Spatial Approaches in Population Studies: Analytical Methods and Representation Techniques

Basic Concepts and Measures in Demography

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Demography

1) **Etymology** – word first used 1855 (Belgian Achille Guillard)

   From dictionary:

   Word origin of 'demography'

   < Gr *dēmos*, the people (see democracy) + -graphy (*Graphein* = to write)

   noun

   the statistical science dealing with the distribution, density, vital statistics, etc. of human populations

Webster's New World College Dictionary, 4th Edition. Copyright © 2010

2) **Formal Demography**

   Demography is a *Science* with focus on:

   Study of <u>human</u> populations and their <u>temporal</u> evolution in relation to their <u>size</u>, <u>spatial distribution</u>, <u>composition</u> and general <u>characteristics.</u>

Demography

VARIABLES

Demography
- Structure
- Dynamics

STRUCTURE – describe the population status (number & structure)– relating to a geographical area and a specific time → ***Population Statistical Analysis***

- Size
- Distribution
- Structure or composition

(age, sex, education level, income, households/family, urbanization, ethnicity,…)

DYNAMICS - dynamic demographic variables for a given geographic space and time:

- Vital Statistics: births (natality), fertility, deaths (mortality), reproduction, marital status (marriage, divorce)
- Migration : Emigration, Commuters, Immigration

Population

Set of Human being with a certain <u>characteristic</u>.

- Inhabitants of the same country or region;

Population

Set of Human beings with a certain <u>characteristic</u>.

- Group of people in a given age group;

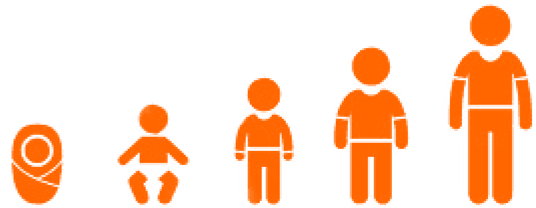
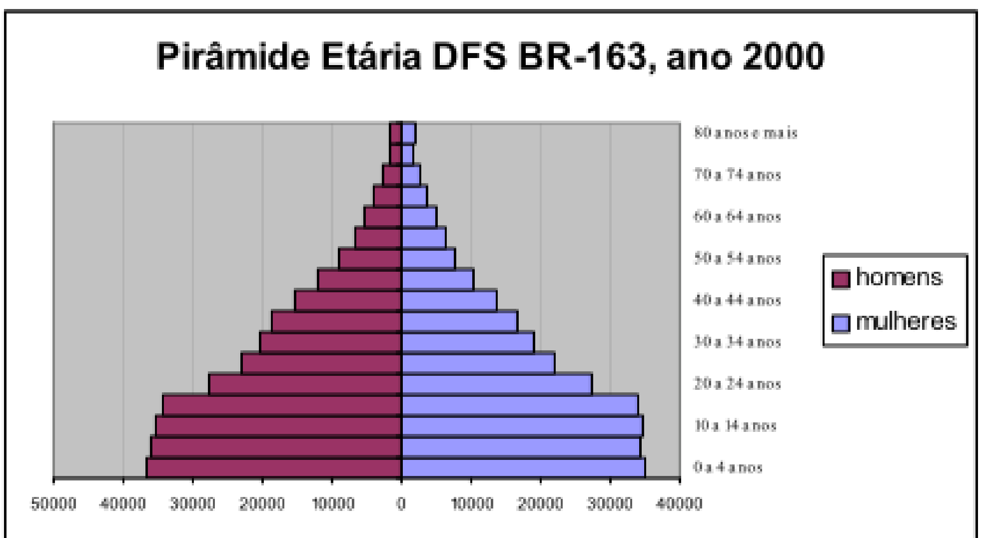


Figura 2. Gráfico da pirâmide etária do Distrito Florestal da BR-163, no ano 2000. Fonte: FIBGE, Censo Demográfico 2000.



Population

Set of Human beings with a certain characteristic.

Inhabitants ?? - Military? Diplomats? Students? People on vacation???

IBGE - Censo 2010: **Population Recorded x Resident**

Recorded (recenseada): people who had the home as a place of residence and were present at the reference date (present residents) + people who had the home as a place of habitual residence and who, on the reference date, they were absent for a period not exceeding 12 months from that date (absent residents).

