Spatial evolution of the population of Minas Gerais (1950 to 1980) via Centrographic Techniques and Directional Research

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This paper aims at analysing, in what concerns the macrogeographic aspect, the population of the State of Minas Gerais from 1950 to 1980, making use of centrographic techniques of dispersion and a statistic adjustment which we call directional research, corresponding to a simplified model of "Trend Surface Analysis" and of the classic Geo-Statistic Methods (Matheron, 1962). The State of Minas Gerais is analysed at municipal level (722 municipalities) and the variables — total population, rural population and urban population — are employed as basic variables. The programmes Centroid and Ajust (Abreu-Machado, 1984), written in Fortran and Basic, are also used.

The study of various kinds of "centres" of region had its origin in the United States in 1870. Later on, "Centrography" came out, and the Centrographic Laboratory Mendeleev was founded by the Russian Chemist D. I. Mendeleev, in 1925. Centrography begins to decline around the '30s, when, due to innumerable failures, it was demonstrated that a region must not be analysed by centroids only, and that Centrography cannot be considered a discipline in isolation. After a period out of use, the centrographic techniques are revived with the studies of Neft (1966), Bachi (1957), Seymour (1968) and Yuill (1971) mainly, who manage to use those techniques adequately, and in association with other tecniques of Spatial Analysis.

For our present work we have used:

- weighed mean centre (WMC)
- weighed standard distance (WSD) and
- Relative Dispersion in relation to the standard radius (RD_{SR}),

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that is,

$$WMC = \overline{X}_w \cap \overline{Y}_w \qquad (1)$$

$$\overline{X}_w = \frac{\Sigma W_1 \cdot X_1}{\Sigma w_i} \qquad (2)$$

$$\overline{Y}_w = \frac{\Sigma W_i \cdot Y_i}{\Sigma w_i} \qquad (3)$$

WMC = weighed mean centre
W_i = weight of the variable
X_i = Longitude of i
Y_i = Latitude of i

$$WSD = \sqrt{\frac{\Sigma W_i (x_i - x)^2}{\Sigma w_i} + \frac{\Sigma W_1 (Y_i - y)^2}{\Sigma w_i}} \qquad (4)$$

WSD = weighed standard distance
W_i = weight of the variable at point i
(w_i, y_i) and (x, y) = defined in formula (3)

Relative dispersion in relation to the standard radius

$$RD_{SR} = \frac{WSD_{Px}}{WSD_{Pb}} \qquad (5)$$

and relative dispersion in relation to the "quartilic rectangle"

$$RD_{QR} = \frac{Q}{A} \qquad (5.1)$$

where,

RD_{SR} = relative dispersion in relation to the standard radius
WSP_{Px} = weighed standard distance of the variable studied
WSP_{Pb} = weighed standard distance of the basic variable
Q = Area of the quartilic rectangle
A = Area studied

The variations in space are studied in detail, with the use of directional research, which consists of finding the correlation between the rate of population variation and the localization in function of latitude and longitude.

The various points present variation rates in the central measures in time. Such variation is also verified at spatial level, and can be measured through the correlation between the growth rate and the localization.

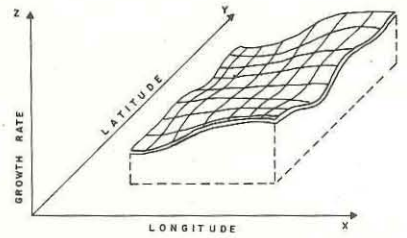
Once the evolution of the mean and median centres of a variable in time is defined, as well as the measures of dispersion, one must analyse in detail the regions or spots that influence the dislocations recorded. The various spots present differentiated population growth rate, and it is this differentiation that causes dislocation in time of the central measures. The growth rate, then, is the variable used to verify if a definite tendency of population dislocation from one region to another has taken place.

One way of checking if there is a definite tendency of population growth is by means of a tridimensional figure where axis *x* means longitude, axis *y* means latitude, and axis *z* is the growth rate, or by means of level curves, which is a projection on the plane of the tridimensional figure (Plate A).

This kind of analysis, though useful for a global visualization of the phenomenon, once it takes into consideration all points, has some inconveniences, such as:

- an extremely difficult tridimensional graphic representation of a large number of points;
- a very complex visualization, unable, at times, to detect tendencies.

PLATE A - GROWTH RATE X GEOGRAPHIC COORDINATES

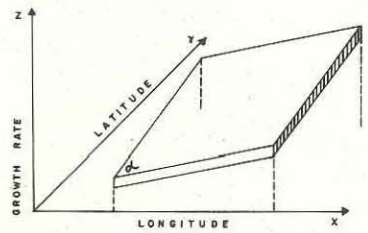


A form of simplification may be the calculation of the plane representative of the surface under consideration, using the method of least squares:

$$z = a_1x + a_2y + a_3 \qquad (6)$$

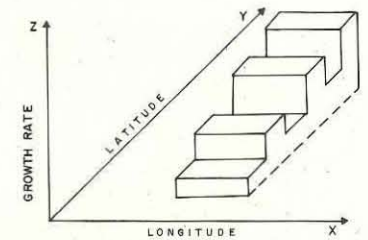
a_1 and a_2 = angular coeficients
a_3 = place intercept
x, y and z = defined in Plate B

PLATE B – PLANE OF THE LEAST SQUARES



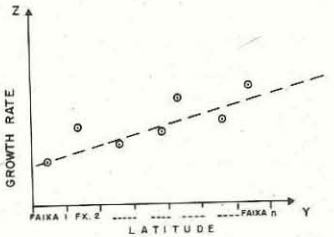
Besides offering an easier visualization and a significant coefficient of explanation p^2, it indicates, through coefficients a_1, a_2 and a_3, the spatial distribution of growth rates. The problem of tridimensional representation persists, as well as that of algebraic analysis of the linear combination of coefficients a_1 and a_2. For simplification, then, one makes use of the division of the region under consideration in strips parallel to axis x. The growth rate of each strip is calculated, which may be represented in space by Plate C.

PLATE C - SPATIAL REPRESENTATION BY STRIPS



With such simplification, axis x is eliminated, as within each strip the growth rate is constant and one has a flat figure to represent the phenomenon (Plate D).

PLATE D - FLAT REPRESENTATION BY STRIPS



In the case represented by Plate D, one can see that there is really a definite tendency with the rates growing in function of latitude, that is, the population of regions with higher latitudes grows more, confirming a dislocation in time, from the weighed mean centre.

The tendency van be now represented by a straight line of regression adjusted through the method of least squares:

$$Y = ax + b \qquad (7)$$

where,

Y = growth rate
X = latitude
a = angular coefficient of the straight line
b = intercept with axis y

The interpretation of the straight line is easier, for, if a is positive, one has a growing tendency, and if it is negative, there is a decreasing tendency of the growth rate in relation to latitude.

