Mortality Estimates and Construction of Life Tables for Municipalities in Brazil, 1980 to 2010

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Structured Abstract

BACKGROUND

The study of mortality level and trends in developed countries is limited by the quality of the vital registration system. The most common problems faced in these countries are incomplete coverage of vital registration systems and errors in age declaration for both population and death counts. he problem is more complex when it is studying small areas and sub-national populations. In recent years, a series of methodological alternatives were developed to provide mortality and life expectancy estimates for small areas.

OBJECTIVE

We aim to study the quality of mortality data for small areas in Brazil and estimate levels and structure of mortality combining demographic methods with Bayesian statistics. From these estimates, we produce a series of life tables for Brazilian municipalities from 1980 to 2010.

METHODS

We use data from the Ministry of Health Database – Mortality Information System – and population data (censuses) from 1980, 1991, 2000 and 2010. Data are available by age and sex for all municipalities of the country. The first step of the analysis uses traditional demographic to evaluate the quality of infant, child and adult mortality in Brazil. In the second step, we use the method suggested by De Beer and the variation proposed by Gonzaga and Schmertman to produce single age mortality estimates. Finally, we use a Bayesian model to estimate quality of data and life tables for all municipalities in the country.

RESULTS

The results show that completeness of death counts in the country is almost 100% in 2010, compared to 85% in the 1990s, but there is still a lot of variation across regions. More developed regions have complete registration whereas less developed areas in the North and Northeast have low registration. We find larger differentials in adult mortality mortality and life expectancy for males than for females. Coastal areas in the northeast observed a fast increase in young adult mortality in the 2000s. Infant mortality is converging to lower levels across all regions.

CONCLUSIONS

We find that the quality of mortality data in Brazil and regions is improving over time, a large part of the country shows almost complete coverage of death counts. We also estimate mortality levels for all municipalities in Brazil, over 5000 estimates, and observed the existence of clear regional spatial patterns of mortality. We also find a clear spatial pattern of mortality across regions in Brazil. Results also indicate a convergence process across regions in Brazil overtime both in the improvement of data quality and mortality levels.

Keywords: small areas, mortality estimation, demographic techniques, empirical bayessian statistics

Introduction

In developing countries, mortality estimates and knowledge of levels and trends of mortality are limited by the quality of data. The most common problems faced in these countries are incomplete coverage of vital registration systems and errors in age declaration for both population and death counts. In recent years, collection of data for death counts has improved, but there are still limitations for studying mortality in several parts of the world, and Brazil is an important example of these limitations (Paes, 2005; Luy 2010, Setel et.al, 2007, PAHO, 2010; The PLOS, 2010).

The inability to produce proper estimates of mortality, especially in small areas, harms the development of public health policies and the understanding of the health transition in the country. Demographic methods for estimating mortality rates, such as methods that estimate the coverage of deaths in relation to the population enumerated by age in the demographic censuses (Brass, 1975; Preston et al., 1980; Benneth and Horiuchi, 1981), are able to produce reasonable estimates for these mortality rates even in populations where the quality of census information and vital records are precarious. However, such methods are based on rigid assumptions, difficult to fulfill in a context of rapid and intense destabilization of the age structure of the population and greater geographic breakdown of analysis. Moreover, such methods do not provide a measure of uncertainty for estimates based on the main sources of errors (Murray et al, 2010).

We aim to study the quality of mortality data for small areas in Brazil and estimate levels and structure of mortality combining demographic methods with Bayesian statistics. From these estimates, we produce a series of life tables for Brazilian municipalities from 1980 to 2010. We use a method that incorporates uncertainties due to the high variability and incomplete coverage of deaths by sex and age in estimates of mortality rates by sex and age in smaller areas.