Resident: the residents of the place of residence at the date of reference, whether they were present or absent. People living in the home who were absent were censused since your absence has not been more than 12 months on that date, for the following reasons: travel, admission in educational establishment or lodgings in another residence, detention without final sentence declared, temporary admission in hospital or similar establishment and boarding the service (shipping).

https://censo2010.ibge.gov.br/materiais/guia-do-censo/glossario.html

Demography

Interrelationships between static analysis and demographic dynamics demographic variables

Size
Distribution
Structure

Birth Rate
Dead Rate
Migration

Structure

Dynamics

Population

- Population Characteristics - Size and Structure
  - ✓ How many people/local / time ?
  - ✓ How many youth/children? Adults? Elderly?
  - ✓ How many male / female ?
  - ✓ How many are economically active?

- Factors that affect population
  - ✓ How many are born?
  - ✓ Die?
  - ✓ Migrate?

➢ How many women of reproductive age?
➢ How many married?
➢ Ratio of effective contraceptive?

Concepts & MEASURES

AGE

the age of the individuals is important to various demographic phenomena

The **age** of an individual can be defined as the number of days, months and years after your birth;

Or the **number of full years**:

- the age group of 20 to 24 years - is formed for all individuals aged between 20 and 24 years

→ <u>on reference date of a census survey</u> *individuals born in the same year may have different ages in terms of full years.*

Calendar year = 1 January to 31 December.

Which population include in the denominator for calculating rates?

Concepts & MEASURES

AGE

→ the denominator should contain the number of people-year, which corresponds to the sum of the time spent (in years) for each component of the population!

Concept of **people-year** : take the population at a given time of the year.

But at what time?

- at the **beginning** of the year – not include people who are born during the year.
- at the **end** of the year - not include people who died during the year and, include people who were born at different times during the year and who were not exposed all the time to the risk of die.

Solution: the total of people-year population in the **middle of the year**, assuming there is uniformity in the event of births and deaths during the year.

Demographic MEASURES

For demographic measures & indicators, one need to identify :

a) Which population subgroup or type of event being analyzed;
b) What is the geographical area
c) Which the instant of time/period considered

Stock statistics - measures refer to a moment of time, for an specific date (until)

Flow measures,- it refer to a calendar-year (Jan-Dec the same year), but can be obtained for any interval of 12 months, or varied .

Demographic MEASURES

1) FREQUENCY - absolute measurement

Total number of persons in the population or sub-group in a specific moment of time, or
total n of occurrences of the event during the period of time considered:

- useful as numerator of population-based measures or guiding public resource allocation
- does not measure the intensity of stock and flow statistics

Ex: N of live births → n vaccines calculation

Without distinguishing RURAL from URBAN births

Are there more men or women? Did the Mortality rate increase?

OBS: Do not use frequency when population have different sizes!

Demographic MEASURES

Relative measurement for Stock statistics

2) RATIO: relationship between values that belong to different populations.

EX: the relationship between the total of MEN and WOMEN in total a population, usually called the SEX RATIO.

Ex: **Brazil Sex ratio (SR)**

2011 Men = 94.7 million

Women = 100.5 million → SR = 94.2 (2011)

$$SR = \frac{P^m}{P^f} \times 100$$

	1991	1996	1999	2000	2010	2013	2014	2018*
BRASIL	97.5	97.3	96.8	96.9	96	94.5	93.9	97
RJ	smaller MAN pop				91.2		88.4	
AM	only state man pop stable				101.3			

*https://www.states101.com/gender-ratios/global/brazil

2014:

More man: MT, PA,RO

AP = 100!!!

Quotient between distinct events

Demographic MEASURES

Relative measurement for Stock statistics

3) PROPORTION:

- relationship between values that come from the **same population**,
- the numerator is part of the denominator.

For example: the proportion of men in a population,

➔ the ratio between the number of men and the total population.

2010 Census:

190,173,694 people;

93,390,532 Man

Proportion = 0.49

Proportion and Percentage – relationship between the part and the whole – pay attention to the issues which refer to relative and absolute data

Demographic MEASURES

Relative measurement for Stock statistics

4) RATE:

Represent the demographic event magnitude in a specific population or part of it, considering an specific **time** period.

For example: Mortality Rate

$$\text{Rate of one event at a time} = \frac{\text{n occurrences in the period}}{\text{pop at risk of having the event}}$$

- In general * 1000 to facilitate interpretation
- Others, like …. of Population Growth Rate.

