# FACTORS ASSOCIATED WITH THE CHANGE IN AGRICULTURAL COMPOSITION OF TWO AREAS IN STATE OF MINAS GERAIS - BRAZIL

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## ABSTRACT

This work analyzes the changes in area under cultivation that occurred between 1985 and 1995/1996 in the meso-regions Triângulo Mineiro/ Alto Paranaíba and Zona da Mata of the state of Minas Gerais, Brazil. The analysis was conducted in two methodological stages. First, variation in the area under cultivation for a specific crop was disaggregated into variation due to change in regional agricultural scale and variation due to the substitution effect. Second, an econometric model of the crop that had the greatest growth in cultivated area and highest substitution effect index value was developed to identify the main factors responsible for these high values. It is observed that the area under rice cultivation was reduced in all regions, a fact related with the high cost of production, that coffee cultivation expanded in Manhuaçu, due mainly to the area's favorable climate and topography, and that the area devoted to pasture expanded the most. It is stressed that the amount of land devoted to pasture increased as labor became scarcer: a 1% reduction in labor availability led to a 0.8% increase in pasture.

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**Keys words**: Agricultural composition, scale effect, substitution effect.

# 1 Introduction

Significant changes have been observed in the composition of agriculture in the state of Minas Gerais, Brazil. Certain crops have migrated and became concentrated in specific areas, while others have lost economic viability and been substituted. In this research, we isolated the changes that occurred between 1985 and 1995/96 in the composition of agriculture in the State of Minas Gerais and try to determine the major factors responsible for these changes.

The evolution of cultivated area in Minas Gerais is analyzed by examining the change in area under cultivation for specific crops in two state meso-regions, the Triângulo Mineiro/Alto Paranaíba and the Zona da Mata, in 1985 and 1995/96. To accomplish this, a group of geo-references was developed to create specific maps that allowed us to visualize the main structural and spatial components of the macro and micro-regions. The crop that had the greatest change in area under cultivation due to both scale and substitution effects was then isolated.

Economic analyses, such as those conducted by Gasquez & Villa Verde (1990) and Monteiro (1997), have been used to explain the evolution of Brazilian agricultural production. These analyses stress the importance of regional studies, rather than aggregated indicators as a more precise expression of reality in certain situations (i.e., when the area being examined is a state rather than a country), to the extent that micro-regional detail improves precision. Church et al. (1988), Martins (1995), and Gomes (1990), while examining the expansion of soy production, employed a modified version of analysis by disaggregation, examining variation of cultivated area due to both variation in the agricultural system's scale (change in land under cultivation for all crops) and variation due to substitution effects.

## 2 Methodology

The theoretical basis of this work is Martins' study (1995), which states that producer economic rationality demands that crops with a competitive advantage occupy new areas or are substituted by other crops. It is from this perspective that the meso-regions of Triângulo Mineiro/ Alto Paranaíba and Zona da Mata are analyzed. The Triângulo Mineiro/ Alto Paranaíba meso-region is extremely important agriculturally, accounting for 95% of Minas Gerais's pineapple production, 67% of its soy production, and 66% of its cotton production. The meso-region also contains the state's largest bovine herd, which represents about 23,2% of the state total. The Zona da Mata meso-region is of intermediate agricultural importance, being a traditional agricultural region occupied by small producers. However, it is the state's second largest coffee and third largest sugar-cane producing region (Curi, 1997).

The micro-regions that form the Triângulo Mineiro/Alto Paranaíba are Patrocíno (the 1985 micro-region of Alto Paranaíba, excluding the municipal district of Indianápolis and including Iraí de Minas); Patos de Minas (the 1985 micro-region of the Mata da Corda); Uberlândia (the municipal districts of Prata and Indianápolis were included after 1985 while Capinópolis, Gurinhatã, Ituiutaba and Santa Vitória were excluded after 1985); Ituiutaba (a micro-region composed by the municipal districts of Capinópolis, Gurinhatã, Ituiutaba and Santa Vitória); Frutal (the 1985 micro-region of Pontal do Triângulo Mineiro, excluding the municipal district of Prata); Uberaba, and Araxá (the 1985 micro-region of Planalto do Araxá, excluding the municipal district of Iraí de Minas).

The Zona da Mata meso-region is composed by the following micro-regions: Ponte Nova (the 1985 micro-region of Mata de Ponte Nova, excluding the municipal districts of Abre Campo and Amparo da Serra and including Guaraciaba); Manhuaçu (the 1985 micro-region of Vertente Ocidental do Caparaó, excluding the municipal districts of Caiana, Divino and Espera Feliz and including Abre Campo); Muriaé (the 1985 micro-region of Mata de Muriaé, including the municipal districts of Caiana, Divino and Espera Feliz); Viçosa (the 1985 micro-region of Mata de Viçosa, excluding the municipal districts of Dores do Turvo, Guaraciaba, Senador Firmino, and including Amparo da Serra); Ubá (the 1985 micro-region of Mata de Ubá, excluding the municipal districts of Piau and Rio Novo and including Dores do Turvo and Senador Firmino); Cataguases (the 1985 micro-region of Mata de Cataguases) and Juiz de Fora (including the municipal districts of Piau and Rio Novo).

