CHAPTER 5

Technical and financial analysis of integrated crop–livestock zero tillage rotations

This chapter uses six case studies to illustrate the technical and financial aspects of ICLZT, compared to the situation prior to adoption of the technology. Results are conservative because the farms were all practising CA before adopting ICLZT and had an above-average management level, so the differences introduced by ICLZT were less marked than if the models had started with average management, using conventional tillage. Integrated crop–livestock zero tillage technology is new in the tropics (Broch *et al.*, 1997) and no farms were encountered which had gone straight from conventional tillage to ICLZT without an intermediate stage of CA crops without pastures. The first case study is described in some detail to show the steps in the farm system's evolution (see Box 18), while case studies 2–5 are summarized (Landers *et al.*, 2005). The sixth case study was included to illustrate its advanced management with a one-year ley.

CASE STUDY 1 – A FARM HISTORY OF THE ADOPTION OF CONSERVATION AGRICULTURE WITH ZERO TILLAGE

General description. The farm selected belongs to a traditional farmer in Vianópolis, Goiás state, who has modernized his operation from 1979, when he purchased a run-down cattle farm with degraded *B. decumbens* pastures, typical of the lower half of the 60 million ha of pastures today in the Cerrado region; he adopted a full ICLZT rotation in 1997.

The farm has 1 175 ha, including mandatory reserves of 280 ha (24 percent of total area), leaving 600 ha of crops (190 ha irrigated and 410 ha in rotation with pasture), 285 ha of pasture and 10 ha of other uses. Annual rainfall is 1 638 mm, latitude 16º 45' S, longitude 48º 30' W.

BOX 18. Phases of development in the adoption of CA with ZT

1979 Removal of erosion gullies with a crawler tractor for the large gully and deep ploughing for small ones and rills, followed by planting of *B. decumbens*, undersown in rice using limited fertilizer, incorporating 3 tonnes/ha of lime and re-making of contour banks for soil conservation.

1980 Fencing off of the river-edge gallery forest to allow self-regeneration.

1982 Production of 1 100 tonnes/yr of silage for dry-season supplement;

1980 - 1987 Conventional tillage with rainfed soybeans and maize, separate from the pasture area; pasture renovation with rice and undersowing of *Brachiaria brizantha*, initial pasture subdivision into 50 ha paddocks.

1987-1997 Gradual adoption of ZT.

1995 Introduction of improved pasture management with pigeon pea planted directly into pastures and installation of watering facilities for a beef fattening operation on grass;

1995 Installation of centre pivot irrigation on 190 ha;

1996 Introduction of an integrated crop–livestock rotation, with subdivision of pastures using electric fences into 1 and 2 ha units; rotational grazing on a 42-day basis.

2000 Conversion to a cow-calf (weaner) operation, with supplemental silage limited to 400 tonnes/yr for supplemental (creep) feeding of calves before weaning and for emergency drought reserve.

The investment model. This model represents the evolution of Cerrado biome farming from medium to high level technology in a mixed crop–pasture farm, which was originally solely pasture. The absentee owner lives 120 km away. The high management level is obtained through local professional consultants (veterinarian and agronomist). This is now common in the region.

The 20-year investment model considers the situation before the farmer decided to improve his management with ICLZT in 1995 and compares this with the results of ICLZT in 2004. Crop yields used for the "without project" situation correspond to the present day expectancy under the "without project" management and incorporate genetic yield improvements over the time-span between the "before" and "with" project situations on this farm. The use of historic yield data of ten years ago would have exaggerated the gains with ICLZT since there have been considerable gains in genetic potential of both soybeans and maize since then. Zero tillage adoption preceded the ICLZT technology on this farm, thus the comparison indicates the gains due to ICLZT alone, excluding the effect of conversion from conventional tillage to ZT. The "without project" situation, Scenario (i), represents approximately the situation of the middle third of producers in the Cerrado region and the "with project" Scenario (ii) situation, that of the upper ten percent. Since the farmer had changed his type of operation from a fattening to a breeding herd after adopting ICLZT, the equivalent herd parameters for a cow-calf operation under the "without project" management level, estimated by the farm veterinarian, were used in the comparison. The lack of good quality dry season feed in the "without project" situation affected calf weight at weaning; ICLZT allows earlier sales at the same weight, but no price increase was imputed in terms of quality, which would probably occur, also due to upgrading with pedigree bulls. Higher cow and calf mortality and lower calving and replacement indices occur in the "without project" situation.

Both scenarios are placed in the same time frame, with February 2004 farm gate prices – the price for irrigated maize was increased by 10 percent for out-of-season sale. In this model both rainfed and irrigated crops are assumed to be 100 percent under ZT in scenario (i), with the exception of conventional cultivation for pasture renovation. For purposes of comparison, the same cropping patterns were used for both scenarios; equipment only differed in heavy levelling disc harrow and plough for pasture renovation in scenario (i). In scenario (ii) a ZT planter with chisel-type furrow opener (Plates 26 and 27) for planting pigeon pea in pasture and electric fences for pasture subdivision were used.

Without project

A medium technology level was used, with the pastures for the cow-calf operation separate from the annual crops. Zero tillage was already used in both rainfed and irrigated areas, with pasture renovation using conventional tillage: the rainfed crop rotation was 3 yrs soybeans – 1 yr maize. The farmer had intensified part of the crop area (190 ha), using pivot irrigation. Irrigation is practiced on less than 5 percent of the crop area in the region. Pasture renovation was done every six years, using conventional land preparation and defraying the cost of establishment by undersowing *B. brizantha* in a crop of upland rice. Paddocks were about 50 ha of *B. decumbens* and more recently *B. brizantha.* Winter carrying capacity of pastures was low and offset by production of 1 100 tonnes of silage to feed the whole herd from August to October. The farm veterinary consultant's estimate of 220 cows plus followers was used for the "without situation" number of cows stocked, based on historical information. The pasture area was permanent and separate from the crops.

