CULTICORE

a long-term experiment to evaluate and understand processes in

SUSTAINABLE CROP ROTATION AND LEY FARMING SYSTEMS FOR THE ACID-SOIL SAVANNAS

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Title: **SUSTAINABLE CROP ROTATION AND LEY FARMING SYSTEMS FOR THE ACID-SOIL SAVANNAS**

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RATIONALE: Intensification of agricultural production on the acid soil savannas of Latin America is constrained by the lack of diversity in acid (aluminum) tolerant germplasm and poor soil fertility. The use of high levels of inputs, especially in monocropping situations, is thought to be unsustainable since it results in deterioration of soil physical properties as well as escalation of pest problems.

Improved legume-based pastures, considered by many as least harmful to the soil resource base, require investments in inputs for establishment which are unattractive or beyond the means of extensive graziers. Establishment of pastures in association with rice (to defray the cost of inputs) has proven to be a very attractive alternative which is rapidly being adopted in frontier areas of the Colombian Llanos. However, as farmers see the profits to be made from rice, this development could easily deteriorate to one of continuous monocropping -- with disastrous results. Alternative systems incorporating components which attenuate or reverse the deleterious effects of monocultures are required, and biophysical measures of sustainability need to be developed as 'predictors' of system performance and 'health'.

Grain legumes, green manures, intercrops and leys are possible components which could increase the stability of systems involving annual crops. This project proposes to investigate a selection of alternatives using these components at two levels of intensification based on lime and, through intensive monitoring under controlled conditions, to identify indicators of sustainability of agropastoral systems in the acid savannas. Since many processes contribute to and interact with each other in determining the stability of any particular system, data will be collected toward the development of integrated models which simulate the effects of system components and management on system sustainability as exemplified by the identified predictors. Recognizing that the deleterious (or beneficial) effects of various agricultural practices are often subtle and only manifest themselves over long periods, the proposed experimentation is intended to extend through at least two rotational cycles.

OBJECTIVES:

1. Contrast soil biophysical measures of sustainability in potentially degrading and non-degrading production systems and, based on these measures, develop predictors of system performance.

2. Understand the biophysical processes which contribute to and interact with each other in determining the stability of any particular system.

3. Develop basic data for modelling integrated soil-plant systems involving rotations and leys to enable the evaluation and extrapolation of the effect of components and management practices on system stability.

HYPOTHESES:

1. Monocropping leads to soil degradation (and increased pest populations) and loss of sustainability.

2. Improved legume-based pastures are sustainable in the medium-to-long term but require inputs and periodic renovation.

3. Soil degradation can be reduced or reversed by rotating monocrops or improved pastures.

4. Inputs are required to maintain productivity and, by implication, sustainability.

5. Nutrient losses are reduced and use efficiency improved in rotational systems.

MATERIALS AND METHODS

Approach: Extremes in production systems involving crops and/or animals will serve as controls and will be contrasted with various intermediate options in long term rotations (5 years). The selection of mixed systems will be based, firstly, on tolerance to soil acidity factors (hence, levels of lime applied); secondly, on maintenance strategies for soil pH; and thirdly, on a reasoned 'best-bet' selection of appropriate crop and pastures species/germplasm for the agroeconomic environment being targeted. All systems will be managed to optimize production and minimize soil degradation; that is, crop residue conservation will be practiced, soil fertility levels will be maintained (unless a specific treatment dictates otherwise), weeds and other pests will be controlled, etc. Plots will be of such a size as to permit the use of conventional machinery which are likely to influence soil physical properties.

Location: CORPOICA/CIAT Research Station, Carimagua, Meta, adjacent the Core Experiment at Introductions II near Yoparé.

Experimental Design: Split-plot in four randomized blocks; mainplots assigned to rice-based (fertilizer lime) systems or maize-based (remedial lime) systems. Subplots assigned to systems.

Treatments: (See **Table 1**.) Selection of systems is based on whether lime is applied as a fertilizer (to supply Ca and Mg to Al-tolerant crop and pasture species) or a soil acidity ameliorant (to enable production of more Al-sensitive species). "Fertilizer lime" systems are based on upland rice grown in continuous monoculture or in rotations with green manures, cowpeas or adapted mixed pastures. "Remedial lime" systems are based on maize in continuous monoculture or in rotations with green manures, soybeans or less-adapted mixed pastures.