The coefficient of correlation *r*, which is the square root of the coefficient of explanation (percentage of the variation of y explained by regression), is an indicator of the degree of adjustment of the curve to the data observed.

$$r = \sqrt{\frac{(y_i - y)^2}{(y_i - y)^2}} = \frac{\text{Variation explained by regression}}{\text{total variation}} \qquad (8)$$

where,

y_i = value of y calculated by the equation of regression for each i

y = arithmetical mean of y

y_i = observed value of y for each i

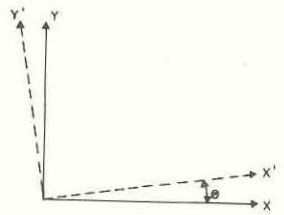
The absolute value of the coefficient varies from 0 to 1. A coefficient approaching 1 means an excellent degree of adjustment of the curve, and a coefficient near 0 indicates little adherence. A value above 0.707 may be considered satisfactory, once 50% (0.5 = 0.707) of the variation of y is associated to x.

In brief, if one detects visually a tendency of the growth rate in function of latitude and the coefficient of correlation has a satisfactory value (above 0.707), one may say that the population flow in the period under study has really had a dislocation in the direction considered. The analyses made, being bidimensional (growth rate X direction), allow an analysis of the populational dislocation in one only direction.

Considering the region divided in strips parallel to axis x, one analyses only the north-south populational flow. In fact, the objective is the identification of significant directions of populational dislocaion, in particular the main direction, that is, that which presents the highest coefficient of correlaction with the growth rate. One must, then, research the correlation of the growth rate with the various possible directions.

That research requires rotations of the conventional coordinated axes (longitude, latitude) for the various values ∅ definers of the desired direction, as shown in Plate E.

PLATE E - ROTATION OF THE COORDINATED AXES



The transformed latitude is defined by:

$$Y' = y \cos \theta \qquad (9)$$

where,

y' = transformed latitude

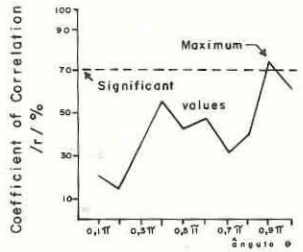
y = conventional latitude

x = conventional longitude

θ = angle definer of the desired direction

There are infinite directions in the interval between 0° and 180°. For each direction one calculates the coefficient of correlation between the rate and the transformed latitude, thus obaining 10 coefficiens of correlation that may be presented as follows (Plate F).

PLATE F - COEFFICIENT OF CORRELATION BETWEEN RATE AND GEOGRAPHIC DIRECTION



The coefficients of correlation between the populational growth rate and the various directions investigated may present a direction of maximum rate of correlation, as shown in the plate. In that case, there is a standard of population growth in one predominant direction. The direction of the flow is defined by the sign of the coefficient of correlation. If it is positive, the variable analysed increases with growing values of "latitude"; if not, it decreases.

RESULTS

The methodologies are applied for spatial analysis of the population of Minas Gerais in the period 1950-80. In general, one detects a significant change in the period, once the State, basically rural in 1950, becomes "urban" in 1980, with over 60% of its population in cities (Table 1).

Besides the relative loss, one detects an absolute decrease of the rural population, changing from 5.5 M to 4.2 M (tabes 2 and Plate 1). In relative terms, the period '50/60 presents the highest growth rate at urban level, decreasing progressively until '80. The same happened at rural level (Table 2). Theses variations in the spatial scope are studied with the use of the techniques mentioned above.

CENTROGRAPHIC AND DISPERSAL MEASURES

In the initial phase, two methodologies are used, aiming at the confirmation of the results obtained: median centre as measures of central tendency, and the standard radius (SR) and the quartilic rectangle (QR) as dispersal measures. Map 2 and Table 3 present the results of the calculations of mean centre, standard radius and relative dispersion in relation to the standard radius. Map 3 and Table 4 present the results of the calculations of median centre, quartilic rectangle and relative dispersion in relation to the quartilic rectangle. The results obained can be summarized as follows:

The dislocation of the mean centre and median centre of the rural population in the direction south-north, mainly in the period 1950/70 (from 1970 to 1980 it remains practically stationary), is the most remarkable fact, being easily visualized in Maps 2 and 3; the movement of the centre of the urban population in that period is also in the direction south-nort, but with much less intensity (43 km for the rural, 22 km for the urban population).

TABLE 1

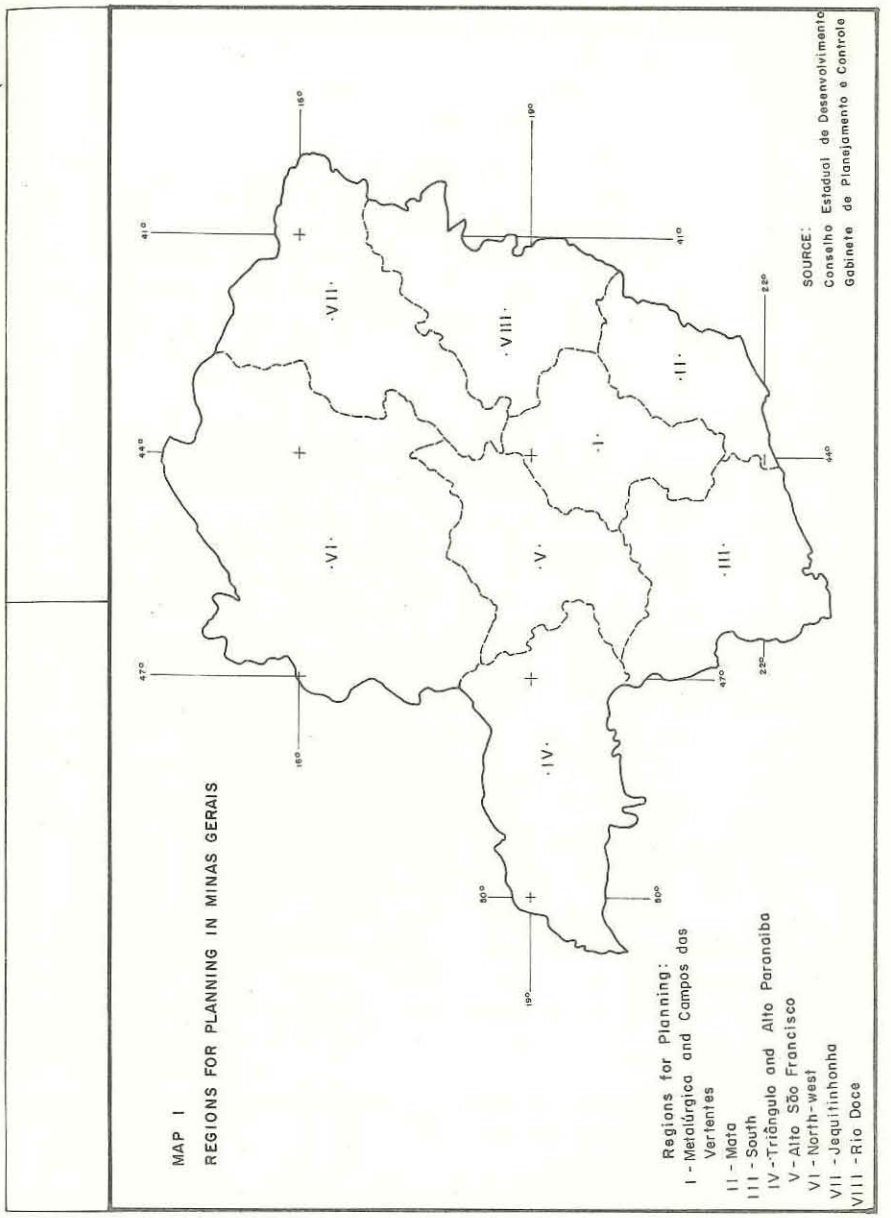
EVOLUTION OF THE POPULATION OF THE STATE OF MINAS GERAIS

