**2002 IFA PRODUCTION AND INTERNATIONAL TRADE CONFERENCE**

**Fairmont Le Château Frontenac – Quebec City (Canada)**
**16-18 October 2002**

# DEMAND FOR FERTILIZERS IN BRAZIL

# 2000 – 2010

**by**

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# DEMAND FOR FERTILIZERS IN BRAZIL : 2000 – 2010

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## 1. INTRODUCTION

This paper is a methodological one. The intention is to present a model of agricultural (animal and crops) fertilizer demand that has been developed for Brazil. It has been used and tested during the last three years. Results suggest that the model is able to capture changes in regional and aggregate fertilizer demand, reproducing the patterns presented currently in Brazil.

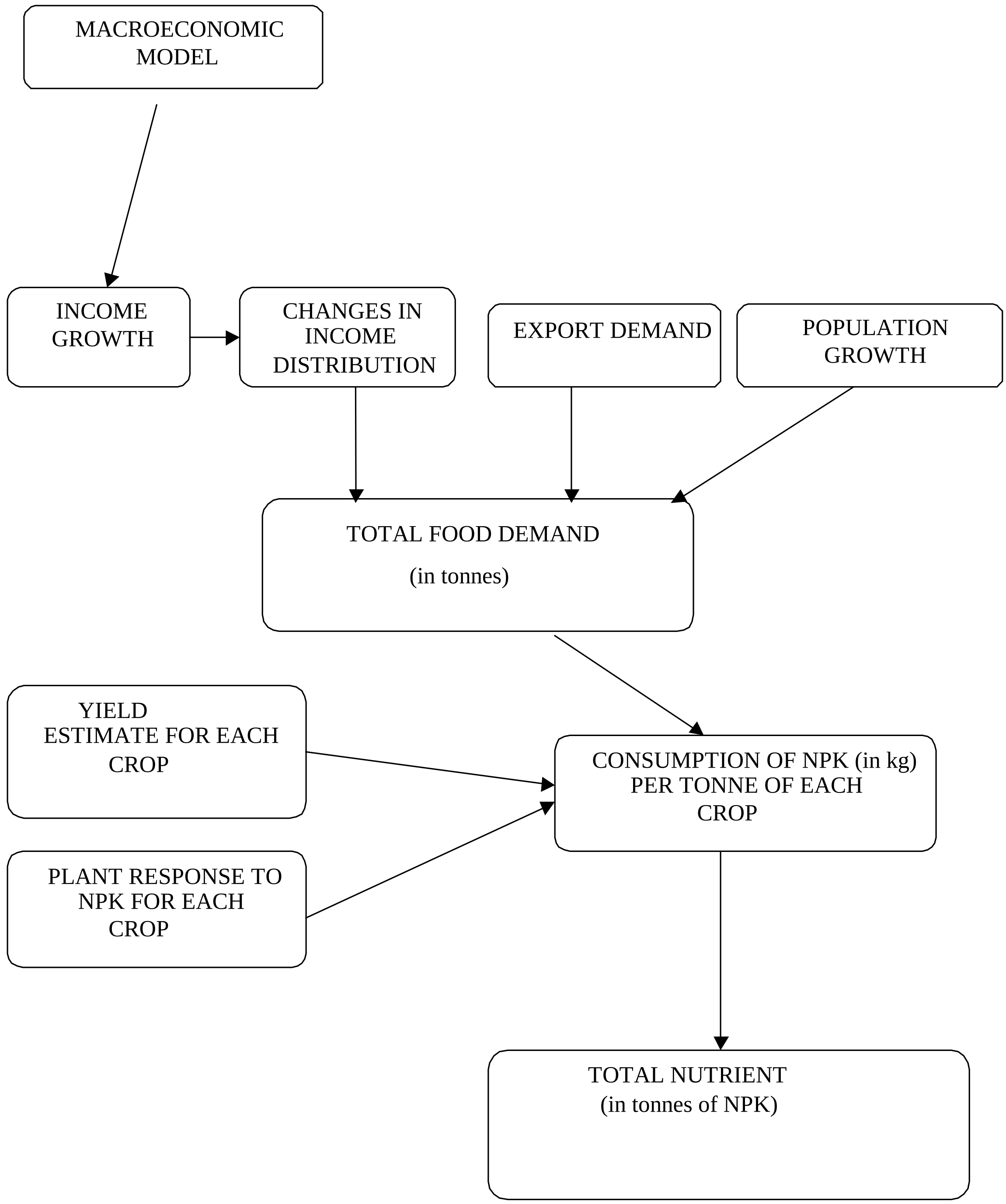
## 2. STRUCTURE

Major structure is quite linear. A consistent macroeconomic model determines GDP growth. Total domestic food demand was estimated for the next ten years based on that model and together with population growth and changes in income distribution. Foreign consumption was added to that amount, generating the total amount of food requirements for the next ten years. With these figures, two different paths were taken. The first was related to crop fertilizer requirement. A set of curve-responses to fertilizer (nitrogen, phosphorus and potash, - from now on will be quoted as NPK) was empirically determined for each one of the major crops produced in Brazil (those that are responsible for more than 95% of total crop fertilizer demand). These curves relate land productivity (tonne/hectare) with nutrient requirement (extraction) ; in other words, a volume of nutrients is required to reach each productivity level. Several projections were then made to determine the productivity level of each crop in a ten-year horizon. With these projections and the curve-response to NPK, nutrient requirement to produce one tonne of each crop was determined. These figures combined with total food demand has determined total nutrient requirement in a ten-year period.

Figure 1 summarizes the work structure.

[1] University of São Paulo and MB Associados

**Figure 1 – Model structure**



The second path developed is related to pasture fertilizer demand. Brazil has the second largest cattle population in the world (170 million heads), distributed over approximately 180 million hectares. During the last 20 years several technological innovations were developed to raise productivity, slowly but continuously. More meat per hectare requires more nutrients applied per hectare. Accordingly, different management techniques were improved, combining pasture rotation with fertilization. As a consequence of this diversity, different production systems were consolidated. Eight different cattle production systems have been built to deal with this diversity. A major difference between these eight systems is the pastureland productivity level, which varies from 0.2 to 3 UA[2] per hectare. Each of these levels is related to a quantity of nutrient extraction that needs to be replaced to ascertain production continuity.

## 3. MACROECONOMIC MODEL

The ability of a country to grow is related to its investment share as a percentage of the GDP. Total investment depends on the savings supply, which depends on both domestic and foreign sources. The model developed in this study herein considers the savings supply as the major macroeconomic constraint to economic growth. Total domestic savings consists of public savings (tax revenues less government expenses) and private savings. If the government runs a deficit, it will pressure private savings, lowering the possibilities for fast economic growth. It is important to note that investment capacity is a flow : it depends on the amount of savings provided yearly by the foreign or domestic capital market. Although it is a flow, the amount of investment depends on total debt of both public and private sectors, which is stock. This debt generates a negative flow of payments. The size of this flow depends on the size of the debt and on the interest rate level : if interest rates rise, then the stream of payments to lenders also does. Moreover, if debts are in dollars, the exchange rate will be a key element, as the external interest rate. Therefore, total investment depends on the net effect of domestic savings minus debt payments plus foreign investment. Our macroeconomic model tries to build the conditions of investment performance over the next ten years, constrained by both the supply of savings and the debt trajectory over the same period.