Plot size and Layout: Plot sizes are based on the total area required to support a minimum of three animals stocked at approximately two animals per hectare when rotated through the replications, after provision for splitting at a later date. Dimensions are chosen for ease of handling conventional machinery and with a view to a probable need to further split the plots in the future. Crop/pastures treatments assigned non-randomly to adjacent plots for logistical reasons in the handling of animals and provision of water to the paddocks. The experiment layout in shown in **Figure 1**.

a) Crop rotations: 3600 m^2 (200 m x 18 m or 180 m x 20 m)
b) Crop/pastures: 7200 m^2 (200 m x 36 m or 180 m x 40 m)

Implementation: The project will be implemented in two stages: rotations based on fertilizer lime rates and rice will be implemented in May, 1993; rotations based on remedial lime and maize will be implemented in April, 1994. During 1993, several satellite (preliminary) trials will be conducted to establish some of the basic agronomic, crop, and residue management questions related to maize production in the Llanos environment, especially with respect to crop-crop rotations.

Lime and Fertilizer Rates and Management: Rates of fertilizer and lime (see **Table 2**) will be based on nutrient requirements of each crop as determined by soil tests and small plot response trials. Adjustments will be made as new information becomes available during the trial. Systems involving pastures will receive lime only in the cropping phase whereas crops will receive lime regularly (annually?) at rates chosen to maintain Ca/Mg fertility or Al-saturation at targeted levels.

(a) Lime: broadcast and incorporated (two passes with a disk at right angles) three weeks before planting.

(b) Fertilizer: applied as a bulk blend of TSP, potash (KCl, one-third of total application), kieserite ($MgSO_4.H_2O$), zinc sulfate and borax in a band 5 cm below the seed at planting in Year-1. In subsequent years, broadcast application with incorporation before planting will be considered, depending on results of satellite trials. Nitrogen and K applications will be split: N will be broadcast as urea at approximately 2, 6 and 9 weeks after planting. The second and third K applications will be applied with the urea at 6 and 9 weeks.

Tillage and Weed Management: Native savanna was broken after burning in December 1992 in all cultivated treatments. Conventional tillage is practiced in all treatments except Treatment 9A; however, the timing of operations depends on the treatment in question and is dictated by the need to control weeds, and manage green manures and crop residues (see **Table 1**). The primary method of weed control is by timing tillage operations and appropriate agronomic practices to reduce infestations (e.g. appropriate sowing densities and row spacing). However, herbicides are judiciously applied when necessary to maintain a reasonable control where tillage practices are inadequate to the task. In Treatment 9A, herbicides are an essential part of weed management under no-tillage.

Pest and Disease Management: Pests and diseases are monitored closely throughout the season. Controls are applied when the need arises. Biological agents are used where they exist; however, where they do not or where severe threats occur, appropriate pesticides will be applied.

Grazing and Pasture Management: The operating principle in the management of pastures in the trial is the maintenance of an adequate legume content. The basic stocking rate is approximately 3 beasts per hectare (yearlings) but is increased or reduced periodically to maintain an appropriate level of biomass on offer and control grass-legume competition. Individual pasture plots are split and animals are rotated between the two halves every two weeks.

MEASUREMENTS AND OBSERVATIONS: Sequential measurements and observations will be made of critical soil properties and the impact of changing properties on crop/system productivity and profitability, resource and input use efficiency, and the environment. An inventory of soil samples taken at regular intervals will be maintained for future use. The following is a summary of observations and measurements considered important in assessing issues of sustainable production in the prototype systems under investigation. The list is not exhaustive and may be added to or reduced as appropriate as the experiment progresses. The frequency of observations will depend on the factors in question and resources available to carry them out. More detailed observations, especially at the process level, will be addressed in satellite experiments located in adjacent areas.

Crop and green manure observations:

(a) Grain yield and/or total above-ground biomass production
(b) Root biomass and distribution
(c) Nutrient concentrations in crop components (grain and residues) and green manure
(d) Crop phenological parameters and harvest parameters based on the IBSNAT minimum data set for the CERES crop models
(e) Incidence of pest and disease problems including weed populations which may affect yield.

Pasture observations:

(a) Botanical composition at regular intervals (every three months)
(b) Standing biomass and feed-on-offer at regular intervals
(c) Nutrient composition of pasture components
(d) Animal stocking rates and liveweight gains
(e) Root biomass production and distribution

Soil physical properties:

(a) Bulk density
(b) Porosity and infiltration rate
(c) Aggregate stability
(d) Penetrometer resistance
(e) Gravimetric moisture content (pre-plant and post-harvest; IBSNAT minimum data set)

Soil chemical properties:

(a)	Soil organic matter	▫ quantity and quality
(b)	Soil acidity	▫ pH, exchangeable Al and H
(c)	Exchangeable cations	▫ Ca, Mg, K
(d)	Soil N	▫ total, NH_4 and NO_3, mineralizable N
(e)	Soil P	▫ available (Bray-2, Olsen, P_i filter strip)
		▫ labile (^{32}P exchangeable)
		▫ organic and inorganic pools (Hedley fractionation)
		▫ microbial P
(f)	Soil S	▫ available SO_4
		▫ total S

Soil biology:

(a) Earthworm populations and dynamics.