Traditional demographic methods to evaluate data quality and provide estimates for mortality, Death Distribution Methods, for small areas estimates (Bhat, 2002; Bignami, 2005; Murray et al.; Brass, 1975; Preston and Hill, 1980; Preston et al., 1980). These methods depend on some assumptions that are difficult to verify in areas of low population, whose population structure is strongly affected by changes in demographic components, especially migration, or (Bennett and Horiuchi, 1981, Hill, 1987, Bhat, 2002, Hill, 2001, Hill and Choi, 2004, Hill and Queiroz, 2004), Hill, Choi and Timaeus, 2005; Bignami, 2005; Queiroz et al., 2013). In addition to the limited applicability, these methods are not able to estimate differences in the degree of coverage by age and do not allow to measure uncertainties in the estimates (Murray et al., 2010).

Methodology

The proposed method to estimate life tables for Brazil from 1980to 2010, is the integrated Bayesian method (Schmertmann & Gonzaga, 2018). To apply the method, we use information about the differential in the quality of under-registration for child and infant mortality at the municipal level, provided by the Active Search Project (Szwarcwald et al., 2011) and estimated using Brass Surviving Children method (Brass, 1975). For estimates of completeness of death counts coverage, at the state level, we use estimates from different authors Queiroz (2012), Queiroz et al. (2013); Freire et al (2015), IBGE (2013) and Queiroz, et.al (2017); in common these estimates use Death Distribution Methods to evaluate quality of death counts registration to obtain adjustment factors for adult mortality. Age specific mortality rates by sex and all regions are obtain using Topals method suggest by Gonzaga and Schmertmann (2016).

Smoothing Mortality Rates at the Local Level

Gonzaga & Schmertmann (2016) proposed a model for estimation and smoothing of mortality rates for areas with low numbers of people exposed to death and, therefore, with excessive variation in mortality rates estimated by sex and age. The technique is based on a relational model that estimates and smoothes the specific mortality rates for any municipality in Brazil (Gonzaga & Schmertmann, 2016). Although it requires a standard that describes the behavior of age rates, the proposed technique is not sensitive to the choice of this standard, making the model very flexible for application in any area whose observed rates vary greatly in age. The proposed method, called TOPALS regression, is a Poisson regression model based on De Beer's (2012) proposal for smoothing and projecting death probabilities.

Bayesian Model for Mortality Rates and Life Tables for Small Areas

In a follow up paper, Schmertmann & Gonzaga (2018) developed a Bayesian model that allows a probabilistic evaluation of mortality rates and life expectancy in small areas as a function of two sources of mortality. errors: high variability in observed rates and incomplete coverage of death by age.

