IMPROVEMENT OF LOW FERTILITY SOILS (OXISOLS) FOR HIGH PRODUCTIVITY AND SUSTAINABILITY OF CROP-LIVESTOCK SYSTEMS IN TROPICAL SAVANNAS OF COLOMBIA

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

E. Amézquita, I. Rao, E. Barrios, M. Rondón, M. Ayarza, Phanor Hoyos, D.L. Molina and I.I. Corrales

International Center for Tropical Agriculture (CIAT). A.A. 6713, Cali, Colombia

E-mail: e.amezquita@cgiar.org; i.rao@cgiar.org; e.barrios@cgiar.org; m.rondon@cgiar.org; m.ayarza@cgiar.org; fhagar16@col1.telecom.com.co; dlmolina1@telecom.com.co; i.i.corrales@cgiar.org

♦ SAVANNAS OF COLOMBIA

- The Latin America savannas occupy about 250 million ha (50% of the world's savanna areas).
- The Eastern Plains of Colombia cover an area of about 17 million hectares.
- The Altillanura (flat savannas) occupies 3.5 million hectares.
- The soils are mostly acid, with high aluminum saturation, dominated by kaolinite (1:1), have very low cation exchange capacity and very low base saturation.

♦ MAJOR SOIL CONSTRAINTS FOR CROP PRODUCTION

For agricultural production these soils have the following limitations:

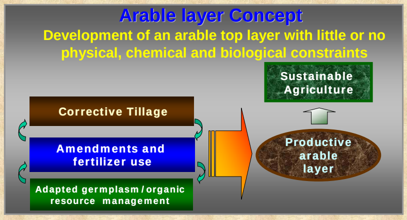
- Are very shallow, A horizon is of 10 to 20 cm thickness
- Have low rates of water infiltration (Photo 1)
- Are susceptible to the erosion and prone to surface sealing (Photo 2)
- They are hard and not easily penetrated by roots
- Have low aeration capacity
- Are very infertile

Photo 1. Low infiltration

Photo 2. Soil sealing

♦ SOLUTION TO OVERCOME THESE CONSTRAINTS IS TO BUILD UP AN "ARABLE LAYER"

To make these soils productive and to avoid degradation, it is necessary to develop an "arable layer". Arable layer, is a top soil layer built-up by farmer to overcome the physical, chemical and biological constraints and to form a rich, productive and sustainable soil in such a way that it is possible in the future to establish in it, a sustainable agricultural production system, that is economically and environmentally friendly.



To build-up an "arable layer" the following actions are needed:

- Evaluate the physical, chemical and biological constraints of the soil to a depth of 40 - 50 cm
- Based on these evaluations plan the soil and crop management practices needed to improve the soil to desirable conditions and depths.
- Vertical tillage with chisels is needed to improve the physical condition, applications of lime and fertilizers to improve the soil chemical conditions and use of tropical forage grasses that are genetically adapted to low fertility acid soil conditions to invade the soil with strong and abundant roots that will improve the biological conditions.

♦ EXPERIMENTAL RESULTS OBTAINED

A) Soil Physical properties

- Reduction of the bulk density (Table 1)

Table 1. Bulk density (Mg m^{-3}) and total porosity (%) according to the depth of soil

System applied to improve the soil	Soil depth 0 – 10cm		10 – 20cm		20 – 30cm	
	Bulk density (Mg m^{-3})	Total porosity (%)	Bulk density (Mg m^{-3})	Total porosity (%)	Bulk density (Mg m^{-3})	Total porosity (%)
Rice+soybean (rotation)						
1 Pass of Chisel	1.2 b	54.9 a	1.4 bac	46.6 abc	1.4 ba	45.1 ab
2 Pass of Chisel	1.2 b	53.6 a	1.3 c	51.1 a	1.4 ba	46.4 ab
3 Pass of Chisel	1.2 b	53.7 a	1.3 bc	49.9 ab	1.4 ba	48.1 ab
Rice+Grass (agropastoril system)						
Andropogon gayanus (Ag)	1.2 b	56.0 a	1.3 c	50.9 a	1.3 ba	49.3 ab
Ag+legume (Pp+Do)	1.2 b	53.7 a	1.3 c	51.3 a	1.4 ba	45.1 ab
Only legume (Pp+Do)	1.1 b	57.8 a	1.3 bc	49.5 ab	1.4 ba	47.8 ab
Native savanna	1.4 a	45.9 b	1.5 a	40.1 c	1.5 a	42.1 b
Pr > F	0.006	0.0033	0.01	0.01	0.50	0.50

Pp: *Pueraria Phaseoloides*; Do: *Desmodium ovalifolium*
Values followed by the same letter in each column are not significantly different (P<0.05)

- Increase of total porosity
- Reduction in mechanical resistance of the soil to penetration by roots (Figure 1)

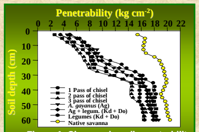


Figure 1. Changes in soil penetrability measured at field capacity and different depths

Photo 3. Native savanna profile: roots are concentrated in the first 5 -8 cm depth

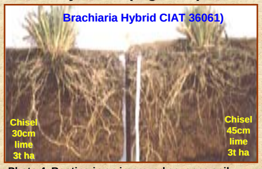


Photo 4. Rooting in an improved savanna soil

- Improvement in water storage capacity and nutrient content, which favors the capacity for rooting of forage grasses (Photos 3 and 4)

Table 2. Changes in the availability of nutrients at different depths after build up of an arable layer.