Censuses: 1950, 1960, 1970 and 1980*

	1950		1960		1970		1980	
	Pop. (10^3)	%	Pop. (10^3)	%	Pop. (10^3)	%	Pop. (10^3)	%
Urban	2.196,9	28,5	3.907,3	40,5	6.054,3	53,4	8.873,0	67,5
Rural	5.515,8	71,5	5.734,7	59,5	5.273,3	46,6	4.281,4	32,5
TOTAL	7.712,7	100,0	9.642,0	100,0	11.372,6	100,0	13.154,4	100,0

* Excluding the 36 municipalities of Table 7, whose data from the 1950 and 1960 censuses are incomplete.

Source: CEMIG — Departamento de Estudos Econômicos e Planejamento de Geração (Department of Economic Studies and Generation Planning) — 1982-



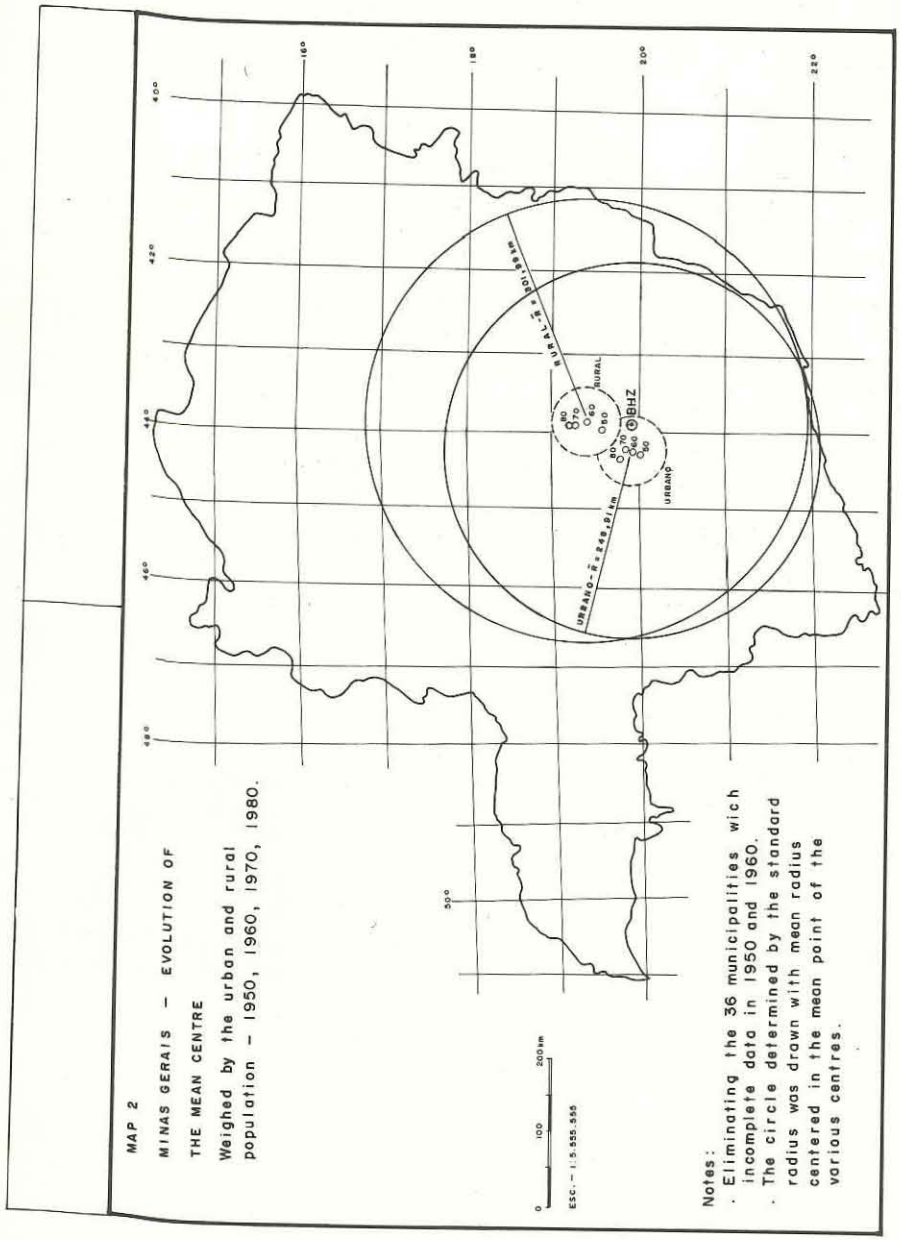


TABLE 2

AVERAGE EARLY GROWTH OF THE POPULATION OF THE STATE OF MINAS GERAIS (%) *

PERIOD	URBAN	RURAL	TOTAL
1950/60	5,9	0,4	2,3
1960/70	4,5	—0,8	1,6
1970/80	3,9	—1,7	1,5

* Excluding the 36 municipalities of Table 7, whose data from the 1950 and 1960 censuses are incomplete.

Source: CEMIG — Departamento de Estudos Econômicos e Planejamento de Geração (Department of Economic Studies and Generation Planning) — 1982-

TABLE 3

MEAN CENTRE AND STANDARD RADIUS WEIGHED BY THE URBAN AREA AND RURAL POPULATION (*)

Area considered: 521.562 km²

	MEAN CENTRE							
	Latitude degrees, min.,sec.			Longitude degrees, min.,sec.			Standard Radius (km)	Standard Radius Radius of the area considered
1950	20	01	09	44	19	47	248.68	58,3
1960	19	57	20	44	18	55	250.61	58,8
1970	19	52	49	44	16	57	247.89	58,1
1980	19	49	06	44	22	24	248.47	58,3
1950	19	32	03	44	00	30	295.38	69,3
1960	19	21	32	43	54	34	298.95	70,1
1970	19	11	43	43	57	02	307.37	72,1
1980	19	09	55	43	56	54	306.26	71,8

* Excluding the 36 municipaliites of Table 7, whose data from the censuses of 1950 and 1960 are incomplete.

