Nutrient Management Challenges in Brazil and Latin America

Luiz Roberto Guimarães Guilherme – Agronomist, PhD
Associate Professor, Federal University of Lavras (UFLA)
Research Fellow, National Council for Scientific and Technological Development (CNPq), Brazil

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Session I: Global Challenges, Regional Priorities and Perspectives

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Outline

• An Overview of Latin America and Brazil
  – Nutrient Balance in Agriculture
  – Sanitation Issues

• An Overview of the Fertilizer Market
  – World vs Latin America & Brazil

• Developments in Farming and Nutrient Management
  – Focus on the Success Story of the Brazilian Cerrado

• Final Remarks
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  – Nutrient Balance in Agriculture
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• Final Remarks
Latin America and Caribbean


Surface area (1,000 km$^2$)
19,460.85

Agricultural land ~ 36%

Population (millions)
568.2
South American & Brazilian Ag. Lands are Extensive (hectares per capita)

Source: Bot et al. (2000)
## Estimated Land Use in Brazil

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Million ha</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical Forest</td>
<td>345</td>
<td>41</td>
</tr>
<tr>
<td>Pastures</td>
<td>220</td>
<td>26</td>
</tr>
<tr>
<td>Legal Reserves</td>
<td>55</td>
<td>6</td>
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<tr>
<td>Annual Crops</td>
<td>47</td>
<td>5</td>
</tr>
<tr>
<td>Permanent Crops</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Cities, Roads, Lakes, Rivers &amp; Swamps</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>Reforestation</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>707</strong></td>
<td><strong>83</strong></td>
</tr>
<tr>
<td>Other Uses</td>
<td>38</td>
<td>4</td>
</tr>
<tr>
<td><strong>Area Still Available for Agribusiness</strong></td>
<td><strong>106</strong></td>
<td><strong>13</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>851</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Unexploited area represents ~ 50% of the Cerrado area

Cerrado (Brazilian Savanna)

Region with greatest perspectives of use increase

~14% of the world’s freshwater supply

~2 X Spain

Source: Adapted from I Congresso Brasileiro de Fertilizantes 07/2011
Brazil

- Area: 8,514,204.86 km² (851.4 million ha)
- Population: ~200 million inhabitants
- Tropical Country (weathered soils)
- 7.367 km of coastline along the Atlantic Ocean

... Good edaphic conditions overall

Many soil fertility constraints, but...

Nutrient availability

Edaphic conditions
“In fact, most Latin American agricultural soils show a negative “nutrient balance,” meaning that more nutrients are lost through plant growth and harvest than are replaced through additions of fertilizer, manure, or legume cover crops.”

“In general, the nutrient balances in the industrial world are positive, especially for N, as crops use less than half of the applied fertilizer, leading to the eutrophication problem just described. In large areas of South America (Wood et al. 2000) and Africa (Smaling et al. 1997; Sanchez 2002), on the other hand, the nutrient balance is negative, leading to declining soil fertility. In the case of South America, the magnitude of the imbalance appears to be decreasing as incomes rise and farmers can afford more fertilizer.”
Nutrient Balance in Brazilian Agriculture (1988-2010)

INFORMAÇÕES AGRONÔMICAS

Nº 135 SETEMBRO/2011

BALANÇO DE NUTRIENTES NA AGRICULTURA BRASILEIRA NO PERÍODO DE 1988 A 2010

José Francisco da Cunha, Valter Casaroli, Luís Ignácio Prochnow

INTRODUÇÃO

Em sequência ao artigo Balanço de Nutrientes na Agricultura Brasileira, publicado no Jornal Informações Agronômicas n° 130 (julho 2010), o IPNI Brasil fez um levantamento histórico do balanço de nutrientes no período de 1988 a 2010. Diferentemente do primeiro levantamento, que considerou o ano agrícola 2008/09 como referência, objetivo-se, com o atual estudo, avaliar a evolução do consumo de fertilizantes, da área plantada, de produtividade, do rendimento e o balanço de nutrientes das 18 principais culturas agrícolas cultivadas no Brasil ao longo dos últimos 23 anos.

