A NEW SOLUTION FOR OLD PROBLEMS IN BRAZIL: CROP-LIVESTOCK ROTATIONS WITH ZERO TILLAGE AS A SUSTAINABLE LAND MANAGEMENT TOOL

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ABSTRACT

Land clearing has been the traditional tool for creating greater agricultural production since time began. All who consume the products of the land, in whatever form, are part of the sacrifice, willing or not, of biodiversity to generate sustenance and wealth (Declaration of Madrid, 2001). The farmer is omnipresent in areas which produce food and fibre and in many where timber is a product ; he should be encouraged to become a "steward of the land", receiving environmental services payments for this responsibility. These are not subsidies, first because the off-farm benefits to society of ZT adoption (achieved, overwhelmingly, at the farmer´s expense) generate huge social transfers and, second, the WTO regulations do not classify these payments as such. The mitigation potential of land use intensification with integrated ZT crop x livestock systems (ICLZT), can vary between 0.8 and 2.5 ha of reduced demand for land clearing for each hectare in the system. By using a ZT crop ley for two to four years, the cost of pasture renovation is defrayed and pasture carrying capacity is trebled, from an average of about 0.7 animal units (AU)/ha to over 2 AU/ha. Both historical data surveyed and five spreadsheet models of real farms developed in this study, substantiate this. The study also shows higher net present value (NPV) and internal rate of return (IRR) values accompanying this new technology. Brazil has now established a national programme for ICLZT. Financial and other incentives, such as farmer and technician training, good technical backstopping from on-farm-research and preferential access to credit, are required to overcome the initial risk of change and incremental investments required to adopt the new technology. Recommendations are made for a fiscal package which emphasizes the "carrot" approach, but which sharpens the "stick", when necessary. Also proposed are international credit projects for large-scale adoption of ICLZT systems.

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INTRODUCTION

Land clearing has been used worldwide to expand agricultural and timber production since time began. The developed countries' industrial revolution had pushed deforestation to its practical limit at least a century ago. Today, when the world cries out against loss of biodiversity in developing countries, the fact that the decimation of natural vegetation was used in developed countries as a prime tool for generating wealth is largely overlooked. In the global economy, consumers demand lower and lower prices. These are attained by higher and higher efficiency in production processes. Agriculture is no exception : Brazil´s farmers have reduced the cost of basic foodstuffs by 5.5% over the last ten years, but the prices of their inputs have risen more. The enormous social transfers in this one-sided relationship have been made possible chiefly as a result of three efficiency factors (i) public and private genetic programmes increasing yield potential in crops and livestock, (ii) increased use of fertilizers and other inputs and (iii) the adoption of Zero Tillage and jettisoning of traditional ploughing lore. Although the latter was foreseen by Faulkner in "Ploughman's Folly", published in 1949, it was only realised *de facto* through the advent of herbicides. Rachel Carson's "Silent Spring" raised the spectre of unsustainable use of agricultural chemicals, polluting soil, water and air. In order to feed an increasing world population, presently over 6 billion, we have to compromise. This may be anathema to the purists, but without fertilisers and agricultural chemicals there would be widespread starvation in a world overtaxed by population growth (Norman Borlaug, in his 1979 speech as Nobel Laureate for Peace).

There is apparently no effective democratic solution to halt population pressure and high consumption, which are the real villains behind deforestation. Bio-fuels could exacerbate this. If the public desire to preserve native vegetation and biodiversity is to be satisfied, there is only one solution – land use intensification (LUI) within the exisitng agricultural frontier. There are three potentially effective routes :

(i) *vegetarianism,* resumed by Robert Goodland, the World Bank's first ecologist, in his 1985 article as "Kill less, eat more";

(ii) *irrigation, now* nearing its limit on available water supplies, while depending on very heavy investments to improve water use efficiency;

(iii) *integrated crop-livestock rotations with Zero Tillage (ICLZT)* in the tropics and sub-tropics, using synergy and symbiosis to maximise the production from ever-scarcer land and water resources.