During the last decade Brazilian economy has undergone several structural changes : inflation has been controlled, government has raised its ability to collect taxes, labour productivity increased sharply, etc. The adjustment process was based on a number of reforms concentrated in few major strategies : government fiscal adjustment, combined with exchange rate appreciation, openness to trade and privatization of public own firms. This last element was essential to attract foreign capital. The purpose of the first group of actions was to lower the pressure of public spending over private saving. This would have allowed faster economic growth due to an increase in savings.

[2] UA stands for animal unit, which is equivalent to a cow weighing 450 kilograms.

An exchange rate appreciation together with openness to trade were fundamental for increased competition through a foreign supply, controlling prices of all tradable products. Time has shown that this strategy was perfect in controlling inflation but not so good for the country's balance of payments. After the first year of the *Plano Real*, Brazil was running a trade deficit that kept increasing until 1999. This deficit was financed by foreign investment and Brazil began to depend heavily on international capital markets. The sequences of international financial crises (Mexico, Asia, Russia) made money scarce all over the world. The only option left to Brazil was to increase its interest rate to continue to attract foreign investors[3].

This has shown to be unsustainable. Despite the fiscal adjustment undertaken by the federal government by creating a primary surplus (defined as tax collection minus expenses, except interest), the increase in total public and private debt stock created a current account deficit due to high interest rates over a long period of time[4], reducing total investment and, consequently, potential GDP growth. As a result, our projection considers that the Brazilian economy should grow at a maximum of 3.5% per year, constrained by the debt amortization during the next decade. This will consume part of the internal savings, reducing investment and, consequently, GDP growth. Table 1 summarizes major macroeconomic projections.

**Table 1 – Macroeconomic projections (% increase per year)**

| | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|
| GNP growth rate (%) | 3,0 | 3,5 | 4,0 | 3,0 | 3,5 | 3,5 | 3,5 |
| Inflation (%) | 5,5 | 5,0 | 4,5 | 4,0 | 4,0 | 4,0 | 4,0 |
| Exchange rate (R$/US$) | 3,0 | 3,2 | 3,4 | 3,6 | 3,7 | 3,8 | 3,9 |
| Interest rate (%) | 15,5 | 14,0 | 12,5 | 12,0 | 12,0 | 12,0 | 12,0 |

*Projection : MB Associados 16/08/2002*

## 4. FOOD DEMAND

Three elements are relevant for estimating the growth of the food demand in the long run, as follows :

a) income growth ;
b) population growth ;
c) changes in income distribution.

[3] Currency depreciation was not seen as a solution viable for eliminating trade deficit because it could have raised inflation of all tradable products, ending price stability that was hardly achieved.

[4] Total debt over GDP nowadays is around 56%.

As mentioned in the preceding section, GDP growth rate was projected according to a macroeconomic model. To estimate the demand growth rate for different foods it requires to know how different products and different income levels affect the demand dynamics of a specific food. In short, it is necessary to know the income elasticity of demand for each product and each group of consumers, classified by income level.

The model used to estimate income elasticity was a polygonal one, taken in log-log form, with constant elasticity within each group, following a specification presented in equation 1, that is[5] :

(Eq.1) $\log(Y_i) = \alpha + \beta\log(X_i) + \sum \delta_h Z_{hi} (\log X_i - \log\theta_h) + u_i$
where :
$Y_i$ food spending per stratum ;
$X_i$ average income of each stratum ;
$\theta_h$ is the upper limit of the h stratum ;
$Z_{hi}$ is a binary variable with $Z_{hi}=0$ for $X_i < \theta_h$ and $Z_{hi}=1$ for $Xi < \theta_h$ .
Parameter $\beta$ is the income elasticity of stratum I, $\beta + \delta_1$ is the income elasticity of stratum II and $\beta + \delta_1 + \delta_2$ is the income elasticity of stratum III.

The following stratum has been considered: stratum I – 1 to 5 minimum salaries ; stratum II - 5 to 20 minimum salaries ; and stratum III – more than 20 minimum salaries.

Table 2 shows income elasticity for a variety of food. The figures presented represent a relation between a percentage change in specific food demand and a percentage change in income. For instance, if there is a 10% increase in total income, there is going to be an increase in 6.4% in sugar demands for stratum I, 3.6% for stratum II and 3.5% for stratum III. It can be noted that there is a pattern in income elasticity : generally, a higher income level is related to shorter income elasticity of demand. Also, animal products and processed food tend to have higher income elasticity.

It is important to note that Brazilian asymmetric income distribution generates a unique kind of aggregate food demand, that is, there is a demand for basic food and for more sophisticated ones. Also, it is important to note that changes in income distribution can alter the food demand pattern. Our model explicitly admits that there is going to be a small change in income distribution, due to better basic education and the end of high inflation, which represented an indirect tax over salaries (an inflation rate of 20% to 30 % a month considerably lowers the purchasing power of a salary)[6].

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[5] For methodological details see : Hoffman, Rodolfo & Maria Cristina Ortiz Frutoso (1981) “Determinação da elasticidade-renda da demanda de alimentos no estado de São Paulo através do ajustamento de uma poligonal”, Sociedade Brasileira de Econometria.

[6] The model is capable of dealing with any income distribution dynamics that a researcher would consider reasonable.

**Table 2 – Income elasticity of demand to three-income stratum, Brazil, 1999**

| Product | Stratum I | Stratum II | Stratum III | Product | Stratum I | Stratum II | Stratum III |
|---|---|---|---|---|---|---|---|
| In home food consump. | 0.61 | 0.38 | 0.35 | Processed meat | 0.73 | 0.40 | 0.39 |
| Tomato | 0.63 | 0.33 | 0.30 | Fresh fish | 0.32 | 0.59 | 0.56 |
| Pasta | 0.61 | 0.08 | 0.06 | Dairy | 0.68 | 0.42 | 0.40 |
| Sugar | 0.64 | 0.36 | 0.35 | Milk | 0.68 | 0.49 | 0.46 |
| Fruits | 0.73 | 0.57 | 0.55 | Powdered milk | 0.44 | -0.06 | -0.05 |
| Wheat flour | 0.64 | 0.10 | 0.08 | Cheese | 0.78 | 1.16 | 1.12 |
| Chicken | 0.50 | 0.17 | 0.14 | Other dairy | 0.89 | 0.53 | 0.53 |
| Beans | 0.43 | -0.18 | -0.20 | Bread | 0.57 | 0.29 | 0.26 |
| Orange | 0.70 | 0.31 | 0.29 | Beverages | 0.64 | 0.54 | 0.52 |
| Beef 1st | 0.96 | 0.54 | 0.53 | Soft drinks | 0.71 | 0.62 | 0.60 |
| Beef 2nd | 0.67 | -0.11 | -0.14 | Beer | 1.05 | 0.80 | 0.79 |
| Banana | 0.54 | 0.14 | 0.10 | Other drinks | 0.59 | 0.72 | 0.69 |
| Rice | 0.54 | -0.09 | -0.11 | Tinned foods | 0.59 | 0.80 | 0.77 |
| Coffee | 0.49 | 0.09 | 0.07 | Tomato sauce | 0.51 | 0.34 | 0.31 |
| Soy bean oil | 0.53 | -0.08 | -0.12 | Processed food | 0.53 | 1.39 | 1.33 |
| Potato | 0.67 | 0.42 | 0.39 | Restaurants | 1.01 | 0.74 | 0.74 |
| Pork | 0.64 | 0.65 | 0.60 | | | | |

*Source : MB Associados*

Data used to estimate income elasticity of demand was taken from a survey conducted by the Brazilian Institute of Geography and Statistics, IBGE (*Instituto Brasileiro de Geografia e Estatística*). This survey, named PNAD (*Pesquisa Nacional de Amostragem de Domicílio*), surveys all family expenditures, classifying each family per income level. This data was taken in 1996 and covered nine capitals around the country.