Dados do balanço de nutrientes no ano agrícola 2008/09 revelaram informações de grande importância sobre aproveitamento de nutrientes, tanto em relação às culturas estudadas, como em relação aos estados do Brasil. Foi possível identificar as culturas com menor índice de aproveitamento de nutrientes, dentro das quais a cultura de café revelou-se em situação mais crítica. Ao mesmo tempo, houve a possibilidade de verificarmos os estados brasileiros com índice deficitário de utilização de nutrientes, é assim localizado principalmente na região Norte e Nordeste do país. Nestes, as entradas de nutrientes, por intermédio de aplicação de insumos, geralmente foram muito inferiores às saídas, por meio das exportações dos elementos pelas colheitas. Essa condição configura-se como agricultura extrativista, de baixa produtividade, no qual são explorados as reservas do solo, não sendo sustentável ao longo do tempo.

A análise do balanço de nutrientes em um longo período, como está sendo proposto neste artigo, permite avaliar a evolução do uso de fertilizantes na agricultura brasileira, representado pelas 18 principais culturas agrícolas, as quais são responsáveis por mais de 90% do consumo de fertilizantes. Dessa maneira, este estudo ajuda a relacionar a evolução da produção agrícola brasileira e o progresso no uso de fertilizantes. Essa relação revela a tendência da agricultura dentro de um processo de manejo sustentável. Por outro lado, pode-se inferir a importância do fertilizante no aumento do rendimento das culturas, inserindo o balanço de nutrientes em um contexto ainda mais amplo, que é o da segurança alimentar.

Com a identificação de culturas e de regiões do Brasil nas quais há subutilização de nutrientes (exportação maior que consumo), pode-se promover programas de conscientização do uso de fertilizantes voltados aos produtores agrícolas. De maneira semelhante, a condição de suplementação de nutrientes (consumo superior à exportação), visa-se estabelecer as boas práticas de uso eficiente de fertilizantes com o objetivo de alcançar altos rendimentos e a sustentabilidade do sistema produtivo.

Source: www.ipni.net/publication/ia-brasil.nsf/0/9CA193D11CE9775583257A8F005D3F2C/$FILE/Page1-7-135.pdf
Role of P and N in Ag. Production and Eutrophication

• “... P often co-limits (with N) plant and animal production on old, highly weathered soils, such as those that dominate tropical Africa, South America, and Australia. Since \( \text{NH}_4^+ \) and \( \text{NO}_3^- \) are both more readily leached out of soils than phosphate, freshwater and some coastal ecosystems are typically more responsive to increases of P than of N, making P the principal driver of eutrophication in lakes and estuaries.

• The main mechanism by which the P leaves the land and enters freshwater ecosystems is soil erosion. Agricultural P is the principal driver of eutrophication. P concentrated in sewage effluents and animal and industrial wastes, including P-containing detergents, makes a relatively small global contribution (Bennett et al. 2001), although it may be important locally.”

Latin America’s Nitrogen Challenge

• In addition to **N excess from human impact**, mining of natural soil N creates **N deficits in some regions**.

• **Biomass burning** transfers a large amount of reactive N from the land to the atmosphere, which is then redistributed regionally to aquatic and terrestrial ecosystems via wet and dry deposition. By 2050, four of the eight LA biodiversity hotspots are projected to have potentially **harmful levels of N deposition**.

• Because of **lack of basic infrastructure**, especially in low-income areas of megacities, **most domestic sewage is released into water bodies without treatment, causing N and P enrichment**, affecting trophic interactions, and increasing public health risks. Exacerbating the problem is **rural-urban migration**, a result of marginalization and extreme **poverty faced by many small farmers**.

• **Agricultural practices must increase functional diversity**, mimicking natural ecosystems. Techniques include **no-till agriculture, cover crops, crop rotation, and enhancement of natural N fixation**. Intensification must only be **encouraged under sustainable practices**, where agroecosystems and neighboring landscapes provide key ecosystem services.
Global Sanitation Trends - 1990–2011

There are 45 countries where sanitation coverage is less than 50 percent

Figure 1. Proportion of the population using improved sanitation in 2011.