This paper will deal with the benefits of the latter technology, which repesents a recent win-win-win breakthrough, and the policy decisions required to make it happen. ICLZT is the most cost-effective investment route to preservation of native vegetation, with a significant international outreach. But the consuming public must understand that it is an investment to be shouldered by all.

The Technology

Zero Tillage requires that crop residues be left on the surface to protect the soil.and provide humus. The latter acts as a substrate for enhanced biological activity, improved soil physical properties, organic matter buildup, nutrient re-cycling and other important soil functions.This technology dispenses with all cultivation practices, except minimal disturbance in the planting operation and permits no burning of crop residues. After pre-plant desiccation of a cover crop and/or weeds, with non-selective herbicides of negligible environmental impact, specialized planters, or drills, cut the crop residue with trash discs and slot the fertilizer and seed into the soil. But Zero Tillage is not just an alternative planting method, it represents a change in agricultural paradigms and has triggered a more responsible attitude towards the environment, regarding nature as an ally, rather than a foe to be overcome. The ZT farmer takes a more systemic view of his farming enterprise, combining 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 is what confers sustainability on the system and maintains a high yield potential.

Integrated ZT crop-livestock systems (ICLZT) rotate high-yielding pastures and ZT crops. The ZT crop phase supplies residual nutrients for cheap pasture establishment and the pasture phase reduces pest, weed and disease levels, reducing the amount and cost of chemical controls and also re-structures the soil and builds up organic matter. Carbon sequestration under ZT has been shown to be enhanced by the presence of nitrogen from legume cover crops (Sisti et al. 2004).

There are 60 milllion hectares of cultivated pastures in Brazil´s central Cerrado (savannah) region and another estimated 20 million in the Amazon. Degradation starts wirth overgrazing, leading to nutrient deficiencies and progressing to loss of soil structure, exacerbating erosion losses (Macedo, 1995). Successful ICLZT adoption requires careful diagnosis of the state of degradation in order to recuperate the soil to produce high crop yields. This may require an initial physical intervention, but thereafter there is ZERO tillage, providing adequate biomass be generated.

A significant breakthrough was achieved in Brazil by adapting an old technique of interplanting corn or upland rice with a pasture grass. Now called the "Santa Fé System", undersowing of *Brachiarias brizantha* and *ruziziensis* and *Panicum maximum* cultivars *(*Kluthcouski et al. 2003) has been shown not to depress maize or rice yields, while coming through with the last rains after harvest to provide strategic winter grazing. Oversowing in soybeans has also been successful, but undersowing still has limitations due to competition from the grass, suppressing soybean yields.

Pasture establishment under a nurse crop effectively increases farm carrying capacity by removing the winter feed bottleneck in permanent pastures, providing supplemental feed from the arable area (Vasconcellos and Landers, 1992). However, stubble grazing does remove some of the crop residues generated by the system and Séguy et al. (2002) have shown a negative correlation between biomass in residues and annual crop yields. One reason why adopting farmers appear satisfied with subsequent annual crop yields is that *Brachiaria spp.* have been shown to exercise considerable control over soil fungi, reducing yield depression from *Fusarium oxysporum, Rhizoctonia solani* and *Sclerotinia sclerotiorum (*da Costa & Rava,2003, & Nasser, 2001*),* while also contributing to soil aggregate formation through root exudates. This has been especially important in the rainfed edible bean crop (*Phaseolus vulgaris)* , where farm yields of over 3000 kg/ha have been reported (Conrado, S., personal communication, 2004). Another feature of first-year *B. Brizantha* is that it stays green for several months after the end of the rains and winter stocking rates of over 3 AU/ha have been reported in West Bahia on corn stubble with *B. Brizantha* (Döwich, I. Personal communication, 2004). Eventual excessive grass growth in the corn crop can now be checked with sub-lethal applications of selective graminicides (Cobucci & Portela, 2003).