RATE – intensity of variation per time unit

Useful for comparisons. It must consider:

- availability of a convenient <u>denominator</u>;
- availability of <u>data</u> that enable the comparability between different periods.

Demographic MEASURES

4) RATE:

Ex: **Vital Rates:** to general, not related to intensity

– **Birth (natality) and Death Rate (mortality)**

– event and population belong to the same universe

General Rate (T)

$$\mathbf{T_1 = A_i / P_i}$$

where:

A_i: vital <u>events</u> vitais – in a certain area and time interval .

ex: Natality

P_i: <u>population over wich the events happened</u> - not necessarily all members are evenly exposed to the risk

ex: Total Population

Demographic MEASURES

4) RATE:

Ex: more **restricted Rates:**

– event and population belong to the same universe

General Rate (T) $T_2 = A_i / (B_i + C_i)$ where:

A_i: vital <u>events</u> vitais – in a certain área and time interval .

ex: Mortality

$B_i + C_i$: <u>population over wich the events happened</u> -

ex: population of an specific age interval

Generic Demographic rates

RATE = N event /people-year exposed to the event risk

Period Demographic Rates:

RATE = N events between t_0 and t / people-year exposed to the event risk betweeen t_0 and t

- Gross Rate, General, Specifics (age, sex),

Demographic MEASURES

4) RATE:

Some measures are called RATE, but by defintion they are not.

Ex:

(a) Rate of Population Growth

$$\frac{P^{t} - P^{t_0}}{P^{t_0}} \times 100 \text{ ou } \frac{P^{t} - P^{t_0}}{P^{\frac{t+t_0}{2}}} \times 100$$

(b) Urbanization Rate

$$\frac{P^{urbana}}{P} \times 100$$

(c) Natality Gross Rate

$$\frac{N}{P} \times 1000$$

WHY ?

Demographic MEASURES

4) RATE:

Some measures are called RATE, but by defintion they are not.

Ex:

(a) Rate of Population Growth

$$\frac{P^{t} - P^{t_0}}{P^{t_0}} \times 100 \text{ ou } \frac{P^{t} - P^{t_0}}{P^{\frac{t+t_0}{2}}} \times 100$$

(b) Urbanization Rate

$$\frac{P^{urbana}}{P} \times 100$$

(c) Natality Gross Rate

$$\frac{N}{P} \times 1000$$

(a) & (b) - the numerator is not the number of occurrences of an event,
(c) the denominator includes people who are not at risk, such as newborn children and elderly pop

Demographic MEASURES

**5) Probability - ** includes risk estimates

Probability of an event in a given period = $\dfrac{\textbf{N} \text{ of events during the period}}{\textbf{Population in risk} \text{ of the event in the begining of the period}}$

- Generally *1000 – better reading and interpretation
- Also a measure of Risk

Demographic VARIABLES

Size and **composition** are considered as static aspects of a population.

Demography also deals with the dynamic aspects of populations, that is, the changes and interrelationships between basic demographic variables - **fecundity, mortality and migration**.

VARIABLES

- Population Size
- Mortality
- Natality
- Fecundity
- Distribution – by sex, age, situation
- Geographic Distribution

SIZE

Giving:

- The population of a given geographic area, at any given time.
- The initial population in the distant past, there was no entry and exit of people from the area.
- A closed population → without migratory movements.

Mértola – castle and general view
www.flickr.com/fotos/cmanuel/

- What is the size of the current population?

SIZE

- What is the size of the current population?

The trajectory between the initial population and the current population can be explained by:

births and deaths + migratory movements, that occurred in the period

It can be represented by the **Basic Equation of the Population Movement:**

$$\boldsymbol{P_n = P_o + N_t - O_t + I_t - E_t}$$

P_n = population in a time n;

P_o = initial population, t=o;

N_t = births in period t (t = n - o);

O_t = deaths in period t (t = n - o).

I_t = Immigrants in period t (t = n - o);

E_t = Migrants in period t (t = n - o).

SIZE

- What is the size of the current population?

(CLOSED Population)>> Evolution from the initial population and the current population is explained by the **deaths** and **births** that occurred in the period. **Without migratory movements**

Population size at any time during this period can be reproduced by:

$$P_n = P_o + N_t - O_t$$

P_n = population in a time n;

P_o = initial population, t=o;

N_t = births in the periodo t (t = n - o);

O_t = deaths in the periodo t (t = n - o).