Sewage disposal is still a big challenge in Brazil

Almost half the houses in Brazil have no sewage disposal services

Houses (%) with sewage disposal services in 2004

<table>
<thead>
<tr>
<th>Em %</th>
<th>Norte</th>
<th>Roraima</th>
<th>Acre</th>
<th>Amapá</th>
<th>Pará</th>
<th>Roraima</th>
<th>Acre</th>
<th>Amapá</th>
<th>Pará</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norte</td>
<td>2.8</td>
<td>1.2</td>
<td>6.4</td>
<td>3.8</td>
<td>2.7</td>
<td>1.8</td>
<td>1.7</td>
<td>1.3</td>
<td></td>
</tr>
</tbody>
</table>

Source: Data from the National Household Sample Survey / National Survey of Basic Sanitation
The Brazilian Institute of Geography and Statistics (IBGE) - www.ibge.gov.br
Sewage (wastewater) treatment is still a big challenge in Brazil.

A 2008 National Household Sample Survey revealed that only 28.5% of Brazilian municipalities had wastewater treatment systems.

Source: The Brazilian Institute of Geography and Statistics (IBGE) - www.ibge.gov.br
Brazil: wastewater treatment systems coverage vs use of lime and mineral N fertilizers (2006) by farmers

- 71.5% of the municipalities did not have a wastewater treatment system (2008)
- 84.1% of the farmers did not use lime and 74.4% did not use mineral N fertilizer (2006)

Source: Data from the 2006 Agricultural Census and the 2008 National Survey of Basic Sanitation, The Brazilian Institute of Geography and Statistics (IBGE) - www.ibge.gov.br
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Brazilian Fertilizer Market: 1990 – 2011

Consumption Evolution by Nutrient (Million tons)

- Potassium (K₂O) – GAGR 6.29%
- Phosphorus (P₂O₅) – GAGR 6.75%
- Nitrogen (N) – GAGR 5.99%

Source: ANDA
Fertilizers: World Consumption by Country

Brazil: world’s 4º largest market; ~ 70-75% of South America’s Market

Source: IFA http://www.fertilizer.org/ifa/ifadata/search
Fertilizers: World Consumption Trend (2007-2011)

1,000 tons NPK

- China
- India
- United States
- Brazil
- Indonesia
- Pakistan
- Canada
- France
- Russian Federation
- Viet Nam
- East Asia
- South Asia
- North America
- Latin America and the Caribbean
- Western and Central Europe
- Eastern Europe and Central Asia
- Africa
- West Asia
- Oceania

Source: IFA http://www.fertilizer.org/ifa/ifadata/search
Fertilizer Market Share: Brazil vs SA and LA

- **Argentina**: 1603.1, 10%
- **BRAZIL**: 11656.5, 74%
- **CHILE**: 1223, 8%
- **COLOMBIA**: 788.4, 5%
- **Others SA**: 503.8, 3%

**Source:** IFA [http://www.fertilizer.org/ifa/ifadata/search](http://www.fertilizer.org/ifa/ifadata/search)

- **2011**
  - 61% N
  - 74% P₂O₅
  - 88% K₂O

**Brazil/SA** ~73%
**Brazil/LA** ~61%
**SA/LA** ~83%

**1,000 tons NPK**
Fertilizer Use in Brazil

Evolution & Share by Crop

N, P$_2$O$_5$ and K$_2$O consumption in Brazilian agriculture from 1970 to 2011, and expansion of the no-till area in Brazil from 1973 to 2006

Brazilian fertilizer market share by crop in 2011 (Source: ANDA)

Source: Lopes, Guilherme & Ramos (2012)
www.ipipotash.org/udocs/e-ifc_no_32_november_2012_hr.pdf
Brazil (1992-2011)

Evolution of Grain Production, Cultivated Area and Fertilizer Sales

During this period, grain yields increased 72% whereas the cultivated area increased 36%.

Graph showing:
- Grain production (mi. tons)
- Cultivated area (mi. hectares)
- Fertilizer sales (mi. tons)

Grain production increased at an annual growth rate of 5.55% (GAGR), cultivated area at 4.77% (GAGR), and fertilizer sales at 1.93% (GAGR).

Regression equation:
Grain (t) = 8.7 * Fertilizer (t) + 15.5

R² = 0.914

(considering 60% of total sales for grain production)

Source: data from ANDA/CONAB/IBGE, * 2012 estimates by RC Consultants – Fertilizers, CONAB/IBGE – Area & Production
Growth in Land and Labor Productivity (1961-2001)

“Globally, 78% of the increase in crop output between 1961 and 1999 was attributable to yield increases and 22% to expansion of harvested area...