Climatic variables: (IBSNAT minimum data set)

(a) Daily minimum and maximum air temperature.
(b) Daily total precipitation.
(c) Daily total solar radiation.
(d) Wet-and-dry bulb temperatures (humidity).
(e) Windrun.

Processes, etc. (to be addressed in microplots or satellite experiments)

(a) N_2-fixation by legume components.
(b) Rates of nutrient mineralization (N, P, S) or release (K, Ca, Mg) from crop residues, green manures and pasture litter.
(c) Gross nutrient (including fertilizer) budgets.
(d) Quantification of pathways of nutrient loss (leaching, fixation, volatilization, etc.).
(e) Dynamics of soil organic and inorganic P.

Table 1. Treatment description: First agropastoral cycle (five years).

Treatment No.	Main Plots	Sub-plots	Description
1	Fertilizer Lime	Rice monoculture	Rice grown in monoculture; one crop per year in the first semester; second semester weedy fallow turned in with early land prepn at end of rainy season.
2		Rice-cowpea rotation	Rice (1st semester) and cowpea (2nd semester) in 1-year rotation; residues incorporated prior to planting in following season.
3		Rice-green manure rotation	Rice (1st semester) and green manure (2nd semester) in 1-year rotation. Legumes incorporated at maximum standing biomass levels in late rainy season.
4		Native savanna (spare plot)	Managed traditionally by burning annually during dry season.
5		Rice-agropastoral rotation	*Brachiaria humidicola / Centrocema acutifolium / Stylosanthes capitata / Arachis pintoi* cocktail sown with rice in year-1; grazed to maintain legume content; rotated every 4 or 5 years depending on pasture composition.
6	Remedial Lime	Maize monoculture	Maize grown in monoculture; one crop per year in the first semester; second semester weedy fallow turned in with early land prepn at end of rainy season.
7		Maize-soybean rotation	Maize (1st semester) and soybean (2nd semester) in 1-year rotation; residues incorporated prior to planting in following season.
8		Maize-green manure rotation	Maize (1st semester) and green manure (2nd semester) in 1-year rotation. Legumes incorporated at maximum standing biomass levels in late rainy season.
9		Native savanna (spare plot)	Managed traditionally by burning annually during dry season.
9A		Maize-soybean rotation (no-till)	Maize (1st semester) and soybean (2nd semester) in 1-year rotation; tillage only to initiate cropping on native savanna; residues left on soil surface (no incorporation).
10		Maize-agropastoral rotation	Maize monocrop in year-1; *Panicum maximum / Glycine wightii / Arachis pintoi* pasture sown with rice in year-2; grazed to maintain legume content; rotated every 4 or 5 years depending on pasture composition.

Table 2. Initial Fertilizer Requirements.

Nutrient	Source	Nutrient Content (%)	Rice (including rice with pastures)		Maize (including maize with pastures)		Cowpeas, soybeans, green manures	
			Rate of nutrient (kg/ha)	Rate of source (kg/ha)	Rate of nutrient (kg/ha)	Rate of source (kg/ha)	Rate of nutrient (kg/ha)	Rate of source (kg/ha)
(Ca,Mg)	Dolomite	~10 (Mg)	50 (Mg)	500		2000		
N 1st appl.	Urea	46	20	43	40	87	20	43
2nd appl.	Urea	46	30	65	40	87	0	0
3rd appl.	Urea	46	30	65	40	87	0	0
P	TSP	20	60	300	80	400	40	200
K	KCl	51	33 x 3	65 x 3	33 x 3	65 x 3	30 x 2	59 x 2
Mg	$MgSO_4.H_2O$	17	15	87	15	87	10	59
S		23	20		20		13	
Zn	$ZnSO_4.6H_2O$	24	10	42	10	42	10	42
B	Borax	11	0	0	10	90	0	0

8 x 7200 = 57,600 m²
32 x 3600 = 115200 m²
Total 172800 m²
17.3 ha

Figure 1. Layout of Culticore experiment located adjacent Introductions-II Core experiment at Yopare.