
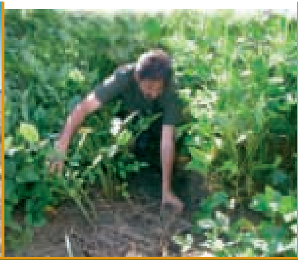

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Tropical crop–livestock systems in conservation agriculture

The Brazilian experience

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FOREWORD

Combining ecological sustainability and economic viability while maintaining or improving agricultural productivity has long been a matter of concern for FAO, as has reducing negative environmental impacts. Conservation agriculture, which aims for zero tillage with the maintenance of a surface mulch to protect the soil surface and increase biological activity in the topsoil, is increasingly becoming recognized as an effective system of crop production that protects the soil from erosion while reducing the overall use of agrochemicals.

Vast areas of forest have been cleared in the tropical areas of Brazil for establishment of pastures that become unproductive once the native fertility of the soil is exhausted; this leads to yet more forest clearing for new pastures. However, rotating pastures with field crops and resowing is one of the most effective ways of maintaining them in a state of high productivity, thereby reducing the need for more clearing.

This publication describes how pasture, fodder and livestock production have been integrated into conservation agriculture systems in Brazil's tropical zones. Integrated crop–livestock zero tillage systems (ICLZT) allow the sustainable production of high-yielding pasture without further deforestation; in this system, grazing livestock convert both pastures and crop residues into cash. The ability of pasture to build up the biological activity and physical quality of the soil is well known.

The lessons learned in Brazil by farmers and scientists can provide valuable insights on what could be done in similar ecologies elsewhere, including in Africa where the details of management will be different, but the biological principles learned in Brazil could be a roadmap to more sustainable intensification of some major crop–livestock production systems.

The manuscript was prepared by John N. Landers of Associação de Plantio Direto no Cerrado, Brazil. It is hoped that this publication will make the Brazilian experience in integrated crop–livestock zero tillage systems accessible to agronomists, advanced farmers, extension workers and agricultural decision-makers in other tropical and subtropical areas so that they can adapt it to their own conditions.

Shivaji Pandey
Director
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Thanks are especially due to the considerable input made by the editors, in particular – retired staff members Jim M. Suttie and Robert Brinkman, and Eric Kueneman, Caterina Batello and Theodor Friedrich of the Crop and Grassland Service for ensuring that this manuscript was brought to publication. Technical input from Josef Kienzle and further editing by Stephen and Mary Reynolds are also appreciated. Finally, all parties involved are very grateful to Dénise Welch, for her valuable inputs and for revising and incorporating the many drafts into this final version.

The technical contribution of Paulo César de Faccio Carvalho, Faculdade de Agronomia – Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Brazil has been much appreciated by FAO in its effort to disseminate information on tropical crop–livestock systems in conservation agriculture. He has also contributed, during his assignment with FAO as a visiting scientist, to reinforcing information knowledge management and partnership with EMBRAPA, UFRGS, IAPAR and Universidade Federal do Paraná (UFPR) on crop–livestock integration systems in Brazil.

The cover design and layout were done by Pietro Bartoleschi and his studio in Rome. Chapter 1–4 photographs, unless otherwise acknowledged, are by the author. Chapter 6 photographs came from Theodor Friedrich.

CONTENTS

ACRONYMS AND ABBREVIATIONS

a. i.	Active ingredient
ANA	(Brazilian) National Water Agency
ANAE	Association Nationale des Acteurs de L'Ecole
APDC	Zero Tillage Farmers' Association for the Cerrado Region
AU	Animal Unit
CA	Conservation agriculture
CEC	Cation exchange capacity
CIMMYT	International Maize and Wheat Improvement Center
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
DAP	Days after planting
DM	Dry matter
DMP	Deforestation mitigation potential
DOEN	Dutch Foundation of Charitable Causes Lotteries in areas of sustainable development, culture and welfare
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
FAO	Food and Agriculture Organization of the United Nations
FEBRAPDP	Federação Brasileira de Plantio Direto na Palha
GTZ	German Agency for Technical Cooperation
GUS	Groundwater ubiquity score
IAPAR	Instituto Agronômico do Paraná
IBGE	Instituto Brasileiro de Geografia e Estatística
ICLZT	Integrated crop–livestock zero tillage system
INEMET	Instituto Nacional de Meteorologia
INPE	Instituto Nacional de Pesquisas Espaciais
INPEV	Instituto Nacional de Processamento de Embalagens Vazias
IPM	Integrated pest management
IRR	Internal rate of return
IUCN	World Conservation Union
LUI	Land use intensity
NPV	Net present value
SOM	Soil organic matter
SSA	Social Security Administration
TDN	Total digestible nutrients (obsolescent energy standard)
UFPR	Universidade Federal do Paraná
UFRGS	Universidade Federal do Rio Grande do Sul
WWF	World Wide Fund for Nature
ZT	Zero tillage

CHAPTER 1
Introduction

Brazil is a world leader in conservation agriculture (CA); initially the emphasis was on crop production through the now well-known principles of maintenance of a layer of crop residues on the surface, zero tillage (ZT) and crop rotations (see definition in Box 1). Now Brazil is pioneering the integration of livestock production, grazed pasture and forage crops into CA, grazing being so managed as to provide adequate surface litter for the needs of ZT. A pasture phase in a rotation is renowned for building up soil organic matter (SOM) and improving soil structure. Pasture in ZT rotations with annual crops can be regenerated much more profitably and with less risk than the older systems where pastures were ploughed out before being resown.