...While the pattern of yield increases outpacing harvested area increases was true for most regions, the proportions varied. For example, only 55% of total output growth was derived from yield increases in Latin American and the Caribbean compared with 80% in South Asia. In contrast, only 34% of increased output was derived from yield increases in sub-Saharan Africa and 66% from harvested area expansion.”

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“Cerrado” Vegetation
Management Technologies for the “Cerrado” region in Brazil
50 years of research-teaching-extension efforts

a) Liming

b) Amelioration of subsoil acidity (gypsum)

c) “Build-up” phosphate fertilization

d) “Build-up” potash fertilization

e) “Build-up” micronutrient fertilization

f) Organic matter management

g) Maintenance fertilization
Crop rotation
Cover crops
Crop sequences
No-till
Minimum tillage
Integration: grain crops/cattle
Green manure
Weed management
Mulching (small farmers)
Manure (small farmers)
Fertilizers
Conserving organic matter – a challenge in tropical agricultural systems

Nutrient Management

**Fertilizer use sequesters carbon by stimulating biomass production.** Judicious fertilizer application also counters nutrient depletion, reduces deforestation and expansion of cultivation to marginal areas, and increases crop yields. **Strategies to promote nutrient use efficiency include the following:**

- Adjusting application rates based on assessment of crop needs;
- Minimizing losses by synchronizing the application of nutrients with plant uptake;
- Correcting placement to make the nutrients more accessible to crop roots (microfertilization and microdosing);
- Using controlled-release forms of fertilizer that delay its availability for plant uptake and use after application;
- Using nitrification inhibitors that hold-up microbial processes leading to nitrous oxide formation;

The average effect size of applying fertilizer was an additional **124 kg C ha\(^{-1}\) yr\(^{-1}\)** sequestered for Latin America, **222 kg C ha\(^{-1}\) yr\(^{-1}\)** for Asia, and **264 kg C ha\(^{-1}\) yr\(^{-1}\)** for Africa.

Source: Carbon Sequestration in Agricultural Soils (2012)
http://hdl.handle.net/10986/11868
Capitalizing on Synergies and Managing Trade-Offs in Soil Carbon Sequestration

Source: Carbon Sequestration in Agricultural Soils (2012)
http://hdl.handle.net/10986/11868
Conserving organic matter – a challenge in tropical agricultural systems

As more nitrogen was applied to the system, the differences in SOC storage between fertilized treatments and controls tended to increase by approximately 2 t soil C ha\(^{-1}\) for each 1 t N fertilizer ha\(^{-1}\) (P = 0.001).

Figure 1. Relationship between carbon content differences of fertilized and control treatments (\(\Delta\)SOC fertilized) and the total nitrogen applied in experiments with crop residues retained.
Attention to the 4 R's of fertilizer application

N content in the 20-60 cm soil depth

<table>
<thead>
<tr>
<th>(kg ha$^{-1}$ N)</th>
<th>April 1997</th>
<th>October 1998</th>
<th>April 1999</th>
<th>August 2000</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>26a$^2$</td>
<td>24a</td>
<td>23</td>
<td>35</td>
<td>27a</td>
</tr>
<tr>
<td>100</td>
<td>18a</td>
<td>22a</td>
<td>18</td>
<td>32</td>
<td>23a</td>
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<tr>
<td>180</td>
<td>32a</td>
<td>34a</td>
<td>24</td>
<td>59</td>
<td>37a</td>
</tr>
<tr>
<td>260</td>
<td>32a</td>
<td>32a</td>
<td>24</td>
<td>50</td>
<td>35a</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>20a</td>
<td>26a</td>
<td>21</td>
<td>32</td>
<td>25a</td>
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<td>100</td>
<td>30a</td>
<td>37a</td>
<td>22</td>
<td>56</td>
<td>36b</td>
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<tr>
<td>180</td>
<td>79b</td>
<td>40a</td>
<td>20</td>
<td>83</td>
<td>55b</td>
</tr>
<tr>
<td>260</td>
<td>59b</td>
<td>79b</td>
<td>22</td>
<td>63</td>
<td>56b</td>
</tr>
</tbody>
</table>

Rainfall in the season preceding soil sampling$^3$ (mm)

<table>
<thead>
<tr>
<th>Oct 96–Apr 97</th>
<th>May 98–Sep 98</th>
<th>Oct 98–Apr 99</th>
<th>May 00–Aug 00</th>
</tr>
</thead>
<tbody>
<tr>
<td>1071</td>
<td>292</td>
<td>1483</td>
<td>107</td>
</tr>
</tbody>
</table>
Better Root Development... Better Nutrient Uptake... Less Nutrient Leaching

Relative distribution of a corn root system with and without gypsum in a clayey Oxisol in central Brazil

Cotton root development in depth without (left) and with (right) application of 3 t/ha of gypsum. Each square is 15 cm by 15 cm.

