Proceedings of a Workshop on Improving Phosphorus Acquisition Efficiency in Marginal Soils

October, 17-22, 1999

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Editor

Embrapa
Milho e Sorgo

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THE DISTRIBUTION AND NATURE OF SOILS WITH LOW PHOSPHORUS IN THE BRAZILIAN SAVANNAS

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INTRODUCTION

With a surface area of approximately 8,500,000 square kilometers of continuous land of which a large part arable, Brazil enjoys abundant water resources; both tropical and subtropical climates and a vast vegetative cover possessing great biological diversity. This diversity of species is attributable to edaphoclimatic characteristics that result in vegetation patterns which can be fitted into six principal ecological regions: the Amazonian Forest, Cerrados of Central Brazil, Caatinga of the Northeast, Mata Atlantic, Southern Forests and Grasslands and the Pantanal of Mato Grosso. In spite of the large extension of arable lands, Brazil has only about 40% of its territory occupied by agro-silvo-pastoral activities. Today, Brazil is the world leader in the production of coffee, sugar cane, citrus juices, the second largest producer of soybeans, and the third largest world exporter of grains.

Brazilian agricultural activities are, traditionally, concentrated in the regions of the Southern Forests and Grasslands and the Mata Atlantic. However, during the last twenty-five years, the country has gone through a phase of significant expansion of the agricultural frontier, principally in the direction of the Cerrados region, the Brazilian savanna, situated in the central part of Brazil. Prior to the 1970s, the Cerrado region was thinly populated with extensive cattle grazing as its main land use. The soils in this area are highly weathered Oxisols with serious limitations for crop production in terms of low natural soil fertility. In addition to these chemical problems, there are other production limitations: a) typically a 5 to 6 months dry season (April to September); b) dry spells during the rainy season generally associated with high evapotranspiration rates; c) low water holding capacity even in clayey soils; and d) limiting rooting depth of many crops as a function of Al toxicity and/or Ca deficiency in subsurface soil layers .

In spite of all these problems, a burst in agricultural development has taken place as a result of governmental incentive programs and the use of new technology, with great emphasis placed on both plant breeding and soil management. Nevertheless, as Nobel Peace Prize winner Norman Borlaug pointed out (Borlaug and Dowswell, 1997), Brazil has failed to emphasize the fantastic current development of the Cerrado, which is converting tens of millions of hectares of formerly worthless land into productive farmland. This is now contributing greatly to food production while at the same time indirectly slowing destruction of the Amazon rain forest. Moreover, it should be emphasized that the vast Cerrado ecosystem, over untold millions of years, was leached of nutrients and made unproductive by Mother Nature, whereas over the last three decades, it is being converted into a huge and highly productive, "bread basket" through the collective efforts of science, effective government and private sector programs, plus aggressive, creative farmers and ranchers. The "Cerrado Revolution" can be described as the Second Green Revolution, concluded Dr. Borlaug. In all probability, much of the technology being developed for the "Cerrados" will be of considerable value in the future in opening areas with similar soil problems to agricultural production, such as the vast plains (*llanos*) of the Orinoco River watershed in Colombia and Venezuela and large tracts in Central and Southern Africa.

THE CERRADO REGION

Cerrado is a name given to different types of savanna like vegetation in which a continuous herbaceous stratum is associated with an arboreal stratum of woody species of varied densities. It can be defined as a subhumid wooded savanna, although there is much variation, from pure grassland to a closed tree canopy (Eiten 1972; Ferri, 1977). The Cerrado region is situated in the central part of Brazil, and small areas fringing other regions such as the Northeast and the North, between the latitudes 6 and 21?S, occupying approximately 25% of the country (Figure 1). Its total area is around 205 million hectares, an area approximately equivalent to the combined areas of Spain, France, Italy, Germany, Portugal and Great Britain.

The average monthly temperature of 22°C is almost constant throughout the year, and the annual rainfall in the region varies from 900 to 2000 mm. The most important climatic characteristic is the seasonal distribution of the precipitation with two well-defined seasons, one rainy, with 5 to 7 months of duration (between November and April), and the other dry (Figure 4). Short-term droughts commonly occur during the rainy season (mainly in January and February) and may be detrimental to crop growth because of high evapotranspiration rates, low soil water retention capacity and adverse chemical conditions for root growth. Dry spells in the rainy season are locally known as "veranicos".

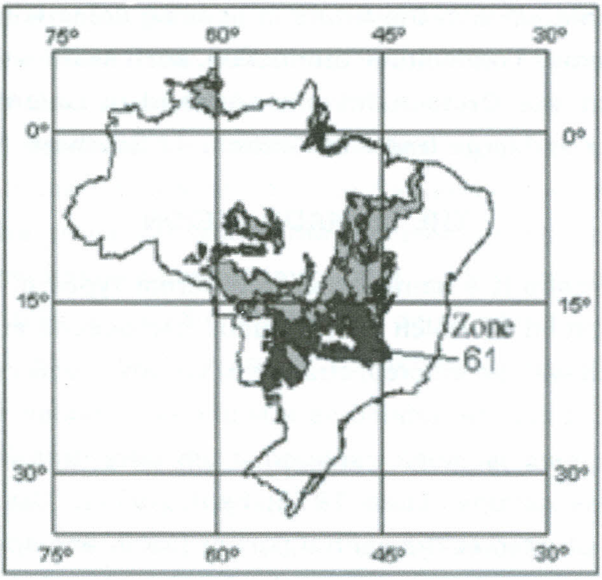

Figure 1. Localization of Zone 61 "Cerrado of Central Brazil" in the Brazilian "Cerrado" Ecosystem