The crops selected for this study are those that have short to medium term productive processes and compete with each other, those that are of importance in the meso-regions, and those that have previously been the subject of other studies. A total of twenty crops were selected: pineapple, squash, cotton, peanut, rice, sweet potato, common white potato, sugarcane, onion, bean, cassava, corn, soy, tomato, wheat, forages, banana, coffee, orange, and planted pasture.

This analysis is divided into two methodological stages. First, the variation in area under cultivation for the above mentioned crops in both macro-regions will be disaggregated into variation due to changes in system scale and variation due to crop substitution. An index corresponding to the ratio between each crop's substitution effect and the total macro-regional variation in cultivated area will then be generated. This index is intended to highlight crops that were substituted in a large percentage (a positive sign) and those that suffered minor changess (a negative sign).

The initial analysis will be accomplished using techniques previously applied by Zockun (1978), Yokoyama et al. (1989), Gomes et al. (1998), Pimentel (1998), and Shikida et al. (1999). Their technique allows an analysis of the change in the amount of land under cultivation for a particular crop to be disaggregated into functions of total productive system size variation (the effects of scale) and variation due to product substitution within the system (the substitution effect).

The first analytic model is represented by the following expression:

$$A_{i2} - A_{i1} = (\alpha A_{i1} - A_{i1}) + (A_{i2} - \alpha A_{i1}), \qquad (1)$$

in which

$A_{i2}-A_{i1}$ =the variation of the area cultivated with a specific crop " i ", during period 2 and 1;

$(\alpha A_{i1}-A_{i1})$ = scale effect;

$(A_{i2} - \alpha A_{i1})$ = substitution effect;

being

$$\alpha = A_{t2}/A_{t1;} \tag{2}$$

$$A_{t1}=\Sigma_i A_{i1}; \tag{3}$$

$$A_{t2}= \Sigma_i A_{i2;} \tag{4}$$

In which $A_i$ corresponds to the area cultivated with the i crop; i = 1, 2,..., n analyzed crops; $A_{t1}$ is the size of the system in period 1; $A_{t2}$ is the size of the system in period 2; and $\alpha$ is the relationship between $A_{t2}$ and $A_{t1}$, which measures the alteration of the size of the production system over the period under study.

The scale effect value gives the expected change in area (hectares) devoted to the cultivation of a specific crop if that crop expanded at the same rate as the entire macro-region's system. A negative value indicates system wide contraction, and a positive value indicates system wide expansion.

The substitution effect value represents the variation in area devoted to a specific crop within a system that is independent of changes in it's own size. When the substitution effect becomes negative, for example, it doesn't always mean that the area devoted to cultivation of that specific crop has been reduced; it can simply indicate that the area in the system devoted to that crop is proportionally less than it had been, implying that the crop has been substituted by another. In the case of a specific crop's substitution effect being positive, the opposite is assumed.

The results obtained for each crop are presented in Tables 1 and 2 and in Figure 1 (thematic maps). These results were generated by IDRISI 2.0 software using geographic information provided by the map of the State Minas Gerais downloaded from the Geominas web site (http//:www.geominas.mg.gov.br).

To identify the main factors responsible for the observed variation in areas under cultivation, a second methodological stage is focused on the crop that showed the most significant area expansion and, to a lesser extent, the most significant substitution effect index.

$$Ln\ EE = \alpha_0 + \alpha_1 F + \alpha_2 I + \alpha_3 M + \alpha_4 D + \mu, \qquad (5)$$

in which

Ln EE = the natural logarithm of the scale effect of the expanding crop, expressed in hectares; F = variation of the values of financing between 1995/96 and 1985, by micro-region, expressed in December 1995 Brazilian reais; I = variation of the value of the total investments (acquired land, buildings, facilities, vehicles and other means of transportation, machinery, and animals), between 1995/96 and 1985, by micro-region in December 1995 Brazilian Reals; M = variation in the number of temporary employees between 1995/96 and 1985 by micro-region; D = Variable Dummy: 0 = Triângulo Mineiro/Alto Paranaíba, 1 = Zona da Mata; ($\mu$ = random error).

The Partial Elasticities of production will be calculated as follows:

Rearranging equation (5): EE = $e^{\alpha_0+\alpha_1 F+\alpha_2 I+\alpha_3 M+\alpha_4 D+\mu}$

$$\xi_{EE,\,F} = \frac{\partial EE}{\partial F}\frac{F}{EE} = e^{\alpha_0+\alpha_1 F+\alpha_2 I+\alpha_3 M+\alpha_4 D+\mu}\ \alpha_1 \frac{F}{EE} = \alpha_1 F$$

$$\xi_{EE,\,I} = \frac{\partial EE}{\partial I}\frac{I}{EE} = e^{\alpha_0+\alpha_1 F+\alpha_2 I+\alpha_3 M+\alpha_4 D+\mu}\ \alpha_2 \frac{I}{EE} = \alpha_2 I$$

$$\xi_{EE,\,M} = \frac{\partial EE}{\partial M}\frac{M}{EE} = e^{\alpha_0+\alpha_1 F+\alpha_2 I+\alpha_3 M+\alpha_4 D+\mu}\ \alpha_3 \frac{M}{EE} = \alpha_3 M$$