The other element that is essential to any food demand projection is the population growth. Again, IBGE was the main source of data. The population census, recently published (2001), showed that the Brazilian population is growing at a much slower pace, converging to a developed world pattern (1.3 % a year). This figure suggests that in the long run income growth together with export growth are going to be the driving forces for agricultural expansion in Brazil.

The combination of income growth (weighted by income elasticity demand), better income distribution and population growth produces the growth estimates of domestic food demand. The annual growth rate of demand for Brazilian agriculture can be calculated by taking the Brazilian market share in world commodities markets and the annual expansion of these markets, together with domestic market expansion.

Tables 3 to 6 summarize these annual growth rates for different agricultural products, considering domestic market and export.

**Table 3 – Annual growth rate of demand for animal products (% per year)**

| | | annual growth rate (%) |
|---|---|---|
| Beef | | |
| | domestic | 3.0 |
| | export | 4.0 |
| Chicken | | |
| | domestic | 2.2 |
| | export | 4.0 |
| Pork | | |
| | domestic | 2.8 |
| | export | 12.0 |
| Milk | | 2.7 |

**Table 4 – Annual growth rate of demand for soybean and soybean products (% per year)**

| | annual growth rate (%) |
|---|---|
| Soybean crushing | |
| Soybean meal domestic | 3.4 |
| Soybean meal export | 3.0 |
| Soybean oil domestic | 2.0 |
| Soybean oil export | 1.8 |
| Soybean grain export | 4.8 |

**Table 5 – Annual growth rate of demand for sugar cane products (% per year)**

| | annual growth rate (%) |
|---|---|
| Alcohol | 0.8 |
| Sugar domestic | 2.5 |
| Sugar export | 1.5 |

**Table 6 – Annual growth rate of demand for different commodities (% per year)**

| | annual growth rate (%) |
|---|---|
| Orange | 1.3 |
| Processed | 0.6 |
| In natura | 2.4 |
| Coffee | 2.3 |
| domestic | 2.1 |
| export | 2.5 |
| Cotton | 3.8 |
| Tomato | 2.2 |
| Wheat | 2.0 |
| Rice | 1.7 |
| Banana | 2.2 |
| Potato | 2.3 |
| Bean | 1.6 |

## 5. MODEL, PART 1 : CROP FERTILIZER DEMAND

Any model that pretends to measure fertilizer demand in a country as large and diverse as Brazil has to be flexible. Climate, soil, logistics, urbanization, etc. differ substantially between the different regions. The model developed is flexible enough to capture these differences. It consists, essentially, by the combination of plant response to fertilization together with data on production, area and productivity for each commodity raised in each Brazilian state.

The first step in estimating crop fertilizer demand was to determine a set of curves that captures plant response to nitrogen (N), phosphorus (P) and potash (K) fertilization. These curves were determined by specialists based on experiments and empirical work.

Figures 2 to 4 show corn response to fertilization of N, P and K, respectively.

**Figure 2 – Corn response to nitrogen fertilization**
**(production in tonne per hectare and fertilization in kilogram per hectare)**

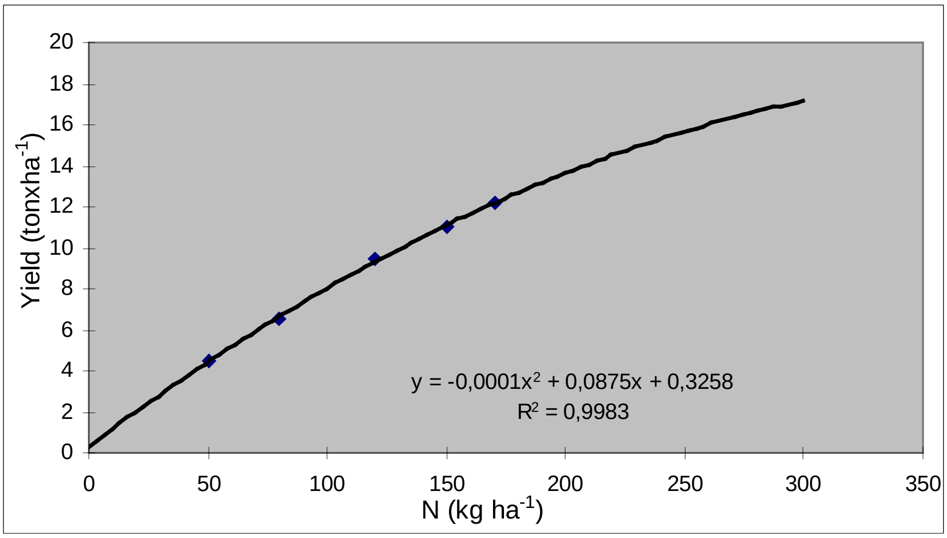



**Figure 3 – Corn response to phosphorus fertilization**
**(production in tonne per hectare and fertilization in kilogram per hectare)**