The present landscape is best visualized as a broad three-level terrain resulting from different types of surface erosion: the upper tableland -"Chapadões" if there are big rivers divides or "Chapadas" if there are small rivers divides, the slightly rolling intermediate level regions (a long pediment) and the river valleys. The upper tableland is at altitudes higher than 850m and slopes vary from 0 to 3% being almost flat in many stretches and are formed of clayey Red Yellow and Dark Red Latosols (Oxisols). The origin of the clayey parent material still remains questionable. The cerrado (savanna), in the broad sense, is the main phytogeographic unit. The upper tableland "breaks" in the second surface is usually formed by abrupt escarpment where shallow soils (Lithosols) or outcropping rocks are common. In some places the transition to this intermediate level is subtle and laterite is common. The unit is typically more rolling than the Chapadão (3 to 8%), but there are flat stretches. The fine-loamy Oxisols developed from sandstone are widespread in this intermediate level, but clayey Oxisols still occurs and the vegetation is still cerrado. The contact with the lowest level occurs in the same way. If there is basaltic rock or limestone it will have fertile soils and the vegetation is basically semideciduous forest but cerrado occurs on the flatter stretches.

Oxisols cover more than 50% of the region, the remainder consisting mostly of Entisols, Inceptisols and Ultisols and sandy soils may cover as much as 15% of the area. Most of the soils are deep and well drained which, together with very good microaggregate stability, makes them easy to cultivate at almost any moisture status. A combination of these factors with the gentle slopes (commonly less than 3%) favors intensive agricultural mechanization. Red Yellow Latosols and Dark Red Latosols, most in the suborder Ustox, have been preferred for intensive agriculture. Their texture is variable, but most are high in clay (over 35% of clay) with kaolinite, gibbsite and iron oxides (goethite and hematite) dominate the clay fraction. The predominance of these low activity clays is responsible for most of the soil behavior, especially in terms of ion exchange, water holding capacity and phosphate adsorption characteristics. The organic matter content is greater than in most tropical ustic conditions (to 3%) and is important as a source of nutrients.

CONSTRAINTS TO SOIL QUALITY

Declining and more erratic yields due to soil degradation and biotic pressures (weeds, insects, diseases and nematodes), are widely reported by farmers in the area. At the same time, they report higher costs of production due to increased use of fertilizers and pesticides in an attempt to maintain yields. On the other hand, the increased use of chemicals pose serious threats to the environment. The main constraints identified are:

Organic Matter - The average values are around 2%. Following land clearing, liming and fertilization, the organic matter content declines. The consequences of organic matter loss are: soil structure destruction, compaction, erosion, CEC reduction, nutrient loss, higher crop vulnerability to drought and reduction in water infiltration.

Soil Acidity - The soils are acid and high in Al saturation (Lopes, 1996). A marked yield response to lime is observed for all crops.

Phosphorus - The soils are poor in P and have high P fixation. The performance of all crops, without addition of P, is poor, and large responses are observed with addition of this nutrient.

Nutrient Balance - The soils have low nutrient availability. Nitrogen fertilization is recommended for most non-legume crops; the rate being a function of expected yield, commonly varying between 30 to 120 kg N/ ha. Split applications usually minimize N losses. Usually K is not a problem, except at continuous planting of soybean monocropping in soils of low K supply. Excessive dolomite limestone applications in some locations have led to narrow Ca:Mg relationship, inducing Mn deficiency.

Compaction - Intensive use of disc harrowing has resulted in the formation of dense plow pans ("plow layer"), in most soils under continuous cultivation. As a consequence, porosity decreases, infiltration rates reduce and runoff and erosion increase .

Erosion - Erosivity in the "Cerrado" region can be very high because 70% of the total precipitation occur between November and March. This coincides with early stages of annual crop growth, which, in most cases have not fully covered the ground. On the other hand, repetitive disk harrowing for every crop, common in the "Cerrado" region, creates one loose superficial layer and a compact subsurface layer, which facilitate erosion.

Monocropping - Continuous planting of soybeans and inappropriate soil management practices has resulted in declining productivity and increased costs of production, particularly in older areas. Sole cultivation of soybeans has been shown to reduce the soil organic matter because of the low C/N ratio and high rates of decomposition.

PREDOMINANT FARMING SYSTEMS

Soybeans have been the main driving force for increased grain production and the expansion of the area planted to annual crops in the region (Spehar, 1996). However, continuous planting of soybeans and inappropriate soil management practices in many farms, have resulted in declining yield and increased costs of production.

Maize has only recently become a major crop in the region. From a share of 17%, it evolved to about one third of the national production Maize has been employed in rotation with soybeans, when it yields as high as in the best areas where it is traditionally cultivated in the country. In the areas where the rainy season is prolonged, maize is also cultivated in double cropping, after the soybeans.

A system which is becoming common is the annual crop-pasture rotation. The grass-legume association in rotation with annual crops offers the following advantages: soil fertility improvement by incorporating nutrients through crop residues; increased biological activity in the subsoil due to the deep root growth of perennial acid tolerant plants and efficient nutrient recycling by plants and animals; improvement of soil physical conditions by better organic matter management; and, consequently, reduced erosion.

Another system which is becoming very successful is no-tillage or Zero Tillage. ZT is based on permanent soil cover with crop residues, crop rotations including cover crops, specialized planters/drills, and maximization of biological activity and enhanced management capabilities of the farmer, leading to environmental responsibility. Besides reducing soil erosion losses by up to 90%, and substantially improving rainfall infiltration rates, ZT generates a series of direct and indirect benefits to the farmer as rapid operation, suitable for double cropping and crop rotation, time and money saving, and more durable machinery.

In a substantial area of the region crops irrigated by center pivot are becoming common. Besides making the growing of a winter crop possible, the irrigation guarantees summer production in the case of "veranicos".