Source: Sousa & Ritchey (1986)

Source: Sousa & Rein (2009)

Photo courtesy of D.M.G. Sousa
Tillage, Crop Residue Management, and Soil Carbon Sequestration Rates (kg C ha\(^{-1}\) yr\(^{-1}\))

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>MEAN</th>
<th>LOWER 95 PERCENT CONFIDENCE INTERVAL OF MEAN</th>
<th>UPPER 95 PERCENT CONFIDENCE INTERVAL OF MEAN</th>
<th>NUMBER OF ESTIMATES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop residues</td>
<td>374</td>
<td>292</td>
<td>457</td>
<td>46</td>
</tr>
<tr>
<td>Mulches</td>
<td>377</td>
<td>159</td>
<td>595</td>
<td>6</td>
</tr>
<tr>
<td>Cover crops</td>
<td>406</td>
<td>298</td>
<td>515</td>
<td>24</td>
</tr>
<tr>
<td>No-tillage</td>
<td>370</td>
<td>322</td>
<td>418</td>
<td>108</td>
</tr>
<tr>
<td><strong>Asia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop residues</td>
<td>450</td>
<td>379</td>
<td>521</td>
<td>189</td>
</tr>
<tr>
<td>Mulches</td>
<td>565</td>
<td>371</td>
<td>759</td>
<td>53</td>
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<tr>
<td>Cover crops</td>
<td>414</td>
<td>233</td>
<td>594</td>
<td>38</td>
</tr>
<tr>
<td>No-tillage</td>
<td>224</td>
<td>97</td>
<td>351</td>
<td>48</td>
</tr>
<tr>
<td><strong>Latin America</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop residues</td>
<td>948</td>
<td>638</td>
<td>1,258</td>
<td>56</td>
</tr>
<tr>
<td>Mulches</td>
<td>748</td>
<td>262</td>
<td>1,108</td>
<td>16</td>
</tr>
<tr>
<td>Cover crops</td>
<td>314</td>
<td>108</td>
<td>520</td>
<td>33</td>
</tr>
<tr>
<td>No-tillage</td>
<td>535</td>
<td>431</td>
<td>639</td>
<td>249</td>
</tr>
</tbody>
</table>

Source: Carbon Sequestration in Agricultural Soils (2012)
http://hdl.handle.net/10986/11868
Agri-technology: no-till at Fazenda Filadélfia
State of Mato Grosso (Cerrado)

No till area (million ha)

Brazil; 25.5
(53% of grain area)

Cerrado; 11.9

Source: FEBRAPDP (2007)
Conserving organic matter with no-till

Short-term soil CO₂ emission after conventional tillage of a no-till sugar cane area

N. La Scala Jr. *, D. Bolonhe

Abstract

The impact of tillage systems on soil CO₂ emission is a complex issue associated with no-till to intensive land preparation. In southern Brazil, the adoption of a new no-till system as well as no burning of crops residues left on soil surface after harvest has decreased CO₂ emission. This practice has helped to restore soil carbon, the tillage impact on soil carbon emissions was evaluated through a study evaluating the effect of moldboard plowing followed by offset disk harrowing in a sugarcane field treated with no-till and high crop residues input in the previous crop, with undisturbed soil CO₂ emissions during a 4-week period by using an infrared gas analyser. Conventional tillage caused the highest emission during almost the whole period, with the following tillage, when the reduced plot produced the highest peak. The lowest emissions were recorded 7 days after tillage, at the

“Although it is known that crop residues are important for restoring soil carbon, our result indicates that an amount equivalent to approximately 30% of annual crop carbon residues could be transferred to the atmosphere, in a period of 4 weeks only, when conventional tillage is applied on no-tilled soils.”