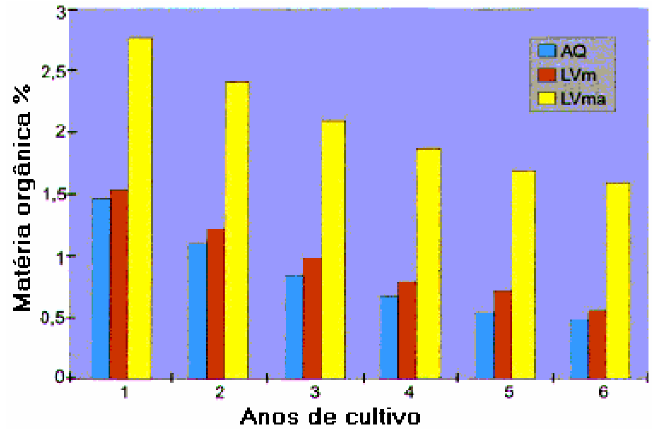
The most common rotations in use are soybeans/soybeans/maize, soybeans/soybeans/soybeans/maize or soybeans/cotton/ maize, followed by a one to three-year pasture phase. On old crop land with a high nutrient status, very high feed quality *P.maximum* cultivars can be used, but after the first or second crop phase on degraded pastures, *B. Brizantha* is used, due to its greater rusticity. Increasingly, *B. ruziziensis* is being favoured due to a considerably lower rate of Glyphosate or Sulphosate herbicides for dessication and also for its ease of germination when oversown. Siince stocking rates fall off rapidly, the option for a one year pasture phase and *P. maximum* cultivars ensures the highest possible winter stocking rate and the smallest proportion of farm area in pasture. Under this system, fat grass-fed steers are being sold at 24 months old (Ake van der Vinne, personal communication, 2004).

Providing there are no physical obstructions (e.g. gullies or termite mounds) and the lime status of the soil is adequate, crops can be planted straight into desiccated pasture, using a trash disc to cut the desiccated biomass, followed by a knife coulter for the fertilizer and an eccentric double disc for the seed. Contrary to early expectations, this removes the surface compaction caused by cattle hooves (maximum depth 10-12 cms) and allows the crop, usually soybeans, to develope normally, taking full advantage of the excellent crumb structure left by the pasture below the surface. Brachiaria roots have been detected at 3 meters depth, re-cycling nutrients and water. In the established rotation, maintenance lime dressings (usually not more than 1 ton/ha) are surface-applied on the last year of pasture. Brazilian-made planters perform well in these conditions, except where large clumps are present (especially the case with thinly-sown *P. maximum).*

Reversal of soil degradation in the tropics

The Zero Tillage technology in the Brazilian tropics has proved to be the turning point for achieving sustainable production in these latitudes, since it actually reverses organic matter loss and builds up soil carbon levels (Derpsch, 2002 and Sisti et al.2004). It is now a model for tropical agriculture worldwide. Oxidation of soil organic matter in soils is extremely rapid when warm soil is cultivated in any way: more than 50% of the total CO_2 in the soil is released in only 24 hours after mouldboard ploughing in USA (Reicosky & Lindstrom, 1995), hence the emphasis on ZERO tillage. Figure 1. shows disastrous levels of SOM loss in Ferralsols and Ferralitic Arenosols in West Bahia (latitude approx. 12ºS) under monocropped soybeans and disc cultivation. Inclusion of maize (or other heavy biomass main crop) and cover crops in the rotation are another requirement for sustainability. SOM is responsible for most of the cation exchange capacity (CEC) in tropical Ferralsols and Ferralitic Arenosols; this leads to greater nutrient efficiency through reduced leaching and higher biological activity resulting from the presence of more organic substrates. Water-holding capacity also increases in proportion to the SOM and also due to improved soil structure.

In terms of soil and water losses, ZT management also generates huge dividends. Average soil losses under conventional tillage practices in the review of 32 experiments carried out by de Maria (1999) were 23.3 ton/ha/yr, reduced by 79% to 5.6 ton/ha/yr under ZT. Surface runoff losses were also reduced by 69%, increasing aquifer recharge and dry-



Source: Silva et al., 1994.

