Probabilistic Population Projection for Brazil Subnational Areas

Abstract

This study presents probabilistic population projections for two Brazilian states—São Paulo and Rio Grande do Norte—based on hierarchical Bayesian models following the methodology adopted by the United Nations. The objective is to evaluate their applicability to the Brazilian subnational context by estimating 80% prediction intervals for population size by sex and age group from 2025 to 2070.

Projections were produced using the cohort-component method, with a hierarchical Bayesian approach applied to fertility, mortality, and migration through the bayesTFR, bayesLife, and bayesMig packages in R, respectively, and integrated via the bayesPop framework. Data from 1980–2023 were obtained from the Brazilian Institute of Geography and Statistics (IBGE) and the Ministry of Health's DATASUS systems (SIM and SINASC). Adjustments were made for birth and death underregistration, and net migration rates were derived from census data and interpolated for intermediate five-year periods.

Results indicate strong convergence between the Bayesian median projections and IBGE's deterministic projections, with the added advantage of quantifying forecast uncertainty. In São Paulo, population decline is expected between 2035 and 2040, with accelerated aging leading to about 315 elderly per 100 young people by 2070. In Rio Grande do Norte, demographic change is even more intense, with population decline beginning in the same period and an aging index projected at 386 elderly per 100 young people by 2070.

These results underscore Brazil's rapid demographic transition and the usefulness of Bayesian methods for generating realistic and policy-relevant uncertainty intervals in subnational population projections.

1. Introduction

Brazil's population has been undergoing significant transformations in its age structure, with evidence pointing to rapid population aging—an increasing share of people aged 65 and over and a decreasing proportion of those under 15. The parameters adopted in the most recent version of the official population projections produced by the Brazilian Institute of Geography and Statistics (IBGE) are based on three main assumptions: the continuing decline of the total fertility rate (TFR), albeit at a much slower pace than in the past, tending toward stability in many states; continued mortality decline, resulting in gains in life expectancy; and convergence of net migration rate (NMR) toward zero in most Brazilian states at some point in the future (IBGE, 2024).

As a result of the sustained decline in both fertility and mortality, the 2024 IBGE projections foresee a rapid shift in Brazil's age structure and a marked slowdown in population growth, with the country as a whole beginning to lose population around 2042. The timing of this inflection varies by state: in São Paulo, the most populous state, the decline is expected to begin as early as 2037; in Bahia in 2035; in Rio Grande do Norte in 2039; in Amapá in 2046; and in Roraima in 2064, among other examples (IBGE, 2024).

Beyond producing point estimates of population size, it is crucial to assess the uncertainty associated with such projections. Prediction intervals provide a key methodological tool for this purpose.

Because IBGE is legally responsible for producing annual population estimates for all Brazilian states and municipalities to serve as the basis for fiscal transfers, incorporating stochastic models and interval estimates into official population projections presents methodological as well as political and operational challenges. Furthermore, understanding the uncertainties related to population growth is highly beneficial for allocating resources for public or private purposes.

The main objective of this study is to address this gap by testing the Bayesian model used by the United Nations in its global projections (United Nations, 2019; Raftery, Alkema & Gerland, 2014) to project the population by sex and age group for two Brazilian states—São Paulo and Rio Grande do Norte—that differ substantially in data quality, socioeconomic conditions, and regional demographic dynamics. The study produces 80% prediction intervals for projected populations from 2025 to 2070, the terminal year of IBGE's 2024 revision.

2. Methods

Since its 2010 revision, the United Nations (UN) has adopted hierarchical Bayesian models developed by the team at the Center for Statistics and the

Social Sciences at the University of Washington for its population projections. According to this methodology, population is projected through the cohort-component method, in which each demographic component—fertility, mortality, and migration—is modeled within a hierarchical Bayesian framework. This approach enables the estimation of full probability distributions and credible intervals for each component (United Nations, 2024; Alkema et al., 2011; Raftery et al., 2013).