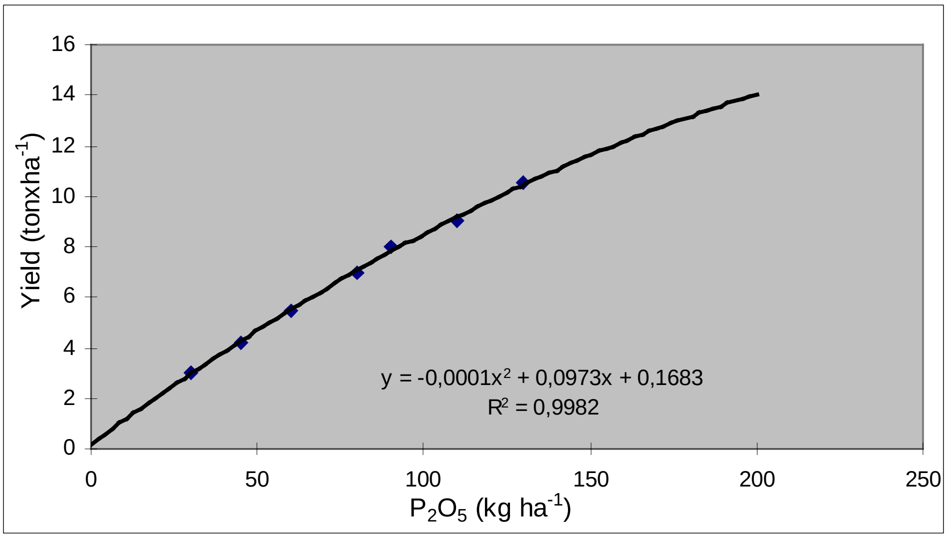
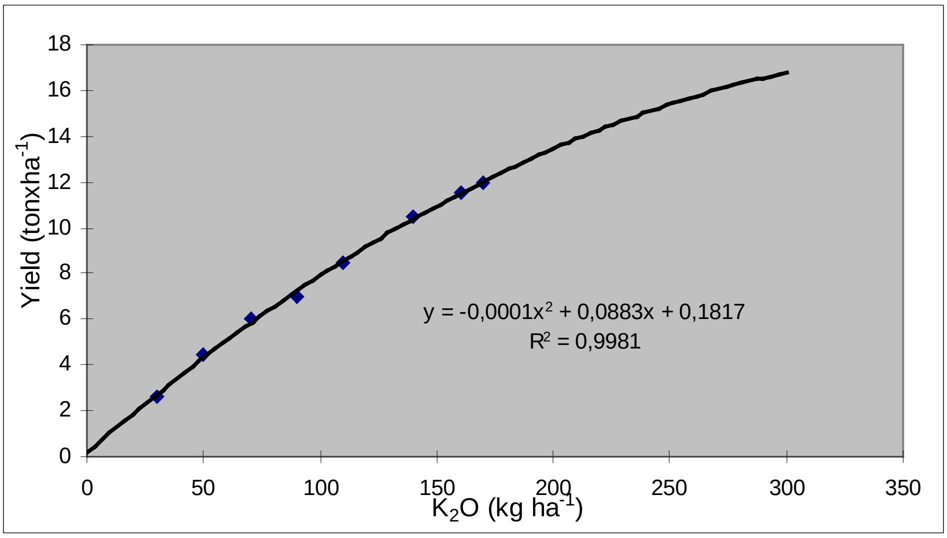


**Figure 4 – Corn response to potash fertilization (production in tonne per hectare and fertilization in kilogram per hectare)**




The key element to determine how many kilograms of nutrient is needed per hectare is the productivity level. If the data is available on cultivated areas, the total nutrient demand based on it could easily be determined.

It is important to note that fertilization shows a decreasing marginal productivity pattern, as can be seen in figures 2 to 4.

Because of that absence of linearity between fertilization and productivity, it would be incorrect to estimate nutrient extraction based only on the volume of production. As productivity grows, more nutrient per tonne produced is required.

The relevance of differences in productivity to nutrient demand determination can be seen with the help of table 7. Differences in productivity level around Brazil reflect on nutrient utilization per area (hectare).

Table 7 shows nutrient requirement per hectare for corn in several Brazilian states. It can be seen that the figures vary considerably. Table 7 indicates also that projected productivity to these states will not close the gap between them, showing a different pattern of future nutrient demand.

**Table 7 – Corn fertilization levels for different Brazilian states in 1999-2001 and 2010 according to respective productivity level (in kilograms per hectare)**

| | 1999-2001 | | | 2010 | | |
|---|---|---|---|---|---|---|
| | N | P | K | N | P | K |
| Brazil | 29 | 28 | 31 | 42 | 39 | 43 |
| Tocantins | 18 | 18 | 20 | 30 | 28 | 31 |
| Minas Gerais | 35 | 33 | 36 | 50 | 47 | 52 |
| Espírito Santo | 25 | 24 | 26 | 30 | 28 | 31 |
| São Paulo | 31 | 30 | 33 | 39 | 37 | 40 |
| Paraná | 39 | 37 | 41 | 54 | 49 | 55 |
| Mato Grosso | 28 | 27 | 30 | 33 | 31 | 35 |
| Mato Grosso do Sul | 35 | 33 | 36 | 49 | 45 | 50 |
| Goiás | 49 | 45 | 50 | 58 | 53 | 59 |

It is possible now to highlight the model logical structure.

Based on the food demand projection, there is a total volume of production for each of the main commodities grown in Brazil. These figures indicate that a certain amount of nutrient is going to be needed to achieve this total production. Total nutrient requirement will, in turn, depend on the productivity level for each crop. The total area required to meet the demand is calculated by projecting these productivity figures and dividing total production (determined by the demand model) by these projected productivity figures. The total NPK demanded can be calculated by multiplying this total area by nutrient fertilization per hectare.

All data (area, production and productivity) are taken from IBGE and are yearly surveyed[7]. It is important to realize that IBGE gives these statistics to each state and to each county. So, our model could be easily extended to determine demand in local municipalities.

[7] The survey that collects information on production, area and productivity yearly is called PAM (*Produção Agrícola Municipal*). The same information are collected from the Agricultural Census, conducted every five years by IBGE.

Table 8 summarizes total production for major crops in Brazil in 1999-2001 and the projected demand for each crop.

It can be seen that there are major differences among products. Cotton, soybean, corn and wheat show a very dynamic standard of projected growth, indicating 3% to 4 % of annual increase.

**Table 8 – Total production in 2001 and projected production in 2010 (in million tonnes)**

| | average 99-2001 | 2011 | average annual growth rate (%) |
|---|---|---|---|
| Cotton | 1,9 | 3,5 | 5,8% |
| Rice | 11 | 13,4 | 1,8% |
| Banana | 0,6 | 0,7 | 1,9% |
| Potato | 2,7 | 3,3 | 1,8% |
| Cocoa | 0,2 | 0,3 | 3,7% |
| Coffee | 29,7 | 38,3 | 2,3% |
| Sugar cane | 336,2 | 374,2 | 1,0% |
| Bean | 2,8 | 3,3 | 1,4% |
| Tobacco | 0,6 | 0,7 | 1,3% |
| Orange | 107,9 | 122,5 | 1,2% |
| Corn | 35,2 | 49,3 | 3,1% |
| Soybean | 33,8 | 49,3 | 3,5% |
| Tomato | 3,1 | 3,8 | 1,8% |
| Wheat | 2,5 | 4 | 4,5% |
| Grape | 1 | 1,1 | 1,6% |

The other key element to project is productivity increase. Several projections were made considering historical trend for each commodity in each state. Over 800 regressions to were run to estimate the change in productivity through time.

Table 9 shows actual and projected productivity for Brazil. It can be seen that if productivity continues to follow a recent trend, in ten years time it will rise considerably, closing the gap between the agriculture of Brazil and developed countries.

**Table 9 – Average productivity in 2001 and projected productivity in 2010 (in tonne per hectare)**

| | average 99-2001 | 2011 | average annual growth rare (%) |
|---|---|---|---|
| Cotton | 2,4 | 2,7 | 0,9% |
| Rice | 3,1 | 3,6 | 1,4% |
| Banana | 1,1 | 1,1 | -0,1% |
| Potato | 17,2 | 19,6 | 1,2% |
| Cocoa | 0,3 | 0,4 | 4,1% |
| Coffee | 13,1 | 15,5 | 1,6% |
| Sugar cane | 68,7 | 74,2 | 0,7% |
| Bean | 0,7 | 0,9 | 1,7% |
| Tobacco | 1,9 | 1,9 | 0,2% |
| Orange | 120,2 | 123,3 | 0,2% |
| Corn | 3 | 3,9 | 2,4% |
| Soybean | 2,5 | 3,2 | 2,2% |
| Tomato | 52,5 | 62,3 | 1,6% |
| Wheat | 1,8 | 2,3 | 2,1% |
| Grape | 16,2 | 17,8 | 0,9% |

By combining total production with productivity it is possible to establish the total area harvested.