It is worth noting that the scale and substitution effects are calculated by starting with variations in the entire system's cultivated area, while the values of the selected variables (F, I, and M) correspond to variations found between 1985 and 1995/96. Total investment values were selected as proxies for the capital and land factors, while temporary employees are part of the labor factor. Finally, we opted for a logarithm-linear model for our estimate (for Ordinary Least Square method), considering that it is representative of the situation under examination. The data was extracted from the FIBGE State of Minas Gerais Agricultural Census for 1985 and 1995/96.

## 3 Results and Discussion

Tables 1 and 2 present the scale and substitution effect values for the meso-regions under analysis. The micro-region thematic maps (Figure 1) illustrate changes in agriculture composition in the area being studied, showing crops that were substituted for others and changes in area under cultivation. Both Tables and the Figure will act as an aid in later discussions of the main factors responsible for the observed tendencies.

Initially, the scale and substitution effects are analyzed for the Triângulo Mineiro/Alto Paranaíba meso-region, in which the total cultivated area occupied by the crops under study expanded 16.77%. However, some crops grew while others diminished. The crops that showed the largest increase in area under cultivation were sugarcane, forage, coffee, corn, and, most noticeably, planted pasture, while bean and, above all, rice showed reduced area under cultivation.

According to Table 1, the area that suffered the greatest reduction was of rice. If the 16.77% total cultivated area increase in the Triângulo Mineiro/Alto Paranaíba meso-region were distributed evenly among all the crops, rice cultivation should have expanded in the same proportion. However, the area under rice cultivation diminished 84.5% between 1985 and 1995/96, from 153,985 ha. in 1985 to 24,000 ha. in 1995/96. This indicates the magnitude to which other crops substituted rice.

Table 1. Scale and substitution effects in the meso-region of the Triângulo Mineiro/Alto Paranaíba

| PRODUCTS | Area in 1985 (ha) | Area in 1995/96 (ha) | Variation of area (ha) | Scale Effect (ha) | Substitution Effect (ha) | Index: (%) |
|---|---|---|---|---|---|---|
| Pineapple | 9,186 | 6,449.5 | -2,736.5 | 1,540.1 | -4,276.6 | -0.664 |
| Sqwash | 415 | 675.4 | 260.4 | 69.6 | 190.8 | 0.03 |
| Cotton | 29,295 | 20,806.1 | -8,488.9 | 4,911.7 | -13,400.5 | -2,08 |
| Peanut | 188 | 243.8 | 55.8 | 31.5 | 24.2 | 0.004 |
| Rice | 153,985 | 24,000.3 | -129,984.7 | 25,817.5 | -155,802.2 | -24.18 |
| Sweet Potato | 67 | 169.1 | 102.1 | 11.2 | 90.9 | 0.014 |
| Common White Potato | 788 | 2,854.9 | 2,066.9 | 132.1 | 1,934.8 | 0.3 |
| Sugarcane | 44,327 | 75,687.5 | 31,360.5 | 7,432.0 | 23,928.6 | 3.714 |
| Onion | 118 | 332.3 | 214.3 | 19.8 | 194.5 | 0.03 |
| Bean | 38,989 | 15575.1 | -23,413.9 | 6,537.0 | -29,950.9 | -4.648 |
| Cassava | 5,421 | 6,703.5 | 1,282.5 | 908.9 | 373.6 | 0.058 |
| Corn | 234,134 | 316,588.2 | 82,454.2 | 39,255.4 | 43,198.8 | 6.704 |
| Soy | 265,538 | 290,315.8 | 24,777.8 | 44,520.7 | -19,743.0 | -3.064 |

Table 1. Scale and substitution effects in the meso-region of the Triângulo Mineiro/Alto Paranaíba.(continue)

| PRODUCTS | Area in 1985 (ha) | Area in 1995/96 (ha) | Variation of area (ha) | Scale Effect (ha) | Substitution Effect (ha) | Index: (%) |
|---|---|---|---|---|---|---|
| Tomato | 1,240 | 3,285.5 | 2,045.5 | 207.9 | 1,837.6 | 0.285 |
| Wheat | 8,222 | 2,114.4 | -6,107.6 | 1,378.5 | -7,486.1 | -1.162 |
| Forages * | 16,189 | 43,310.7 | 27,121.7 | 2,714.3 | 24,407.4 | 3.788 |
| Banana | 2,420 | 2,7567 | 336.7 | 405.7 | -69.0 | -0.011 |
| Coffee | 55,361 | 102,163.8 | 46,802.8 | 9,282.0 | 37,520.8 | 5.823 |
| Orange | 9,521 | 24,270.1 | 14,749.1 | 1,596.3 | 13,152.8 | 2.041 |
| Pastures | 2,967,682 | 3,549,124.0 | 581,442.0 | 497,568.4 | 83,873.6 | 13.017 |
| Total | 3,843,086 | 4,487,426.7 | 644,340.7 | - | - | - |

Source: The area data came from the State of Minas Gerais Agricultural Census (FIBGE, 1985 & 1995/96), while the scale and substitution effects were calculated by analysis of the disaggregated variation in area. The index (%) corresponds to ratio substitution effect/variation of the area, calculated by the division of each substitution effect value by the total variation of the chosen area within the analyzed region. * Elephant Grass + Forage Cane + Forage Corn.