From the posterior distributions of these demographic components, a large number of population trajectories are generated, forming a pseudo-distribution of projected populations. This makes it possible to derive prediction intervals for the total and age-specific population.

2.1 Fertility

The projection of the Total Fertility Rate (TFR) follows the model proposed by Alkema, Raftery, and Gerland (2011). The theoretical framework is based on three model phases that correspond to different stages of the fertility transition: Phase 1 - countries or regions with high fertility, in the pre-transition stage; Phase 2 - countries undergoing the fertility transition; Phase 3 - countries with very low fertility that have completed the transition and may experience a modest rebound in TFR over at least two consecutive five-year periods.

For São Paulo and Rio Grande do Norte, the Phase 2 model was adopted, reflecting the fact that both states are still in the process of fertility decline. Implementation was carried out using the R package bayesTFR, developed by Ševčíková et al. (2010).

2.2 Mortality

The mortality component also follows the UN methodology, which applies a hierarchical Bayesian model to the parameters of a double logistic function used to represent gains in life expectancy at birth, as described by Raftery et al. (2013). This model captures both the initial acceleration and later deceleration of mortality improvement over time.

Implementation was conducted in R using the bayesLife package (Ševčíková et al., 2024). The resulting posterior distributions for life expectancy are then combined with model life tables to estimate age-specific mortality rates for each sex.

2.3 Migration

For net migration rates (NMRs), the model employed is a first-order autoregressive process (AR(1)) with hierarchical Bayesian estimation of parameters, as proposed by Azose and Raftery (2015). This approach allows migration trends to reflect both state-specific characteristics and broader regional correlations. Implementation was performed in R using the bayesMig package (Azose, Ševčíková & Raftery, 2024).

2.4 Population Projection

Once the probabilistic trajectories for fertility, mortality, and migration are obtained, the population projection is carried out using the cohort-component method (Raftery et al., 2012; Raftery et al., 2014). Each simulation of the three components generates a distinct population trajectory, resulting in a distribution of future populations from which prediction intervals can be computed.

The integration of these components is implemented using the bayesPop package (Ševčíková & Raftery, 2016). This framework ensures consistency across demographic components and allows the derivation of population projections by sex and age group for each state over the 2025–2070 horizon.

3. Data

To serve as input for the Bayesian models of the three demographic components, we used historical data beginning in 1980. Information on mortality, fertility, and migration was compiled in five-year intervals. Estimates of deaths and births correspond to quinquennial averages derived from data collected by the Department of Information Technology of the Unified Health System (DATASUS) of Brazil's Ministry of Health (MS). Migration information was obtained from the Brazilian demographic censuses, complemented by additional estimates as described later in this section.

Below we detail the sources and adjustments applied to each variable used as input for the projection models—population, deaths, births, and migration—by sex and age at the state level.

3.1 Population

Population data were obtained from the Brazilian Institute of Geography and Statistics (IBGE). We used population counts from the 1980, 1991, 2000, 2010, and 2022 censuses, as well as IBGE's 2024 revision of population projections, which extends forecasts to 2070 and provides retro-projections for years preceding the 2022 census. The 2024 revision corrects the census population for undercounting identified in the most recent enumeration.

The base population adopted in this study is the IBGE retro-projected population for 2020 (IBGE, 2024). This choice solves two methodological issues: it aligns the projection with the start of a five-year interval (2020 instead of 2022, the census year), and it begins from a population adjusted for census undercounting.

3.2 Deaths

Mortality data were extracted from the Mortality Information System (SIM) of DATASUS and, together with population data, served to estimate life expectancy and age-specific mortality rates (ASMRs).

Because the historical series begins in 1980, temporal differences exist in data coverage and completeness, particularly for auxiliary variables such as age and sex of the deceased. Cases with missing information on sex or age were redistributed proportionally according to the observed age-sex distribution of registered deaths.

For death underregistration, correction factors proposed by Queiroz et al. (2017) were applied for the years 1980–1999. For 2000–2023, correction factors were computed using life table retro-projected by IBGE in its 2024 revision. Specifically, the correction factor for each ASMR in a given year was defined as the ratio between the IBGE retro-projected life expectancy at birth and that obtained from raw data for that year.