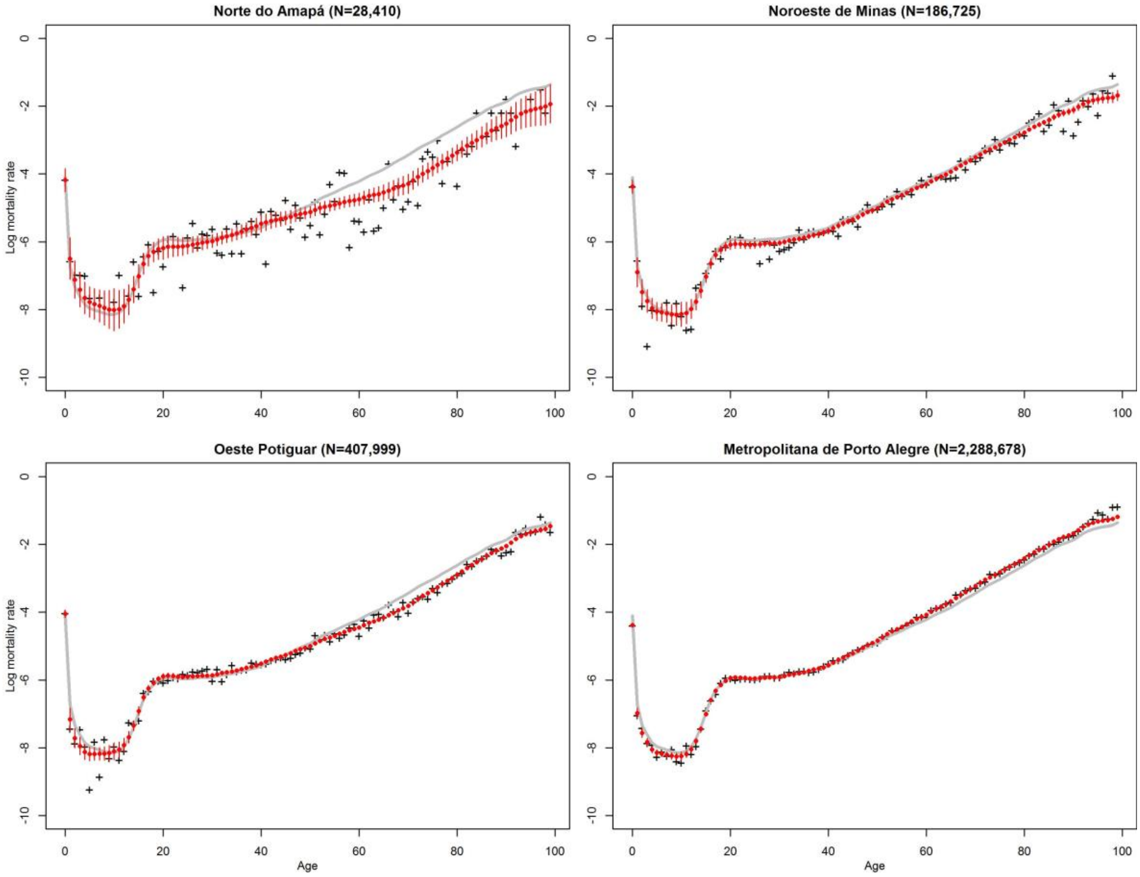
In summary, for each area of interest, a number of exposed individuals Nx and a total of deaths recorded Dx in each age x are observed. In the hypothesis of underreporting of deaths, it is observed that the true number of deaths (Dx *) is not observed, that is, Dx * is greater than or equal to Dx (number of registered deaths). It is assumed that the true number of deaths follows an independent Poisson distribution at each age, which depends on an age-specific mortality rate.

We can conclude from the results that the proposed model incorporates the sources of uncertainties in mortality rates by age from a statistical perspective, thus not ignoring the Demographer's experience and knowledge about the possible range for the degree of coverage from the Demographic Methods. It is emphasized that an explicit statistical model, as proposed, highlights the uncertainty of the results. However, although not all regions in Brazil can be considered small areas in terms of population size, the results show that the uncertainty in the life expectancy of these areas is much greater than the differences between one-off estimates, thus revealing how difficult is to position the small areas of Brazil in terms of the level of mortality synthesized in life expectancy at birth.

Preliminary Results

Figure 1 shows the fitted schedule of males mortality rates by age in all mesoregions within four selected Brazilian’s state. We choose four states from different large areas of the country. The results showed that assuming equal pattern of mortality rates by age can lead to unreasonable estimates. The selection of mesoregions was based on different size of male’s populations exposed to mortality rates during the period from 2009 to 2010. After smoothing the age-specific rates we correct the level of mortality applying an R package developed by Riffe, Lima and Queiroz (2017). The package called DDM allows to estimate the undercounting of deaths using different Death Distribution Methods (Bennett and Horiuchi, 1981; Hill, 1987; Hill and Choi, 2009). In all graphs of Figure 1 one can see the underlying mortality pattern for each mesoregion. The results confirm that the TOPALS allows estimating the entire schedule of single-year rates even for a relative small exposure (see results for “Norte do Amapá” mesoregion which recorded 28,410 males according to 2010 Census).

