Agropecuária

second generation problems. NGO network active in on-farm R&D and professional ZT training. Widespread adoption by extensionists and teaching establishments. Incentives to intensification in ZT. Full private sector support.			

C. TECHNICAL, ECONOMIC AND SOCIAL ASPECTS OF ZERO TILLAGE

In Brazil, CT, predominantly with offset disks and disk plows, leaves the soil surface exposed to heavy rains and insolation for periods of up to three months, while the use of trifluralin as a pre-plant incorporated selective herbicide in soybeans encouraged excessive tilth to promote herbicide efficiency. In dry weather, soil was pulverised, in wet weather hardpans and surface caps formed, while the window of ideal moisture conditions for tilth was too small for the farmer's equipment capacity, leading to soil preparation under unfavourable conditions for structure maintenance. Using ZT technology, virtually all soil movement is eliminated by weed control through herbicides, leaving protective crop (and weed) residues on the surface and using specialised ZT planters/drills to slot the seed and fertiliser into the soil, through the relatively undisturbed cover. Principal crops under ZT in medium/large mechanised farms are Soya (*Glycine max* (L.) Merril.), corn (*Zea mays* L.), edible beans (*Phaseolus vulgaris* L.*),* spring wheat (*Triticum aestivum* L. emend. Fiori et Paol.) irrigated and upland rice (*Oryza sativa* L.) and on a lesser scale, cotton (*Gossypium hirsutum* L.) (Séguy et al. 1998a) tobacco (*Nicotinana tabacum* L.), onions (*Allium cepa* L.) (both transplanted), tomatoes (*Lycopersicum esculentum* Miller nom. cons.*)* and others. Principal cover crops in the sub-tropics are black oats (*Avena strigosa* Schreber), Italian rye grass (*Lolium italicum* Lam.), hairy vetch (*Vicia vellosa, Roth*) mucuna (*Mucuna pruriens* Piper et Tracy, Holland) corn spurrey (*Spergula sp)* and three lupin species (*Lupinus albus, L., L. luteus, L. and L. angustifolia, L.)*. In the tropics, cover crops are limited to millet (*Pennisetum americanum* (L.) Leeke), sorghum (*Sorghum bicolor* (L.) Moench.) forage turnip (*Raphanus sativus* L.), while pigeon pea (*Cajanus cajan* L. Millsp.*)* is used in pasture renovation. Aerial overseeding is commonly used with millet, black oats and sorghum into soybean, to plant up to 20 days pre-harvest.

Related soil management technologies practised in Brazil on a lesser scale are : (i) strip till (ST), (ii) minimum tillage(MiT), (iii) MiT followed by ZT in irrigated rice (Mello, 1995) (iv) upland minimum tillage with a chisel plow or subsoiler plus planter attachments and trash disc or (v) a closed levelling disc over broadcast cover crop seeds. ST in annual crops has been practically confined to small farmers, usually on soils with stones or small boulders, spreading recently to sugar cane (*Saccharum officinalis L.*) coffee (*Coffea arabica L.)* and other tree crops.

With CT, water-stable soil aggregates, organic matter and infiltration rates decline (Freitas, 1994; Silva et al, 1994; Resck et al, 1991). These effects are shown in Figure 2. The effects of ZT in reversing the degradation of soils caused by CT are also evident and Fabrizio et al. (1999) showed an increase of 8.5 times in infiltration rate on a dystrophic tropical red latosol after 3 years of ZT following 10 of CT. Figure 3 emphasises this reversal, showing higher accumulation of soil carbon under ZT. **The adoption of this technology is the gateway to full sustainability in modern Brazilian agriculture.**

Erosion Losses

As the agricultural frontier expanded outside the traditional areas of eutrophic soils with higher clay contents and lower erodibility, to more fragile podsolics, oxisols, quartz sands and cambisols of the new frontiers, soil degradation and erosion became serious limiting factors to sustainability. Existing soil conservation methods using contour banks merely checked overland flows, doing nothing to protect exposed soil between the contours, which was subject to severe degradation.