This publication is aimed at agronomists, advanced farmers, extension workers and agricultural decision-makers. It describes how CA has been developed in the tropical and subtropical areas of Brazil and broadened from a crop production system to an integrated crop–livestock way of farming. Within Brazil there are many nuances in approaches adopted by farmers and ranchers; there is not one fixed package for all situations. However, the biology of the sustainable intensification made possible by adoption of ZT has common principles.

Lessons learned in Brazil not only help Brazilian agriculture, but provide insight on what farmers can do elsewhere. While the examples described in Chapter 5 refer to large farms, many smallholders are now applying ZT technology as well, giving proof that the principles are not scale specific. Farming systems have to be developed to suit the agro-ecological and economic characteristics of a region, but it is hoped that many of the lessons learned and technologies developed in the Brazilian tropics and subtropics can be adapted for use by farmers in other regions.

BOX 1. **The definition of conservation agriculture (CA)**

CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.

CA is characterized by continuous minimum mechanical soil disturbance (i.e. direct planting of crop seeds); permanent organic soil cover, especially by crop residues and cover crops; and diversified crop rotations in the case of annual crops or plant associations in the case of perennial crops.

Source: Adapted from FAO, conservation agriculture homepage.

Broadly similar agro-ecological conditions to those in the Brazilian ZT areas are widespread in parts of Africa and South and Southeast Asia, for example (see maps in Nachtergaele and Brinkman, 1996).

CONSERVATION AGRICULTURE IN THE BRAZILIAN TROPICS

This publication concentrates on integrated crop–livestock zero tillage (ICLZT) technology which has developed principally in the Cerrado biome (wet-dry tropical savannahs), extending to the Atlantic Forest biome (see Figure 1). In principle, wider application is possible for the Amazon and the Caatinga biomes, the latter representing the northeast semi-arid tropics. There has been little development with ICLZT systems in the Caatinga, but there is some research and farmer experience in the Amazon biome, principally with soybeans and upland rice sown into degraded pastures.

This publication has six chapters. The introduction gives an overview of CA, ZT and ICLZT systems before outlining their history and development in the tropical areas of Brazil. The second Chapter describes livestock and field crop production in the wet-dry and humid tropical areas of Brazil and provides the background for ICLZT. The third chapter gives the principles of the integrated systems and gives

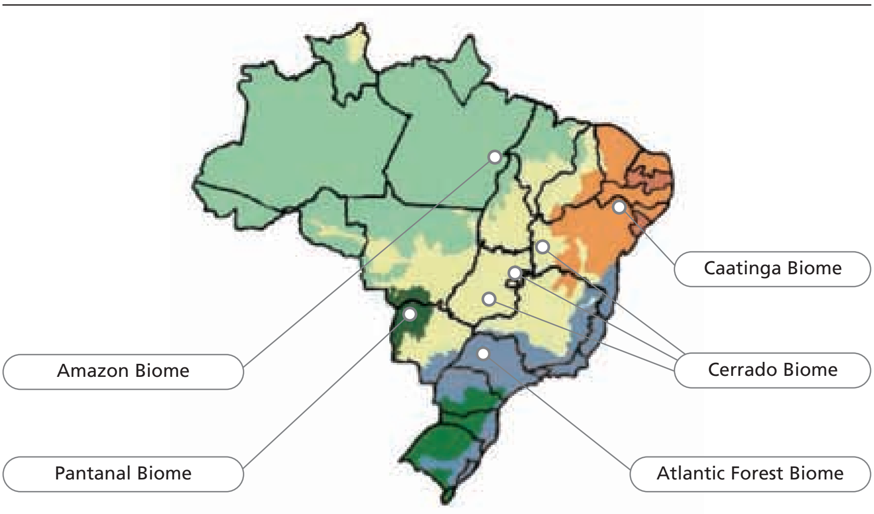

FIGURE 1: Location of the Cerrado, Amazon and other major biomes

Source: Instituto Brasileiro de Geografia e Estatística - IBGE, Brazil.

summaries of the ten main technologies as well as discussing fodder, crops, stubble grazing, pasture crops, grazing management and the grazing of cover crops. The fourth chapter discusses mechanized operations and soil fertility management under ZT. The fifth provides financial analyses and a series of case studies. The final chapter on sustainable agriculture and policy considerations describes how land use intensification can mitigate or obviate further forest clearing for pasture establishment and deals with the positive environmental benefits of CA and its impact on reducing the use of agrochemicals. The chapter ends with policy recommendations for conversion incentives to ICLZT technology, particularly for small farmers.

Background

Agriculture has had different emphases in the Amazon and Cerrado regions: beef, upland rice and small-scale dairying in the former; large-scale beef and soybeans in the latter, with maize, upland rice and cotton of secondary importance. Most clearing for pasture in the last 20 years has been on infertile soils, subject to rapidly falling stocking rates as initial fertility declines and little or no fertilizer is used. This has led to even more clearing to compensate for loss of carrying capacity.

About 55 percent of the Cerrado biome has been cleared (Machado *et al.*, 2004), as opposed to 16 percent of the Amazon biome (INPE, 2006). Land prices have risen; cattle farmers are selling to crop growers and moving to frontier areas to continue clearing. Land use intensification, through integrating ZT crops with livestock systems is the most viable route to preserve biodiversity on a large scale, provided that there are policy incentives for it and disincentives to clearing new land.

The Cerrado biome

The descendants of seventeenth century mining pioneers grew subsistence crops (on the less than 7 percent of the area which had fertile soils) and reared beef cattle on the savannas, which were gradually impoverished through burning at the end of every dry season to generate regrowth.