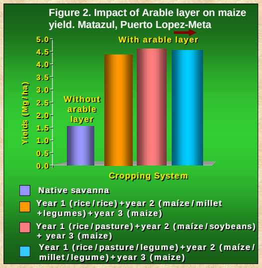
Treatments	Depth (cm)	P mg kg^{-1}	K (cmol kg^{-1})	Ca	Mg	Al
Rice/soybean (rotation) 1Pass of Chisel	0-2.5	38.00	0.24	2.22	0.94	0.43
	2.5-5	31.50	0.15	2.24	0.96	0.43
	5-10	20.70	0.12	1.54	0.68	0.62
	10-20	3.20	0.07	0.54	0.34	1.35
	20-40	1.80	0.05	0.19	0.14	1.46
Rice/soybean (rotation) 2 Pass of Chisel	0-2.5	30.80	0.42	1.74	0.80	0.31
	2.5-5	38.30	0.23	1.64	0.71	0.31
	5-10	15.50	0.14	1.37	0.68	0.31
	10-20	4.50	0.02	0.60	0.36	0.94
	20-40	1.50	0.04	0.13	0.12	1.25
Rice+Grass (agropastoril) Ag+legume (*Pueraria phaseoloides+D. ovalifolium*)	0-2.5	18.20	0.30	0.77	0.39	1.04
	2.5-5	12.00	0.17	0.76	0.34	1.14
	5-10	4.60	0.10	0.60	0.30	1.35
	10-20	1.20	0.06	0.19	0.13	1.25
	20-40	0.55	0.04	0.09	0.06	1.14
Native savanna	0-2.5	4.62	0.11	0.17	0.10	
	2.5-5	2.70	0.06	0.13	0.06	1.98
	5-10	1.95	0.05	0.12	0.06	1.93
	10-20	1.43	0.04	0.11	0.05	1.69
	20-40	1.08	0.02	0.11	0.04	1.25

B) Chemical properties:

- The application of lime and fertilizers improved the availability of nutrients at different depths and reduced the Al toxicity (Table 2)
- The availability of the phosphorus was improved.

C) Biological properties:

- The improvement of the physical and chemical properties facilitated development of vigorous root growth thereby increasing the soil biological activity.



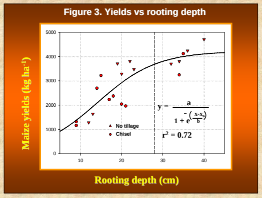
D) The yields

- There was a strongly increase of maize yields (Figure 2)
- The improvement of the physical, chemical and biological conditions facilitates the development of roots of maize (Photo 5)

E) Root development

- Good relation ships were found between depth of rooting (Photo 5) and yields of maize, which indicates that as the soil is improved, maize yields will improve (Figure 3)

Photo 5. Maize root development after *Panicum maximum*



F) Economic analysis

Table 3. Profitability of three alternatives for the building-up of an arable layer in Colombian savannas

System	Indicators of economic Profitability * Net present value (US$/ ha)	Internal Return rate (%)
1	117	19.9
2	531	37.4
3	685	57.4

*Period of evaluation: 10 years
System 1: Year 1 (Rice/Rice) + Year 2 (Maize/millet + legume) + Year 3 (Maize)
System 2: Year 1 (Rice/Grass) + Year 2 (Maize/soybean) + Year 3 (Maize)
System 3: Year 1 (Rice + Grass + Legume) + Year 2 (Maize/millet + legume) + Year 3 (Maize)

- Three alternatives were considered in the construction of an arable layer in the Altillanura. They were very attractive from the economic point of view (Table 3)
- The present values in the three options were positive and the internal rate of return was higher than the real interest rate (16%)

♦ CONCLUSIONS

- The development of an arable layer shows the interdependence of the biotic and abiotic components of the soil and it promotes their mutual interaction.
- The building an arable layer is a key strategy to improve food security and environmental sustainability in the tropics, particularly on infertile soils.
- For the "arable layer" concept to be widely adopted, more attention needs to be given to the driving forces behind farmer decision-making and the existing policies for intensifying agriculture on infertile savanna lands.

♦ ACKNOWLEDGEMENTS

Mariela Rivera P., Luis Fernando Chávez, Jaime Bernal Riobo