Table 10 summarizes data on harvested area for different crops in 2001 and projected harvested area in 2011. It can be seen that the projection indicates a 10% increase in the total harvested area.

**Table 10 – Harvested area 2001 and projected harvested area (in million hectares)**

| | Average 1999-2001 | 2011 | Annual growth rate (%) |
|---|---|---|---|
| Cotton | 0,8 | 1,3 | 4,9% |
| Rice | 3,5 | 3,7 | 0,4% |
| Banana | 0,5 | 0,6 | 2,0% |
| Potato | 0,2 | 0,2 | 0,6% |
| Cocoa | 0,7 | 0,7 | -0,4% |
| Coffee | 2,3 | 2,5 | 0,8% |
| Sugar cane | 4,9 | 5 | 0,3% |
| Bean | 3,9 | 3,8 | -0,3% |
| Tobacco | 0,3 | 0,4 | 1,1% |
| Orange | 0,9 | 1 | 0,9% |
| Corn | 11,9 | 12,8 | 0,7% |
| Soybean | 13,5 | 15,6 | 1,3% |
| Tomato | 0,1 | 0,1 | 0,2% |
| Wheat | 1,3 | 1,7 | 2,3% |
| Grape | 0,1 | 0,1 | 0,7% |
| Total | 44,8 | 49,3 | 10,1% |

Combining the total area with nutrient fertilization per hectare, considering the productivity level, gives the total NPK demand in 2010.

Table 11 synthesises major results for Brazil and its five main regions. Figures are presented in thousands of tonnes.

Table 12 indicates percentage variations on fertilizer demand.

Table 13 shows the same results for each Brazilian state.

**Table 11 – NPK consumption in 2001 and projected consumption in 2010 ('000 tonnes)**

| | average 1998-2000 | | | | 2010 | | | |
|---|---|---|---|---|---|---|---|---|
| | N | P2O5 | K20 | NPK | N | P2O5 | K20 | NPK |
| North | 44 | 31 | 45 | 120 | 60 | 44 | 60 | 165 |
| Northeast | 124 | 125 | 179 | 429 | 168 | 198 | 265 | 631 |
| Southeast | 603 | 386 | 633 | 1,621 | 728 | 462 | 770 | 1,961 |
| South | 395 | 677 | 724 | 1,796 | 591 | 986 | 1,034 | 2,611 |
| Center west | 190 | 565 | 587 | 1,342 | 338 | 984 | 1,011 | 2,332 |
| BRAZIL | 1,355 | 1,784 | 2,168 | 5,307 | 1,885 | 2,674 | 3,141 | 7,700 |

**Table 12 – Variation between NPK consumption in 2001 and projected consumption in 2010 (%)**

| | Variation % (2010/1998-2000) | | | |
|---|---|---|---|---|
| | N | P2O5 | K20 | NPK |
| North | 37 | 44 | 34 | 38 |
| Northeast | 36 | 58 | 48 | 47 |
| Southeast | 21 | 20 | 22 | 21 |
| South | 49 | 46 | 43 | 45 |
| Center west | 78 | 74 | 72 | 74 |
| BRAZIL | 39 | 50 | 45 | 45 |

**Table 13 - NPK consumption in 2001 and projected consumption in 2010 for each Brazilian states ('000 tonnes)**

| | average 1998-2000 | | | | 2010 | | | | % change (2010/average1998-2000) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P2O5 | K20 | NPK | N | P2O5 | K20 | NPK | N | P2O5 | K20 | NPK |
| RO | 19,5 | 9,5 | 16,0 | 45,0 | 24,8 | 10,6 | 18,3 | 53,7 | 27 | 11% | 15% | 19% |
| AC | 1,2 | 1,1 | 1,5 | 3,7 | 1,2 | 1,2 | 1,5 | 3,9 | 2 | 9 | 3 | 4 |
| AM | 3,5 | 2,2 | 4,4 | 10,1 | 5,6 | 3,6 | 7,1 | 16,3 | 61 | 62 | 60 | 61 |
| RR | 0,9 | 1,1 | 1,0 | 3,1 | 1,8 | 2,0 | 1,9 | 5,8 | 103 | 82 | 89 | 91 |
| PA | 19,1 | 16,7 | 21,9 | 57,7 | 27,0 | 26,6 | 31,3 | 84,9 | 42 | 59 | 43 | 47 |
| TO | 6,5 | 11,2 | 9,8 | 27,5 | 7,6 | 15,2 | 13,8 | 36,6 | 17 | 35 | 41 | 33 |
| AP | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,1 | 106 | 89 | 99 | 97 |
| MA | 9,0 | 19,0 | 19,2 | 47,2 | 12,9 | 31,3 | 30,7 | 75,0 | 44 | 65 | 60 | 59 |
| PI | 3,5 | 5,7 | 6,5 | 15,6 | 2,2 | 6,9 | 8,2 | 17,3 | -37 | 22 | 26 | 11 |
| CE | 9,8 | 8,1 | 13,1 | 31,0 | 10,6 | 9,0 | 14,8 | 34,5 | 8 | 12 | 13 | 11 |
| RN | 2,8 | 1,4 | 3,4 | 7,6 | 3,6 | 2,1 | 4,5 | 10,3 | 29 | 50 | 34 | 35 |
| PB | 5,8 | 2,8 | 7,1 | 15,6 | 6,4 | 3,3 | 7,7 | 17,4 | 11 | 19 | 9 | 11 |
| PE | 16,4 | 8,2 | 19,0 | 43,6 | 19,5 | 10,9 | 22,8 | 53,2 | 19 | 33 | 20 | 22 |
| AL | 26,7 | 13,2 | 29,1 | 69,0 | 31,8 | 15,4 | 34,6 | 81,8 | 19 | 16 | 19 | 19 |
| SE | 5,7 | 4,6 | 5,7 | 15,9 | 6,1 | 4,8 | 5,9 | 16,9 | 8 | 6 | 4 | 6 |
| BA | 44,2 | 62,4 | 76,4 | 182,9 | 74,8 | 113,9 | 135,7 | 324,4 | 69 | 83 | 78 | 77 |
| MG | 198,4 | 139,5 | 210,7 | 548,6 | 257,4 | 179,2 | 282,3 | 718,9 | 30 | 28 | 34 | 31 |
| ES | 71,1 | 19,8 | 55,0 | 145,9 | 102,2 | 26,9 | 80,5 | 209,6 | 44 | 36 | 46 | 44 |
| RJ | 9,9 | 4,9 | 10,9 | 25,7 | 9,7 | 4,9 | 10,7 | 25,3 | -2 | 2 | -2 | -1 |
| SP | 323,2 | 222,1 | 356,0 | 901,3 | 359,1 | 251,2 | 396,4 | 1.006,8 | 11 | 13 | 11 | 12 |
| PR | 187,4 | 352,9 | 375,3 | 915,6 | 267,9 | 522,1 | 544,0 | 1.334,0 | 43 | 48 | 45 | 46 |
| SC | 65,5 | 80,0 | 88,4 | 233,9 | 96,1 | 111,7 | 121,8 | 329,7 | 47 | 40 | 38 | 41 |
| RS | 142,2 | 243,9 | 260,1 | 646,2 | 226,8 | 352,4 | 368,5 | 947,8 | 59 | 45 | 42 | 47 |
| MT | 75,2 | 293,4 | 300,2 | 668,9 | 170,6 | 590,2 | 602,7 | 1.363,5 | 127 | 101 | 101 | 104 |
| MS | 35,4 | 97,4 | 103,3 | 236,1 | 56,2 | 151,9 | 155,9 | 363,9 | 59 | 56 | 51 | 54 |
| DF | 2,2 | 3,9 | 4,3 | 10,4 | 2,2 | 3,6 | 4,0 | 9,8 | 2 | -8 | -8 | -6 |
| GO | 70,4 | 159,2 | 169,5 | 399,1 | 101,1 | 222,7 | 234,9 | 558,7 | 44 | 40 | 39 | 40 |
| BRAZIL | 1.355,4 | 1.784,2 | 2.167,6 | 5.307,3 | 1.885,4 | 2.673,8 | 3.140,6 | 7.699,9 | 39 | 50 | 45 | 45 |