It can readily be seen from Table 1 that ZT has a marked influence in reducing erosion and increasing rainfall infiltration in both the sub-tropics and tropics. Results of soil loss estimates with the USLE in the São Francisco valley by Chaves et al (1995) with very limited adoption of ZT show erosion losses (correlated with sediment levels) varying from 2- 10 ton/ha/yr in the slope class 0-2 per cent rising to 10-18 ton/ha/yr for slopes of 2-6 per cent. On fertile eutrophic soils, Hernani ***et al.*** (1996) concluded that the reduction in soil loss with ZT was logarithmic, indicating a reduction in erosion susceptibility with time. This can explain why farmers tend to remove all contour banks against the advice of soil conservationists (Bertol, 1995). For farmers, planting in straight lines, without obstacles or dead ends, increases machinery output, eliminates superposition of inputs and is financially attractive, in spite of the (probably underestimated) risk of an exceptional rainfall, of a return period of, say, greater than 50 years. This question merits a re-evaluation of erosion factors as related to crop residue cover in land use capability classifications. To emphasise this point, on a 5% slope, Ruedell (1994) cites erosion losses of 13,7 ton/ha from bare soil and zero with 2.2 ton/ha of dry matter in crop residues.

Benefits of Zero Tillage to the farmer

Zero tillage, in the 90's, has shown a series of positive impacts for the farmer, resulting in higher profitability. However, the pioneer farmers faced the opposite situation. IAPAR (1981) showed that direct costs of ZT were 9.8 % and 7.8% **highe**r than CT, in soybeans and corn respectively. By the mid 90.s there were significant cost savings with ZT over CT, amounting to a **reduction** in costs of 19.8 % in a 2 year soybean/wheat/corn/oats rotation and 12.9 % for corn in PR (Guerra, 1998), while for soybeans and corn in the tropical state of Goiás (GO) direct costs of ZT were 12.4 % and 9.2% **lower** (Ferreira, S. personal communication). And while the pioneers in the 70's and early 80's suffered yield penalties (Bartz, 1994), Bragagnolo et al. (1997) showed gains in 4-year average yields (1990-1993) on 120 microcatchments in PR of (i) 60-65% in edible beans, (ii) 87% in corn, (iii) 26% in soybeans and (iv) 61% in wheat. These differences are principally due to ZT adoption and the higher management levels which going ***through the Zero Tillage gateway*** entrains.

Melo (1995) showed considerable advantages in RS to rotating ZT cropping with pasture leys or winter forage crops. And Mello (1995) demonstrated the viability of ZT soybeans into native pasture with a 2700 kg/ha yield; profits of US$400/ha/year were also reported for a soybean/wheat rotation with oats for winter forage.

The analysis below of a large mechanised dryland operation, planting 2 years soybean and one year of corn, without second cropping, indicates a substantial advantage of ZT as compared to CT, in spite of little difference in direct costs at that time (1994), in the tropical region, In the medium term, the effect of reductions in machinery replacement is an important factor in the higher financial returns to ZT. Total payroll costs were also reduced by 30% due to the lower number of tractor drivers required. If the current differential in direct costs, mentioned by Guerra or Ferreira above, were applied to this model, the advantages of ZT would be enhanced. An APDC farm survey showed an average reduction of 44% in tractor investment, expressed as hp/ha, with dryland indices for ZT ranging from 0.26 to 0.40 hp/ha and 0.32 to 0.54 hp/ha for irrigated conditions (Landers, Ed., 1994, referring to the wet-dry tropics). Mello (1995) measured reductions from 1.6 hp/ha with CT to 0.85hp/ha for ZT in the humid sub-tropics. A single farm survey on a 2110 ha farm showed 10,662 tractor hours for the year 1992, before ZT and only 4,761 hours under total ZT in 1996 (Sementes Primavera – Planaltina, DF – private communication), while Gentil (1995) estimated a reduction in machinery investment of 47% due to ZT adoption.

Enhanced drought resistance under ZT indicates yield increases of up to 25% in soybeans over CT for droughts over 25 days (CAT Bom Jesus – GO, private communication). This is backed up by research data showing reductions of 25% in water use for an erect edible bean variety under irrigation and with a thick mulch vs no mulch (Stone and Moreira, 1998).

Unquantified, but generally acknowledged, additional benefits from adopting ZT are (i) earlier planting (more planting days), (ii) greater efficiency and lower maintenance costs of machinery, (iii) more time for management decisions and technical upgrading (iv) less dusty and muddy work environment, (v) more time for the family, (v) less stress and shorter working hours and (vi) greater satisfaction derived from caring for the environment. In a survey of small farmer ZT adoption Darolt and Wall (1999) indicated the following benefits perceived by small farmers in South Brazil **:** (i) lower labour demand and less drudgery, (ii) ability to plant at the right time, (iii) better yields, (iv) control of erosion, (v) enterprise diversification and (vi) a future on the land for their children.