Improved pasture choices in the Cerrado were dictated by soil fertility. On the few areas of fertile soils under forest (Nitisols) (IUSS, 2006), mostly colonized by 1970 (Goedert, 1985), Molasses Grass (*Melinis minutiflora*), Jaraguá (*Hyparrhenia rufa*) and to a lesser extent, Colonial Guinea Grass (*Panicum maximum)* were sown. From 1972 these were replaced by *Brachiaria* spp. as fertility dwindled, or the pastures were renovated after a crop phase. In the latosols and quartz sands (Ferralsols and Arenosols) (IUSS, 2006) of the Cerrado the opportunity to mine native fertility by burning the sparse scrub is low, compared to Amazon forest. Pastures were established after one or two pioneer crops of rice, using very low fertilizer rates and minimal levels of lime, with little or no maintenance fertilizer. Sano *et al*. (1999) estimated that over 70 percent of Cerrado pastures were degraded.

Soybean production, the principal engine of development in the Cerrado, began significant growth from 1980. The Cerrado, with its gentle topography, wide interfluves, many tablelands, but essentially infertile soils, was opened for grain crops by migrant farmers from the southern states, mostly Rio Grande do Sul, using soil amendment technology from the 1960s (McClung *et al*., 1958; Mikkelsen *et al.,* 1963). This technology was refined by the Brazilian Agricultural Research Corporation (EMBRAPA), but only came into its own with the advent of the first real tropical soybean cultivars “Cristalina” and “Doko” in the late 1970s.

Early development of large-scale arable cropping was based on subsidized agricultural credit. Conventional tillage was mainly with disc harrows which caused disc pans and surface capping, and progressively lower rainfall infiltration rates with erosion losses of up to 20 tonnes of topsoil/ha/year (de Maria, 1999) and rapid depletion of the already low soil organic matter, exacerbated by monocropping of soybeans. Contour banks, required as a precondition for rural credit, were inadequate for downpours of over 100 mm/hr and economic losses due to erosion gradually worsened as soil structure deteriorated. Zero tillage came into use when conventional tillage on infertile Cerrado soils was becoming unattractive, since soil amendments amounted to about 25 percent of direct costs and erosion losses were significant in terms of replanting and lost soil amendments. Since about 1990 a significant number of crop farmers have diversified into beef cattle, moving towards ICLZT systems, as they acquired capital and diversified their risks, or bought degraded pastures to expand soybean production.

On Cerrado latosols and quartz sands (Ferralsols and Arenosols), (IUSS, 2006), improved pastures were based on *Brachiaria decumbens* with some *B. humidicola* from 1972 onwards, usually undersown in upland rice, with low initial fertilizer levels. The *B. decumbens* cultivars (Basilisk and IRI 562) were replaced from about 1990 by *B. brizantha* cv. Marandu and, to a lesser degree *B. ruziziensis.* Improved cultivars of *Andropogon gayanus, Paspalum atratum* and *Setaria anceps* and attempts to introduce pasture legumes had limited success. Predominantly extractive management led to progressive pasture degradation (Macedo, 1997) and impoverishment of cattle farmers, who tend to sell land to crop farmers and move to new frontiers. In rotation with crops, on amended Cerrado soils, new, less stemmy and less clumpy *Panicum maximum* cultivars (Tanzânia, Mombaça, Centenário and Vencedor) have supplanted the old Guinea grass since 1990.

The Amazon biome

In the nineteen-seventies, farmers began to develop areas with fertile soils in the Amazon in southern Pará, Acre, central Rondônia and northern Tocantins states, where a forest-covered region with areas of podsolic soils of some initial fertility (Acrisols) (IUSS, 2006), supported

Colonial Guinea Grass for up to 15 or 20 years. Guinea grass was short-lived on poorer soils and was replaced by *Brachiaria humidicola* and *B. decumbens*, and since about 1990, by *B. brizantha,* with a cycle of up to 10 years before requiring renovation. Large areas of short-lived Guinea grass, colonised by weeds and bush were abandoned due to high renovation costs, especially where there were unrotted stumps. Cattle expansion has pushed land clearing into rain forest on infertile soils with a much shorter depletion cycle.

Pasture development was mostly by incomers from south Brazil, spurred by subsidized credit (Mahar, 1989). Small farmers (local and immigrant) in the Amazon opened forest land with subsistence crops, intersown with pasture in the second or third year as increased weed pressure made annual crops unprofitable. Pasture was established cheaply between the stumps. Large farmers either bought land with established pasture, or carried out more expensive mechanical clearing and broadcast pasture seed after a burn. Pastures were established without ploughing so there was some erosion control.

Where pastures are renovated with full land preparation, usually undersown in rice, the only conservation measure, when present, is contour banks, which can only be made once the stumps have rotted (about 20 years after forest clearance). Contour banks are only effective so long as the soil maintains a good infiltration capacity. This decreases after pasture renovation due to compaction from cattle hooves and reduced ground cover, through overgrazing, exacerbated by clumpy grasses like Colonial Guinea. Weeds from South Brazil were introduced in dirty pasture seed. Residual effects from former widespread use of Picloram herbicide for brush control in annual cropping have not been assessed on a regional scale.

As pasture quality declined, migrant small farmers were forced to intensify into milk production or depend on weaner-calf operations in conjunction with extractive crops like cassava. Few had the capital to invest in perennial crops on a significant scale, and extension services in the Amazon and access to credit have historically been weak for this sector (Camargo *et al*., 2002). Many farmers are in settlement projects with 100 ha plots and have nearly exhausted the forest as a fertility source. Where small farmers adopted conventional tillage it was almost invariably with machinery hired from larger farmers, rarely employing contour banks.