With ICLZT

The farmer directed his attention to improving the winter pasture situation for the cattle as the best route to improve profit. In 1996, he adopted a high-technology ICLZT rotation – annual rainfed ZT crops in rotation with pastures and irrigated ZT cropping separate. This was accompanied by more intensive grazing management through pasture subdivision with electric fences.

The original 220-cow herd was increased gradually by retaining replacement heifers until full carrying capacity under ICLZT was reached. Herd size used with ICLZT (380 cows plus followers) was actual, from farm records, and equal to the farmer's estimate of optimum pasture carrying capacity. Investment in higher pasture technology was stimulated by the adoption of ICLZT and improvements in performance were assisted by buying high quality bulls from progeny-tested sires.

Pasture stocking levels are considerably enhanced with ICLZT by:

(a) rotating with a crop phase;

(b) sowing pigeon pea into the pasture, with phosphate fertilizer and a band application of desiccant herbicide to check the pasture in the row;

(c) subdividing paddocks with electric fences; and
(d) oversowing millet into rainfed crops for winter stubble grazing.

The higher organic matter and the improved weed, pest and disease control from the pasture phase contribute to 10 percent higher yields for rainfed soybeans and maize, with the project. The crop budget-yield and costs of pasture maintenance were considered equal after planting for both scenarios. This is conservative, since the rotation of crops with pasture will also reduce the costs of weed, disease and pest control; records did not permit an accurate assessment of these aspects.

The pasture is renovated every four years, accompanying the crop rotation. Summer pasture is subdivided with electric fences into 2 ha paddocks, grazed intensively for seven days, with 35 days for recovery. All pasture in rotation with crops is planted with high digestibility *Panicum maximum* cultivars (Tanzânia and Mombaça), or with *Brachiaria brizantha*. *Paspalum atratum* cv. Pojuca, which is less palatable but tolerates poor drainage, is planted as permanent pasture in the bottomlands. Renovated pasture is planted with pigeon pea, which lasts about three years and acts as a winter protein supplement, increasing average protein content in the diet and maintaining good rumen throughput and hence weight gain. Three quarters of the soybean crop area is oversown broadcast with pearl millet (*Pennisetum americanum* cv. BN2) as the soybean is maturing. The cattle go onto the millet in soybean stover in May, and in June-July-August onto the maize stover. In late August, the whole herd goes back onto the upland *P. maximum* pasture sown with pigeon pea. With the first rains (mid-Oct.), the cattle are moved to the bottomlands, which give strategic grazing at this time, allowing the upland pastures to recover. About 30 ha of soybean stover sown to millet is left for seed and grazed after harvest. Fallen millet seed and weeds germinate with the first rains (Sept–Oct) and produce ground cover, which is desiccated in Nov–Dec for the next crop.

Irrigated crop management – with and without project

With and without ICLZT, the three centre pivots, covering 190 ha, receive identical management. Cropping intensity is 200 percent, preferred over higher intensity because of easier planting-harvest schedules. The rotation is: year 1 maize-for-grain/kidney beans; year 2 soybeans/wheat; year 3 maize-for-seed/kidney beans. Average irrigation period for beans is 90 days per crop; maize-for-grain receives an average of 35 days of supplemental irrigation between September and October; wheat consumes some 400 mm/crop in 100 days and soybeans are not irrigated. Irrigation is guided by tensiometers. Irrigated stovers are not grazed. Yields are equal with and without project, as this area is kept separate from the cattle/rainfed crops rotation.

Analysis of the Model Results

Herd performance improved after adoption of ICLZT and rotational grazing, as shown in the summary in Table 14. The number of cows increased from 220 to a steady 380 from year 9 onwards and stocking rate on the pasture increased from 1.0 to 1.76 AU/ha. Maize silage area was reduced from 22 ha to 8 ha with ICLZT, where it is only used as supplemental feed for unweaned stock and as a tactical drought reserve. Together with small increments in rainfed crop yields under ICLZT (10 percent) due to rotation with pasture, this gave IRR and NPV values as shown in Table 14.

For a modest incremental investment, a ZT planter and drill, electric fences, establishment of direct-seeded pigeon pea in pasture and watering facilities, IRR increases from 14.16 percent to 19.96 percent and average annual net profit (undiscounted) from R$229/ha to R$372/ha, a gain of 63 percent, making this investment in technology extremely attractive to the farmer who has the management capacity. If compared with average management levels in the region, this increase would be even higher.

Table 15 shows the results of three alternative scenarios applied to Case Study 1, compared with the "with project" situation, as Scenario (i). In this scenario, the rainfed crop enterprise shows a small deforestation mitigation potential (DMP)[4] of 0.11 ha of native vegetation preserved for each hectare under crops (due to small increments in maize and soybean yields with project). In addition, the cattle enterprise shows a gain of 0.76 ha/ha in total AU carrying capacity, giving a total mitigation potential (crops + pasture) of 0.87 ha/ha in ICLZT.

[4] Defined as the percentage capacity of expansion in production achievable by land use intensification within the existing area.