Economic Implications of Zero Tillage for society

In Box 2, below, a series of benefits and economies generated by ZT for society as a whole is summarised. **The value of these is so considerable that it merits polices of financial stimuli for ZT, which should be classified as social transfers of benefits generated AND NOT AS SUBSIDIES.** So far in Brazil, these have been limited to a national reduction of 1 percentage point on some crop insurance premiums (Bank of Brazil, private communication, 1999), a system of small grants for environment-friendly farm machinery, effluent control, reforestation and other actions in three IBRD[12] small farmer projects (RS, SC and PR states) and a low-interest state credit line for small and medium farmers to purchase specialised ZT machinery in São Paulo state. **Financial incentives for good land stewardship under Agenda 21 have not yet materialised,** These should be extended to sustainable intensification of land use within existing frontiers, using ZT as a strategy to regenerate degraded pastures through integration of crops and livestock.

Box 2. Benefits Generated for Society by Adoption of Zero Tillage.

- Reduction of silting in reservoirs, lakes and watercourses proportional to 70-90% less erosion (Chaves H.M.L in Saturnino and Landers, 1997) - a very conservative estimate of the annual value for the Cerrado region was given as 33 million US dollars per year (Landers, 1996);

[12] World Bank – International |Bank for Reconstruction and Development

- Consequent reduction in the pollution and eutrophication of surface waters by agricultural chemicals carried in erosion runoff (Sorrenson and Montoya, 1984);
- Substantial reduction in treatment costs of municipal water drawn from surface sources (Bragagnolo and Parchen, 1991);
- Considerable reductions in maintenance costs of rural roads;
- Reduced wear on hydro-electric turbines from the passage of cleaner water;
- Flooding risks are reduced by 30-60% greater rainfall infiltration (Chaves,H.M.L in Saturnino and Landers, 1997) and delay to overland flows by surface residues, increasing times of concentration;
- By the same token, aquifer recharge is enhanced, improving groundwater reserves and dry season flows in springs and streams;
- Reductions in diesel fuel of 50 to 70%, or more, (Gentil *et al.*, 1995) and proportional reductions in greenhouse gas emissions;
- ZT per se has a major impact in reducing carbon dioxide emissions when compared to Conventional Tillage, by immobilising carbon in incremental soil organic matter and surface residues (Derpsch,1997)
- It is axiomatic that, by promoting high-yielding sustainable agriculture and increasing pasture carrying-capacity, through rotation with annual crops, ZT takes pressure off the demand for agricultural frontier expansion via deforestation;
- Provision of winter feed (crop and weed seeds not incorporated) and shelter, lower soil temperatures and reduced water pollution levels increases populations of terrestrial, soil and aquatic fauna;
- a high-yielding, prosperous and sustainable agriculture ensures lower food costs and improved food security for the population as a whole.

Adapted from Landers, Ed., 1994

Bale et al. (1997) in a World Bank dissemination note based on Landers (1996), stated*:*

> *"Direct drilling (i.e. ZT) is a practice with no substantial negative effects. The reduction in negative environmental impacts also justifies greater government attention, principally in the area of research and extension, by disseminating and promoting a practice that is economically sustainable, privately profitable and environmentally friendly".*

Society, which is benefiting from low costs of farm products, has a historical and ongoing co-responsibility in preserving natural resources; in Brazil, the fact that over one fifth of annual crops is under ZT has gone unnoticed by the urban society, the bulk of whose sewerage is discharged raw into Brazil's polluted rivers.

With adverse agricultural and credit policies coupled with unstable economic and climatic environments, adopting and creating more efficient ZT technology has been the Brazilian farmer's response to economic survival. One example of this is a small farmer in Rio Grande do Sul who produced 5 ton/ha of corn planted after *Crotalaria juncea* with only 200kg/ha of Ammonium Sulphate (Herbert Bartz, personal communication, 1999) Other examples of cost efficiency are (i) fertilisation of the cover crop to reduce main crop planting time, (ii) surface application of lime and fertiliser, (iii) on-farm fertiliser calibration (iv) heavy cover crops to reduce or eliminate post-emergent herbicide requirements, (v) Baculovirus biological control of caterpillars (Herbert Bartz, on 500ha in

Rolândia PR, Brazil, has not used aerial-applied insecticides for 6 years), (vi) increase of cropping intensity with second cropping (wet-dry tropical region), (vii) reductions in water use under irrigation and (viii) reductions in herbicide and insecticide applications through higher application precision and selective use. .Brazil's public and private sector geneticists have distinguished themselves by having resistant lines in the pipeline so that the impact of new diseases, like soybean stem canker, had only a small effect and public/private partnerships are increasing the screening capacity for new materials several times over. The three World Bank projects in RS, SC and PR states are examples of *de facto* agrarian reform, through technological upgrading of small farmers, which is far more cost-effective than distributing free land with inadequate provisions for appropriate technology and the investments required for intensification of the small farm to make it a viable unit.