SIZE

Basic Equation – Specific terms:

$$P_n = P_o + N_t - O_t$$

- Vegetative Growth: ***N - O***
- Migration balance: ***I - E***
  (Net migration Rate)
- Population Growth: $\boldsymbol{P_n - P_o}$
- Population Growth Rate: $\boldsymbol{(P_n - P_0) / P_0 \times 100}$

SIZE

Population growing with geometric progression…

$$\boxed{P_n = P_o\,(1+r)^t}$$

r = Growth rate by time period;

t = period, in time unit, between 0 and n

How to calculate **r**?

$$P_n = P_0(1+r)^t$$

$$\frac{P_n}{P_0} = (1+r)^t$$

$$\log\frac{P_n}{P_0} = t\log(1+r)$$

$$\frac{1}{t}\log\frac{P_n}{P_0} = \log(1+r)$$

$$(1+r) = anti\log\left[\frac{1}{t}\log\frac{P_n}{P_0}\right]$$

$$r = anti\log\left[\frac{1}{t}\log\frac{P_n}{P_0}\right] - 1$$

or(log 10base)

$$r = 10^{\left[\frac{1}{t}\log\frac{Pn}{P0}\right]} - 1$$

SIZE

Population growing with geometric progression

To calculate the size of the population in the future ... or
to calculate the time required to reach a given population volume, from a given initial population and a growth rate....

$$P_n = P_0(1+r)^t$$

Consider the Brazilian population:
in 2000: 169,799,170 residents, and
in 2010: 190,755,799 .
(without considering migrations)

$$\frac{P_n}{P_0} = (1+r)^t$$

$$\log\frac{P_n}{P_0} = t\log(1+r)$$

Calculate:

- Annual growth rate;
- Intercensal value for 2007;
- If this growth rate is maintained,

how long would the population double?

$$t = \frac{\log\frac{P_n}{P_0}}{\log(1+r)}$$

SIZE: IBGE Projection estimates – BR & UF

Population Projection (2013) - **Demographic component Method**

It incorporates information on observed *trends in mortality, fecundity and migration* at the national and regional levels

Demography's fundamental **population component estimating equation**:
(*Equação compensadora ou equação de equilíbrio populacional*):

$$\boldsymbol{P_{(t+n)} = P_{(t)} + B_{(t,\, t+n)} - D_{(t,\, t+n)} + I_{(t,t+n)} - E_{(t,t+n)}}$$

$P_{(t+n)}$ = population in year t + n;
$P_{(t)}$ = population in year t;
$B_{(t,\, t+n)}$ = births occurring between t and t + n;
$D_{(t,\, t+n)}$ = deaths occurring between t and t + n;
$I_{(t,\, t+n)}$ = immigrants , period t, t + n;
$E_{(t,\, t+n)}$ = migrants, period t, t + n;
t = initial year;
n = range size (interval)

ftp://ftp.ibge.gov.br/Projecao_da_Populacao/Projecao_da_Populacao_2013/srm40_projecao_da_populacao.pdf

SIZE: Projections

Demographic Component Method

In a given year **t**,

the population of men and women in the age x (with x = 1,2,3, ..., 89) is P_x^t,

and

the proportion of people of a specific age who survives a year is S_x^t.

The population at age x + 1 in year t + 1 is given by:

$$\boxed{P_{x+1}^{t+1} = P_x^t * S_x^t + M_x^t}$$

Where: M_x^t represents the migratory component.

ex. For the age group of 90 years or over (P_{90+}) :

$$P_{90+} = P_{89+} * S_{89+} + M_{89+}$$

ftp://ftp.ibge.gov.br/Projecao_da_Populacao/Projecao_da_Populacao_2013/srm40_projecao_da_populacao.pdf

SIZE: IBGE Projection estimates – BR & UF

Population Projection (2013)
Demographic Component Method – MCD

Componentes demográficas, parâmetros utilizados e construção de hipóteses: cálculo e projeção (...)

https://ww2.ibge.gov.br/home/estatistica/populacao/projecao_da_populacao/2013/default.shtm

ftp://ftp.ibge.gov.br/Projecao_da_Populacao/Projecao_da_Populacao_2013/srm40_projecao_da_populacao.pdf

SIZE: IBGE Projection estimates – BR & UF

Instituto Brasileiro de Geografia e Estatística

https://www.ibge.gov.br/apps/populacao/projecao/notatecnica.html

POPULAÇÃO

Projeções e estimativas da população do Brasil e das Unidades da Federação

nota técnica

Popclock Projeção 2013

(1° de julho de 2000 a 01 de julho de 2020)