Figure 1 Maximum likelihood TOPALS fit of log mortality rates by age, males, selected mesoregions, Brazil (2010)



Source: Population Censuses (2000, 2010), Ministry of Health (http://www.datasus.gov.br)..
Note: The symbols "+" represent observed ln(deaths/pop) for each single year of age for three years period around the 2010 Brazilian Census. Red points represent the fitted ln(deaths/pop) by TOPALS method with a 95% Confidence Interval (vertical red segments). The grey solid curve represent the standard schedule for males log mortality rates by age (standard = Brazilian males age-specific log mortality rates in 2010).

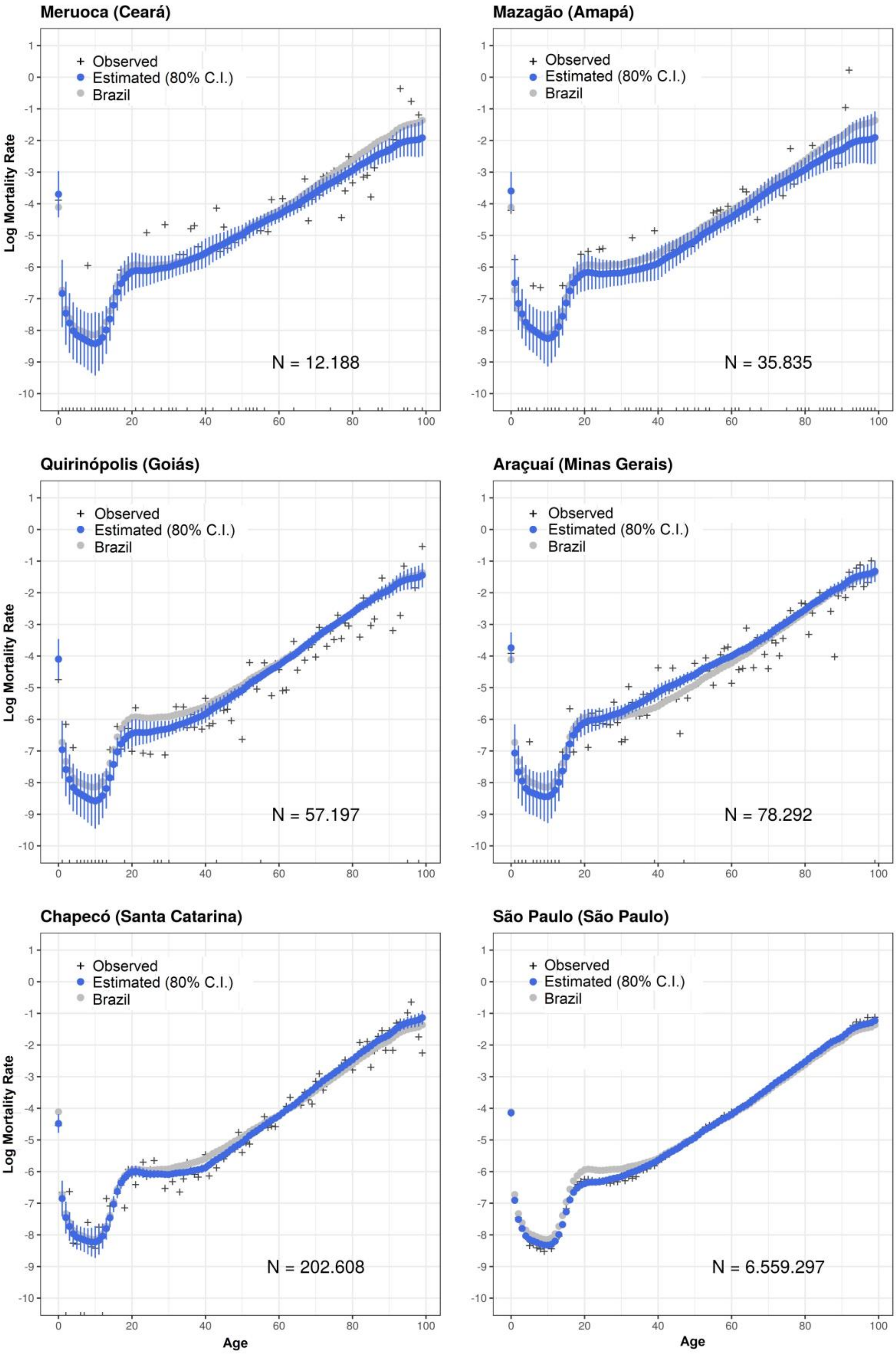
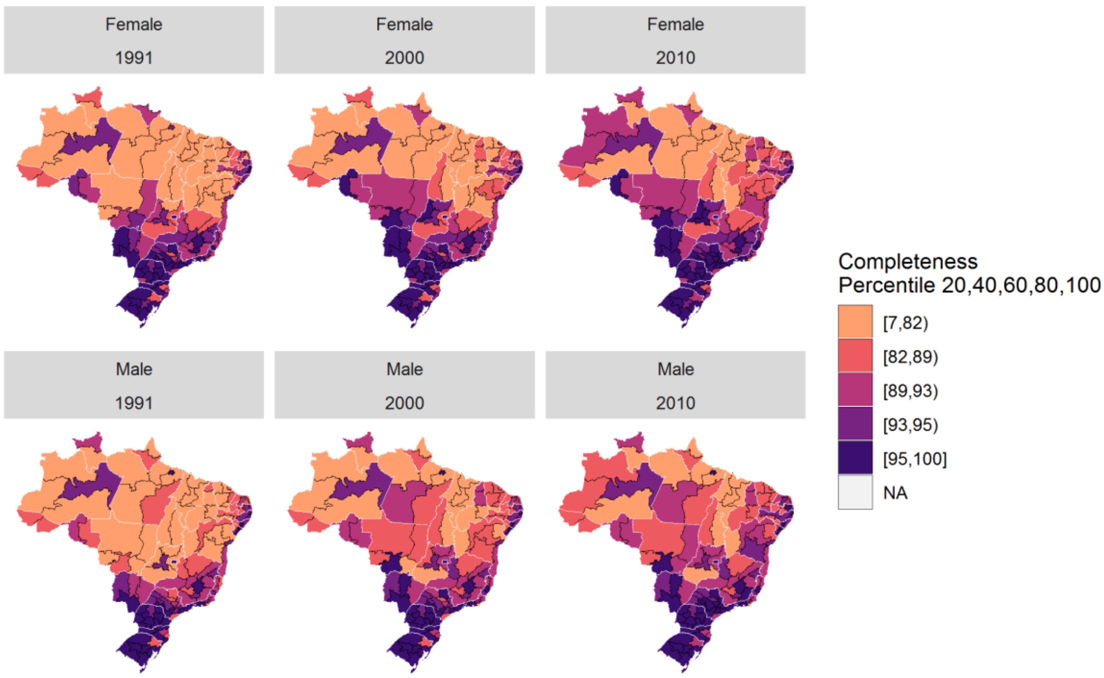