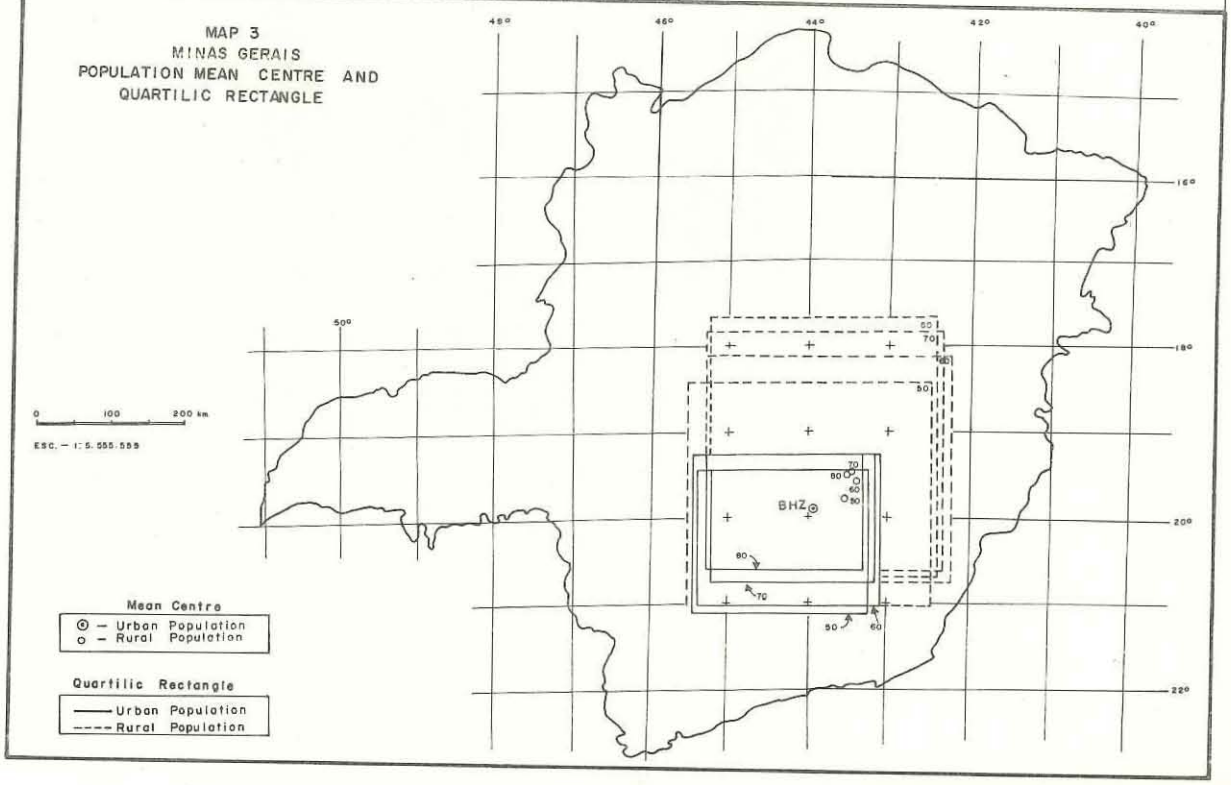
The mean centre of the urban population is not dislocated, due to the influence of Belo Horizonte. The result does not come to be contradictory, and even justifies the inerti aof the mean centre, vary near Belo Horizonte, with some dislocation during the 30 years analysed:

- as to east-west movements, one detects a small move of the urban population from 1970 to 1980, with a west-bound dislocation. In Map

MAP 3

MINAS GERAIS

POPULATION MEAN CENTRE AND QUARTILIC RECTANGLE



MAP 4

MINAS GERAIS

LONGITUDINAL EVOLUTION OF THE WEIGHED MEAN CENTRE BY THE URBAN POPULATION FROM 1970 TO 1980 THROUGH STRIPS OF 1 DEGREE OF LATITUDE.

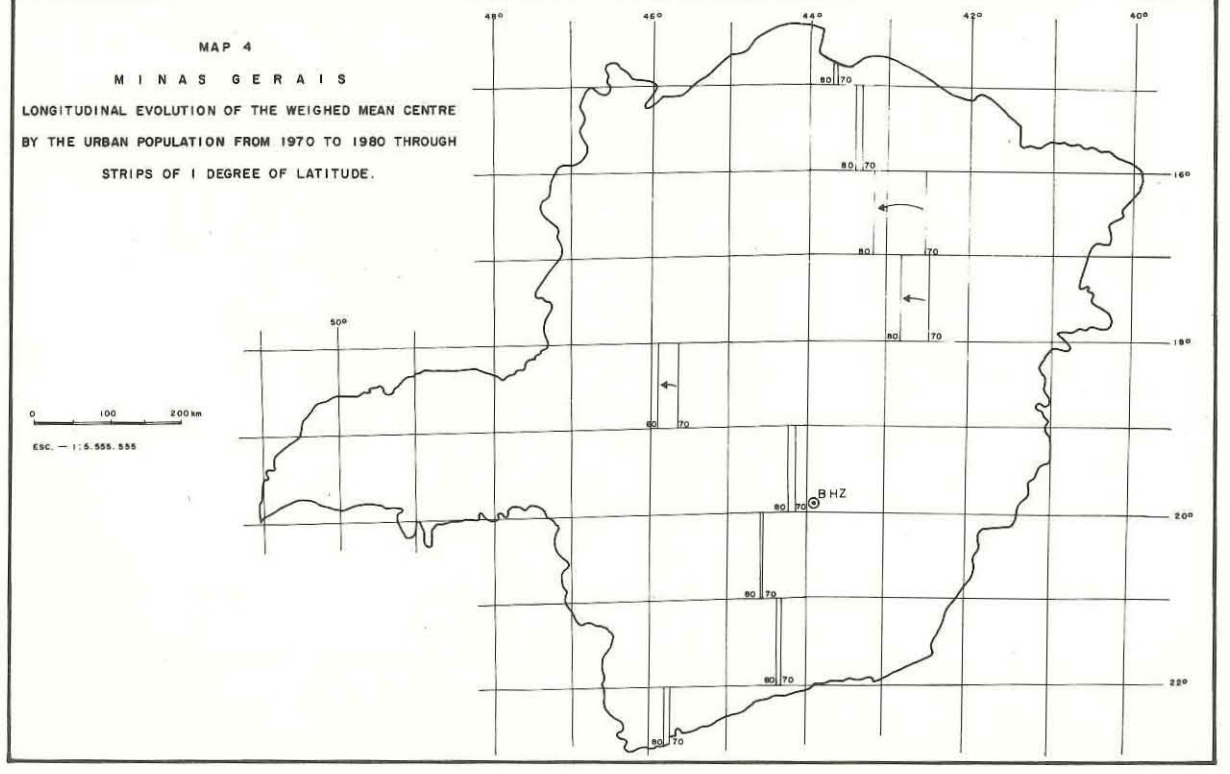
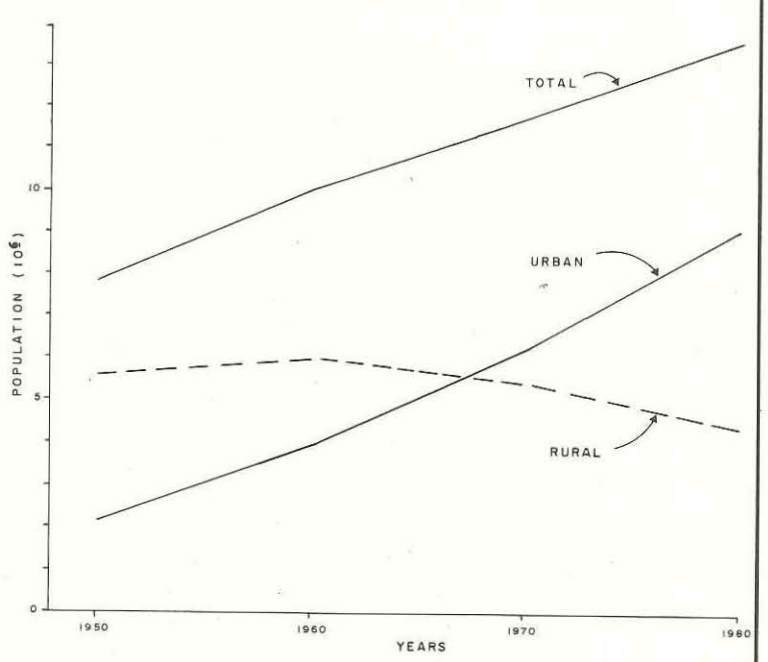