METODOLOGIA DE CÁLCULO

O Popclock calculado a partir da nova Projeção de População do Brasil 2013 apresenta a população residente do Brasil, ajustada a cada segundo, e estimada da seguinte forma:

- Foram utilizadas as populações projetadas para 1° de julho, cobrindo os anos de 2000 a 2020, extraídas da Projeção de População do Brasil 2013, elaborada pelo Método das Componentes Demográficas (MCD) para cada uma das 27 unidades da federação, com as seguintes características:
    - População de partida – Estrutura ajustada por sexo e grupos quinquenais de idade para o Censo Demográfico 2000;
    - Mortalidade – oriunda da Projeção da população do Brasil 2013 por sexo e idade para o período 2000 – 2060, utilizando as tábuas construídas para 2000 e 2010;
    - Fecundidade oriunda da Projeção da população do Brasil 2013 por sexo e idade para o período 2000 – 2060, utilizando as taxas específicas de fecundidade construídas para 2000 e 2010; e
    - Migração internacional – oriunda da Projeção da população do Brasil 2013 por sexo e idade para o período 2000 – 2060.

Para detalhes adicionais, ver em:
www.ibge.gov.br/home/estatistica/populacao/projecao_da_populacao/2013/default.shtm

SIZE: IBGE Municipal Projection estimates

Population Estimates – MUNICIPALITIES - July 1, 2017:

Madeira & Simões (1972) Methodology: "the trend of population growth of the municipality, between two consecutive demographic census, is given in relation to the growth trend of a hierarchically superior geographical area (greater area)."

- Basis of projection for each Federation Unit –UF (larger area)
- UF - Population value (2017)→ demographical component method
- Pop T municipalities - Censuses 2000 and 2010, linear adjustment + calibration factor: values applied for the respective UF (reference date on July 1, 2017)

http://biblioteca.ibge.gov.br/visualizacao/livros/liv100923.pdf

SIZE: IBGE Projection estimates – BR & UF

Population Estimates – MUNICIPALITIES - July 1, 2017:
Demographical component - Population estimates UF (2013) → *P (t)*

Larger Area (UF) → P(t) = pop estimated at ***t***, subdivided in smaller areas ***i***