Traditional populations used slash and burn on small 2–3 ha forest plots with a long fallow and were close to sustainable, but with marginal income.

History of zero tillage in the tropical zones of Brazil

The first known tests with ZT in tropical Brazil were in Matão, São Paulo state (Atlantic forest biome) in the 1960s, with a sod-seeder for introducing legumes into pasture – however, this did not become general practice (J. Harrington, personal communication, 1998). Herbert Bartz began ZT on his farm in Rolândia, Paraná state, in 1972, just north of the Tropic of Capricorn, and has used it continuously thereafter. His experience is mainly suited to southern Brazil.

According to Landers (1994), in 1979 small farmers in Rondônia were already jab planting beans (*Phaseolus vulgaris*) into rice straw after desiccation with paraquat as a means of weed control. From 1981 onwards, mechanized tropical ZT began to develop, with soybeans, maize and other crops in the Cerrado, reaching over 9 million ha in the tropical areas in 2004–05, with some encroachment on the transition forest in Northern Mato Grosso. Nearly all of this is in mechanized grain production. Today ZT is being further developed in Roraima, Rondônia, Amazonas and Pará.

The advent of tropical ICLZT technology in the mid 1990s enabled the sowing of grain crops directly into desiccated pastures, revolutionizing crop and pasture production through a synergy which benefited both. Since 1992 the Zero Tillage Farmers' Association for the Cerrado Region (APDC) has actively promoted ZT and, latterly, has been in the forefront of promoting the ICLZT technology (Lara Cabezas and de Freitas, 1999; Landers, 2001). Zero tillage is now the dominant production system for annual crops in Brazil and is increasing rapidly in importance for pasture renovation and establishment of perennial crops. ICLZT has shown tremendous potential for land use intensification, reducing the rate of clearing of native vegetation (see discussion in Chapter 6).

CONSERVATION AGRICULTURE

The term "conservation agriculture" was adopted during the First World Congress on Conservation Agriculture, Madrid 2001, organized by FAO and the European Conservation Agriculture Federation (Saturnino and Landers, 2002).

Zero tillage is the preferred technology for CA[1], the principles of which are summarized in Box 2.

BOX 2. **The 3 main principles of conservation agriculture (CA)**

1. Direct planting of crop seeds
2. Permanent organic soil cover
3. Crop rotation

Source: Adapted from FAO, conservation agriculture homepage.

The distinguishing and most important element of CA is that crop residues remain on the surface, including those of cover crops (green manures). The many functions of this surface organic layer, slowly decomposing to humus, transform an untilled soil into a living, dynamic system which must be managed to maximize these functions and derive the benefits which they confer, resulting in increased SOM, greater P availability and faster breakdown of agricultural chemicals. Conservation agriculture replicates the closed cycle of nutrients and surface litter of a mature rain forest, bringing highly productive farming into harmony with nature. Water-holding capacity increases in proportion to SOM and improved soil structure through an increase in water-stable aggregates (Blancaneaux *et al.*, 1993); water economy also improves since mulch reduces evaporation losses. Stone and Moreira (1998) measured reductions in irrigation demand of over 30 percent with an erect cultivar of *Phaseolus vulgaris* planted in a thick mulch. The functions of surface residues are shown in Box 3.

To plant in permanent residue cover it was necessary to develop specialized planters and drills that cause minimal disturbance. These are now available worldwide in manual, animal-drawn and mechanized models (see Chapters 4 and 6). The sowing mechanism consists of a

[1] In the pure interpretation of CA, tillage is not considered necessary for the creation of soil structure. Therefore, CA encourages ZT, with the aim being no soil disturbance whatsoever. However, CA is also a process with differing degrees of perfection, and in some cases a minimum disturbance of the soil may be unavoidable. Examples of this include strip tillage in cold and wet climates, superficial ripping of the seedrow after pasture to break up the compaction caused by animals, or even ripping in the row as long as the soil is too degraded to maintain a structure (Friedrich, personal communication).

BOX 3. **The functions of crop and weed residues kept on the soil surface**

- Weed suppression by shading or allelopathy;
- Retention of soil moisture through the mulch effect;
- Improvement of soil surface temperatures to within the limits for biological activity;
- Reduction of the velocity of surface flow, reducing erosion potential and increasing total rainfall infiltration;
- Elimination of the direct impact of rain drops on the soil, thus preserving soil aggregates and avoiding surface capping;
- Nutrient recycling with slow liberation throughout the growth period of the crop;
- Alteration of crop residue breakdown products through essentially aerobic decomposition, in favour of the less acidifying humic acids and complexing of aluminium in organic non-soluble forms;
- Alteration of the microclimate for emerging seedlings, protecting them from wind-blown sand and excessive insolation (only applies to standing stubble);
- Provision of organic substrates to feed soil flora and fauna;
- Generation of humus and other products of organic matter decomposition which stabilise and increase organic carbon (Amado and Costa, 2004) and improve soil structure;
- Food and shelter for wildlife.

Source: FAO, conservation agriculture homepage.

trash disc which cuts the crop residue and allows the fertilizer and seed to be placed beneath it with minimum soil disturbance, leaving the soil protected against rain and sun.

Multi-annual crop rotations, which are complementary to ZT in CA systems, may include cover crops to build up residue levels, provide fodder, and improve nutrient recycling from the subsoil. By not repeating the same crop in the same season in successive years, the cycles of diseases, pests and weeds are broken, promoting biological controls and reducing agricultural chemical use and costs of production – this is discussed in Chapter 3.