Meruoca (Ceará)
N = 12.188
Mazagão (Amapá)
N = 35.835
Quirinópolis (Goiás)
N = 57.197
Araçuaí (Minas Gerais)
N = 78.292
Chapecó (Santa Catarina)
N = 202.608
São Paulo (São Paulo)
N = 6.559.297
Observed
Estimated (80% C.I.)
Brazil
Log Mortality Rate
Age

Figure 2 shows the evolution of underreporting of deaths - preliminary estimates - by sex and mesoregion in Brazil from 1980 to 2010. The results were developed from the work of a research group that presented methods and estimates in different publications (Queiroz , et al., 2018, Queiroz et al., 2017, Lima and Queiroz, 2014, Freire, et.al, 2013) using a combination of Topals – to smooth single-age mortality rates – and a combination of DDM.

Figure 2 – Quality of Adult Mortality Data, by sex, mesoregions, Brazil 1980-2010.



The results indicate a constant advance in the quality of mortality information in Brazil. The quality of the registry of deaths in Brazil has presented significant improvements in recent years, with coverage of the death registry, for both men and women, above 95%. However, there is still great regional variation. States located in the South and Southeast have records of 100% of deaths, for both men and women. In some states in the Northeast and North, the quality of information is lower, but these have recent significant advances when compared to the period 1991 and 2000. In 2010, all the federative units of the South and Southeast regions, as well as some federative units of the Northeast and Central West, presented complete coverage of the death registry. In addition, there was a great improvement in the quality of mortality information in the poorer federative units of the Northeast and North regions, especially those that had the worst record quality in previous periods.

Figure 3 shows estimates of quality of death counts registration for infant mortality for small areas in Brazil from 1980 to 2010. The main result is the improvement in the data quality, as observed for adult mortality, and a convergence process across regions overtime.

Figure 3- Estimates of Completeness of Death Counts Coverage for Infant Mortality, Brazil, 1980 – 2010