PLATE I

EVOLUTION OF THE POPULATION OF THE STATE OF MINAS GERAIS FROM - 1950 TO 1980



4, one has, for each strip of 1 degree, the longitude of the mean centres in 1970 and 1980. There was a dislocation in all the strips from east to west, justifying the phenomenon, but the remarkable fact is that the strips comprised between 16º and 19º present a significant dislocation. A socio-economic study of the region could provide information of the explanation of the phenomenon;

- the centres representatives of the rural population are placed more in the east and north than centres representative of the urban population (Maps 2 and 3). This confirms the notion that the regions South ,Mata, Metalurgica and Campo das Vertentes and Triângulo are more urbanized than regions Northwest, Jequitinhonha and Rio Doce;
- as might be expected, the rural population is much more dispersed than the urban one, by its own nature. This phenomenon is reinforced by the existence of the metropolitan region of Belo Horizonte;
- the relative dispersion of the rural population, in relation to the standard radius as well as to the quartilic rectangle, increases slightly in time (occupation of the north periphery of the State by the rural population). The dispersion of the urban population is practically constant. Map 3 shows a dislocation of the quartilic rectangle, in the direction south-north. confirming the results.

The results obtained, mainly the south-north dislocation, must be further confirmed, for wich another analysis is made: the study of the population growth rate in relation to latitude.

VARIATION RATE IN FUNCTION OF LATITUDE

The dislocation of the weighed mean centre from south to north in the period 1950/1980, urban as well as rural, indicates a higher relative growth of the northern population. In order to confirm this result obtained through the previous methodology and check existence of absolute growth of the northern population, one divides the State of Minas Gerais in strips 0 5º, as shown in Plate 2, and calculates the variation rate of the population (urban, rural and total) for each strip, during that period. The results obtained are shown in Plates 4, 5 and 6.

Plate 4 presents the results for the rural population: there is a very clearly lefined tendency of the rural population growth rate. The more southern regions present negative variation rates. As a north-bound dislocation is verified, the rates grow more rapidly. From parallel 18º up to the northernmost part of the state, the variation rates become positive and crescent (Plate 3). The result obtained complements the analysis made by the mean centre, wich only demonstrates the existence of a higher relative growth the north than in the south. The changes of the variation rate with the latitude makes evident the existence of an absolute growth of the northern population, despite the decrease detected in the rural population as a whole.

Plate 5 presents the results for the urban population: the variation rate of the urban population increases as it goes north, but the dispersion of the points is higher, wich means that the tendency is not so well defined as that of the rural population;

- the strips between 19º30' and 20º30', wich comprise the metropolitan region of Belo Horizonte, present quite different changes, with a higher growth rate, comparable to those of the north of the State, to the north of parallel 17º. That means a tendency of concentration of the urban population in the metropolitan region.

PLATE 2 - DIVISION OF THE STATE OF MINAS GERAIS IN LATITUDINAL STRIPS

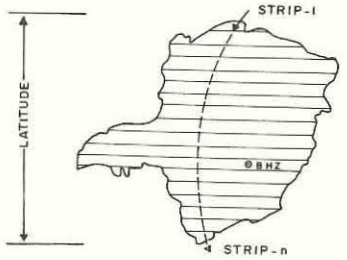


PLATE 3 - MINAS GERAIS - POPULATION GROWTH RATES

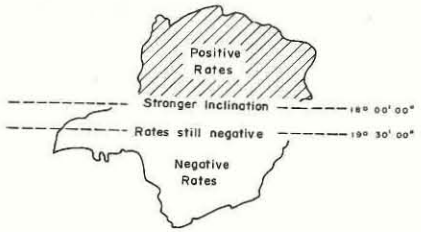


PLATE 4

MINAS GERAIS - POPULATION GROWTH RATE X LATITUDE (1950-1980)

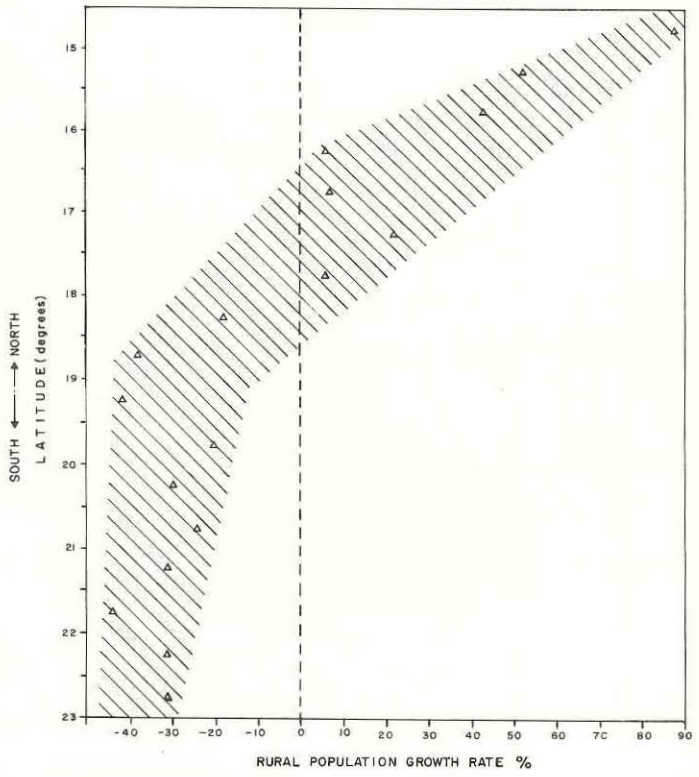
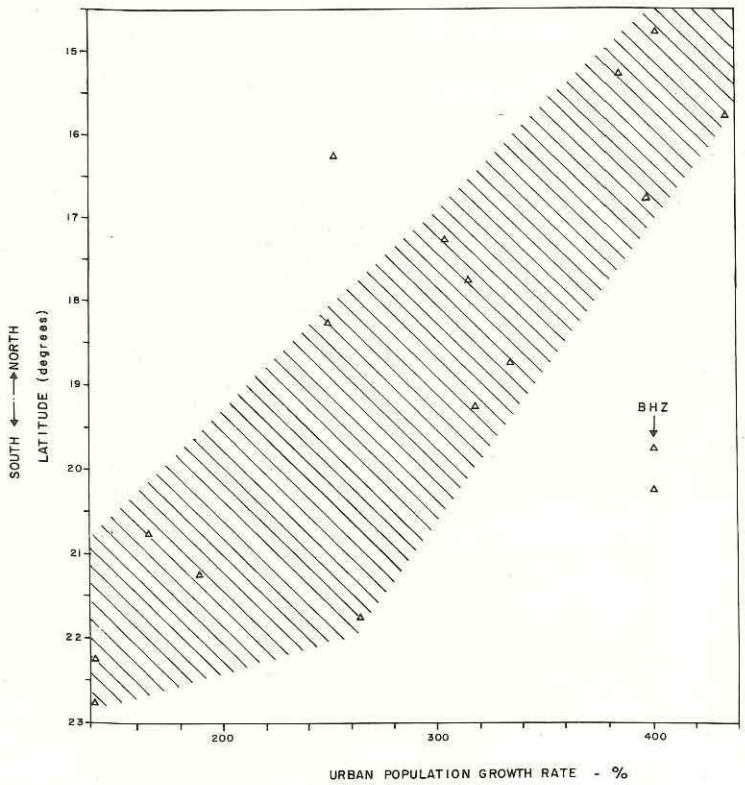