Contrary to early predictions, once all plough-pans are removed (as a pre-condition to adoption) and movement of lorries and heavy grain trailers is restricted to roadways, ZT maintains soil structure at depth by the preservation of macropores derived from old root holes and the galleries and burrows of soil mesofauna, such as earthworms, beetles and their larvae. Basic infiltration rates after two hours under these conditions have been measured at 120 mm/hr, far higher than even tropical rainfall intensity over the same period (Amado, 2005); without such macropores this drops to 30 mm/hour or even 20 mm/hr when soil is compacted. The macropores thus provide effective erosion control under ZT; long term ZT farmers are removing their contour banks because they no longer need them when they have infiltration rates higher than rainfall intensity and a good residue cover protecting the soil. An average of 30 erosion experiments in Brazil (De Maria, 1999) showed a reduction of 79 percent in soil losses under ZT compared to conventional tillage (5.6 tonnes/ha/annum under ZT and 23.3 tonnes/ha/annum with conventional tillage, while soil regeneration is estimated at 10 tonnes/ha/annum).

The reduction in the negative impacts of erosion on-farm and off-farm is, in itself, a huge environmental advantage. Farmers report increases in terrestrial and aquatic fauna under CA. Aquifer recharge is discussed in Chapter 6, which analyses the deforestation mitigation potential of land use intensification with ICLZT. Perhaps the most impressive point about farmers using CA is their change of attitude to working with nature instead of against it (see Figure 2 below and more details in Chapter 6).

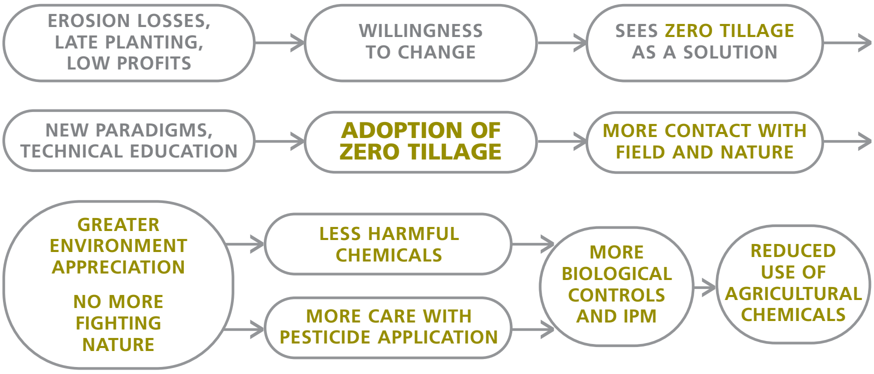

FIGURE 2: Zero tillage, the pathway to lower use of agricultural chemicals

PLATE 1: A trash disc cutting through crop residue – note the heavy spring to aid penetration.

PHOTO: CASE DO BRASIL

PLATE 2: Planting into a flattened cover of black oats (in areas with cool winters). The tractor has double rear wheels and 4 wheel-drive to reduce compaction. The cover after planting is poor, but adequate to stop erosion.

How does conservation agriculture work?

The first operation of the agricultural year is desiccation of cover crops and/or weeds with non-selective contact herbicides of negligible environmental impact. Thereafter, specialized planters, or drills, cut the crop residue with trash discs and slot the fertilizer and seed into the soil with minimal residue disturbance (Plates 1 and 2). The only subsequent operations are application of agricultural inputs (if required) and harvesting. Combine harvesters are fitted with straw spreaders or choppers to give even cover of crop residues.

Conservation agriculture has engendered a more responsible attitude towards the environment, regarding nature as an ally, and not as a foe. The CA farmer combines crop rotations and maintenance of surface residue with cover crops, integrated management of weeds, pests and diseases, rational fertilizer practices, integration of crop and livestock enterprises, watershed management and other environmental concerns. This confers sustainability on the system and assures zero or low levels of chemical residues in agricultural products, well within prescribed legal limits. Landers (2001) estimated values for ZT and ICLZT environmental impacts in Brazil.

INTEGRATED CROP–LIVESTOCK SYSTEMS WITH ZERO TILLAGE

Zero tillage has facilitated the development of ICLZT in the Cerrado biome, with wider application, in principle, in the Amazon, Atlantic Forest and Caatinga biomes. Arable CA systems encompass a whole farm, with both crops and livestock. Integration of beef fattening or rearing with annual crops started as diversification under conventional tillage. The new tropical ZT technology (Broch *et al*., 1997; Lara Cabezas and de Freitas, 1999) eliminated the erosion risk from ploughing, gave higher crop yields and tripled pasture carrying capacity while reducing costs, as shown by Landers *et al.* (2005) in Chapter 5.

Farmers have encouraged technology development, facilitated trials on their farms and often used technology ahead of research results. The backup of wide-spectrum and interdisciplinary field research (governmental and private) has resulted in credible long-term farm results, specialised training and extension programmes.

A new era for tropical CA began in the 1990s, triggered by ICLZT, which gave the potential to increase farm profitability and reduce clearing of native vegetation through land use intensification. A crop phase is the most cost-effective means of maintaining highly productive pastures. Many cattle rearers lack cropping skills – in which case a long term rental agreement with a crop farmer, guaranteeing winter grazing on the stubble until the first crop land reverts to pasture, can satisfy both sides, especially if *Brachiaria* spp. are undersown in the summer crop. Crop farmers diversify into cattle more readily, not least because, in good years, they have capital to invest and wish to spread their financial risk; ranchers are more averse to ICLZT because of (generally unfounded) fears of losing carrying capacity.

