Optimizing Nutrient Use in Low Fertility Soils of the Tropics

By Luís I. Prochnow

This article presents some general principles for soil management in the tropics for efficient use of indigenous soil fertility or added nutrients, facilitating high and economical yields.

The tropical regions generally contain soils with low fertility, incapable of sustaining high and economical yields. These soils have to be carefully managed to guide production and achieve the goals of long-term sustainability. Especially in times of high input prices, it is important to employ all techniques that will lead to such sustainability. Some of the techniques are based on general concepts applied worldwide and others are specific for these agro-ecological areas. As a general worldwide concept, input application should aim to more adequately lead to optimum plant nutrition (lime, fertilizers, and gypsum), with the right product, at the right rate, right time, and right place.

With that in mind, let's consider some aspects with the goal of optimizing farmer activities and final results. The topics discussed are: (1) definition of area to crop, (2) soil evaluation and control, (3) nutrient rate strategy, (4) crop rotation, (5) liming, and (6) gypsum to ameliorate subsoil acidity. It should be emphasized that the techniques presented are not specific for times of high fertilizer prices, but are fundamental to seeking profit in this situation.

1. Definition of Area to Crop

Many times, farmers in the tropics try to crop areas too large for their technical and economical capabilities. This generally leads to inefficient soil and crop management and inadequate final yield and profit. Often, better results can be obtained by optimizing the management of smaller areas with higher nutrient application, as opposed to the extensive and inadequate cultivation of larger areas, with low input of nutrients. The optimum area to crop will depend on several factors, but especially on the type of response to the target nutrient. Consequently, access to previous yield data as related to the nutrient rate applied is important for a better definition. Farmers should carefully plan the areas to be cropped in terms of size and adequate management. There is no advantage in cropping larger areas, with more work and less profit at the end.

2. Soil Evaluation and Control

Soil chemical analysis (testing) should be the basis for all programs of plant nutrition. It can be complemented by other techniques, but it is the only one that efficiently, on a routine basis, makes it possible to anticipate the crop's nutrient needs. High soil acidity, low cation exchange capacity, and low amounts of available nutrients are common problems to be overcome in the tropics to enable the soil to sustain crops for high yields and profits. Soil chemical analysis will guide in many ways, possibly even cutting down on nutrient expenses. **Table 1** shows how this technique can help avoid mistakes. Note that the soil analysis would lead to different rates of P applied, as opposed to only one average common rate applied by the farmer when not using laboratory analysis. Compared to rates indicated by the soil chemical analysis, the general farmer practice at field area A would lead to less P than necessary with consequent lower yield potential. At the same time, field area C would receive more P than necessary and only field area B would be on target. By simply transferring the extra amount of P from field area C to A, the farmer would increase final yield with the same expense in fertilizer. This is a simple example of how by using soil testing, farmers would more efficiently monitor their fields with a much larger chance of success.

Photo by A. Pavinato.

Second crop (late planted) corn in a no-till crop rotation system at SLC farm, Brazil, leading to optimization of fertilizer inputs.

3. Nutrient Rate Strategy

The goal should always be to apply the most economical rate of fertilizer, which will depend in part on the price ratio of the crop produced and fertilizer and also on the type of response to the nutrient in that specific field. **Figure 1** conceptually shows the gross US$ return in yield (curve A) and the cost of

Table 1. Rate of P_2O_5 application comparing normal farmer practice versus when utilizing soil chemical analysis.

Area	Soil P[1]	Rate of P_2O_5 Applied by farmer	Rate of P_2O_5 Required[2]	P_2O_5 balance
	mg/dm³	kg/ha	kg/ha	
A	3	60	90	- 30
B	12	60	60	0
C	44	60	30	+ 30

[1]Soil P (mg/dm³): 0 to 6 = very low, 7 to 15 = low, 16 to 40 = medium, 41 to 80 = high, > 80 = very high.

[2]According to maize calibration and response curve studies by the resin method to evaluate the bioavailable pool of P in the soil.

Abbreviations and notes for this article: P = phosphorus; K = potassium; Fe = iron; Mn = manganese; Cu = copper; Zn = zinc; Al^{3+} = aluminum; Mo = molybedenum; Cl^- = chloride; Ca^{2+} = calcium.