TABLE 14: **CASE STUDY 1 SUMMARY**

INPUT/OUTPUT DATA	WITH ICLZT	WITHOUT ICLZT	(%) DIFF.
Investment Yr 1 (R$ total)	1 290 363	1 268 581	1.72
New Investment Yrs 1–5 (R$/ha)	1 458	1 433	1.72
TOTAL INVESTMENT OVER 20 YRS			
IRR (%)	19.96%	14.16%	40.98
NPV (R$ ´000)	1 454 183	542 340	168.13
Annual output of grain (average) tonnes/ha	4.53	4.29	5.78
Net profit/ha/yr	372	229	62.64
Total area (ha)	1 175	1 175	0.00
Area in reserves (ha)	280	280	0.00
Area of rainfed crops yr 20 (ha)	410	410	0.00
Area of irrigated crops yr 20 (ha)	190	190	0.00
Area of pasture yr 20 (ha)	285	285	0.00
Percentage of pasture (exploited area)	32.20%	32.20%	0.00
No. of cows yr 0	220	220	0.00
No. of cows yr 20	380	220	72.73
Total Animal Units yr 20	501	299	67.59
AU/ha yr 20	1.76	1.05	67.59

Source: Expanded from Landers and Weiss (2005).

Scenarios (ii), (iii) and (iv) begin with the typical degraded pasture situation of a winter stocking rate at 0.5 AU/ha on the whole farm. In Scenario (ii) crop expansion of 600 ha generates 0.68 ha/ha, plus 0.11 ha/ha yield gain and 0.13 ha/ha for a 13% gain in carrying capacity, totalling 0.92ha/ha DMP.

Scenario (iii) shows renovating the pasture with lime and fertilizer, with no crops and in scenario (iv) there is a pasture/crop ratio of 1:1, with pasture renovation based on the residual fertility of the crop phase.

Both show greater mitigation potential (2.52 and 1.35 ha/ha respectively), than Scenario (ii) and Scenario (i), which was limited by the already high stocking rate of the "without project" situation, with above average pasture management of 1.0 AU/ha in winter. It is notable that, should fertilizer costs come down enough to make their use attractive (not the present case), in scenario (iii) the incremental carrying capacity of the land could reach 252 percent. Scenario (iv) shows an intermediate position of the more likely situation for adoption with equal areas of crops and pasture. This has considerable significance for the environmental aspects of livestock development, firstly in the potential to mitigate deforestation, but also in reduction of erosion losses from degraded pastures through improvement in soil cover.

TABLE 15: **CASE STUDY No.1 – IMPACTS OF DIFFERENT PROPORTIONS OF CROPS/PASTURES ON DEFORESTATION MITIGATION POTENTIAL**

PARAMETER	WITH PROJECT SCENARIO (i)	SCENARIO (ii)	SCENARIO (iii)	SCENARIO (iv)
Total exploitable area (ha)	885.00	885.00	885.00	885.00
Degraded pasture area *	285.00	885.00	885.00	885.00
Stocking rate w/out project AU/ha	1.00	0.50	0.50	0.50
AU/farm w/out project	285.00	442.50	442.50	442.50
Renovated pasture area	285.00	285.00	885.00	442.50
Renov. stocking rate AU/ha	1.76	1.76	1.76	1.76
AU/farm with project	501.60	501.60	1 557.60	778.80
Increase in AU/farm (fraction)	0.76	0.13	2.52	0.76
Hectares cropped	600.00	600.00	0.00	442.50
Increased crop yield	0.11	0.11	0.00	0.09
Crop area expansion	0.00	0.68	0.00	0.50
Mitigation potential (ha/ha)**	0.87	0.92	2.52	1.35

* Based on Case Study No. 1.
** Absorption of crop area is less efficient in mitigation than better pasture management including fertilization. Note; if highly producing maize/soybeans replace low-yielding upland rice there could be a yield gain of 100%.

Source: Expanded from Landers and Weiss (2005).

CASE STUDIES OF OTHER ICLZT TECHNOLOGIES

Below are short descriptions of case studies 2–6 and a summary table of their results.

Case study 2. A net area of 1 130 ha is farmed (not counting environmental reserves). A rainfed maize and soybean rotation is integrated with a cow/calf operation. ICLZT is introduced to rotate pasture with crops, and the crop stubble in grazed during the dry season, thus intensifying the cattle operation. After the summer crop, hay is taken from volunteer grass and millet, to supplement the permanent summer pasture, which becomes limiting in view of the ratio of 6.5:1 of stubble grazing to permanent pasture. An expansion scenario is also examined, using “without project” medium technology level and clearing new land. Initial low soil fertility, light scrub savannah vegetation and flat topography are typical of the Cerrado biome in this region bordering the drier Northeast “sertão”. Case study 2 is situated in Formoso do Rio Preto, West Bahia. Source: adapted from Landers and Weiss, 2005.

Case study 3. Weaned calves are brought in, reared on renovated and subdivided ZT pasture and sold as steers (for fattening to slaughter weight). A soybeans-soybeans-soybeans/maize arable phase follows the pasture, with 3 ICLZT rotations (2 rainfed and 1 rainfed + irrigated) on 3 200 ha, including environmental reserves. The “without project” situation uses a medium/high technology level without rotating crops and pasture, the latter with large 200 ha paddocks. Initial soil fertility, low, open scrub savannah vegetation, gently undulating topography, Cerrado biome. Location: Cristalina, GO.

Case study 4. Integrated breeding/rearing/fattening pasture operation on 1 000 cleared ha; ICLZT is introduced to renovate old pastures with mechanized crops, also providing dry season stubble grazing. The “without project” scenario represents the clearing cycle in traditional practice. Initial soil fertility moderate, originally heavy rainforest vegetation, Amazon biome. Marabá, PA.