TABLE 2. Scale and substitution effects in the meso-region of the Zona da Mata

| Products | Area in 1985 (ha) | Area in 1995/96 (ha) | Variation of area (ha) | Scale effect (ha) | Substitution Effect. (ha) | Index: (%) |
|---|---|---|---|---|---|---|
| Pineapple | 9.0 | 12.7 | 3.7 | 1.4 | 2.3 | 0.002 |
| Sqwash | 560.0 | 472.5 | -87.5 | 87.4 | -174.9 | -0.15 |
| Cotton | 18.0 | 2.6 | -15.4 | 2.8 | -18.2 | -0.016 |
| Peanut | 122.0 | 130.8 | 8.8 | 19.0 | -10.2 | -0.009 |
| Rice | 78,677.0 | 23,347.6 | -55,329.4 | 12,278.1 | -67,607.5 | -58.053 |
| Sweet Potato | 615.0 | 96.5 | -518.5 | 96.0 | -614.5 | -0.528 |
| Common White Potato. | 272.0 | 46.7 | -225.3 | 42.4 | -267.8 | -0.23 |
| Sugarcane | 56,286.0 | 40,847.1 | -15,438.9 | 8,783.8 | -24,222.7 | -20.799 |
| Onion | 319.0 | 210.5 | -108.5 | 49.8 | -158.3 | -0.136 |
| Bean | 114,046.0 | 86,288.5 | -27,757.5 | 17,797.7 | -45,555.2 | -39.117 |
| Cassava | 3,668.0 | 2,828.3 | -839.7 | 572.4 | -1,412.2 | -1.213 |
| Corn | 201,290.0 | 115,941.3 | -85,348.7 | 31,412.8 | -116,761.5 | -100.26 |
| Soy | 204.0 | 51.1 | -152.9 | 31.8 | -184.7 | -0.159 |

TABLE 2. Scale and substitution effects in the meso-region of the Zona da Mata.(continue)

| Products | Area in 1985 (ha) | Area in 1995/96 (ha) | Variation of area (ha) | Scale effect (ha) | Substitution Effect. (ha) | Index: (%) |
|---|---|---|---|---|---|---|
| Tomato | 662.0 | 1,629.8 | 967.8 | 103.3 | 864.5 | 0.742 |
| Wheat | 0.0 | 0.9 | 0.9 | 0.0 | 0.9 | 0.001 |
| | | | | | | |
| Forages * | 18,375.0 | 37,751.4 | 19,376.4 | 2,867.6 | 16,508.9 | 14.176 |
| Banana | 4,540.0 | 5,824.1 | 1,284.1 | 708.5 | 575.6 | 0.494 |
| Coffee | 157,715.0 | 170,190.8 | 12,475.8 | 24,612.6 | -12,136.8 | -10.422 |
| Orange | 2,754.0 | 4,233.5 | 1,479.5 | 429.8 | 1,049.7 | 0.901 |
| Pastagem | 106,125.0 | 372,809.0 | 266,684.0 | 16,561.6 | 250,122.4 | 214.773 |
| Total | 746,257.0 | 862,715.9 | 116,458.9 | - | - | - |

Source: The area data came from the State of Minas Gerais Agricultural Census (FIBGE, 1985 & 1995/96), while the scale and substitution effects were calculated by analysis of the disaggregated variation in area. The index (%) corresponds to ratio substitution effect/variation of the area, calculated by the division of each substitution effect value by the total variation of the chosen area within the analyzed region.

* Elephant Grass + Forage Cane + Forage Corn.

Referring to Figure 1, it can be seen that rice was substituted in all the micro-regions. Among the economic factors that may explain this behavior is the competitive advantage enjoyed by rice produced in states in the South of Brazil, which is of better quality, especially the long grain variety, and less expensive to bring to the market. High production costs linked with fixed labor expenditures also hindered rice production in Minas's meso-regions. In 1994/95, the costs of production per hectare of rice in Minas Gerais were US$ 925.05; US$ 159.38 of this cost arose from expenditures on fixed labor. In 1995/96, total production costs were reduced to US$ 902.93/ha; yet labor costs increased to US$ 177.23/ha. Foreign competition has also depressed Minas's rice production. Rice production costs in Brazil's neighbor Uruguay are US$ 819.49/ha., and the price for rice landed in Brazil from Asian countries dropped from US$ 17.73 per bag in 1990 to US$12.22 per bag in 1995 (FNP, 1999).