3.3 Births

Birth data, required to estimate fertility rates, were obtained from two different sources. For the period prior to 1994, data were taken from Vital Statistics compiled by IBGE. For 1994–2023, data came from the Live Birth Information System (SINASC) of DATASUS.

As with deaths, birth records required adjustment. Births with unknown maternal age were distributed proportionally according to the age distribution of mothers with valid information. To correct for underregistration, we used the Total Fertility Rate (TFR) retro-projected by IBGE in the 2024 population projection revision as the reference. The correction factor for each age-specific fertility rate (ASFR) was defined as the ratio of the retro-projected TFR to the TFR calculated from raw data for the corresponding year. This assumes that the level of underregistration is uniform across all reproductive age groups.

For 1980–1999, correction factors recommended by IBGE (2022) were applied.

3.4 Migration

Migration was estimated from the fixed-date migration question included in Brazilian demographic censuses. Respondents are asked where they lived exactly five years prior to the census reference date, allowing the construction of a migration matrix among all Brazilian states and the estimation of internal net migration balances. Using this information, we calculated net migration rates (NMRs) by dividing the net migration balance by the closed-interval population at the end of each five-year period.

Following IBGE's 2024 methodology, international migration was excluded from these balances because the censuses do not reliably capture emigration abroad; thus, international migration was assumed to be zero. Individuals who did not report a previous place of residence were also excluded.

Because the fixed-date question refers to the place of residence five years before the census, it does not directly measure migration among children under five years old. For this group, we used the place of birth variable as a proxy: children aged 0–4 residing in a different state from their state of birth were considered migrants, with the state of birth treated as the origin. Since these children were born within the past five years, this method provides a reasonable approximation of migration flows in this age group.

This procedure allows direct estimation of migration for the second quinquennium of each decade (e.g., the 2005–2010 period using the 2010 census). For intermediate periods without direct data—such as 2000–2005—linear interpolation of NMRs was used between adjacent censal periods, following the procedure in IBGE's 2024 projection revision. Analogous interpolations were performed for other five-year intervals lacking direct observations.

4. Results and Discussion

The results are presented by comparing the projections produced in this study with the official IBGE 2024 population projections. The upper and lower bounds represent 80% credible intervals for each of the three demographic components—fertility, mortality, and migration.

This section is organized as follows: first, we present the projections of the demographic components, followed by the resulting population projections. Sections 4.1 and 4.2 refer to the state of São Paulo, while 4.3 and 4.4 present the corresponding results for Rio Grande do Norte.

4.1. Demographic Component Projections for São Paulo (SP)

Fertility Component

Figure 1 illustrates the fertility trend for São Paulo, showing a steady and continuous decline over time, tending toward stabilization at around 1.5 children per woman. The credible interval widens in the final decades of the projection, ranging from a lower bound of approximately 1.0 to an upper bound of 2.0, suggesting that a return to replacement-level fertility is highly unlikely. Notably, the median estimate of the Bayesian projection closely aligns with the IBGE's deterministic projection (IBGE, 2024).

Figure 2 displays the projected age-specific fertility pattern, highlighting a relative decline in fertility among younger women aged 15–24, and a proportional increase among women aged 25–34. This reflects a postponement of childbearing consistent with broader demographic transition trends observed in Brazil.