Case study 5. Small intensive beef cow/calf operation on 261 ha rotates with ZT maize for silage and ZT pigeon pea in pastures. The latter and ZT adoption are the sole changes in the operation. Old cleared area (1940s), originally high soil fertility (old coffee land), Atlantic Forest biome, Poloni, SP.

Case study 6. Medium-sized mechanized operation on 800 ha (excluding reserves), with fattening of steers or heifers on a dark red clayey latosol (Ferralsol), originally forest vegetation, at Maracajú MS at approximately 20º S latitude. Cropping pattern is a 1 year pasture ley in rotation with 3 years of annual cropping: soybeans-cotton-maize. Stocking rate on this *P. maximum* pasture reaches 5 AU/ha, but if continued in the second year this would drop to 3 AU/ha. Winter grazing consists of finger or pearl millet and black oats, after soybeans; cotton is harvested late and is followed by winter fallow. The finger millet is also used as a nurse crop for the Panicum, to give early bite. No supplemental feed is used, except proteinized salt.

This system produces 3 hectares of arable crops and carries 5 AU per 4 hectares. To achieve the same production without integration of crops and livestock, 3 hectares would be needed for annual crops plus another 10 hectares to maintain 0.5 AU per hectare in the customary grazing system on degraded pasture cleared from forest. Four hectares of this intensive integrated crop–livestock system thus save 9 hectares of forest from clearance and land degradation. In short, 2.25 hectares of forest is saved per hectare used.

CONCLUSIONS FROM THE CASE STUDIES

From the case studies, it can be seen that the pasture phase (ley) after crops varies from 1 to 6 years, depending on the intensity of the system. A one-year ley, as in Case study 6, maximizes the carrying capacity of the pasture and also the proportion of crops in the rotation. Crop phases with ICLZT are between 3 and 4 years, allowing sufficient time for a significant build-up in fertility, which is exploited by the pasture phase, at zero cost. In return, the soil conditioning and breaking of pest, disease and weed cycles during the pasture phase results in reduced costs and higher yields for the crops. Under the traditional system of pasture establishment and renovation, undersowing in an upland rice crop with about 250 kg/ha of NPK fertilizer 4–14–8 for one year (maximum 2), generated far too little residual fertility, which is the reason why most Brazilian tropical pastures have fallen rapidly into degradation. The economic significance of the cropping phase in an ICLZT system is that it permits cheap establishment of high quality pasture and provides the mechanism to renovate it on a sustainable basis, besides improving annual crop performance.

The simplest ICLZT system is that of Case study 2, using winter grazing and haying of stubble to improve dry season carrying capacity. This can be improved, as in Case study 1, by oversowing pasture seed (usually in soya) or undersowing in maize or another nurse crop – these pastures can either be annual or perennial grasses (even the annual weed grass *B. plantaginea* could have application here). The former and *B. ruziziensis* are preferred for oversowing, because they come away faster. Case study 3 shows the greatest variety of rotations and uses *Brachiaria* spp. to suppress kidney bean diseases in the non-irrigated and irrigated rotations, and *B. ruziziensis* from seed as an annual catch crop for grazing in the irrigated area, in the window between maize harvest and bean planting. As shown in Case study 4, ICLZT has relevance for the Amazon biome, but will only have significant uptake when clearing new land becomes more expensive. Enriching permanent pastures with pigeon pea, as in Case studies 1 and 5, or other legumes, is a good means of improving their efficiency (alternatively, legume protein banks can be used, but these have not had significant uptake in Brazil). The most advanced system of grazing is that of the one-year ley in Case study 6, which maximizes pasture stocking rates and the percentage of total farm area in crops and hence, total farm income.

In Table 16 the results of economic analyses of the above case studies are summarised (except Case study 6, included as an example of the most intensive rotation possible).

The results of Table 16 indicate:

1. That the investment in intensifying to an ICLZT system is viable;
2. That investment levels are relatively modest;
3. That the highest impact of ICLZT is obtained with a high ratio of winter grazing (on stubble or second crop areas) to permanent pastures;
4. That the highest stocking rates are achieved with a one-year ley.

All ICLZT systems show clear financial benefits in terms of IRR and NPV, with the exception of Case study 4, where the inclusion of land sale value in the expansion in the "without project" scenario inflates the IRR when compared with the "with project" ICLZT scenarios, in which renting land to a crop farmer shows a lower return than planting with own machinery. However, these scenarios have attractive net returns and very adequate IRRs as well.

Also, there is a large variation in Deforestation Mitigation Potential (DMP), due to different proportions of crop to pasture and variations in incremental stocking rates, with two extremes: Case study 5 has the lowest proportion of crops and a high DMP of 2.52 ha/ha, but Case study 6 has 75 percent of annual crops and a DMP of 2.25 (see Table 17), due to the very high stocking rate allowed on a one-year ley. These systems, especially the latter, will be the trend for the future.