C. ANALYSIS OF THE ADOPTION PROCESS FOR ZERO TILLAGE

General pre-conditions for adoption are: (i) farm-tested technology and specialised planters/drills, (ii) awareness of benefits, (iii) technical training (iv) removal of serious soil physical and chemical constraints and problem weeds, (v) availability of cover crop seeds.(IAPAR,1993) and (vi) enabling legislation for community management of micro-catchments. **ZT is the GATEWAY to a fundamental change in base values, representing a qualitative leap in Brazilian agriculture**, where the farmer progresses towards higher profits and greater environmental responsibility. This is illustrated in Figure 4.

There is also a social conscience in the ZT movement, shown by technology transfer from large to small farmers, from South to North (last two national ZT meetings in the tropics) and from adopters to non-adopters. **The major part of ZT area adopted in Brazil was implemented with farmers' own resources.** The process at small farmer community level introduces other elements, starting with the involvement of state extension and research, acting through farmer associations. Table 2 illustrates the adoption process for Zero Tillage in a small micro-catchment in SC.

Darolt and Wall (1999) indicated the acquisition of specialised equipment, such as planters, drills, mini-Argentine rolls and sprayers as a capital barrier to small farmer adoption of sustainable intensification of NRM, well addressed by the three World Bank projects mentioned. Other constraints indicated were the control of weeds during the adoption phase and adjusting to a more complex management system (including higher technology).

The Technology Transfer Process

In 1993, insufficient or no technical information constituted 74% of the replies on reasons for not adopting ZT in the tropics (Landers, Ed., 1994), underlining the importance of all forms of technology transfer.

In the medium to large (mechanised) farm sector, private sector mechanisms, drawing on both official and private sector research and development results, have largely carried out technology transfer. The small farm sector depends principally on state extension services, which lack trained extensionists in the tropical region, where adoption is incipient**. Utilisation of the micro-catchment as the planning unit for soil conservation actions is generalised** and will help integration with the new national water policy, to be implemented by user-controlled river basin committees

Mechanisms involved in Zero Tillage adoption

The principal mechanisms involved in the adoption of ZT are partially confounded. These are listed in Table 3 in approximate order of impact on area adopted, with an indication of the principal agents involved in each case.

In this process, the involvement of agribusiness was fundamental and **isolated efforts by researchers or farmers did not cause notable impact until the farmer NGO dimension was added.** State extension and research support through small farmer associations was essential for small farmers and is becoming more effective in the World Bank projects **where the principle of participatory planning has been introduced.** Recent public/private sector partnerships have also been successful in southern Brazil, such as the METAS project in RS, in part responsible for the 2.8 million ha under ZT in that state in 1997/8 (Denardin, 1997 and EMATER-RS, 1998) and the PROPALHA project in SC, initiated in 1998.

As a motive for adoption, improved financial performance in the 90's has been of paramount importance for all farmers and explains the exponential growth of the ZT area. Perception of a series of other benefits is also important. When all such effects are aggregated (Table 2) the financial advantage of ZT over CT climbs from an advantage of 10 to 22 percentage points of Internal Rate of Return (IRR).

Research and Development

ZT represented a breakthrough in erosion control, which encouraged further development of the technology. Cover crops and rotations were tested (Derpsch et al 1991, IAPAR 1981, Calegari, 1998, Melo 1995, Neto, 1995)**.** Collaboration between farmers, researchers and manufacturers has led to many improvements in planter design (Sattler, 1995), the most important being the guillotine disk cleaner, a principle invented by a farmer in RS. Animal drawn and manual jab planters/drills, sprayers and small Argentine rolls were adapted for small farmers (Ribeiro et al 1998, Ribeiro et al 1993; Almeida, 1993) weed control methods and mechanisms were studied (Almeida, in IAPAR, 1981; Velloso, 1993; Neto,1995), biological controls (Gassen and Jackson, 1992) soil fertility and fertiliser/lime recommendations were developed for the ZT situation (Pöttker, 1995; Rizzardi, 1995; Sá, 1993; Muzilli, 1981,) and soil physical conditions were studied by Blancaneaux, Ed. (1998), Ruedell (1995}, Castro et al.(1987) and others.