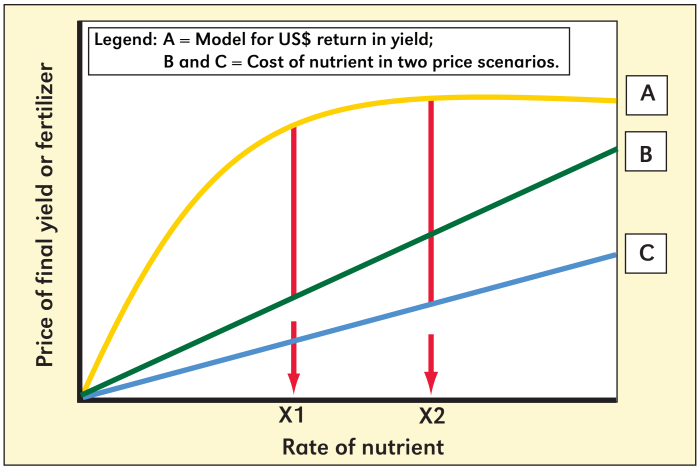

Figure 1. Concept for maximum economical rate of fertilizer.

a given nutrient in two scenarios of price (lines B and C). It is possible to visualize that a lower rate (X1) would be more economical when the nutrient cost is higher (B). This concept is valid only if the US$ return in yield is the same with variation only in the nutrient price. The decision regarding rates is site-specific and agronomists and farmers should monitor their fields and prices to define the best possible rate of fertilizer.

It is a good practice to study the responsiveness of the nutrients at the farm level. This consists of applying different rates of nutrients while keeping the other factors of production at optimum level. The final yields will help to make predictions for the future as related to fertilizer amounts to use. A more modest approach is to start by having at least a control plot or strip (no nutrient applied…for example K) in the field and compare the final yield with regular practices in the farm. This will lead to the calculation of a delta yield (yield with regular practices minus yield at control), which in turn will give guidance as to how much of the nutrient should be added in future crops in the same field or in similar conditions. While the delta yield may vary with yearly specific climatic conditions (especially for N), it will serve to guide the recommendations.

Soils testing medium to high for a specific nutrient can be an excellent indicator that rates can be decreased if capital is in short supply. Well-conducted programs for lime and fertilizer recommendation already take this into consideration by having different response curves for soils testing very low, low, medium, or high for a specific nutrient. As an example, when utilizing the anionic resin method to test for soil bioavailable P in Brazil, values varying from 16 to 40 mg/dm^3 would be considered medium (90% to 100% of maximum yield). Note that the recommendation would be the same, no matter the P content in this range (for example: 17 or 38 mg/dm^3 would both lead to a P_2O_5 recommendation of 60 kg/ha for maize with a yield target of 8 to 10 t/ha). When closer to the upper level limit, i.e., 40 mg/dm^3, the closer we are to the high level of P in the soil. Thus, adjusting to apply lower rates of nutrient would be a possibility. It is important that consultants have a clear idea that the levels of nutrients recommended in technical bulletins serve as a guide, but can be modified according to specific year and targets.

4. Crop Rotation

Nutrient management should target the cropping system. A well-conducted crop rotation program can help to achieve this goal, due to benefits related especially to root development, nutrient requirement, and capability in extracting nutrients from the soil. For example, farms of the SLC group in Brazil have been able to use balanced nutrition for second crop (late planted) corn leading to addition of nutrients (N-P_2O_5-K_2O) through soil fertilization similar to crop removal of these nutrients. (See photo on previous page.) Crops included in this rotation include soybean, cotton, millet, Brachiaria grass, and corn (A. Pavinato, personal communication).

The situation above is only possible due to planning and management of the system, which includes careful site-specific selection of the best corn cultivar, inter-row spacing of 45 cm, and plant population varying with time of seeding, in addition to crop rotation. Also very important to achieving effective results in the crop nutrition of second-crop corn are the practices utilized in the other crops in rotation, and especially for the soybean crop that precedes the corn. These practices include, but are not limited to: no-till practices with periodic subsoiling; application of herbicide at the correct time; and use of early maturity soybean cultivars.

Another good example of a successful cropping system is inclusion of pasture with the cultivation of cereal crops. This approach has been used with great success in parts of Brazil to produce plant residues of good quality for no-till cultivation, or even to be used as feed during winter. This combination generally consists of annual crops—corn, sorghum, millet, or upland rice—with pasture crops, usually Brachiaria. The best crop rotation system, and management that goes with the system, should be defined locally and only agronomic experimentation will lead to optimum results.

EMBRAPA rice and bean researcher Dr. Corival Silva, center, explains the advantages of growing corn and Brachiaria grass together.