The principal benefits of adopting CA using ICLZT are summarized in Box 4. At present, many of them are financial intangibles, but farmers report them consistently as indirect financial benefits; direct financial benefits are analysed in Chapter 5.

The gross margins at different levels of intensification of land use are analysed in the real farm example shown in Figure 3. The benefits of ICLZT are higher than for crop and livestock systems conducted separately, illustrating that the benefits discussed above translate into profits. In Figure 3, from left to right, beef cattle and crop enterprises progress to an integrated crop livestock system on pasture and, finally, to fattening yards with green chop and silage from an irrigated area. The average of the first two bars is 26 percent; this should be compared with the 46 percent of the third bar.

BOX 4. **Benefits of adopting CA using ICLZT**

1. Increased profits through reduced production costs;
2. Risk reductions through diversification;
3. Very low, or zero, pasture renovation costs;
4. Opportunities for strategic winter grazing on crop areas;
5. Increased whole-farm herd carrying capacity as a result of point 4;
6. Reduced disease, pest and weed pressures in crops;
7. Great reduction in environmental pollution through erosion control;
8. Consequent reductions in use of agricultural chemicals;
9. Maintenance of a high average stocking rate on rotated pastures;
10. Consequent mitigation of the demand for clearing new land;
11. Improved soil structure for annual crops through soil aggregation by grass roots;
12. Increased biomass generation for surface residues;
13. Increases in SOM, CEC and water-holding capacity;
14. Reduced fertilizer needs through recycling and reductions in leaching and phosphorus fixation;
15. Improved rainfall infiltration rates, reducing erosion and flood peaks and increasing aquifer recharge;
16. Reduced silting of reservoirs, especially those used for hydro-electricity generation;
17. Faster depreciation of farm machinery;
18. Rationalization of overhead costs;
19. Professionalization of farmers and employees, with higher returns to labour;
20. Evening-out of income and labour peaks over the year;
21. Stabilization of the rural population and agribusiness job creation;
22. Generation of incremental employment in agro-industry.

Source: Adapted from Broch, personal communication (2002).

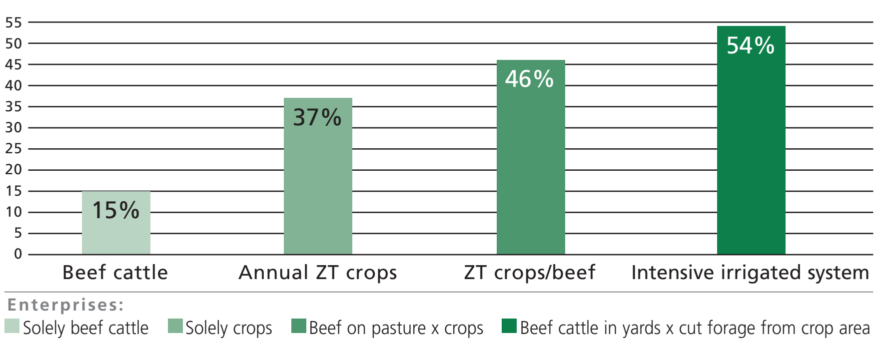

FIGURE 3: A comparison of gross margins at different levels of crop x livestock integration

Source: R. Merola, unpublished farm data.

Dissemination of ICLZT technology

A series of seminars, demonstrations, farmer technology meetings and training courses involving ICLZT have been carried out since 1997, mostly initiated by the private sector, more recently with active participation of EMBRAPA, which now leads these efforts (Landers, 1999). State extension agencies, which primarily serve family farmers, have been active in ICLZT in the last few years. In 2003 the Rice and Beans centre of EMBRAPA published a complete manual of results on ICLZT (Kluthcouski *et al.*, 2003) and in 2005, the Ministry of Agriculture, Livestock and Food Supply launched a programme specifically to promote ZT, with training, demonstrations and research. In 2004 APDC initiated its "Stewards of Our Water" project with Petrobras and in 2006 a joint APDC-National Water Agency (ANA) project was launched, using ZT and ICLZT as the principal instruments to improve on-farm water conservation. The "Pure Oil from Soya" project financed by Stichting DOEN from the Netherlands aims to reduce chemical use in soybean production. These projects obtain secondary financial support from the private sector, state and municipal governments.

CHAPTER 2

Livestock and annual crop production in wet-dry and humid-tropical Brazil

LIVESTOCK TYPE

Beef cattle breeds in tropical Brazil are dominated by the Ongole zebu from India, which has been the subject of selective breeding since the first importations in 1870. The Nelore is the principal breed of Indian origin, which has other minor derivatives (Oliveira, 2002). Other breeds from the sub-continent are losing popularity as they are upgraded with superior Nelore bulls. *Bos taurus* breeds dating from the colonisation period and Santa Gertrudis (*B. taurus* x *B. indicus*) are of minor importance. European beef breeds are not adapted to the tropics. For fattening, crosses of Nelore or other zebus and European breeds are favoured; artificial insemination is also used. Cows from these crosses come into heat at about 24 months, as opposed to 30 months for pure Nelore (A. C. Campos, personal communication, 2005). Magnabosco *et al.*, (2002) demonstrated the effect of genetic selection for performance on pasture: superior genotype animals showed a 26 percent improvement in weight gain over poorer ones.

Most of Brazil's milk comes from Holstein-Friesian cattle and their crosses, of which the Girolanda is the most popular. At tropical elevations over 600 metres, pure Holstein-Friesian perform well when given optimal conditions of feed and shade. Progeny testing and selective breeding programmes are advanced, as are specialised suppliers of semen and embryo transplant services. Holsteins were predominantly of North American origin, but recent imports of stock and semen from New Zealand and other countries are genetic types selected for performance on pasture. There are a few specialized Jersey herds.