Pi (t) ; i = 1, 2, 3, ... , n

$$P(t) = \sum_{i=1}^{n} P_i(t)$$

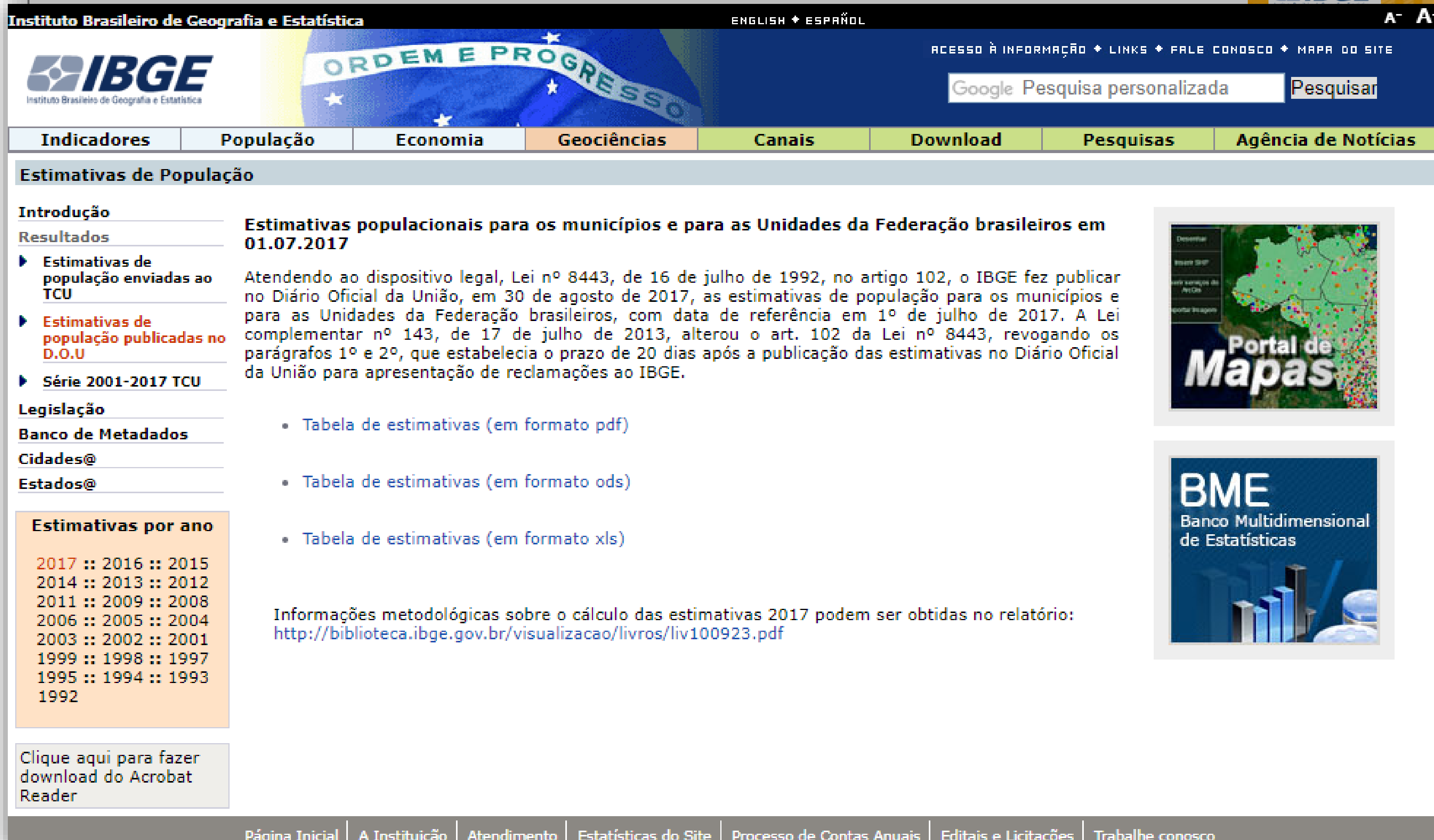
$$\boxed{P_i(t) = a_i\, P(t) + b_i}$$

a_i = proportion of pop increase from smaller area (i) /larger area
b_i = linear coefficient for adjustment
t_0 & t_1 = Demographic Censuses 2000 and 2010

$$\begin{aligned} P_i(t_0) &= a_i\, P(t_0) + b_i \\ P_i(t_1) &= a_i\, P(t_1) + b_i \end{aligned} \Rightarrow \begin{aligned} a_i &= P_i(t_1) - P_i(t_0) / P(t_1) - P(t_0) \\ b_i &= P_i(t_0) - a_i\, P(t_0) \end{aligned}$$

http://biblioteca.ibge.gov.br/visualizacao/livros/liv100923.pdf

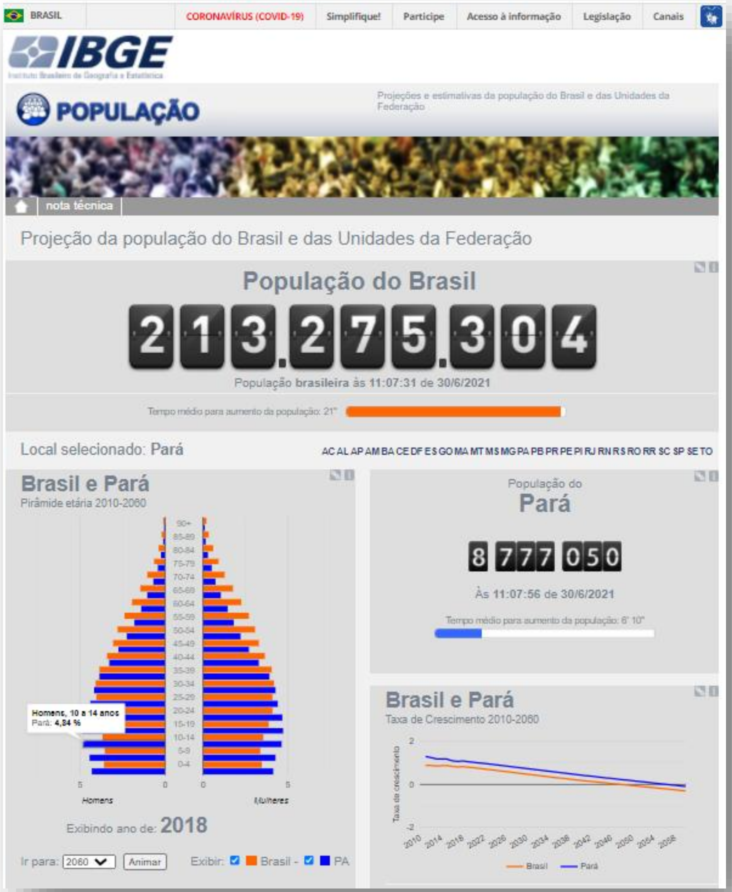
SIZE: IBGE Projection estimates – BR & UF