TABLE 16: **A SUMMARY OF THE RESULTS OF FINANCIAL ANALYSIS OF THE CASE STUDIES**

CASE STUDY DESCRIPTION	SYSTEM	CROPS + PASTURES (ha)	INVESTMT. YRS 1–4 (R$/ha)	IRR (%)	NET RET. R$/ha/yr	STOCK. RATE AU/ha
Study No. 1, Cerrado – cow/calf, annual rainfed/ irrigated crops on 1 175 ha. total area. Med. high mgt. – Goiás state.	ICLZT	885	1.458	19.96	372	1.76
Without ICLZT.	Without	885	1.433	14.16	229	1.05
Study No. 2, Cerrado – cow/calf, annual rainfed crops, 1 130 ha. Total area.	ICLZT	820	1.000	8.85	84	2.18
400 ha expansion – crops not rotated with pasture, cow/calf. Med. mgt. – Bahia state.	Expansion	1 220	1.340	5.38	83	0.52
Without expansion, without ICLZT.	Without	820	933	3.30	53	0.52
Study No. 3, Cerrado – rainfed crops x beef rearing high mgt. – Goiás state. 3 200 ha total area.	ICLZT Rot.1	2.400	2.598	19.63	187	1.49
Intensive grazing with electric fences.	ICLZT Rot.2	2.400	2.598	27.16	262	1.74
Irrigated crops.	ICLZT Rot.3	2.400	4.098	26.71	301	1.93
Without rotation with pasture.	Without	2.400	2.432	12.65	114	0.93
Study No. 4, Amazon – beef Itinerant 10 yr clearing cycle med. low mgt. – South of Pará state. 1 000 ha of pasture.	Clearing Scen.(i)	1 000	-559	35.7	37	0.98
Pasture renovation in situ med. mgt.	Renov. Scen.(ii)	1 000	805	9.72	203	1.22
ICLZT with rice/soybeans med. high mgt.	ICLZT Scen (iii)	1 000	698	11.68	310	1.60
Pasture renovation via renting 20% of pasture – med. low mgt.	ICLZT Scen.(iv)	800	742	6.48	173	1.58
Study No. 5, Atlantic – small farmer 261 ha. ZT + legumes in pasture – med. high mgt – São Paulo state.	ICLZT	261	1.552	6.41	138	1.79
Conventional tillage, no legumes.	Without	261	1.504	negative	16	1.20
Study No. 6	With Without	800 800	n. a. n. a.	n. a. n. a.	n. a. n. a.	5.0 0.5

Source: Expanded from Landers *et al.* (2005).

An analysis of DMP in Table 17 compares the effects of the best alternative management systems on this parameter (taking the best scenarios of those analysed). The land use intensification through increased stocking and absorption of crop expansion in areas of degraded pasture allows mitigation of land clearing on the scale of approximately 0.25 to 2.5 hectares for every hectare in ICLZT, depending on the system. It can be seen that the two most important variables are the increase in stocking rate in the pasture and the proportion of pasture to crops.

TABLE 17: **DEFORESTATION MITIGATION POTENTIAL OF THE BEST ALTERNATIVES IN THE MODELS**

PARAMETER	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
Degraded pasture area* (ha)	885.00	980.00	2 400.00	1 000.00	252.00	800.00
AU/farm w/out project	442.50	490.00	1 200.00	500.00	126.00	400.00
Renovated pasture area (ha)	285.00	150.00	1 200.00	800.00	241.00	200.00
Renov. stocking rate AU/ha	1.76	1.96	2.03	1.22	1.82	5.00
AU/farm with project	501.60	294.00	2 436.00	780.80	439.00	1 000.00
Increase in AU/hectare	0.13	-0.40	1.03	0.56	2.48	1.5
Crop area (proportion)	0.68	0.85	0.50	0.20	0.04	0.75
Mitigation potential (ha/ha)**	0.81	0.45	1.53	0.76	2.52	2.25

* Assumes that the farm starts as 100% degraded pastures, with a stocking rate (winter) of 0.5 AU/ha.
** Crop yield increases (decreases) and reduced time to sale of animals were not considered and are much smaller effects. These factors are almost invariably positive, thus these assumptions are conservative.

Source: Landers *et al.* (2005).

CHAPTER 6

Sustainable agriculture and policy considerations

A sustainable approach to agriculture calls for a system that is not only environmentally friendly, but economically viable and socially responsible as well. Important allies for such an approach therefore include the CA farmers, but also the governments and societies that support these farmers. The environmental awareness of a CA farmer is considerably enhanced and his/her operation more profitable – mostly through ZT, and especially by increasing land use intensity (LUI) through ICLZT. However, societal investments in the transition to CA are important catalysts in the sustainable agriculture movement. It is important to recall that farmers worldwide have considerably reduced the cost of basic foods over the last decades (Vieira *et al*., 2001), and with the increased efficiency of ZT, a net transfer of value is generated to the consumer. In addition, food security, biodiversity conservation and the sustainable use of natural resources are common concerns for each member of society, so conversion investments to CA, ZT and ICLZT will be important agenda items for many national governments. Many of these governments need assistance with the promotion of conversion to such sustainable systems, which will result in economic gains for small farmers while increasing important environmental services for society as a whole. Therefore, funding by international donors and donor countries for programmes to extend CA, ZT and ICLZT in the tropics and subtropics will need to be continued and expanded, with technical support by international and national organizations such as CIMMYT, FAO, CIRAD[6], ANAE[7], EMBRAPA, FEBRAPDP and GTZ[8].

[6] A CIRAD project in the mountainous areas of Vietnam has promoted the inclusion of forage production in cropping systems as a means for adopting direct seeding systems that successfully integrate livestock. This project has contributed to increased food and feed system performance, soil improvement, and forest conservation (Husson *et al*., 2006).

[7] Direct seeding, mulch based cropping systems in the humid tropical east coast of Malagasy, supported by ANAE have contributed to soil conservation, fodder production, reduced forest clearing and the intensified sustainable production of annual crops, leading to improved socio-economic conditions for small farmers (Séguy *et al*., 2006).