Once NPK demand was estimated, a survey has been conducted to determine all major formulas used for each crop in each state.

Those formulas were essential to determine row material requirements.

Table 14 exemplifies the data kind collected in our survey.

**Table 14 – Most used formula in corn production in Paraná state**

| PARANÁ | | Formula 2000 | Formula 2010 | % use 2000 | % use 2010 |
|---|---|---|---|---|---|
| Corn | 1st | 8-20-20 | 8-20-20 | 25% | 25% |
| | | 8-28-16 | 8-28-16 | 20% | 20% |
| | | 4-20-20 | 4-20-20 | 20% | 10% |
| | | 4-20-10 | 4-20-10 | 15% | 15% |
| | | 8-20-10 | 8-20-10 | 15% | 15% |
| | | 10-20-20 | 10-20-20 | 5% | 15% |
| | 2nd | 8-20-20 | 8-20-20 | 25% | 25% |
| | | 8-28-16 | 8-28-16 | 20% | 20% |
| | | 4-20-20 | 4-20-20 | 20% | 10% |
| | | 4-20-10 | 4-20-10 | 15% | 15% |
| | | 8-20-10 | 8-20-10 | 15% | 15% |
| | | 10-20-20 | 10-20-20 | 5% | 15% |
| | 3rd | 20-00-20 | 20-00-20 | 10% | 10% |
| | | 36-00-12 | 36-00-12 | 5% | 5% |
| | | 30-00-10 | 30-00-10 | 5% | 5% |
| | | 20-05-20 | 20-05-20 | 10% | 10% |
| | | NITRATE | NITRATE | 1% | 1% |
| | | UREA | UREA | 35% | 35% |
| | | SULPHATE | SULPHATE | 34% | 34% |

## 6. MODEL, PART 2 : FERTILIZER DEMAND FOR PASTURE LAND

The methodology applied here follows a distinctive pattern from cropland session. Demand expansion to be met in 2010 is 35% higher than indicated in the first session but an increase in output will be achieved through investment in a set of production systems indicated in Table 15.

**Table 15 – Cattle production systems**

**Production Systems**

**1) "pantanal" wetlands, "caatinga" semi-arid, native "cerrados" savannas**
**2) Climate transition zones (600 a 1000 mm), degraded cerrados savannas**
**3) Planted "cerrados" savannas, degraded forests**
**4) Upgraded "cerrados" savannas (A), planted in forest soils**
**5) Upgraded forests (A), deferred "cerrados" savannas (B)**
**6) Deferred forests (B), deferred "cerrados" savannas (C)**
**7) Deferred forests (C), heavy fertilized "cerrados" savannas (D)**
**8) Heavy fertilized forests and "cerrados" savannas (E)**

An average level of animal sustainability throughout the year is attached to each system. In each state we simulated a combination of different systems in order to reproduce the average sustainability per hectare of pastureland found in the Agricultural Census of 1995/1996, projected to year 2000.

The aggregate data for Brazil is shown in the Table 16.

**Table 16 – Productivity and total area per cattle system**

| SYSTEMS | UA/HA | AREA (%) | AREA (HÁ) |
|---|---|---|---|
| 1 | 0,175 | 28 | 49.261.000 |
| 2 | 0,375 | 24 | 42.119.000 |
| 3 | 0,675 | 20 | 35.365.000 |
| 4 | 0,875 | 20 | 36.375.000 |
| 5 | 1,175 | 5 | 9.669.000 |
| 6 | 1,375 | 2 | 3.426.000 |
| 7 | 1,675 | 1 | 1.145.000 |
| 8 | 2,000 | 0 | 315.000 |

*Note : UA stands for animal unit, equivalent to an adult female animal.*

Systems 4 to 8 require different levels of fertilizers and lime applications according to levels and frequency indicated in Table 17.

**Table 17 – Fertilizer requirements for each cattle production system**

| SYSTEMS | INPUTS | FREQUENCY |
|---|---|---|
| A | Lime<br>40 kg/ha $P_2O_5$ – Brachiaria<br>60 kg/ha $P_2O_5$ – panicuns | 10 years |
| B/C | Same as A, plus:<br>40 kg per hectare of $P_2O_5$<br>50 kg per hectare of N | 10 years<br>3 years<br>Annually |

| | | |
|---|---|---|
| **D/E** | **Same as system A and B/C, plus :**<br>**60 kg per hectare of $P_2O_5$**<br>**200 kg per hectare of N**<br>**50 kg per hectare of $K_2O$** | **2 years**<br>**Annually**<br>**2 years** |
| **Grass silage** | **60 kg per hectare of $P_2O_5$**<br>**100 kg per hectare of $K_2O$**<br>**300 kg per hectare of N** | **Annually**<br>**Annually**<br>**Annually** |

The average year demand for each major nutrient is given in the Table 18.