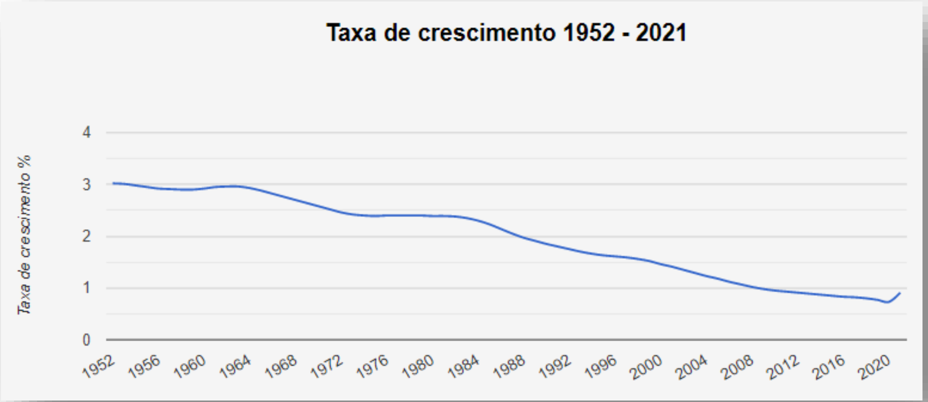


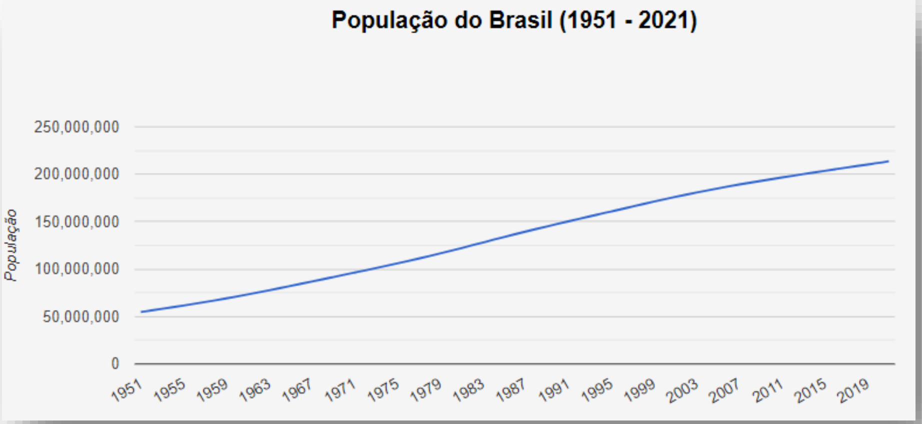
http://biblioteca.ibge.gov.br/visualizacao/livros/liv100923.pdf

Population - Projection estimates

https://www.ibge.gov.br/apps/populacao/projecao/







http://countrymeters.info/pt/Brazil

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SIZE: IBGE Municipal Projection estimates

Population Projection (2013)
Demographic Component Method

Componentes demográficas, parâmetros utilizados e construção de hipóteses: cálculo e projeção (...)

ftp://ftp.ibge.gov.br/Projecao_da_Populacao/Projecao_da_Populacao_2013/srm40_projecao_da_populacao.pdf

Tamanho

- **Results**:
  - Annual Growth Rate **(r = 0.0117, ou 1,17 %a.a.)**
  - Valor intercensitário para 2007
    - $P_{2007} = P_{2000} (1 + r)^{t}$ ➔ **184.210.802**
    - **183 987 291 recenseados**
  - Se mantida esta taxa de crescimento,

 em quanto tempo a população duplicaria

T_2 = 60 anos

$$P_n = P_0(1+r)^t$$

$$\frac{P_n}{P_0} = (1+r)^t$$

$$\log\frac{P_n}{P_0} = t\log(1+r)$$

$$t = \frac{\log\frac{P_n}{P_0}}{\log(1+r)}$$