[8] Besides medium and large farms, thousands of smallholders in Paraguay are practising conservation agriculture, with support from GTZ, which has resulted in improved incomes and labour savings; these tend to be reinvested in intensification and diversification of their production systems (Lange, 2005).

FARM-BASED ECONOMIC BENEFITS OF CA, ZT AND ICLZT

Conservation agriculture shows a clear trend in increased yields and reduced use of agricultural chemicals; and even if their amount would remain constant, their use per tonne of product would be reduced, thereby saving farmers money. In addition, CA farmers tend to have more time for their families and for professional training, and larger CA farmers generally train their personnel and pay higher wages.

The case studies on ICLZT systems in the Brazilian Amazon, Savannah and Atlantic Forest biomes described in chapter 5 were selected in order to determine what kinds of incentives might be necessary for the farmer to change his/her economic decision from land clearing to land intensification. Results showed that ICLZT technology would allow productive annual crops to be grown on a significant proportion of the approximately 80 million hectares of cultivated pastures present in the Amazon and Cerrado biomes today, of which 70–80 percent are classified as degraded (Sano *et al*., 1999; Vilela *et al*., 2004).

In twenty-year investment models, the study shows increased long-term financial returns to ICLZT (improved NPV, net return/ha and IRR), but incremental investments in the transition and new management skills are needed to achieve the best returns. The expression, "a farmer in the red cannot look after the green" is especially poignant here, since many small farmers are not able to make the needed one-time investments without some support. When farmers improve their levels of land stewardship, they merit environmental services payments, not just because of the extra costs involved in the transition, but also as a quid pro quo for the reduced off-farm impacts and consequent public savings generated.

FARM-BASED ENVIRONMENTAL BENEFITS OF CA, ZT AND ICLZT

Zero tillage substitutes for, or reduces the use of, many leachable herbicides used in conventional tillage, such as Trifluralin and Atrazine (a very soluble maize herbicide used widely in conventional tillage), that have recognized pollutant effects. Other chemicals used are the same as for conventional tillage, but the environmental conscience awakened in CA farmers increases the adoption of integrated pest management (IPM), ensuring reduced use and safer handling and application of these products. Most modern selective post-emergent herbicides are applied at very low dosages of active ingredients, (often only grams/ha) and these, along with all other agricultural chemicals, are subject to intense biological breakdown by the action of the bacteria and fungi which feed on the surface humus, besides being bound to soil organic matter and mineral surfaces. Zero tillage systems avoid Atrazine or reduce its use to post-emergence, thereby creating a ZT buffer effect, whereas pre-emergence herbicide use is the norm in most conventional systems.

Desiccant herbicides, whose use in ZT have given rise to some criticism, are either practically unleachable because they are bound to soil colloids within minutes of application (Prata *et al.*, 2000; Goellner 1989), which is the case of Glyphosate, or have a very short half-life due to biodegradability or instability, as for Ammonium Gluphosinate. Table 18 shows that the principal desiccants are alone in the least leachable category of the groundwater ubiquity score (GUS). For example, Glyphosate, by far the most widely used desiccant in ZT systems, is classified in the lowest toxicology rating in Brazil (Class IV, green stripe),

TABLE 18: **GROUNDWATER CONTAMINATION POTENTIAL OF DESICCANTS AND OTHER HERBICIDES**

HERBICIDE	Koc* (ml/g)	T (time in days)	GUS**	POTENTIAL FOR CONTAMINATION OF GROUNDWATER
Glyphosate	24.000	47	-0,6357	Very low
Ammonium Gluphosinate	100	7	1.6902	Low
Paraquat	1 000 000	1.000	-6.0000	Very low
Alachlor	124	21	2.5209	Medium
Atrazine	100	60	3.5563	High
Chlorimuron	110	40	3.1378	High
Cyanazine	190	14	1.9727	Medium
2,4-D DMA salt	20	10	2.6990	Medium
Diuron	480	90	2.5773	Medium
Fomesafen	60	100	4.4437	Very high
Metholachlor	200	118	3.5201	High
Nicosulfuron	30	21	3.3358	High

* Organic carbon partitioning coefficient (used for measuring how tightly bound a pesticide is).
** Groundwater ubiquity score: Calculated by the formula GUS = log T 1/2 x (4 – log Koc); values below 1.8 indicate low potential for groundwater contamination.

Source: Adapted from the Herbicide Handbook, SSA, 7th Edition (1994).

based on its very low toxicity to humans and non-leachability. This, however, does not mean that these products can be used carelessly. Farmers applying CA mainly use crop rotations, cover crops and mechanical means like the knife roller for weed management, and use desiccants and herbicides only if and as needed.

On CA farms, proof of enhanced biological activity abounds, principally the increased levels of soil fauna and flora, of which the mesofauna are the most evident, exemplified by earthworms and the burrows of scarab beetle larvae. Hayes *et al*. (2003) showed that concentrations of as little as 0.1 ppb of Atrazine have been shown to cause hermaphroditism and genital deformity in frogs on conventional farms, and although Atrazine-resistant populations are now appearing, amphibian population decline continues to be a serious global matter. According to the World Conservation Union (IUCN, 2001), agricultural lands continue to be an important focus for biodiversity conservation, and one of the keys to continued conservation is ecological education of decision-makers and farmers, which allows them to continue adopting more environmentally friendly farming methods. By limiting the amount of chemicals released into air, soil and water, CA farmers can continue to play a crucial role in biodiversity conservation by the protection of specific habitats.