Figure 1. Organic matter losses in three tropical soils under continuous soybean cultivation
AQ = Arenosol; LVm = Ferralsol (Dark Red Latosol, medium texture);
Lvma = Ferralsol (Red-Yellow Latosol, heavy texture)

season base flows. These results are confirmed by experienced ZT farmers with a high residue level on their soil, who have eliminated their contour banks, with no deleterious effects, on slopes of up to 4% and ramps of over 2 kms. Blancaneaux et al. reported infiltration rates of over 300mm/hr on cerrado soils under ZT for several years. Removal of contour banks is not recommended without these pre-requisites (high residue levels and infiltration rates and moderate slopes). Reduction of the height of contour banks, or simply not maintaining them, is preferred. Alongside roads, Brazilian law requires the farmer to receive the road drainage and here contour banks and stilling basins are very necessary. Hernani et al. (2004) estimated the annual cost of losses caused by erosion in Brazil at US$5.3 billion and Landers et al. (in press) estimated the annual economies generated by the adoption of Zero Tillage at US$ 2 billion.

Table 1. Average soil and water losses from 30 experiments in Brazil, comparing Zero and Conventional Tillage

Category	**Conventional Tillage**	**Zero Tillage**	**Reduction ZT vs CT**
	(ton/ha/yr)		**(%)**
Soil Loss	23.3	5.6	76
	(mm/yr)		
Runoff loss	137.4	42.4	69

Source : derived from de Maria (1999)

To achieve all these benefits, the three pillars of Zero Tillage must be respected :

(i) no use of tillage implements to turn over the soil;

(ii) higher bio-diversity through pluriannual crop rotations and biological controls;

(iii) maintenance of crop residues on the surface, i.e. NO BURNING.

Mitigation of De-forestation

Landers & Weiss (2004) carried out five case studies with farm data, analysing the financial and technical implications of these systems in the Amazon, Cerrado and Atlantic Forest biomes of Brazil. Detailed costings of crop and animal production data were projected in 20 year financial models. The study also shows higher NPV and IRR values accompanying adoption of ICLZT (Table 2). While these technologies are more profitable, they also demand both capital investment and higher management capacity. The results are conservative, since the farms studied were already at a relatively high management level without ICLZT.

By using a fertility-bulding ZT crop phase for two to four years, the cost of pasture renovation is defrayed and winter pasture carrying capacity (the bottleneck for increasing herd size) is improved. In the models, the winter stocking rates were significantly increased, with increments of 0.72 to 1.53 AU/ha over a stocking rate of 0.5AU/ha on degraded pasture, derived from Table 3. This table also shows an average mitigation potential of the ICLZT system of 0.99ha of reduced demand for de-forestation per hectare in ICLZT. This ranges from 0.1 ha/ha to 2.52 ha/ha, depending on the proportion of crops to renovated pastures and the relative increase in winter stocking rate, which affect total farm carrying capacity. Also analysed were the different policy options to stimulate adoption of ICLZT technology and generate the potential mitigation effect of LUI on the demand for clearing new land.

Vilela (2004) monitored farm results from Uberlândia, Minas Gerais state showing conversion from cerrado vegetation to pasture and the process of pasture renovation with a crop phase, beginning in 1983 with 100% degraded pasture and a stocking rate of 1.1 head/ha (yearly average), progressing to 70% crops and 30% pastures in 2003, with a stocking rate of 2.6 head/ha; this results in a mitigation potential of 2.2 ha/ha. This farm has been practicing ZT for 13 years.

Principal Policy Recommendations to Mitigate Deforestation through ICLZT

Landers & Weiss (2004) recommended the following incentives for sustainable land-use ICLZT technology:

1. Recognition of ICLZT as a Best Management Practice (BMP) as a basis for labelling sustainable products and justifying higher consumer prices;
2. Payment of environmental services grants to farmers who practice sustainable agriculture or forestry BMP systems (for ICLZT 50% on planting crops in pastures, 50% on reverting to pasture, for re-forestation, a monthly payment for number of trees surviving);
3. A package of tax rebates or reductions, more favorable credit conditions and credit priority – these need not be part of Incentive 1, above;
4. Updating of potential land use calssifications to include ZT in zoning plans;
5. A public awareness campaign to recognize the farmer as a "steward of natural resources" and thus legitimize environmental services payments.
6. Support for technology development and promotion through grants for farmer-led on-farm experimentation with farm-scale equipment and dissemination programs.
7. It is recommended that consideration be given to an internationally-supported sustainable timber futures market to fund widespread re-forestation for small farmers using ZT;

