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Soil Fertility Dynamics in Crop Rotations/Agropastoral Systems ("Culti-Core" and satellite experiments at Carimagua and Matazul)

In 1993, the CIAT Savannas Program in collaboration with the Colombian national program, ICA, established the "Culti-Core" experiment at the CORPOICA/CIAT Research Station at Carimagua on the Colombian Llanos. The goal was to study the biophysical and agronomic processes contributing to sustainability or lack of sustainability in a spectrum of alternative production systems based on component tolerance to soil acidity. The experiment includes "fertilizer lime" systems (lime applied at low rates solely as a source of calcium and magnesium) based on Al-tolerant upland rice grown in continuous monoculture or in rotations with green manures, cowpeas or adapted mixed pastures, and "remedial lime" systems (lime applied to reduce levels of soluble Al in soil) based on maize in continuous monoculture or in rotations with green manures, soybeans or less-adapted but better quality mixed pastures. All systems are managed to optimize production and minimize soil degradation by conserving crop residues, maintaining soil fertility, controlling weeds and other pests, etc. The plots are also large enough to allow grazing in the case of pastures, and to permit the use of conventional machinery which are likely to influence soil physical and biological properties.

"Culti-Core" is a multi-disciplinary project involving several institutions with complementary types of expertise:

- CIAT — germplasm, crop physiology and nutrition, root dynamics and systems.
- CORPOICA — germplasm, crop agronomy and management, soil physics.
- IFDC — soil fertility, nutrient cycling and management.
- CIMMYT — germplasm.
- CIRAD-EMVT — savanna ecology.
- ORSTOM and U. Complutense — soil biology.

The rice-based ("fertilizer" lime) rotations were initiated in 1993 while logistical difficulties required that installation of the maize-based ("remedial" lime) rotations be delayed until 1994. Cereal crops are sown at the beginning of the rainy season (about mid-April) and harvested in late-August. The second crop in the rotations (a grain legume or green manure) is sown as soon as possible thereafter. The fourth crop is now in the field in the case of the rice-based systems while the second crop has just been sown in the maize-based systems. Salient results currently available at this time are:

- average first year rice yields -- approximately 3.4 t/ha of paddy over an area of 7 ha.
- a well-established pasture undersown with the rice crop put to animals 3 months after harvest.
- no significant influence of undersown pasture on rice grain yields.
- average animal liveweight gains during 3 months of dry season -- 333 grams/day
- grain legume cowpea yields -- approximately 1130 kg/ha of seed over an area of 3 ha.
- marked increases in mineral nitrogen concentrations in the soil profile during the dry season due to incorporation of green manure (1.54 t-dry weight/ha) and cowpea crop residues (1.7 t/ha)
- lower weed infestations in the 1994 rice crop compared to monoculture rice due to the ground cover provided by legumes during the latter part of the previous rainy season.

- maize grain yield in the "remedial" lime treatments are about 2.5-3 t/ha (preliminary estimate), somewhat below its potential due to less than ideal germination and emergence.

Complementing the Culti-core systems trial on the Llanos are a number of satellite experiments designed to more accurately assess the nutrient requirements and constraints of component crops, and estimate nutrient losses and use efficiency under alternative management strategies on soils (Oxisols and Ultisols) whose mineralogical properties are not conducive to the efficient use of nutrient inputs. Experiments include the following:

- lime-potassium-magnesium balance trials (Carimagua, Matazul, La Florida) -- to determine the optimal balance of lime, Mg and K for component crops, to study the dynamics of applied cations and soil acidity, and the interaction of amendments on nutrient fluxes, fate and residual value.
- phosphorus residual value trials (Carimagua, Matazul) -- to determine the optimal levels of soluble phosphate fertilizer for the component crops, to characterize the fate of P applications, and to determine the residual value of phosphate applications and parameterize a model of P residues in highly weathered soils.
- silicon response trials (Matazul, La Florida) -- to identify a potential constraint to rice production on highly-weathered (desilicated) soils.

Results obtained thusfar from these experiments demonstrate the following:

- strong responses to Mg in rice and cowpeas with virtually no rice yield without Mg.
- K requirements of 80-120 kg/ha for rice and maize depending on soil texture.
- minor rice (acid soil tolerant O. Sabanas 6) responses to lime (as calcite) indicating a minimal lime application of 300 kg/ha as dolomite principally as a Mg source.
- somewhat higher cowpea requirements for lime (about 600 kg/ha applied to preceding rice crop).
- maximum yields (3.5 t/ha) of CIMMYT Al-tolerant maize germplasm with less than 1.6 t/ha of calcite (exchangeable Al saturation reduced to approximately 50%). Without lime (90% Al saturation), yields reduced to 2.6 t/ha or 77% of the observed maximum.
- P rates of approximately 40 and 80 kg/ha produced maximum yields with rice and maize, respectively, suggesting that these soils are not as strongly P fixing as expected. Preliminary observations also indicate large residual effects.
- rice yield increases of 500-1000 kg/ha and a dramatic reduction in the incidence of blast when Si is applied.

It is intended that these experiments continue for a period of four years to provide both basic data with respect to nutrient requirements in the Culti-core component crops, but also to quantify residual effects and nutrient losses in order to more intelligently manage inputs in the long-term trial.

Dynamic phosphorus pools (Brachiaria-kudzu trial, Carimagua; agropastoral trial, Matazul).

At Carimagua,

- the microbial P pool was larger in the grass-legume pasture compared with the grass alone, which in turn was slightly higher than the native savanna.
- microbial P was in general 2-5 times greater than the available P pool measured by the standard $Bray_2$ P soil test, clearly indicating the importance of microbes in P cycling and availability.
- grass-legume pasture maintained a higher amount of applied P in the surface soil apparently caused by more efficient cycling of P through labile P pools compared to grass-only pastures and native savanna.

At Matazul farm,

- microbial P levels were higher in systems involving rotations of rice with pastures than in rice monocultures.

Investigations such as these will be extended to the Culti-core experiment to determine whether short-term rotations with grain legumes and green manures have similar effects as those observed in long-term rotations with pastures.