In addition to the reduction of herbicides used, the increased environmental awareness of CA farmers in Brazil has led to a number of farmers' groups (Clubes Amigos da Terra) managing, or actively collaborating with, centres for the recycling of used agricultural chemical containers. In 2005 alone, Brazil recycled approximately 65 percent of these containers (INPEV, 2005).

Compared to conventional agriculture using ploughs and discs, ZT actually improves soil quality over time, reversing the loss of SOM. In the pampas of Argentina, which were originally fertile soils, top yields were produced without fertilizer, but SOM has declined from 6 percent a century ago to 2 percent today, as a result of exploitation with conventional land preparation, provoking continuous oxidation of organic matter, in order to mine soil fertility and generate agricultural exports. The pampas example further underlines the need for a sustainable approach to modern agriculture, such as through ZT and ICLZT.

SOCIAL BENEFITS OF ICLZT AND INCREASED LAND USE INTENSITY

The fundamental changes in soil behaviour and management, referred to in Chapter 1, bring a number of benefits to society, besides reducing on-farm production costs (Landers *et al*., 2001). Adjusting the approximate first estimate for Brazil (which requires revision, but used the most conservative data available at the time) for 50 percent versus 35 percent of adoption, the total gains with CA were estimated at US$ 1.9 billion in 2004/5. Besides the direct benefits to farmers (26 percent of the total), the principal indirect-use benefits constitute reductions in public spending. These derive from the value of the reduced clearing of native vegetation (57 percent of the total); reduced off-farm effects of soil erosion (silting, road maintenance and water treatment); lower emissions of greenhouse gases; carbon sequestration; and enhanced aquifer recharge (due to increased rainfall infiltration).

Besides these quantifiable benefits, a number of un-quantified benefits have been noted after the conversion to CA, usually increasing over time. Dust clouds from land preparation are eliminated in rural towns, as are the effects of residue burning on air quality; flood peaks are lower; and base flows of watercourses increase and springs have begun to flow again due to the 70 percent greater rainfall infiltration (De Maria, 1999). Also, the cost of reservoir silting may have been seriously underestimated, since another estimate (Carvalho *et al*., 2000) was 76 times higher than the conservative value chosen by Landers *et al*. (2001). These assumptions require more in-depth study, which may well increase the recognized benefits of converting to CA, ZT and ICLZT systems. It is implicit that not paying environmental services for preservation of native vegetation is a negative stimulus to conservation.

In many tropical and subtropical regions, land clearing is a response to increased demand for agricultural products. Land clearing, in turn, leads to loss of biodiversity, which is a growing concern in many societies. But without a value placed on the preservation of natural vegetation, land clearing will continue to be the cheapest route to increase food and fibre production. However, if environmental services payments were offered for increased LUI, deforestation could become economically less attractive.

Table 17 in Chapter 5 shows, in the bottom line, how many hectares of decreased demand for clearing native vegetation correspond to each hectare of LUI with ICLZT, starting from a base of degraded pasture. The realization of this mitigation potential depends on effective policy stimuli to ICLZT and constraints to clearing; the former implies a value put on each hectare of native vegetation spared, to use as a base for an environmental services payment to the farmer who intensifies the use of his land, thereby eliminating the need for frontier expansion. The latter implies tighter control of licensing to clear new land and effective policing of this, which will be enormously facilitated if farmers feel they are being fairly treated with incentives to LUI. With the right incentives it is possible to address this problem, as studies show that farmers respond logically to economic stimuli, thereby making LUI more attractive than clearing.

The mitigation potential of each system in Table 17 ranges from 2.52 ha of reduced demand for clearing new land for every hectare in the ICLZT system of Model No. 5, to 0.45 ha/ha in Model No. 2. The average of all models and their variants adopting ICLZT was 0.99 ha saved from clearing per ha converted to an intensified integrated crop–livestock ZT system. The differences are due to different proportions of annual crops to pastures (stubble grazing to permanent pasture) and different increases of stocking rates over the "without-project" situation. This shows considerable potential for policy actions to mitigate the loss of native vegetation, if society were willing to contribute to the transition costs of LUI and supply technical capacity-building and credit for the investments required. The largest of these is a relatively short-term increase in incremental working capital for purchase of additional animals to take advantage of the greater forage availability.

SOCIAL SUPPORT FOR CONVERSION INVESTMENTS IN ICLZT

As a result of minimizing erosion, increasing, or even maximizing, crop yields, soil biological activity and nutrient recycling, reducing market and climate risks and improving profits, farmers in Brazil are focusing on ICLZT, which intensifies land use and, consequently, mitigates the demand for further land clearing. This win-win-win situation merits the recognition of society, through a policy of both financial and non-financial incentives.

Farmers in other tropical and subtropical regions have also started focusing on ICLZT, but reliable support facilities to aid in the transition appear to be the key to conversion from conventional farming systems to intensive ZT systems, especially for small farmers. Without the appropriate incentives, training, or equipment, many small farmers may see conversion as too risky an undertaking.

Addressing the conversion needs of small farmers

In addition to training and up-to-date information on ICLZT systems, more tangible items such as cheap and simple equipment are considered the first step in addressing the needs of small farmers wishing to convert. Examples of simple and easily adaptable equipment, which can be used manually or drawn by animals, can be seen in Plates 19–27 on the following pages. Institutions or extension services can support small farmers by providing equipment or micro-loans needed to purchase the equipment, as well as the necessary training and information needed to begin.