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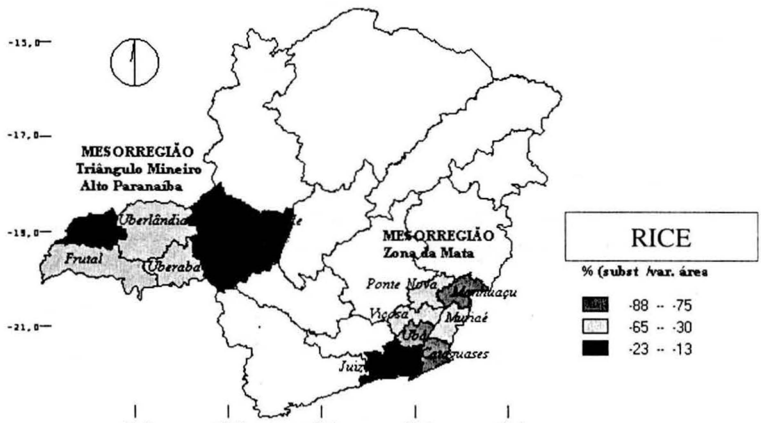


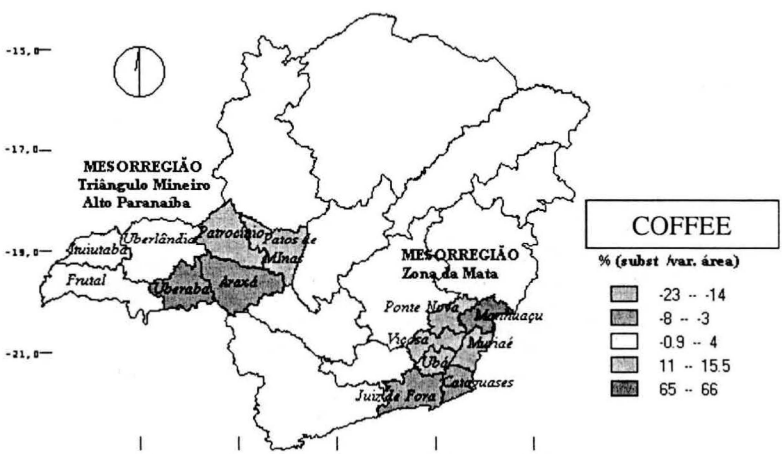
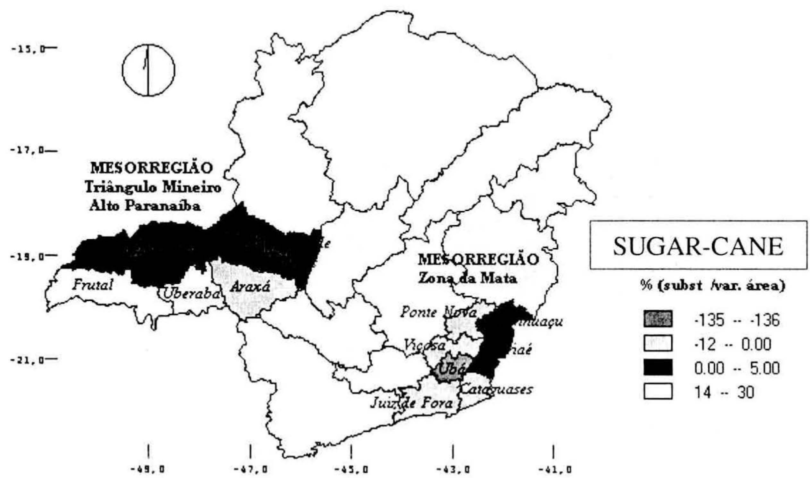




Figure 1- Maps of the State of Minas Gerais with the substitution effect/ variation of the area ratio.



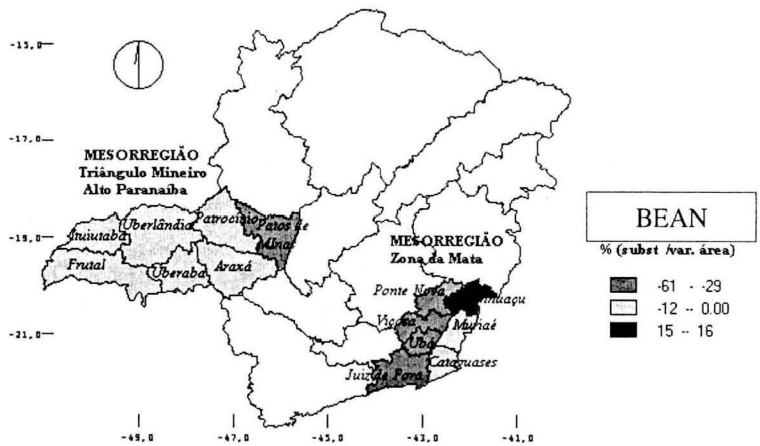
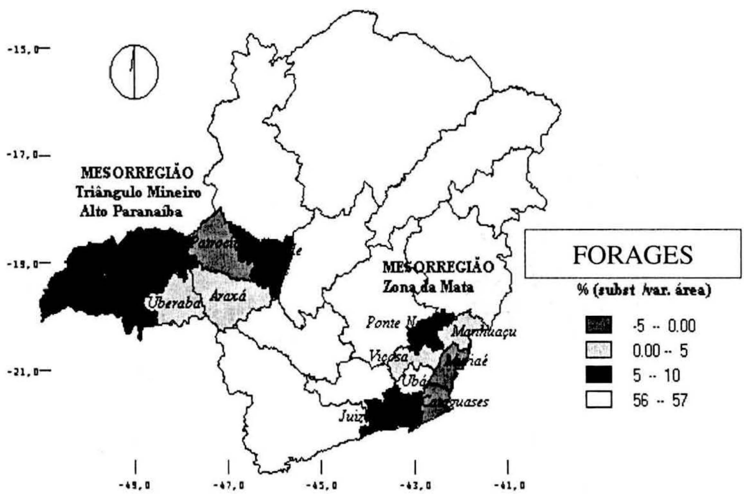