   To these can be added:

8. A special mechanism for funding of carbon sequestration in ZT agriculture to redress this omission in the Kyoto protocol.
1. Urgently needed also is a reform to the land tax system which presently penalises undeveloped land outside statutory reserves and forces landowners into a long and costly bureauocratic process to declare the area as a private reserve; exempting native vegetation from all taxes would be much simpler and far more effective.

This study suggests that, although ICLZT technologies are profitable, due to risk aversion and higher demands on management and investment capital, it would be best that a straight grant or annual payments accompany promotional activities, where farmers organizations should play an important role.

Why can't Brazilian society afford to make this technology more attractive to farmers?

For this to happen, society as a whole would have to recognize its collective responsibility for deforestation and not use the farmer as a scapegoat. The Declaration of Madrid resumed the situation quite poignantly, stating "*the conservation of natural resources is the co-responsibility - past, present and future - of all sectors of society, in the proportion that they* *consume products resulting from the exploitation of these resources*". (Saturnino & Landers, 2002). In Brazil, the unfair public image of all farmers as anti-environment villains and renegers on debts needs to be reversed and the sustainable ZT farmer seen as a vital element in preservation and conservation actions. This is in consonance with Margulis (2003), who advocates bringing the cattle farmers into the environmental policy discussion in Amazon de-forestation.

Development Strategy

The public conscience needs to accept that land clearing occurs basically in response to public demand for agricultural goods As a first step in changing the ZT farmer´s public image, in order to establish the farmer as the "Steward of Brazil's Natural Resources" and, therefore, meriting environmental services payments, APDC/Petrobras will be organising three workshops for journalists in order to convince them of the new environmental conscience of the ZT farmer and by extension, the voting public.

A fiscal and policy package is required which emphasizes the "carrot" approach, but which sharpens the "stick", when necessary: the present punitive approach is not working well. Different development strategies are required for the Amazon biome and the Cerrado and Atlantic Forest biomes, but their interactions in the national agricultural economy need also to be taken into account. Policy changes need to be Brazilian-led and will take time and additional studies before coming into play. However, massive funding is required to make sufficient impact to permit a brake on de-forestation to be effective. Especially important will be inducements for the cattle sector to adopt ICLZT as the most cost-effective route to pasture renovation, higher profits. The farmers must also receive the recognition they merit for their role as stewards of natural resources. Presenting the results of Landers & Weiss (2004) in Brazil and internationally would assist in this effort. Immediate attention needs to be given to overcoming existing barriers to rental agreements.

Based on the above and other studies, by Broch et al. (1997) and the Empresa Brasileira de Pesquisa Agropecuária (Embrapa), summarized in Kluthcouski et al. (2003), in 2004, Brazil established a national programme for ICLZT entitled "Programa para a Transferência de Tecnologia de Integração Lavoura-Pecuária" (PROTILP) led by Embrapa. Private sector initiatives are also under way, led by the Associação de Plantio Direto no Cerrado, with funding from Petrobras and the Dutch DOEN Foundation, promoting training courses for technicians and farmers, pilot projects with Clubes Amigos da Terra; research by farmer foundations such as the Fundação Mato Grosso do Sul has also been fundamental

(Broch et al., 1997). There is already considerable private/public collaboration, avoiding duplication. Backstopping from on-farm-research, adoption grants and preferential conditions and access to credit, are required to overcome the initial risk of change and incremental investments required to adopt the new technology at a significant rate.

There is a clear need for an inter-ministerial working group to develope policy changes to implement incentives to ICLZT adoption, discussed above. Landers and Weiss (2004) have laid out a detailed discission which can serve as a point of departure.