Plates 19–27 were chosen from a photo gallery of FAO-supported projects to illustrate equipment that can be adapted for resource-poor farmers. Their use in different regions shows that CA, ZT and ICLZT systems are adaptable for a range of biophysical environments.

PLATE 19: Hand jab planter demonstrated for direct seeding by hand. Guantanamo, Cuba. October, 2006.

PLATE 20: Manual traction boom sprayer used for desiccation of degraded *Brachiaria* pasture as preparation for no-till maize planting. Goiania, Brazil. September, 2006.

PLATE 21: Animal traction no-till planter used for direct planting of maize into knife-rolled and desiccated spontaneous vegetation (weeds) used as soil cover. Posoltega, Nicaragua. June, 2005.

PLATE 22: Animal traction boom sprayer used for desiccation of cover crop. Posoltega, Nicaragua. June, 2005.

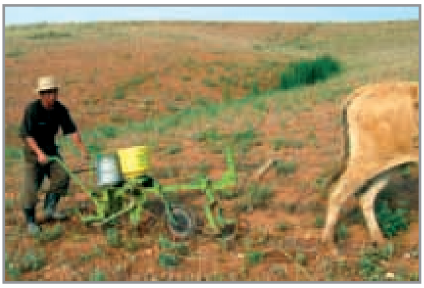

PLATE 23: Animal traction no-till planting of maize on degraded hill site. Jung San Up farm, Democratic Peoples Republic of Korea. June, 2004.

PLATE 24: Animal traction rolling punch planter made in Kenya for direct seeding into unprepared soil. Jinja, Uganda. May, 2002.

PLATE 25: Animal traction no-till planter used for planting beans into desiccated sorghum. Guantanamo, Cuba. October, 2006, (details in Plates 26 and 27).

PLATE 26: Chisel-type fertilizer boot (furrow opener) behind cutting disc; offset double-disc seed furrow opener at rear. Brazilian type animal traction no-till planter, used in various countries.

PLATE 27: Close-up view of the cutting disc, fertilizer boot and offset double-disc seed furrow opener (of a tractor-mounted ZT planter).

Equipment suitable for small farmers as illustrated in Plates 19–27, which should be easily adaptable for a wide range of biophysical conditions, is necessary for promoting ICLZT systems in the different tropical and subtropical regions of the world. The most important concept to keep in mind is that while the principles of CA, ZT and ICLZT are universal, the solutions are local and farmer-led (which crops to rotate, which equipment to use, access to inputs, etc.). Therefore, institutions or extension services supporting small farmers must inquire from the farmers themselves about the bottlenecks they are facing. They should assure availability and accessibility of low-cost equipment, facilitated and supported by local and national government actions and enabling policies. Technical solutions to local problems during the adoption phase have to be found in collaboration among farmers, extension technicians and scientists. The classic roles of technology development and transfer have proven not to work well for CA and to take too much time. The farmer him/herself is often the most creative developer when it comes to finding locally adapted solutions. Technical support from organizations such as FAO and CIMMYT, EMBRAPA and CIRAD, and funding from the World Bank, Regional Development Banks and donor countries are especially important to further encourage governments to facilitate the spread of ICLZT.

CONCLUSION AND POLICY RECOMMENDATIONS

In the drive to meet the demands of present-day society, without compromising the ability of future generations to meet their own needs, sustainable forms of agriculture are an essential element. Farmers are all too often caught in the cross-fire of differing societal demands for products that are cheap, yet produced in an environmentally friendly and socially responsible way. Since CA, ZT and ICLZT systems as described in this publication address some important societal needs such as food security, biodiversity preservation and natural resource conservation, they constitute a major step towards systems that can truly be called sustainable.

While the specific technologies vary depending on local conditions, the approaches toward sustainable intensification based on incorporation of pastures and livestock into ZT crop production are very promising. The biology of the approaches of what is found to work in Brazil will give useful insights on what farmers in other parts of the world, including smallholders in African savannahs, might consider when developing their own sustainable intensified production systems. This publication can therefore be used as a starting reference, benefiting not only farmers and consumers in tropical and subtropical regions, but possibly expanding into other regions as well, thus serving to benefit human society as a whole.

Policy recommendations for promoting ICLZT in tropical and subtropical regions

- Equipment lending, especially to small farmers
- Providing farmers with seed for cover crops, including through producer training and market development
- Support to the input supply sector to make suitable ZT equipment and inputs available and accessible to farmers in the long term
- Promotion and funding of farmers clubs
- Micro-loans enabling small farmers to convert to CA and diversify
- Reduced premiums on crop insurance
- Payments for environmental services performed (such as erosion control, carbon sequestration, forest/biodiversity preservation, watershed protection and habitat conservation)
- Increased cooperation among governments, agricultural extensionists and research institutes
- Increased information exchange networks between national and international research organizations, development organizations, private companies, producers and cooperatives, and donors
- Further funding of ICLZT projects by international donors and donor countries.

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Tropical crop–livestock systems in conservation agriculture
The Brazilian experience

This publication describes how pasture, fodder and livestock production have been integrated into conservation agriculture systems in Brazil's tropical zones. 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.

Integrated crop–livestock zero tillage systems allow for 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 fertility and biological activity of the topsoil is well known. The economics of the system are discussed and its very positive ecological effects are described at length.

This publication is geared towards agronomists, advanced farmers, extension workers and agricultural decision-makers throughout the tropics and subtropics. It is hoped that the many lessons learned and technologies developed in the Brazilian tropics can serve, with the necessary local adaptation, as a starting reference for other tropical (and subtropical) zones.

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