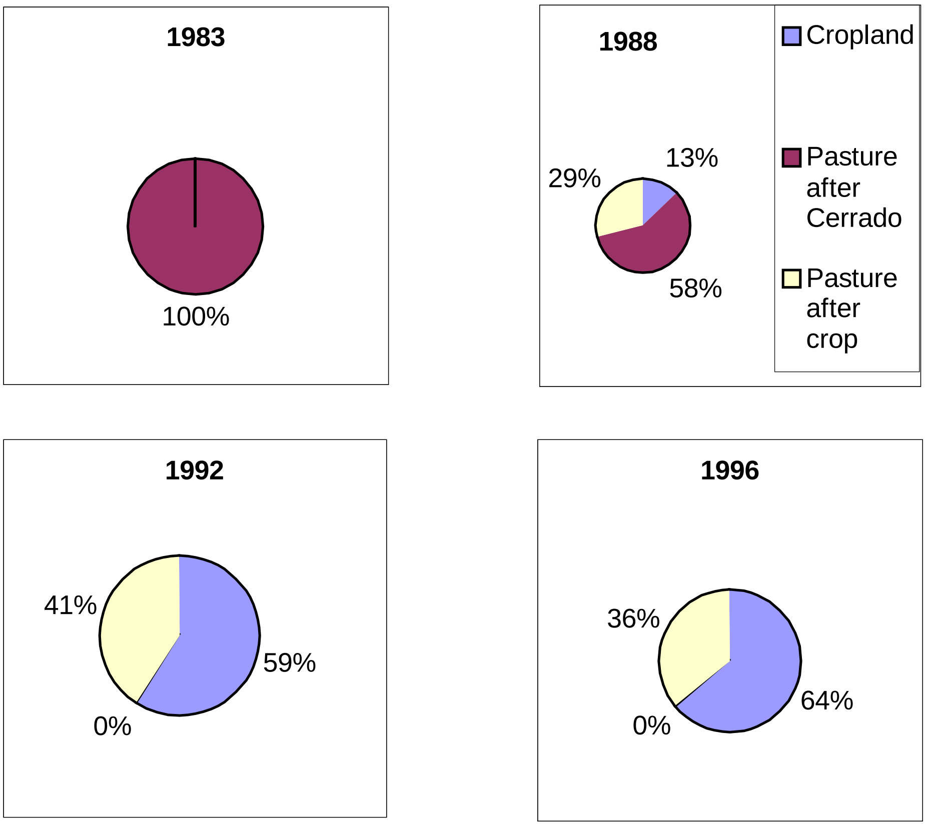
**Table 18 – Nutrient requirement per hectare per cattle production system**

| SYSTEMS | N (kg/ha/year) | $P_2O_5$ (kg/ha/year) | $K_2O$ (kg/ha/year) |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 |
| 4 | 0 | 2.5 | 0 |
| 5 | 3.75 | 6.25 | 0 |
| 6 | 10.00 | 8.33 | 0 |
| 7 | 12.50 | 10.67 | 5 |
| 8 | 32.50 | 11.33 | 5 |

In order to meet demand requirements, livestock production is assumed to expand in the same total area of pasture by upgrading the structure of the production systems, within each state. Each of them will attain a higher average level of sustainability according to the level of competition with cropland for the unused land as given by the Agricultural Census.

There is enough evidence to sustain this process from the agronomic and economical point of view as indicated in Table 19.

**Table 19 – Pasture land occupation**




| Years | Herd | Sust. Rate (ua/ha) |
|---|---|---|
| 1983 | 1094 | 1.1 |
| 1988 | 821 | 1.9 |
| 1992 | 1150 | 2.3 |
| 1996 | 1200 | 3.2 |

*Source : Vilela et. Al. (2001)*[8]

[8] Vilela L., Ayarza M., Miranda J.C.C. Agropastoral systems : activities developed by Cerrados Agricultural Research Center-Embrapa Cerrados ; Brasilia 2001.

Several simulations were done for each state of the country. We chose one to be presented in this text that respected a general constraint of land competition between pasture and crop, allowing for a restrict increase in the total area under utilization. Table 20 gives these general constraints.

**Table 20 – Constraints to pastureland transition**

| Potential Expansion of Area under Utilization | Dominant Production Systems | States |
|---|---|---|
| 0 - 5 % | 5, 6, 7 and 8 | ES, SP, PR, MS, GO |
| 5 - 10 % | 5 and 6 | MG, RJ, SC, RS, MT, TO, PA, PE, AL, BA |
| 10 - 20 % | 2, 3, 4 and 5 | RO, AC, AM, RR, AP, MA, PI, CE, RN, PB, SE |

The final outcome of this simulation is reported in Table 21.

**Table 21 – Projected area per cattle production system**

| SYSTEMS | AREA (%) 2000 | AREA (%) 2010 | AREA HA |
|---|---|---|---|
| 1 | 28 | 28 | 49,144,000 |
| 2 | 24 | 18 | 31,684,000 |
| 3 | 20 | 19 | 33,252,000 |
| 4 | 20 | 17 | 29,634,000 |
| 5 | 5 | 8 | 14,989,000 |
| 6 | 2 | 6 | 9,985,000 |
| 7 | 1 | 4 | 6,874,000 |
| 8 | 0 | 1 | 2,314,000 |

With the area increment in the more fertilizer intensive production systems we can calculate the final demand for them in 2010, values reported in Table 22.

**Table 22 – Total pastureland demand for nutrients in 2010, Brazil**

| NUTRIENTS | N (tonne/year) | $P_2O_5$ (tonne/year) | $K_2O$ (tonne/year) |
|---|---|---|---|
| **CONSUMPTION in 2010** | **317,179** | **350,517** | **45,937** |

To meet the large growing demand in a decade (+35%) the fertility rate must also increase from 60% to 80%, slaughter rate from 16% to 17.6% that by itself will require an improvement in mineral salt nutrient intake. For our purpose, the input highlighted here is bi-calcium phosphate, with 120,000 tonnes of additional demand.

The final increase in demand for fertilizer nutrients in given in Table 23.

**Table 23 - Total increase in demand for nutrients, Brazil – Summary**

| SYSTEMS | N (tonne/year) | $P_2O_5$ (tonne/year) | $K_2O$ (tonne/year) |
|---|---|---|---|
| **Fertilizer** | **222,117** | **154,821** | **38,639** |
| **Mineral Salt** | **0** | **119,282** | **0** |
| **Total** | **222,117** | **274,103** | **38,639** |