PLATE 5

MINAS GERAIS – URBAN POPULATION GROWTH RATE

X LATITUDE

(1950 - 1980)



In short, the urban population is concentrated around Belo Horizonte and dislocates slightly towards the north of the State.

Plate 6 presents the results for the whole population:

- as was expected, the results are a combination of the two tendencies already analysed, wich means that, in general, the population has grown;
- in short, the population of the State is concentrating in the metropolitan region of Belo Horizonte, and the rural population, though decreasing, is becoming more important in the north of the State, with a positive growth rate between 1950 and 1980.

Plate 7 presents the urbanization rate per strips of latitude of the State of Minas Gerais in 1980, except the strip that comprises Belo Horizonte, which has a high growing urbanization rate as it goes south. In opposition, the northern region, at present less urbanized, presents a higher growth rate.

Despite this relative growth in the north, the southern population remains more urbanized, as the north has grown mainly in terms of its rural population.

This analysis can be further developed in two points:

(1) analysis of the various directions of population dislocation, that is, research on tendency towards all directions, starting from the latitudinal and arriving at the longitudinal, verifying through the analysis of coefficient of correlation between localization and growth rate, the significant directions of population dislocation;

(2)division of the period of analysis in decades, checking what has occurred from 1950 to 1960, from 1960 to 1970, and from 1970 to 1980.

RESEARCH ON THE MAIN DIRECTIONS OF THE POPULATIONAL FLOW

As explained above, one researches into the correlation of the rate of varius possible directions, making the rotation of the conventional coordinated axes (longitude, latitude) for the various values definers of the directions desired.

Ten directions between 0º ande 180º are considered, varying from from 18º to 18º. This research is carried out for the total population, urban and rural, during the period from 1950 to 1980, and the sub-periods 1950/1960, 1960/1970 and 1970/80.

Plates from 8 to 19 present, for each kind of population and period under consideration, the coefficients of correlation for each direction, varying from 0º to 180º.

PLATE 6

MINAS GERAIS - TOTAL POPULATION GROWTH RATE X LATITUDE
(1950 - 1980)

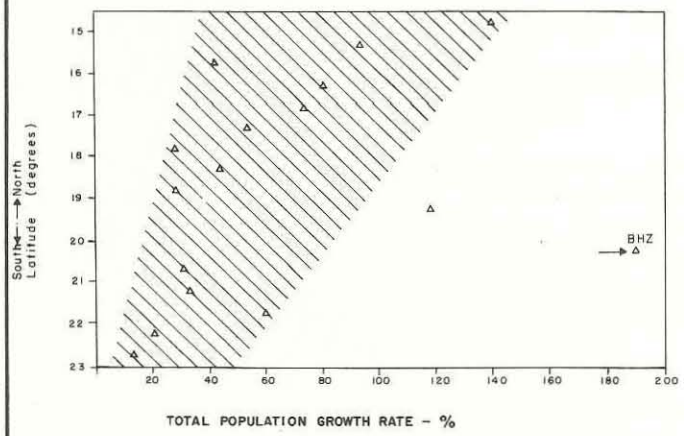


PLATE 7

MINAS GERAIS - URBANIZATION RATE X LATITUDE (1980)

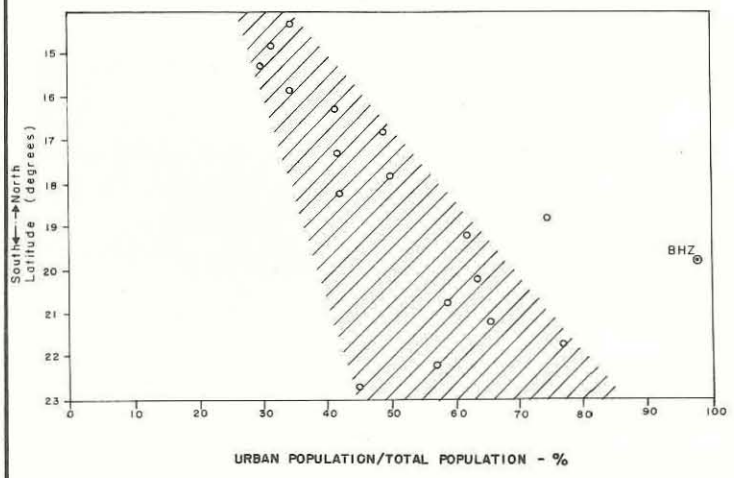


PLATE 8

TOTAL POPULATION - GROWTH RATE
1950 - 1980

Coefficient of Correlation between rate and geographic direction

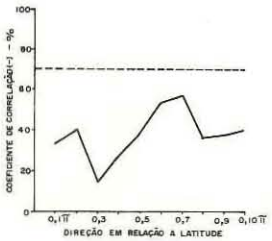


PLATE 9

TOTAL POPULATION - GROWTH RATE
1950 - 1960

Coefficient of correlation between rate and geographic direction

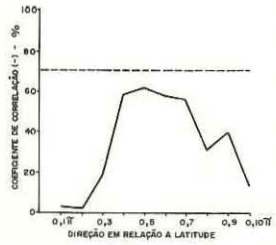


PLATE 10

TOTAL POPULATION - GROWTH RATE
1960 - 1970

Coefficient of correlation between rate and geographic direction

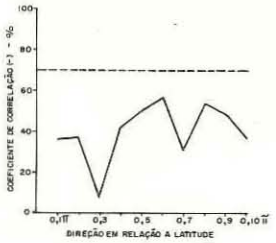


PLATE 11

TOTAL POPULATION - GROWTH RATE
1970 - 1980

Coefficient of Correlation between rate and geographic direction

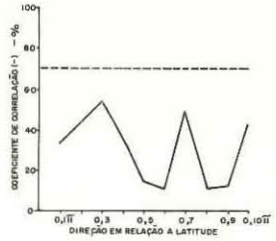


PLATE 12
RURAL POPULATION - GROWTH RATE
1950 – 1980

Coefficient of correlation between rate and geographic direction

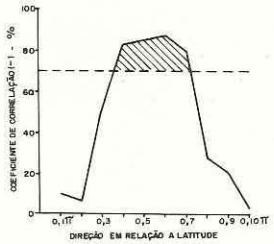


PLATE 13
RURAL POPULATION - GROWTH RATE
1950 - 1960

Coefficient of correlation between rate and geographic direction.