Agronomic research in ZT is especially important in the post-adoption phase, when a **new biological balance** evolves (Gassen and Gassen, 1996, Buck, 1994). Questions such as control of the increase in certain weed species, measures to control the enhanced susceptibility to certain diseases (Reis, 1995) and pests (Gassen, 1995), new alternatives for cover and cash crops to improve rotations; revision of fertilizer and lime recommendations (Anghinoni, 1995) requires a lead time for effective results and should be started early to ensure continued profitability of ZT. There has been a small, but significant reversion to CT in the tropical area due to problems with soil pests and lack of knowledge that this is not a good control measure (Gassen,D.N., personal communication 1999). At the 6th National ZT event in 1996, the president of Embrapa indicated that research was lagging on the farmer and exhorted his researchers to catch up (Portugal, 1997). **The principle of farmer-led innovation and technology demand has been the most efficient route to workable and profitable farming practices in ZT.** Today, both the Embrapa Wheat Centre (Passo Fundo, RS) and the Embrapa West Regional Centre (Dourados, MS) have adopted ZT as the norm for experimentation.

The resistance of researchers, academics and extensionists to change was much greater than that of farmers. In economic terms of marginal satisfaction. The farmer sees immediate benefits over and above the cost of change, while the professionals cited see a positive cost in the effort of change and no foreseeable economic benefits accruing to this extra effort. **They must be motivated by non-financial stimuli, which takes longer.**

The Institutional Framework for ZT Dissemination

The complex institutional framework which surrounds the Brazilian farmer and through which actions in support of ZT flow is shown in Figure 5. This demonstrates an inner circle of organisations in which the farmer has significant control and an outer circle where the farmer has little or no direct control over priorities and actions.

A variety of institutional arrangements have participated in transferring the ZT technology to farmers (see Table 3): For large and medium mechanised farmers the formula is ad hoc, where locally the most appropriate combination of entities emerges, through practical considerations. In the case of small farmers, official support, first with specialised research then followed by extension activities with small farmer communities (Ribeiro, 1998), are necessary for this sector to adopt ZT, where commercial interest is smaller.

FEBRAPDP has been, since 1992, a constant facilitator and promoter of ZT through its 60 member organisations, more especially the CONCATs in RS and APDC in the Cerrado region. Figure 6 shows how the Brazilian NGO network is organised and linked to other organisations in the Americas.

The Friends of the Land Clubs represent the local units of this NGO network and are cited as a practical bottom-up solution to the adoption and improvement of ZT; their activities are summarised in Box 3. These clubs are farmer-based NGO's focusing solely on ZT practice and promotion.

Box 3 Activities of Friends of the Land Clubs

Activities of Clubes amigos da Terra (CATs)
(Friends of the land Clubs)

Adoption Phase

- Basic instruction
- Farmer-to-farmer exchanges
- Short courses
- Lectures, farm visits/field tours
- Planter clinics for adoption

Mature Phase

- Specialist seminars
- Field days
- Ad hoc On-farm research/data collection
- University links
- Field tours
- Planter clinics for trouble-shooting
- Professionalization of rural workers

Advanced Phase

- Rural leadership courses
- Cost accounting
- On-farm research partnerships (new crops, varieties, fertilizer, trials)
- Advanced management groups
- Field tours
- Discussion groups/workshops

CONCLUSIONS

The varied mechanisms and wide agrologic basis of the Brazilian experience serve as useful examples for development of ZT in other countries.

NOTE ON TERMINOLOGY

There is an imperative need to change terminology to signal the mindset change in thinking engendered by Zero Tillage, No-Till, No-Tillage, Direct Drilling or Seeding and other synonyms. This will underline the spirit of no-return which is required to generate that persistence which has solved all major limitations to ZT in Brazil to date. Thus "green manure crops" which propagates the idea of ploughing the crop down would be substituted by "cover crops" and "Reduced Tillage" "Minimum Tillage" or "Conservation Tillage" which are catch-all terms, embracing an obfuscating ZT while still admitting turning the soil over (an anti-conservation act because any cultivation oxidises soil organic matter). This generalized usage should be replaced by specifying "Zero Tillage" or "Direct Seeding". "No-Till' and 'No-Tillage" sound more popular, less technical terms. Direct Drilling de-classifies itself as a generic term since it does not cover planters. Finally, the very term "soil conservation" omits any mention of crop residues and should be replaced by "crop residue and soil conservation" in that natural order of priority.

There is a complicating factor since both Webster's and the Oxford English Dictionary define tillage in the wide sense of crop husbandry, including planting weeding and harvest (items tillage, to till.). However ZERO Tillage has a finite ring to it, indicating a radical change in base values, and while "Direct Seeding" is technically correct, it does not cover the case of transplanting into residue, which also is part of Zero Tillage. Q.E.D.

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