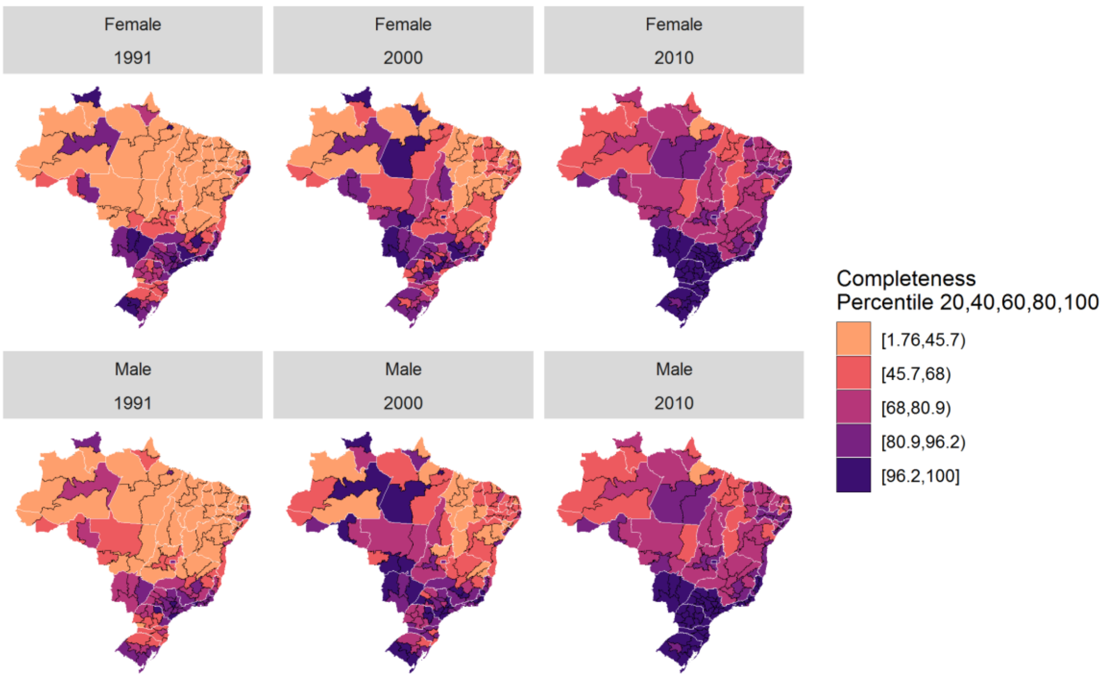
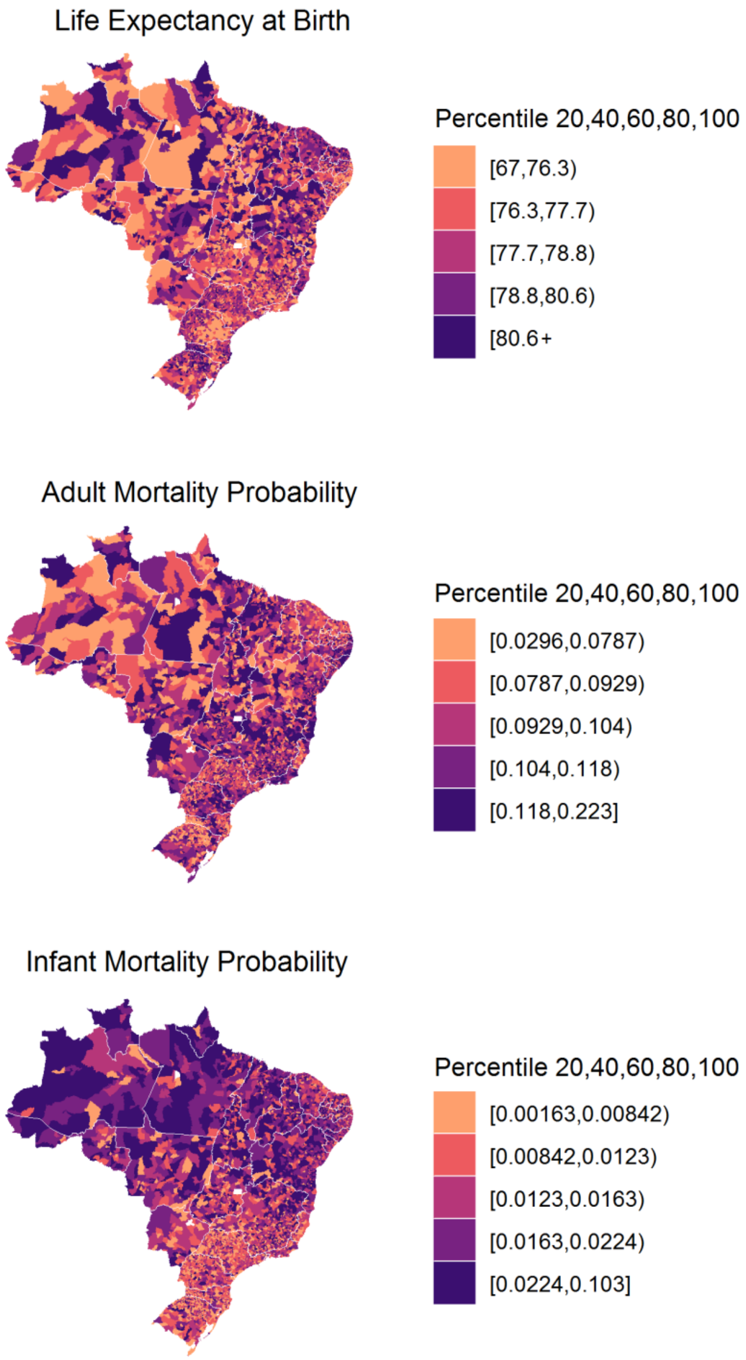


Figure 4 shows estimates at the city level for 2010, for males, of life expectancy at birth, infant mortality and adult mortality (45q15). The results indicate that the life expectancy at birth of women is much higher than that of men over. In addition, there is a process of convergence of female life expectancy in 2010 with a significant reduction in differences between regions over that period. In the case of males, there is a greater differential in life expectancy between regions. The gap between locations with higher life expectancy and lower ones is still quite large. In addition to the child mortality differentials between regions, a second factor that explains the observed differentials is the different levels of mortality in young adults, often explained by the high concentration of external cause mortality in younger groups and in certain localities.

Figure 4 – Estimates of Life Expectancy at birth, 45q15 and 1q0, Males, municipality level, Brazil, 2010



Next Steps and Expected Results to be presented at the meeting

1. Estimate life tables by sex and small areas in Brazil from 1980 to 2010 (2010 is ready)
2. Analyze trends in mortality by regions over time
3. Spatial Analysis of mortality in Brazil

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