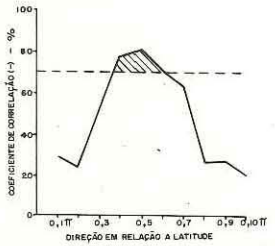


PLATE 14
RURAL POPULATION = GROWTH RATE
1960 - 1970

Coefficient of correlation between rate and geographic direction

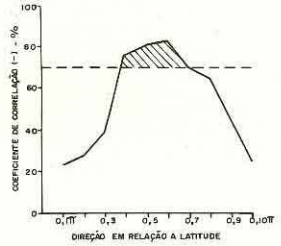


PLATE 15
RURAL POPULATION - GROWTH RATE
1970 - 1980

Coefficient of correlation between rate and geographic direction

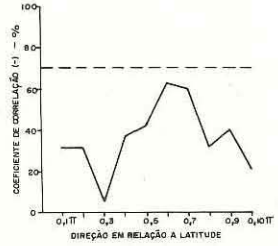


PLATE 16
URBAN POPULATION - GROWTH RATE
1950 - 1980

Coefficient of correlation between rate and geographic direction

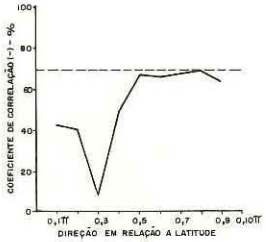


PLATE 17
URBAN POPULATION - GROWTH RATE
1950 – 1960

Coefficient of correlation between rate and geographic direction

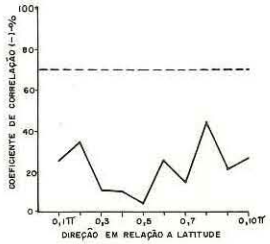


PLATE 18
URBAN POPULATION - GROWTH RATE
1960 – 1970

Coefficient of correlation between rate and geographic direction

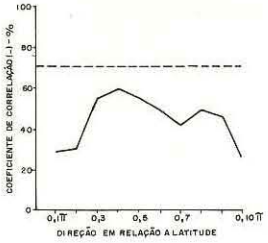


PLATE 19
URBAN POPULATION - GROWTH RATE
1970 – 1980

Coefficient of Correlation between rate and geographic direction.

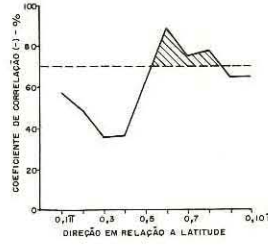


PLATE 20 - MINAS GERAIS - MAIN DIRECTIONS OF DISLOCATION OF THE RURAL POPULATION IN THE PERIOD 1950 - 1980

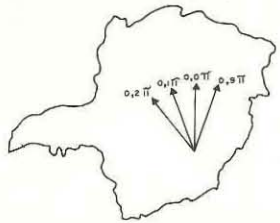
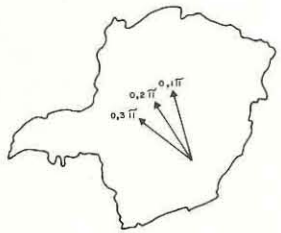


PLATE 21 - MINAS GERAIS - MAIN DIRECTIONS OF DISLOCATION OF THE URBAN POPULATION IN THE PERIOD 1970 - 1980



ANALYSES OF THE RESULTS

Total population:

Plate 8 presents the coefficients of correlation for the various directions in the period from 1950 to 1980. The periods 1950/60, 1960/70 and 1970/80 are represented in Plates 9, 10 and 11.

One verifies a marked randomness during the whole period. In the period 1950/60, the shape of the curve indicates a certain tendency towards higher coefficients of correlation near the directin N—S. Despite that, the coefficients are not significant. From 1960 to 1980, the curves are rather indefinite.

Although one doesn't find a well-defined tendency of population dislocation in the state as a whole, one can divide the population into the categories rural and urban and verify if each one, individually, present remarkable tendencies.

Rural population — Period 1950 1980

In Plate 12, there is a very well-defined behaviour of the populational flow. In the direction of the conventional longitude (E—W) and nearby directions, one has a practically null coefficient of correlation, as no tendency is verified which conforms the result obtained by the analysis of the weighed mean centre.

The coefficients of correlation grow as they approach the latitudinal direction (N—S), becoming significant for the angles of rotation 0.9; 0; 0.1, which is represented by Plate 20.

The most significant direction is 0.1, that is, the population dislocation from south to north, slightly tending towards the north-west, in opposition to the Jequitinhonha.

Map 5 presents the growth rate of the rural population from 1950 to 1980, showing three categories of municipalities:

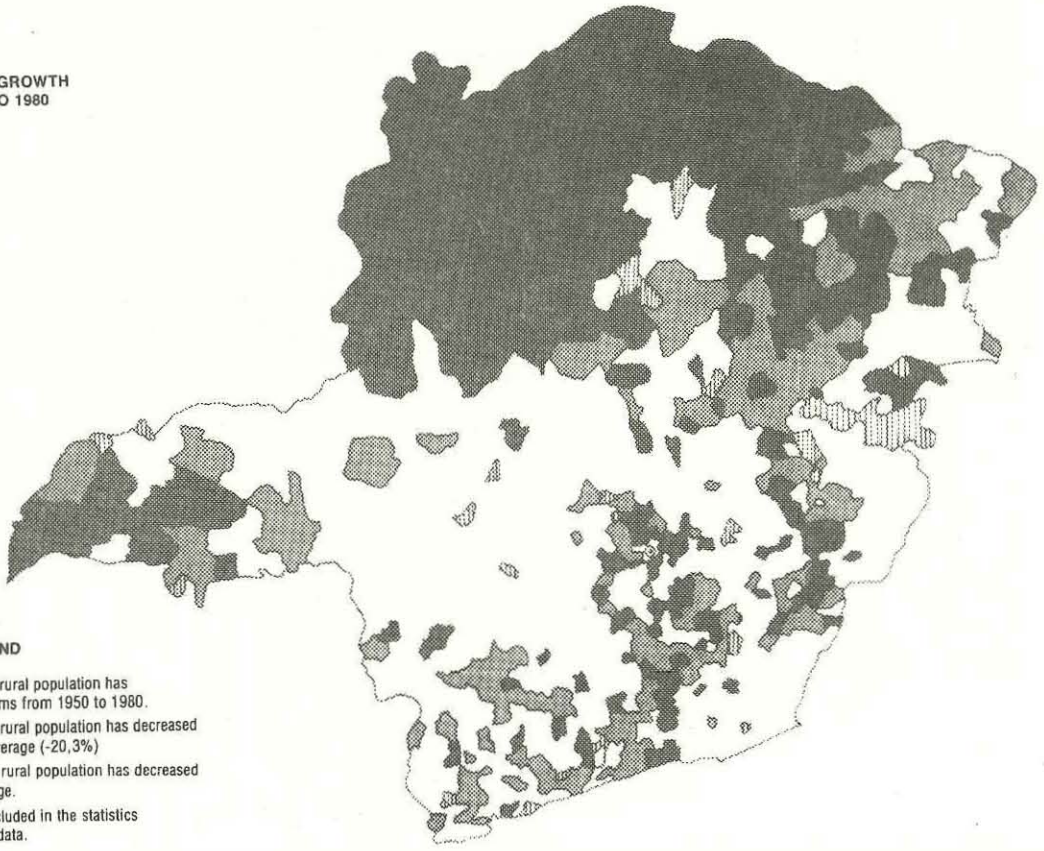
- municipalities whose rural population has grown in the period;
- municipalities whose rural population has decreased less than the state average;
- municipalities whose rural population has decreased more than the state average.