Figure 1- Maps of the State of Minas Gerais with the substitution effect/ variation of the area ratio.(continue)



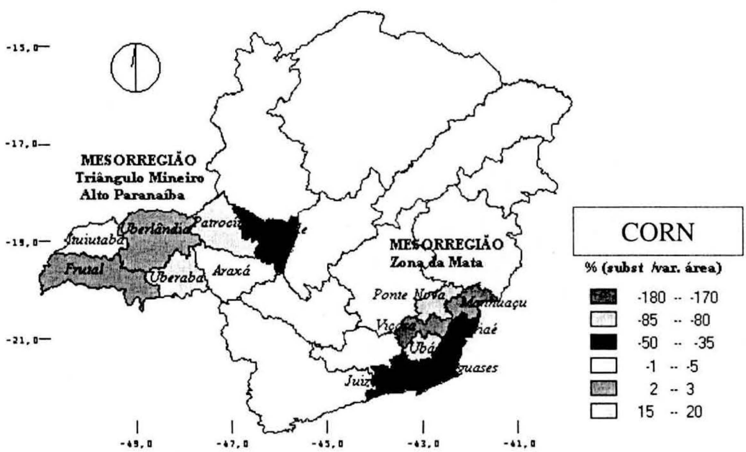




Figure 1- Maps of the State of Minas Gerais with the substitution effect/ variation of the area ratio.(continue)

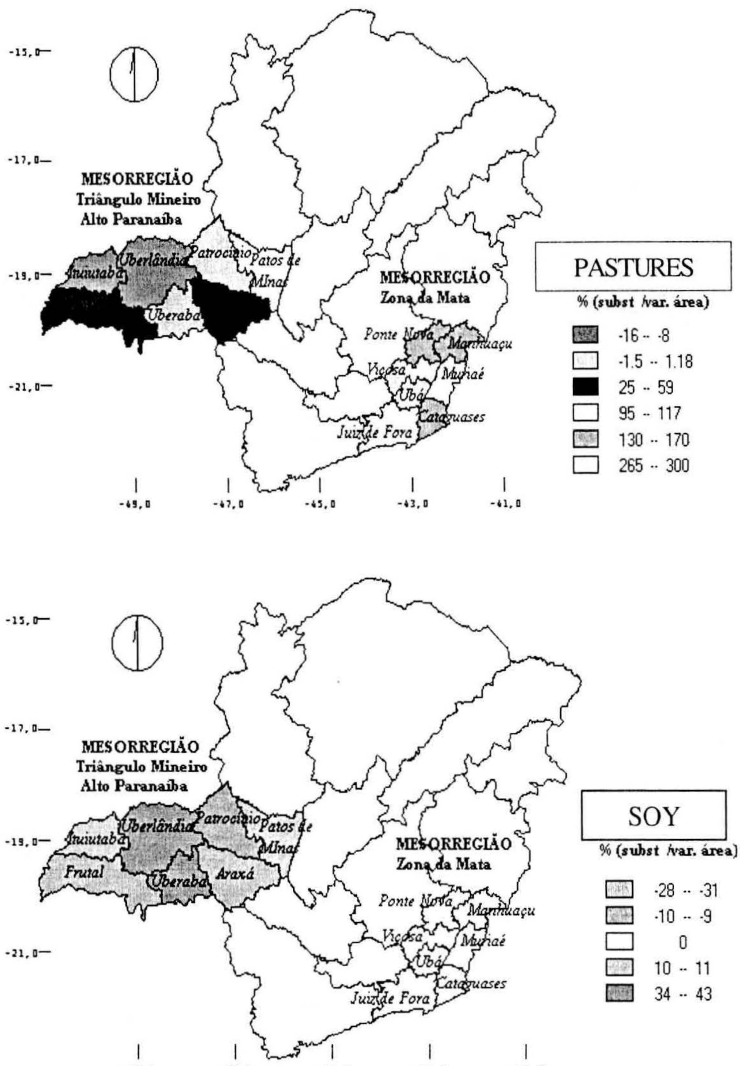



Figure 1- Maps of the State of Minas Gerais with the substitution effect/ variation of the area ratio.(continue)

