Improving Productivity and Sustainability of Crop-Livestock Systems in Tropical Savannas of South America

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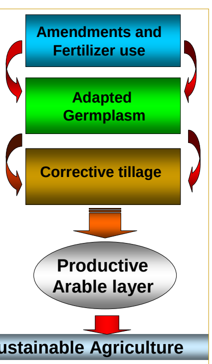
SUMMARY

The neotropical savannas (243 million hectares) in South America are among the most rapidly expanding agricultural frontiers in the world. Experience of commercial farmers and scientists in the Brazilian Cerrados has shown that most crop and pasture monocultures are not sustainable even under high levels of fertilizer use, due to pest and disease build-up, soil degradation and runoff and erosion. The challenge for farmers and scientists is to develop strategies for overcoming biotic and edaphic limitations to the achievement of sustainable crop and livestock production while minimizing environmental risks. To meet this challenge, scientists, in collaboration with farmers, must acquire a more thorough understanding of the processes that lead to degradation and develop alternative strategies for the amelioration of these negative factors. These processes are as yet not well documented . An analysis of major soil constraints to sustainable, highly productive crop-livestock systems in the Colombian Llanos lead to the conclusion that the soils needed improvement in terms of chemical, biological and physical conditions to make them more productive and suitable for conservation agriculture (no-tillage) systems. This conclusion is supported by the results from a long-term experiment in Colombia. A field experiment was established in 1993 to test the '***arable layer concept '.*** The concept is based on the use of (1) amendments and fertilizers; (2) adapted crop and forage germplasm; (3) vertical tillage to overcome soil physical constraints; and (4) agropastoral systems to build up an arable layer for sustainable agriculture. No-tillage, minimum tillage, and integrated crop/livestock systems are already proving successful in terms of farmer adoption. However, to ensure that, over the long-term, these marginal savanna lands are being developed in a sustainable manner, we need to understand the principles and functioning of these systems; appreciate the social, cultural, and economic aspects involved; promote a favorable policy environment; and seek a clearer understanding of the components of sustainability and their measurement.

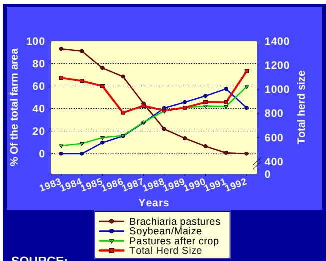
THE ARABLE LAYER CONCEPT

The build-up of an arable layer involves a combination of:

- **Use of chemical amendments to enhance soil fertility**
- **Use of adapted crop and forage germplasm**
- **Vertical tillage to overcome soil physical constraints**
- **Use of agropastoral systems to increase rooting depth and soil quality**



CROP/PASTURE INTEGRATION CASE HISTORY



An example of the striking potential for increased productivity through crop/pasture integration:
In 10 yrs, stocking rate increased from 1.1 to 2.8 A ha^{-1}.

Fzda. Santa Terezinha, Uberlandia, Brazil

SOURCE: Ayarza et al. (1993)

SITE CHARACTERIZATION

A long-term field experiment (Culticore) was established in 1993 on a well drained silty clay loam soil (Tropeptic Haplustox, isohyperthermic Kaolinitic) under mean annual rainfall of 2240 mm and mean temperature of 27 ºC. Soils have a pH of around 4.5 with very low values of exchangeable Ca, Mg, K, and P and very high Al saturation (about 90%). Bulk density and susceptibility to compaction are high.

EXPERIMENTAL APPROACH

Rotational Systems at Low and High Inputs

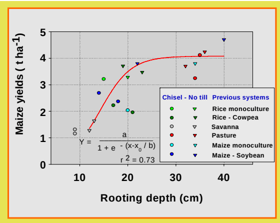
Fertilizer Lime	Remedial Lime
Monocultures	
Rice	Maize
Cereal-grain legume rotations	
Rice-cowpea	Maize- soybean
Cereal-green manure rotations	
Rice - forage cowpea	Maize - perennial soybean
Cereal-pasture rotations	
Rice with pastures	Maize with pastures
B. humidicola + S. capitata + A. pintoi	*P. Maximum + G. wightii + A. pintoi*

Source: Friesen et al., 1997

The experiment included lime rates of 2000 and 500 kg ha^{-1} for maize and rice respectively. Rice plots received an annual application of 200 kg ha^{-1}of dolomitic lime, 80 kg-N ha^{-1}, 60 kg-P ha^{-1} and 100 kg-K ha^{-1} and the maize plots 120 kg-N ha^{-1}, 80 kg-P ha^{-1} and 100 kg-K ha^{-1}. Legumes (cowpea, soybean or green manure) received 20 kg-N ha^{-1}, 40 kg-P ha^{-1} and 60 kg-K ha^{-1}. Pastures were fertilized every two years with 20 kg-P ha^{-1} and grazed for 5 years (4 years after maize). Native savanna plots were maintained for baseline comparisons.