The visualization of the map confirms the results obtained, showing that almost all the northwestern municipalities present positive growth rates.

SUB-DIVISION OF THE PERIOD

Plates 13, 14 and 15 present the coefficients of correlation of the growth rates of the sub-periods 1950/60, 1960/70 and 1970/80. It is the sub-periods 1950/60 and 1960/70 that determine the shape of the curve from 1950 to 1960. In the period 1970/80, the direction 0.1 is still the one of highest

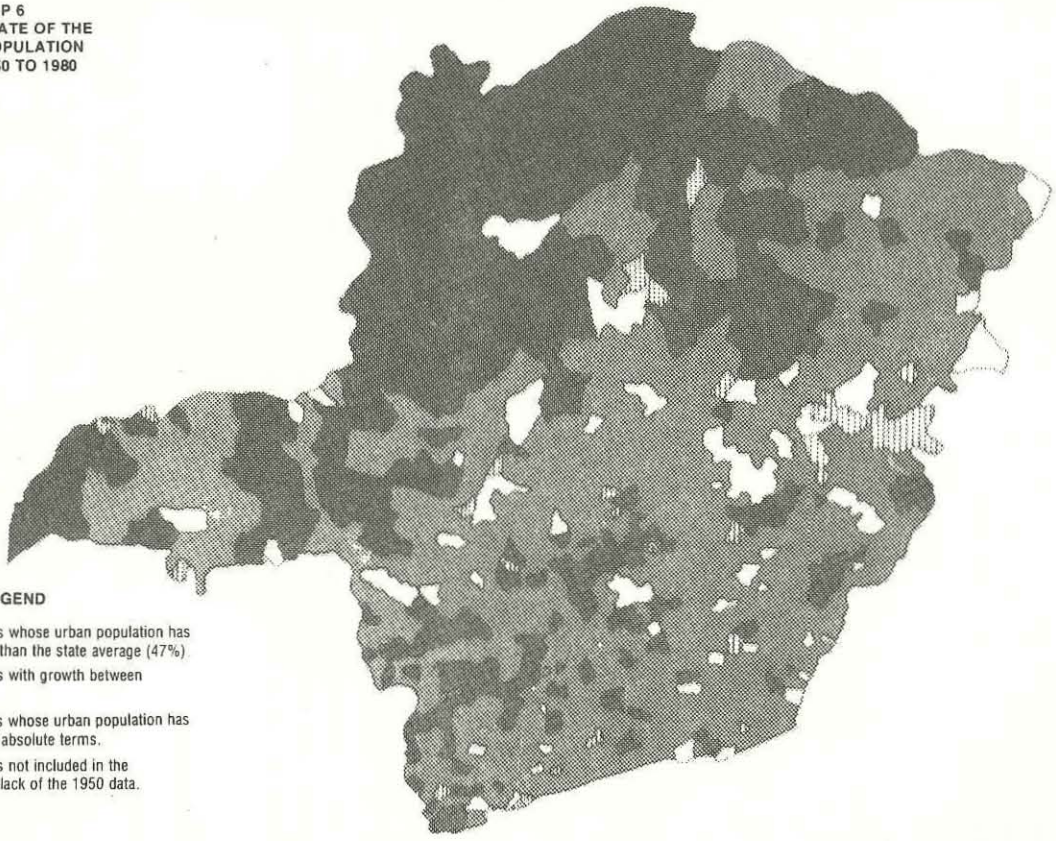
MAP 5
RURAL POPULATION GROWTH
RATE FROM 1950 TO 1980



LEGEND

- Municipalities whose rural population has grown in absolute terms from 1950 to 1980.
- Municipalities whose rural population has decreased less than the State average (-20,3%)
- Municipalities whose rural population has decreased more than the average.
- Municipalities not included in the statistics for lack of the 1950 data.

MAP 6
GROWTH RATE OF THE
URBAN POPULATION
FROM 1950 TO 1980



LEGEND

- Municipalities whose urban population has grown more than the state average (47%)
- Municipalities with growth between 0 and 47%.
- Municipalities whose urban population has decreased in absolute terms.
- Municipalities not included in the statistics for lack of the 1950 data.

coefficient of correlation, but its value is not significant (below 70%). One must notice that the shape of the curve is more defined.

The movement of the rural population dislocating from south to north was a remarkable phenomenon of the period 1950/70. From 1970 to 1980, there is no tendency, and the process of out-migration of the rural area is generalized all through the State.

URBAN POPULATION

Plate 16 presents the coefficients of correlation of the period 1950/80 for the various directions. For 0.8, one has a minimum of correlation. From 0 to 0.3, one has a maximum of correlation, though the tendency is not significant.

Plates 17, 18 and 19 present the sub-division of the periods. From 1950 to 1970, there isn't a well-defined tendency. From 1970 to 1980, directions 0.1, 0.2 and 0.3 present significant coefficients of correlation. As shown in Plate 21, there was a tendency to growth of the urban population in the regions Triângulo and north-west of the State. This phenomenon took place at the same time as the urban concentration around Belo Horizonte, as demonstrated above.

Map 6 presents the urban population growth rate from 1970 to 1980, divided into three intervals, according to its position in relation to the average growth rate of the State (47%):

- municipalities whose population has grown more than the State average;
- municipalities whose urban population has decreased in the period.

The results obtained ore confirmed by the visualization of the map. One can see that the region near Belo Horizonte, the northwest of the State, and certain strips of the Triângulo, present high growth rates.

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SUMMARY: — This research focuses on an analysis of the evolution of the population of the State of Minas Gerais from 1950 to 1980, making use of centrographic techniques of dispersion and a statistic adjustment called directional research. In general, one detects a significant change in the period, once the State, basically "rural" in 1950, becomes "urban" in 1980. An east-west movement of the urban population is detected and a south-north movement related to rural population is found.