The area cultivated with corn is declining in the Zona da Mata, a consequence of climatic and topographical factors. However, in the Triângulo Mineiro/Alto Paranaíba meso-region, the area under corn cultivation has been growing due to improved managerial techniques and more favorable climatic and geographical conditions. Corn production costs in the Triângulo Mineiro are the second lowest in Brazil, averaging US$ 4.35 per bag(US$ 4.30/bag in the state of Paraná). In the Zona da Mata, production costs have risen to an average US$ 6.50/bag, the area under corn cultivation has diminished, and production has dropped: 115,941 bags in 1995/96 (Table 2), 105,000 bags in 1996/97, 95,000 sacks in 1997/98, and an estimated 87,000 bags in 1998/99 (EMATER 1999). Corn production in the Zona da Mata has not even kept up with local demand: corn for the Minas Gerais cities of Ponte Nova and Visconde do Rio Branco is being supplied by distant areas in the Triângulo Mineiro and the neighboring state of Goiás.

Though the area under coffee cultivation in the Zona da Mata has grown 12,475 ha., this growth is proportionally smaller than the growth in the scale of the region's agricultural system, as coffee has been substituted by other crops (coffee substitution effect is –12,136, Table 2). The dissolution of the AIC program (Arise International Coffee) in 1989 did away with a coffee production quota scheme for the main producer countries and held down coffee prices. Also, the end of the IBC (Brazilian Institute of Coffee) in 1990 contributed to the coffee price crisis in 1992/93. Beginning in 1994, increased international demand for coffee resulted in a recovery in its international market price, stimulated production, and lead to an increase in the area under coffee cultivation. This increase in production is clearly observed in the Triângulo Mineiro/ Alto Paranaíba, a region with topographical features that helped the adoption of production cost reducing technologies, especially mechanization. The Zona da Mata, specifically Manhuaçu, was less affected than Triângulo Mineiro /Alto Paranaíba by the unfavorable institutional changes mentioned earlier. This was most likely due to the traditional nature of the region's coffee culture and of the existence of a strong coffee marketing structure, which cushioned the regions' coffee producers in the years of crisis and supported them in the years of recovery.

Sugarcane cultivation in the Triângulo Mineiro/Alto Paranaíba micro-regions of Frutal and Uberaba increased greatly, due to favorable climatic conditions and the close proximity of Brazil's largest and most technologically developed sugarcane production area, the state of São Paulo. On the other hand sugar cane cultivation declined in most of the Zona da Mata's micro-regions as other crops were favored (-20.799% sugarcane substitution effect/area variation index, Table 2). One of the factors that contributed to this decline was the end of the Proálcool program, that has stimulated the production of sugarcane alcohol. The end of this support program lead to a decrease in alcohol production and an increase in cane conversion into sugar, lowering sugar prices: sugar prices declined from US$ 11.81/t in 1989 to US$ 10.73/t in 1993 (EMATER, 1999).

Tables 1 and 2 show a decline in the area under bean cultivation in the two meso-regions from 1985 to 1995/96. However, over the last few years, this decrease has been offset on the production side by the introduction of a third yearly harvest, most significantly in the Manhuaçu micro-region. By virtue of the bean crop's short harvest cycle (a maximum of 90 days), production can quickly respond to market price variations, government intervention, and climatic change, further mitigating the need to devote more land to meet potential production shortfalls (GOMES et al., 1998).

The amount of land under cultivation of the soy crop has grown in the Triângulo Mineiro/Alto Paranaíba micro-regions of Ituiutaba, Uberaba, and Uberlândia, while the crop is minimun in the Zona da Mata macro-region. In a study of the change in the state of Goiás's agricultural composition from 1969 to 1985, IGREJA et al. (1988) highlighted the importance of increased soy cultivation. They observed that the increase in area under soy cultivation at the expense of other crops continues to be impressive in the micro-regions of Goiás that boarders Minas Gerais. However, it should be noticed that the deterioration of soy prices to US$ 8.50/bag price in mid 1995 led many soy producers into debt restructuring to avoid bankruptcy; a definite disincentive to soy crop enlargement. fortunetly for soy producers, prices for the 1995/96 crop recovered to US$ 13.51/bag.

Forage (elephant grass, forage cane and forage corn) and, more significantly, pastureland expanded in most of the micro-regions. High pastureland substitution effect values were observed, especially in the micro-regions that compose the Zona da Mata. Over the period under study, Minas Gerais's cattle herd, about 21,296,131 animals, became Brazil's largest, surpassing the herd in the state of Mato Grosso do Sul (21,129,651). It is worth noting that from 1985 to 1995/96, fattened ox prices increased from US$ 14.10/@ to US$ 26.20/@, stimulating growth in the area devoted to pasture (FNP, 1999).