| | STATES | MG | ES | RJ | SP | PR | SC | RS |
|---|---|---|---|---|---|---|---|---|
| SYSTEMS | UA /HÁ | % | % | % | % | % | % | % |
| 1 | 0.175 | 0.360 | 0.170 | 0.060 | 0.000 | 0.000 | 0.030 | 0.080 |
| 2 | 0.375 | 0.120 | 0.100 | 0.100 | 0.060 | 0.050 | 0.080 | 0.080 |
| 3 | 0.675 | 0.130 | 0.170 | 0.220 | 0.150 | 0.100 | 0.100 | 0.180 |
| 4 | 0.875 | 0.230 | 0.250 | 0.355 | 0.220 | 0.200 | 0.210 | 0.320 |
| 5 | 1.175 | 0.115 | 0.150 | 0.200 | 0.230 | 0.220 | 0.325 | 0.230 |
| 6 | 1.375 | 0.030 | 0.100 | 0.050 | 0.190 | 0.220 | 0.230 | 0.100 |
| 7 | 1.675 | 0.010 | 0.040 | 0.010 | 0.100 | 0.140 | 0.020 | 0.010 |
| 8 | 2.000 | 0.005 | 0.020 | 0.005 | 0.050 | 0.070 | 0.005 | 0.000 |
| | UA/HÁ | 0.600 | 0.822 | 0.838 | 1.115 | 1.197 | 1.028 | 0.870 |
| | | MS | MT | GO | DF | RO | AC | AM |
| SYSTEMS | UA /HÁ | % | % | % | % | % | % | % |
| 1 | 0.175 | 0.180 | 0.240 | 0.180 | 0.200 | 0.000 | 0.000 | 0.000 |
| 2 | 0.375 | 0.150 | 0.280 | 0.200 | 0.200 | 0.080 | 0.080 | 0.080 |
| 3 | 0.675 | 0.170 | 0.160 | 0.160 | 0.160 | 0.160 | 0.160 | 0.160 |
| 4 | 0.875 | 0.200 | 0.160 | 0.200 | 0.200 | 0.400 | 0.400 | 0.400 |
| 5 | 1.175 | 0.150 | 0.110 | 0.120 | 0.120 | 0.260 | 0.260 | 0.260 |
| 6 | 1.375 | 0.100 | 0.040 | 0.090 | 0.080 | 0.100 | 0.100 | 0.100 |
| 7 | 1.675 | 0.040 | 0.010 | 0.040 | 0.030 | 0.000 | 0.000 | 0.000 |
| 8 | 2.000 | 0.010 | 0.000 | 0.010 | 0.010 | 0.000 | 0.000 | 0.000 |
| | UA/HÁ | 0.778 | 0.596 | 0.741 | 0.714 | 0.931 | 0.931 | 0.931 |
| | | RR | PA | AP | TO | MA | PI | CE |
| SYSTEMS | UA /HÁ | % | % | % | % | % | % | % |
| 1 | 0.175 | 0.800 | 0.180 | 0.800 | 0.480 | 0.340 | 0.360 | 0.280 |
| 2 | 0.375 | 0.100 | 0.210 | 0.100 | 0.300 | 0.160 | 0.160 | 0.140 |
| 3 | 0.675 | 0.020 | 0.240 | 0.100 | 0.120 | 0.180 | 0.180 | 0.160 |
| 4 | 0.875 | 0.060 | 0.220 | 0.000 | 0.080 | 0.180 | 0.180 | 0.220 |
| 5 | 1.175 | 0.020 | 0.110 | 0.000 | 0.020 | 0.130 | 0.110 | 0.140 |
| 6 | 1.375 | 0.000 | 0.040 | 0.000 | 0.000 | 0.010 | 0.010 | 0.030 |
| 7 | 1.675 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.020 |
| 8 | 2.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.010 |
| | UA/HÁ | 0.267 | 0.649 | 0.245 | 0.371 | 0.565 | 0.545 | 0.661 |
| | | RN | PB | PE | AL | SE | BA | BRASIL |
| SYSTEMS | UA /HÁ | % | % | % | % | % | % | |
| 1 | 0.175 | 0.300 | 0.380 | 0.260 | 0.100 | 0.280 | 0.420 | |
| 2 | 0.375 | 0.160 | 0.160 | 0.140 | 0.140 | 0.240 | 0.220 | |
| 3 | 0.675 | 0.200 | 0.140 | 0.160 | 0.210 | 0.160 | 0.140 | |
| 4 | 0.875 | 0.210 | 0.140 | 0.180 | 0.230 | 0.180 | 0.120 | |
| 5 | 1.175 | 0.120 | 0.120 | 0.160 | 0.160 | 0.110 | 0.070 | |
| 6 | 1.375 | 0.010 | 0.060 | 0.080 | 0.120 | 0.020 | 0.030 | |
| 7 | 1.675 | 0.000 | 0.000 | 0.010 | 0.030 | 0.010 | 0.000 | |
| 8 | 2.000 | 0.000 | 0.000 | 0.010 | 0.010 | 0.000 | 0.000 | |
| | UA/HÁ | 0.586 | 0.567 | 0.698 | 0.836 | 0.578 | 0.479 | 0.696 |

| PASTURELAND | (1.000 ha.) | | | | | | |
|---|---|---|---|---|---|---|---|
| SYSTEMS | MG | ES | RJ | SP | PR | SC | RS |
| 1 | 9,125 | 310 | 93 | 0 | 0 | 70 | 934 |
| 2 | 3,042 | 182 | 155 | 544 | 334 | 187 | 934 |
| 3 | 3,295 | 310 | 340 | 1,359 | 668 | 234 | 2,102 |
| 4 | 5,830 | 455 | 549 | 1,994 | 1,335 | 491 | 3,738 |
| 5 | 2,915 | 273 | 309 | 2,084 | 1,469 | 760 | 2,686 |
| 6 | 760 | 182 | 77 | 1,722 | 1,469 | 538 | 1,168 |
| 7 | 253 | 73 | 15 | 906 | 935 | 47 | 117 |
| 8 | 127 | 36 | 8 | 453 | 467 | 12 | 0 |
| SUM | 25,349 | 1,821 | 1,545 | 9,062 | 6,677 | 2,339 | 11,680 |
| SYSTEMS | MS | MT | GO | DF | RO | AC | AM |
| 1 | 3,926 | 5,148 | 3,493 | 19 | 0 | 0 | 0 |
| 2 | 3,272 | 6,007 | 3,881 | 19 | 234 | 49 | 42 |
| 3 | 3,708 | 3,432 | 3,105 | 15 | 468 | 98 | 85 |
| 4 | 4,362 | 3,432 | 3,881 | 19 | 1,169 | 246 | 212 |
| 5 | 3,272 | 2,360 | 2,329 | 12 | 760 | 160 | 138 |
| 6 | 2,181 | 858 | 1,746 | 8 | 292 | 61 | 53 |
| 7 | 872 | 215 | 776 | 3 | 0 | 0 | 0 |
| 8 | 218 | 0 | 194 | 1 | 0 | 0 | 0 |
| SUM | 21,811 | 21,452 | 19,405 | 96 | 2,922 | 614 | 529 |
| SYSTEMS | RR | PA | AP | TO | MA | PI | CE |
| 1 | 1,234 | 1,342 | 196 | 5,318 | 1,824 | 863 | 737 |
| 2 | 154 | 1,566 | 24 | 3,323 | 858 | 384 | 368 |
| 3 | 31 | 1,789 | 24 | 1,329 | 966 | 432 | 421 |
| 4 | 93 | 1,640 | 0 | 886 | 966 | 432 | 579 |
| 5 | 31 | 820 | 0 | 222 | 697 | 264 | 368 |
| 6 | 0 | 298 | 0 | 0 | 54 | 24 | 79 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 53 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 26 |
| SUM | 1,543 | 7,456 | 245 | 11,078 | 5,365 | 2,398 | 2,632 |
| SYSTEMS | RN | PB | PE | AL | SE | BA | BRAZIL |
| 1 | 374 | 704 | 554 | 86 | 323 | 6,086 | 42,760 |
| 2 | 199 | 296 | 298 | 121 | 277 | 3,188 | 29,939 |
| 3 | 249 | 259 | 341 | 181 | 185 | 2,029 | 27,455 |
| 4 | 262 | 259 | 384 | 198 | 208 | 1,739 | 35,358 |
| 5 | 150 | 222 | 341 | 138 | 127 | 1,014 | 23,920 |
| 6 | 12 | 111 | 170 | 103 | 23 | 435 | 12,427 |
| 7 | 0 | 0 | 21 | 26 | 12 | 0 | 4,324 |
| 8 | 0 | 0 | 21 | 9 | 0 | 0 | 1,572 |
| SUM | 1,246 | 1,852 | 2,131 | 862 | 1,154 | 14,490 | 177,754 |