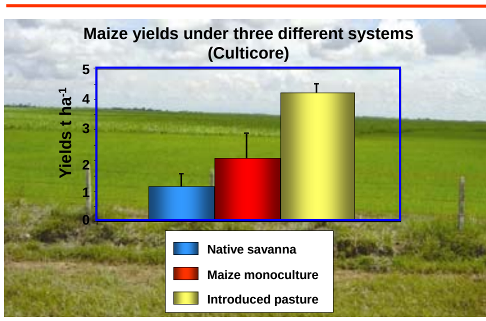
RESULTS

Maize roots after four years of crop/pasture rotation



As maize rooting depth increased, grain yields increased. Low yields (1 t ha^{-1}) were found when rooting depth was restricted to the 0-10 cm depth which occurred when maize was planted after native savanna. Higher grain yields were obtained when roots were able to penetrate to 40 cm depth, which occurred in maize plots after 4 years of the *P. maximum* pasture. As rooting depth increases roots had a higher volume of soil to explore and therefore could acquire more nutrients and water.

IMPACT OF ARABLE LAYER ON MAIZE YIELDS



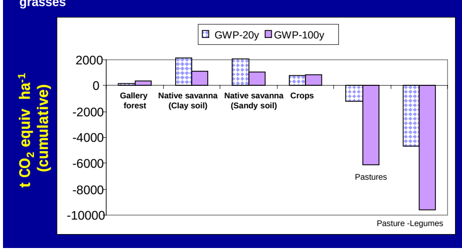
Average maize yields after 5 years of establishment of treatments show the effects of deep-rooted improved pasture on grain yield of maize in the agropastoral system compared with maize in monoculture plots.

INDICATORS OF SUSTAINABILITY

VARIABLE	OPTIMUM VALUES
Bulk density (g cm^{-3})	1.1 - 1.3
Water infiltration (cm h^{-1})	6 - 10
Hydraulic conductivity (cm h^{-1})	3 - 6
Available water (% vol)	25 - 30
Penetration resistance (kg cm^{-2})	5 - 10
Shear strength (KPa)	30 - 45
Macropores (%)	12 - 15
Mesopores (%)	20 - 25
Micropores (%)	12 - 15
Organic matter (mg kg^{-1})	4 - 6
Available P (mg kg^{-1})	15 - 20
Ca saturation (%)	40 - 50

Long-term experiments contributed to identify optimum values of soil quality indicators that are associated with high productivity. These also helped to quantify the reduction of greenhouse gas emissions of the systems tested below.

The introduced pasture-legumes system also reduced Global Warming Potential (GWP) mainly due to the reduction in gas emissions from biomass burning and to CO_2 sequestration as soil organic carbon by deep-rooted grasses



ECONOMIC PROFITABILITY

Alternative	Indicators of yield [1/]	
	Net present value (US$ ha^{-1})	Internal annual rate of return (%)
Grass alone	117	19.9
Grass-legume	531	37.4
Agropastoral	685	57.4

[1/] Period of evaluation: 10 years

Using the arable layer concept and agropastoral technology it was possible to improve profitability of production systems in the tropical savannas of Colombia.

CONCLUSIONS

1. Soil chemical, biological and physical factors limit agricultural development in the Colombian Llanos.
2. There is a need for improving chemical, biological and physical characteristics of infertile acid soils before they can be managed under no-till systems.
3. Improving and increasing the depth of the arable layer had a very positive impact on maize yields which were highly correlated with rooting depth.
4. Maize yields increased over time due to improvements in soil quality.
5. Further research is needed to understand the principles and functioning of crop-livestock systems in neotropical savannas; appreciate the social, cultural, and economic aspects involved; promote a favorable policy environment; and seek a clearer understanding of the components of sustainability and their measurement.

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