5. Liming

Few agricultural practices in the tropics can add as many valuable advantages to crop development and final yield as liming of acidic soils. The advantages vary from improving soil physical and microbiological conditions to improving the use of nutrients by plants. Also very important is the neutralization of toxic Al^{3+}, which severely damages root and crop development. Some nutrients are more bioavailable at low soil pH (Fe, Mn, Cu, and Zn) and others that have an opposite behavior, with higher bioavailability at high soil pH (Mo, Cl) (**Figure 2**). The challenge is to modify the soil pH to have the best possible availability for all plant nutrients. The optimum pH is crop-specific and this should be taken into consideration in recommendations for lime, which is generally the most economical product to adjust soil pH. The concepts and practices of lime application are generally best defined by a local research group, so they are region-specific. Liming the soil should always be considered by farmers of the tropics to, among other advantages, lead to more efficient use of plant nutrients, native to the soil or added through fertilizers.

6. Gypsum to Ameliorate Subsoil Acidity

While liming has several advantages in ameliorating soil acidity and leading to better plant development, liming materials contain low solublility compounds ($CaCO_3$ and/or $MgCO_3$ for natural lime) that react and promote such advantages only close to the locality of application. Liming deep soil layers (below 30 cm) is generally not economical, so soil acidity may persist and influence root development at those deep layers, once the presence of Al^{3+} and/or absence of Ca^{2+} (very normal in acidic soil conditions) severely restricts root development.

Gypsum ($CaSO_4$)—natural or a byproduct of the production of phosphoric acid—is a more soluble compound than lime. Applied at correct rates, it was proven to ameliorate subsoil acidity (adding Ca^{2+} and/or decreasing Al^{3+} activity), allowing roots to grow more efficiently. **Table 2** shows agronomic trial results comparing the root development (root density, relative root distribution, or root length) when gypsum was applied or not applied in rates to ameliorate subsoil acidity. Note that in all cases, more root developed in deep soil layers with the application of gypsum. As a result of more root development, plants can absorb more nutrients and water, with higher yields. BC

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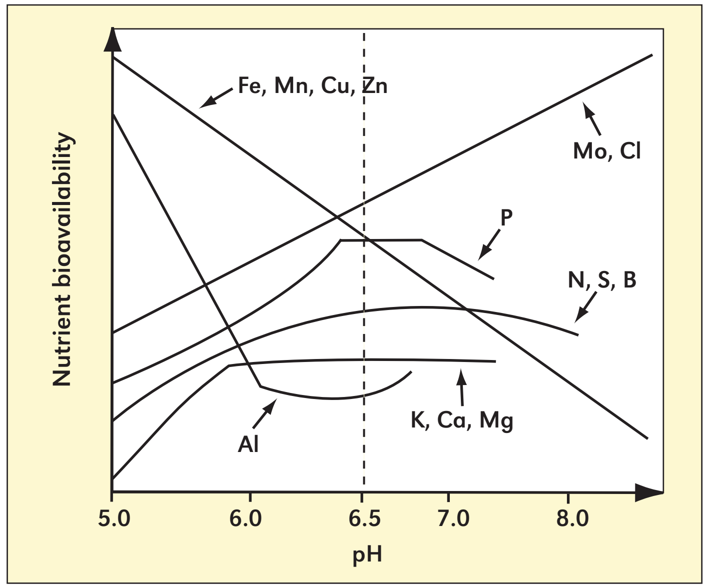

Figure 2. Nutrient bioavailability according to soil pH. Source: Malavolta (2006).

Table 2. Effect of gypsum ($CaSO_4 \cdot 2H_2O$) application in the root distribution for various crops and/or location in soils of the tropics.

Soil layer	Corn South Africa 1 Root density		Corn Brazil 2 Relative root distribution		Apple Brazil 3 Root density		Alfalfa Georgia, USA 4 Root length	
	Control	Gypsum	Control	Gypsum	Control	Gypsum	Control	Gypsum
cm	----- m/dm^3 -----		------- % -------		------ cm/g ------		------ m/m^3 ------	
0-15	3.10	2.95	53	34	50	119	115	439
15-30	2.85	1.60	27	25	60	104	30	94
30-45	1.80	2.00	10	12	18	89	19	96
45-60	0.45	3.95	8	19	18	89	10	112
60-75	0.08	2.05	2	10	18	89	6	28

Source: [1] Farina and Channon, 1988; [2] Sousa and Ritchey, 1986; [3] Pavan and Bingham, 1986; [4] Sumner and Carter, 1988.

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