CONCLUSION

The bottom line is that society can opt to compensate farmers for extra costs involved in LUI and thus achieve its goal of preserving biodiversity. The argument that the technology is profitable and so farmers should fund this themselves is self-defeating:

(i) adoption would not be fast enough to significantly affect de-forestation and,

(ii) increases in agricultural efficiency are passed directly on to the consumer.

In a just socoiety, the environmental services of farmers who produce sustainable products must be recognized.

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Table 3 Calculation of Mitigation Potential when Compared to Degraded P+A17astures (1).

	Case Study Models								
Parameter	**#1**	**#2**	**#3 Rot. 1**	**#3 Rot. 2**	**#3 Rot. 3**	**#4 Rot.1**	**#4 Rot. 2**	**#4 (iv)**	**#5**
Reduction in demand for new areas (ha/ha of renovated pasture) = **Mitigation Potential**									
Degraded pasture area (1)	885	980	2400	2400	2400	1000	1000	1000	252
AU/farm w/out project	442,5	490	1200	1200	1200	500	500	500	126
Renovated pasture area	285	150	1200	1200	1200	800	499	400	241
Renov, stocking rate AU/ha	1,76	1,96	1,49	2,03	1,93	1,22	1,6	1,58	1,82
AU/farm with project	501,6	294	1788	2436	2316	780,8	399,2	253	439
Increase in AU/hectare	**0,13**	**-0,40**	**0,49**	**1,03**	**0,93**	**0,56**	**-0,20**	**-0,49**	**2,48**
Crop area expansion	0,68	0,85	0,50	0,50	0,50	0,20	0,50	0,60	0,04
Mitigation Potential (2)	**0,81**	**0,45**	**0,99**	**1,53**	**1,43**	**0,76**	**0,30**	**0,11**	**2,52**

(1) Assumed that the farm starts as degraded pastures with a stocking rate (winter) of 0.5UA/ha
(2) 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.

Case Study Description	System	Crops + Pasture (ha)	Investmt. Yrs 1-4 (R$/ha)	IRR (%)	NPV R$)	Net Return R$/ha/yr	Stocking Rate AU/ha
Model #1, Cerrado Goiás state							
Cow/calf, annual rainfed/ irrigated crops high mgt.	ICLZT	885	3.265	10.98	133.760	187	1.76
Without, idem– medium .mgt level.	Without	885	3.190	8.21	-214.417	119	1.00
Model #2 Cerrado, West Bahia (drier)							
Cow/calf, annual rainfed crops,	ICLZT	820	1.188	17.09	521.969	260	1.65
400 ha expansion - crops not rotated with pasture, cow/calf,	Expansion	1020	1.422	12.38	326.519	239	0.40
idem without expansion.	Without	820	1.111	9.52	-27.170	170	0.40
Model #3 Cerrado,. Goiás							
Rainfed crops x beef rearing	ICLZT Rot.1	2400	885	32.67	3.169.357	260	1.77
idem + intensive grazing with electric fences	ICLZT Rot. 2	2400	885	16.92	970.676	146	1.96
idem + irrigated crops	ICLZT Rot. 3	2400	1.510	18.63	1.487.862	187	1.63
idem Rot. 1 withoout rotation w/pasture	Without	2400	816	24.52	1.832.688	183	0.93
Model #4 Amazon Beef - South Pará							
Itinerant 10 yr clearing cycle	Clearing cen.(i)*	1000	405	25.64	200.474	48	0.85
Pasture renovation *in situ*	Renov. Scen.(ii)	800	552	11.32	52.922	71	1.24
ICLZT with rice/soybeans	ICLZT Scen (iii)	1000	893	12.69	243.424	177	1.16
Pasture renovation via renting 20% of pasture for annual crops	ICLZT Scen.(iv)	800	556	16.45	241.649	86	1.20
Model #5 Atlantic Forest							
Small farmer, ZT with pigeon pea in pastures	ICLZT	261	1.607	4.23	-137.612	115	1.20
idem conventional tillage, no pigeon pea	Without	261	1.558	negative	-315.438	-14	1.79

Table 2. Summary results from the farm models

Source: Landers & Weiss (2004), field case studies * Includes land sale and purchase