Water buffalo thrive where they have access to water. Except for Pará's Amazon flood-lands the water buffalo population is low in the rest of Brazil. They are now expanding from the Amazon lowlands to the lower tropics, due to their hardiness and adaptation to poorer feed. There is an excellent example of almost subtropical ICLZT with water buffalo in Rolândia-PR, of many years standing, where biomass in excess of 6 tonnes/ha is made into hay for winter feed on permanent pasture (H. Bartz, personal communication, 1994).

Herd size and performance

Brazil's cattle herd grew from 153 million in 1995–1996 to 205 million in 2004, an annual growth rate of 3.7 percent. Of these, 60 percent are in the humid and wet-dry tropical states comprising the Amazon and Cerrado biomes. The Cerrado figure is estimated since IBGE figures are by state, not biome. The importance of the Cerrado in beef production is evident. About 60 percent of Brazil's 99 million ha of planted pastures are in wet-dry and humid tropical regions: see Table 1.

TABLE 1: **CATTLE POPULATION AND PASTURE AREAS IN BRAZIL IN 2004**

REGION	CATTLE	NATIVE PASTURE	CULTIVATED PASTURE
	(HEAD)	(HECTARES)	
Brazil	204 512 737	78 048 463	99 652 009
Cerrado*	84 596 782	17 443 641	45 320 271
Amazon**	39 787 138	9 623 763	14 762 858

* States of Mato Grosso, Mato Grosso do Sul, Goiás and Federal District, Bahia west of the São Francisco river, plus 50 percent of Minas Gerais.
** States of Amazonas, Rondônia, Tocantins, Acre, Amapá, Pará and Roraima.

Source: Instituto Brasileiro de Geografia e Estatística - IBGE data for 2004 - website (2006).

Average performance parameters for Brazil's cattle herd are given in Table 2. The southern winter offsets the dry season in the Cerrado, and most of Brazil's herd is in these two regions, so these figures are considered representative for the wet-dry and humid tropics. The livestock sector in tropical Brazil is at the end of an extractive phase where the solution has traditionally been to expand onto newly cleared land. From about 1980, expansion was mainly on dystrophic latosols (Ferralsols) or quartz sands

(Arenosols), which required liming and had little inherent fertility. Pasture establishment under rice, seldom using more than 300 kg/ha of NPK 4.14.8, was common. Stocking rates fell fast and clearing continued to compensate for both loss of carrying capacity and herd expansion.

TABLE 2: **AVERAGE PARAMETERS FOR BRAZIL'S CATTLE HERD AND IMPROVED TECHNOLOGY SYSTEMS**

INDEX	NATIONAL AVERAGE	IMPROVED SYSTEM	HIGH TECHNOLOGY SYSTEM
Calving rate (%)	60	>70	>80
Mortality to weaning (%)	8	6	4
Weaning rate (%)	54	65	75
Post-weaning mortality (%)	4	3	2
Calving interval (months)	21	18	14
Age at slaughter (years)	4	3	2.5
Herd offtake (%)	17	20	22
Carcass weight (kg)	200	220	230
Kill out (%)	53	54	55
Stocking rate (AU/ha)	0.54	0.72	0.96
Liveweight gain (kg/ha/yr)	64	98	145
Weight gain (kg of beef/ha/yr)	34	53	80

Source: Macedo (1999).

BACKGROUND FOR ICLZT

Integration of beef fattening or rearing into annual crop systems began as a hedge against low soybean prices, but with the advent (*ca*. 1994) of the new tropical ZT technology (Broch *et al.*, 1997; Lara Cabezas and de Freitas, 1999), its multiple benefits to both crops and pastures soon became evident.

Dry season pasture production determines a farm's year-round carrying capacity and beef prices rise in this period. In this publication "carrying capacity" refers to the dry season stocking rate. Typical rainfall patterns are shown for Amazon and Cerrado sites in Figure 4. Rainfall intensity increases to the northwest and is greater in the large cattle-growing area of South Pará, with a dry season of 2–3 months, compared to 4–6 months in the Cerrado. Better winter rainfall in the Amazon region allows higher dry season stocking rates and cattle enterprises give a higher average return per hectare than in the degraded

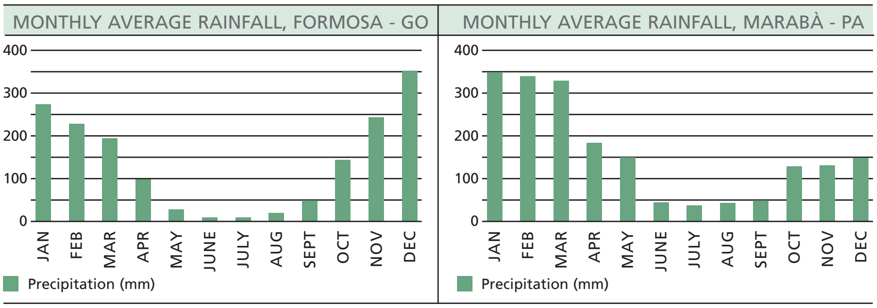

FIGURE 4: **Monthly rainfall distribution at typical Cerrado and Amazon sites**

Source: Instituto Nacional de Meteorologia - INEMET.

pastures of western São Paulo (models No. 4 and No. 5 respectively in Chapter 5 and Camargo *et al*., 2002).