Pasture was the crop which most substituted other crops in both meso-regions, presenting substitution effect indexes of 13.02% and 214.77% in the Triângulo Mineiro/Alto Paranaíba and Zona da Mata respectively (last column of Tables 1 and 2). It was therefore selected for use in identification of the main factors responsible for our results, employing the following model:

$$\underset{(24{,}17)}{\mathrm{Ln\ EEP} = 11{,}0027^{***}} + \underset{(0{,}40)}{0{,}000010\ F^{NS}} +$$

$$n=14 \qquad R^2 = 0{,}96$$

$$+ \underset{(3{,}15)}{0{,}000013\ I^{**}} \underset{(-5{,}10)}{-0{,}000210\ M^{***}} \underset{(-5{,}80)}{-\ 2{,}9096\ D^{***}}$$

$$\text{Test F} = 24{,}3275^{***}$$

* * * 1% significance; * * 5% significance; NS: Not significant.

The coefficients related with the labor factor (M) and the total investment value (I) were significant at 1% and 5% respectively, while the coefficient related with the cost of financing (F) was not significant. In relation to the signs of the coefficients above, the investment value links positively with growth in area devoted to pasture, while a negative relationship is linked with the labor factor. Financing limitations for the acquisition of pastureland is one of the factors that explains the model's financing variable's lack of significance. The Dummy Variable's significance at 1% of probability reveals that the equation for pastures is not the same in all the areas under analysis, due to climatic and geographic factors. It is important to note that the scale effect for the Zona da Mata is smaller than the one for the Triângulo Mineiro/Alto Paranaíba, and the Dummy is negative when the model applied is the Zona da Mata. The difference in the magnitude of the two meso-region's scale effect is quite impressive: 16,561 for the Zona da Mata and 497,568 for the Triângulo Mineiro/Alto Paranaíba. The magnitude of the substitution effect between the two meso-regions was also quite differentiated: 250,122 for the Zona da Mata and 83,873 for the Triângulo Mineiro/Alto Paranaíba. Thus, it can be inferred that the increase in pastureland represents a more profound change in the Zona da Mata's agriculture sector than in the Triângulo Mineiro/Alto Paranaíba agriculture sector.

One way of verifying multicollinearity in the model is to calculate the correlation among the independent variables.

Table 3. Correlation among the independent variables

| | I | M | K |
|---|---|---|---|
| I | 1.000000 | 0.339740 | -0.498703 |
| M | 0.339740 | 1.000000 | -0.295642 |
| K | -0.498703 | -0.295642 | 1.000000 |

Source: research data.

The low correlation levels among the independent variables found in Table 3 do not characterize multicolinearity.

The model presented a high coefficient of determination ($R^2 = 0.96$), indicating that the model explains 96% of the dependent variable's variations. The " F" test was significant at 1% of probability, which means that the linear logarithmic model of the pastureland scale effect has statistical support. Examination of the Partial Elasticities of Area ($\xi_{EE, I}$= 0.35 and $\xi_{EE, M}$ = -0.79) reveals an inelastic relationship between all factors related to the expansion of pasture area. An increase of 1% in investment provokes a 0.35% expansion of the pastureland scale effect if the investment in bovine meat production is medium to long term.

The drive to minimize both risk and the labor are among the factors responsible for the increase in land devoted to pasture in the meso-regions. The model revealed that there is an inverse relationship between labor requirements and pastureland expansion (verified by the scale effect).

## 4 Conclusions

The total area planted with the crops under analysis grew 16.77% in the Triângulo Mineiro/Alto Paranaíba and 15.61% in the Zona da Mata, although the growth was not evenly distributed among all crops. The most notable changes were found in the amount of land under rice, corn, coffee, sugarcane, bean, and pasture cultivation.

The area under rice cultivation was reduced in all the analyzed regions, due to the high costs associated with producing a crop in swamp, the crop's great dependency on manual labor, and fierce international competition, especially from Uruguay and the Asian rice exporting countries.

Topographical factors and climatic problems contributed to rise corn production costs in the Zona da Mata causing a yearly decline in the area under corn cultivation. The situation in the Triângulo Mineiro/Alto Paranaíba is very different. The area under corn cultivation in that region increased, due to the reduction in production costs brought about by favorable climatic conditions and improved management techniques.

Following the removal of two artificial production stimulants, the AIC in 1989 (reducing coffee prices) and the IBC a year later, coffee production declined in both meso-regions. The situation began to improve in 1994, and coffee cultivation expanded considerably in the Manhuaçu (Zona da Mata) micro-region. Recovery was also observed in the Triângulo Mineiro/Alto Paranaíba meso-region, as the region's topography facilitated the use of recently developed, cost reducing mechanization technologies.

Sugarcane cultivation increased in the Triângulo Mineiro/Alto Paranaíba micro-regions of Frutal and Uberaba, due to climatic conditions, technological innovation, and the micro-regions' close proximity to the country's largest center of sugarcane production, São Paulo. The situation was reversed in the Zona da Mata, and other crops were substituted by sugarcane.

The area under bean cultivation declined in the two meso-regions, due to the reduction of coffee spacing in both regions and reduction of the area planted with corn in the Zona da Mata.

In both meso-regions, the increase in area devoted to pasture was impressive, far greater that for any other crop. This increase was mainly due to two factors: the farmers' effort to minimize risk and reduce labor costs.

In general, this work is a creative effort to unite statistical models of a descriptive nature and inference. With our study, we hope to have increased the understanding of regional dynamics through use of this association of methodologies and that our study will improve policy making.

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