No-till emits ~ 6 times less CO₂ than conventional tillage
Conserving organic matter – avoid burning

Changing from pre-harvest burning to green cane harvesting (GCH) has two main consequences with respect to GHG emissions:

1. The sugarcane harvest after burning emits CH$_4$ and N$_2$O, besides polluting the atmosphere with smoke and soot. Although mechanized harvesting increases consumption of fossil fuels, the elimination of burning decreases total GHG emissions that occur at harvest by almost 80%;

2. The maintenance of straw on the ground preserves nutrients, especially N and S, besides maintaining soil moisture and protecting the soil surface from erosion.

Source: www.cnpm.embrapa.br/publica/download/Doc_77.pdf
Conserving organic matter in Jamaica

Moving Towards Green Cane Harvesting

Ever since the start of pre-harvest burning there have been periodic debates surrounding its pros and cons compared with the previous system of harvesting “green.” The switch to pre-harvest burning however involved more than just the passage of fire through the cane field for trash removal. Fire sweeping through the field would blunt cane spines, drive away pests such as wasps, centipedes, the occasional snake, and reduce the tangle of vines, cow itch or other weeds which create an inhospitable environment for cane cutters. Most of all, it was part and parcel of a new technology, introduced during the sixties, facilitating loading of cane by machines, and which marked the end of manual loading.

Very soon, the disadvantages of pre-harvest burning became apparent, triggering a nostalgic yeaming for a return to green cane harvesting (GCH). One estate, Long Pond, succeeded in returning briefly to GCH during the eighties. Since then chopper harvesters have entered the picture. These are sometimes used to harvest cane without burning, but with some loss of quality and, if not carefully managed, at higher cost.

Economics however has always been at the heart of the debate. It is not so much a question of whether green cane harvesting can or should be done, but at what price. Would green cane harvesting result in greater viability, would it assist in reducing cost? - these are some of the questions.

New Challenges

Today the Industry is faced with a new set of challenges. Urban areas are getting closer to and are springing up within traditional cane growing areas. For those citizens, the smoke and soot from pre-harvest burning, although momentary in duration, are an unbearable nuisance. For those with respiratory problems a cane fire may trigger a medical emergency.

The Sugar Industry must therefore take the lead by adopting more enlightened approaches. With tourism playing an ever increasing role in the economy, and as people get more aware of what is good for the environment, the daily burning of cane during crop becomes less and less acceptable. Furthermore, the whole world is moving towards conduct that improves rather than degrades our surroundings in any way. Countries that do not conform may very well find themselves ostracised.
## Agroforestry and Soil Carbon Sequestration Rates (kg C ha\(^{-1}\) yr \(^{-1}\))

Source: Carbon Sequestration in Agricultural Soils (2012)

http://hdl.handle.net/10986/11868

<table>
<thead>
<tr>
<th>PRACTICE</th>
<th>MEAN</th>
<th>LOWER 95 PERCENT CONFIDENCE INTERVAL OF MEAN</th>
<th>UPPER 95 PERCENT CONFIDENCE INTERVAL OF MEAN</th>
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<tr>
<td><strong>Africa</strong></td>
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<td>Include trees in field</td>
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<td>Improved fallow</td>
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<td>2,941</td>
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<td>Diversify trees</td>
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<td>Intercropping</td>
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<td>2,063</td>
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Examples of a “Green Agriculture” in the Cerrado one of the most productive regions in Brazil in terms of grain, beef cattle, and agro-energy production, as well as reforestation

Brachiaria as a cover crop in maize field

Crop-livestock-forest production system

Final Remarks

• Adoption of better agronomic practices (e.g., no-till, cover crops, crop rotation, agroforestry systems, intercropping, avoid burning) is a need to improve nutrient use efficiency and nutrient cycling in LA countries with positive nutrient balance due to fertilizer use.

• Yet, in many LA countries, there is still a demand for nutrient replenishment in order to support adequate plant growth and agricultural production.

• Issues concerning nutrient release into aquatic environments caused by the uncontrolled discharge of untreated urban wastewater need also to be addressed in most LA countries for improved water quality.
Thank you !!!
Obrigado!!!

guilherm@dcs.ufla.br
luiz.guilherme@pesquisador.cnpq.br
ascheidl@dcs.ufla.br