The author estimates that about 85 percent of pastures in the Cerrado are *Brachiaria* with somewhat less in the Amazon biome, while *Panicum maximum* cultivars make up less than 5 percent in the Cerrado. Introduction of *Brachiaria* in the Cerrado raised average carrying capacity from 0.3 AU/ha to 1.0 AU/ha (Macedo, 1997). *Brachiaria* pastures on Cerrado latosols can last up to 5 years without further fertilizer; Guinea grass cultivars give higher carrying capacity on more fertile soils, but decline rapidly with loss of fertility. The winter carrying capacity of native pasture is between 0.1–0.05 ha/AU with annual burning to generate regrowth at the height of the dry season. Under this regime mortality was high and steers lost weight badly over the dry season, reaching slaughter (220–240 kg carcass weight) in three to four years.

Extensive beef producers have been slow to invest in management technology, (e.g. fertilizing pastures, electric fencing, pasture legumes and integrated crop–livestock rotations) but have rapidly taken up new grasses, such as *Brachiaria brizantha* and new cultivars of *Panicum maximum,* which show a very high benefit/cost ratio (Camargo *et al*., 2002). Extractive management led to gradual decapitalization of beef farmers, which, together with resistance to change, has impeded the modernization of the industry. Growing maize and sorghum for silage is quite widespread and dry season fattening pens have gradually increased since the early 1970s. Since about 1990, there has been a significant diversification of crop farmers into beef, moving towards ICLZT.

Vaccination against foot-and-mouth disease, control of ectoparasites and ear tagging are obligatory in beef-exporting states and the rule in the other states, except for ear tagging. Mechanical milking is increasing rapidly, although most small producers still hand-milk; silage or green chop are used extensively in winter and concentrate feed is based on maize and soybean meal with additives. Small farmers are traditionally milk producers on improved pastures; in the South of Pará there is a concentration of small milk producers, currently in crisis due to falling carrying capacities and lack of access to new land (Homma *et al*., 2001).

Available pasture technology permits profitable intensive cattle operations (Yokoyama *et al*., 1999; Landers *et al*., 2005; and Vilela *et al*., 2001). Electric fencing facilitates rotational grazing and the adoption of ICLZT is a low-cost way to turn residual fertility from the crop phase into profit. Fertilizing pastures is considered uneconomic at prevailing beef prices.

The process of pasture degradation

Inadequate replacement of nutrients and overstocking are the chief causes of pasture degradation in the Cerrado (Vilela *et al*., 2004); Figure 5 shows the general sequence of degradation processes. Before going into an ICLZT system the degree of pasture degradation must be taken into account, to decide whether full land preparation is required. Besides fertility decline and overstocking, brush invasion and large paddock size are the major limitations to pasture productivity in the Amazon.

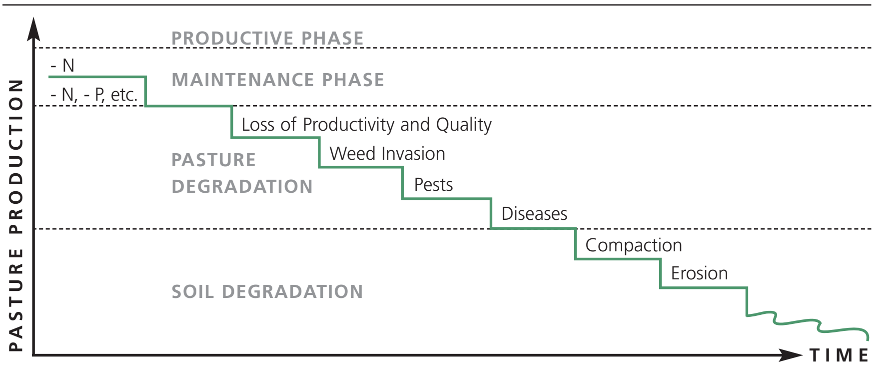

FIGURE 5: Schematic representation of the soil degradation process

Source: Macedo (1999) in Vilela *et al*. (2004).

PLATE 3: Light green/yellowish colour may be an indication of N deficiency.

PHOTO: C. BATELLO

PLATE 4: An overgrazed *Brachiaria* pasture, with low regrowth capacity, invaded by termite mounds.

Continuous degradation through extractive management (as shown in Figure 5) brings successive reductions in carrying capacity. These begin with N and P deficiencies, as shown in Plate 3, and end up in the loss of soil cover and consequent soil degradation through compaction and erosion. Overgrazing is the most common form of poor pasture management. Ideal management seeks to keep the pasture with full ground cover and always in the productive phase, by adjusting stocking rates or rest periods to avoid over-grazing, and adding fertilizer and lime when necessary. Short high stocking periods in the maintenance phase are tolerable. An example of the end of the pasture degradation phase, about to enter the soil degradation phase is shown in Plate 4, where annual beef production would be about 40–50 kg/ha/year and dry season stocking rate is below 0.5 AU/ha. Nitrogen deficiency is the principal limiting factor in Brazilian tropical pastures (Boddey *et al.*, 2004) followed by phosphorus, sulphur, calcium, magnesium and zinc (Vilela *et al.*, 2004).

In the Amazonian pasture areas of southern Pará the 2–3 month dry season and better quality Guinea grass carried 1 to 2 AU/ha over the first five years, depending on initial fertility. When it dropped to about 0.5 AU/ha, due to fertility decline or bush encroachment, the pasture was renovated with *Brachiaria* spp., with carrying capacity ranging from 1.5 to 2 AU/ha in its first five years. Thus, *B. brizantha* or *B. humidícola* replaced Guinea grass as fertility was mined, restoring profitability with a second extractive phase (Kaimowitz and Angelsen, 2001).