Fig 1 –Projection of the Total Fertility Rate, São Paulo

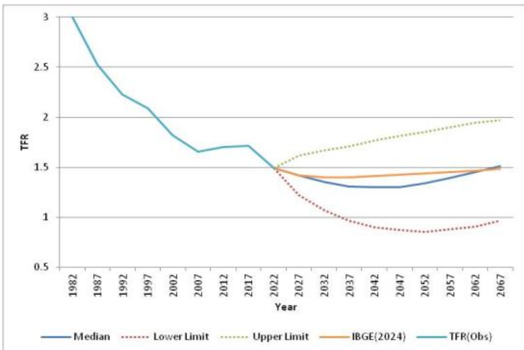
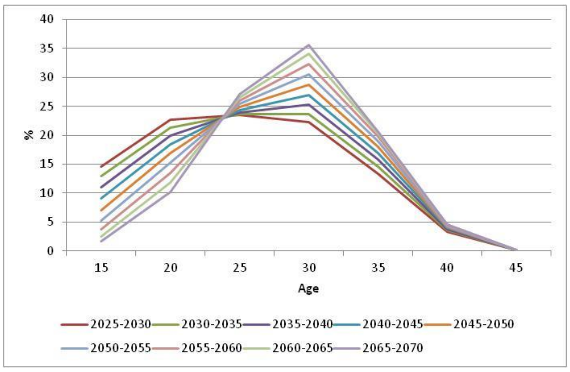


Fig 2 – Projection of Age-Specific Fertility Rates, São Paulo



Source: Demographic Census (IBGE, 2022); Population Projections based on IBGE, SIM, and SINASC data; IBGE Population Projections, 2024 revision.

Mortality. Component

Figures 3 through 6 depict the projected levels and patterns of mortality by sex in São Paulo. Figures 3 and 4 show that female life expectancy at birth is projected to exceed 86 years between 2065 and 2070, while for males it will reach approximately 81 years. Both results are consistent with the IBGE projections (IBGE, 2024).

A visible inflection appears in 2022, corresponding to the COVID-19 pandemic, when life expectancy temporarily declined before resuming its upward trend. As with fertility, uncertainty increases with the projection horizon.

Figures 5 and 6 show that the overall mortality pattern is not expected to change substantially over time. For both sexes, mortality levels will decrease across all ages, while the shape of the age pattern remains broadly stable.

Fig 3 – Observed and Projected Female Life Expectancy at Birth, São Paulo.

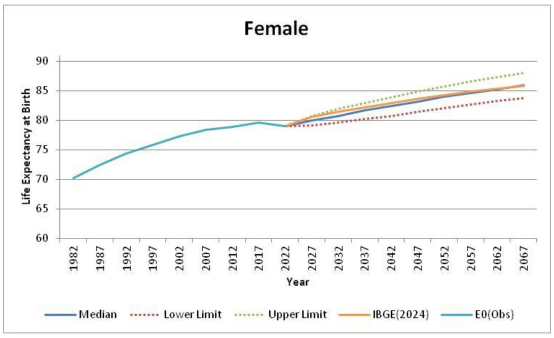


Fig 4 – Observed and Projected Male Life Expectancy at Birth, São Paulo

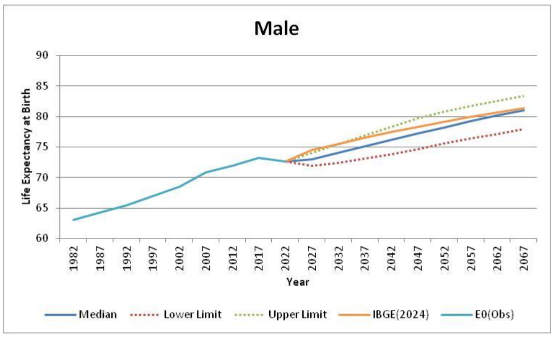


Fig 5 – Projected Age-Specific Mortality Rates, Females, São Paulo

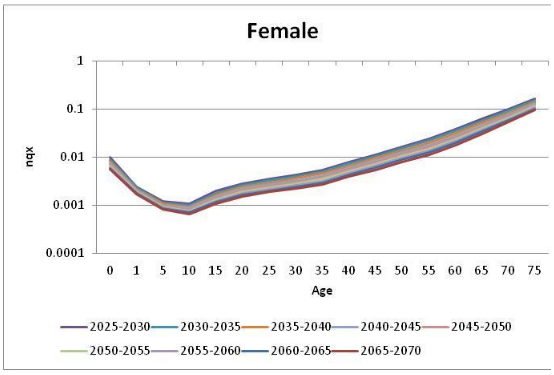
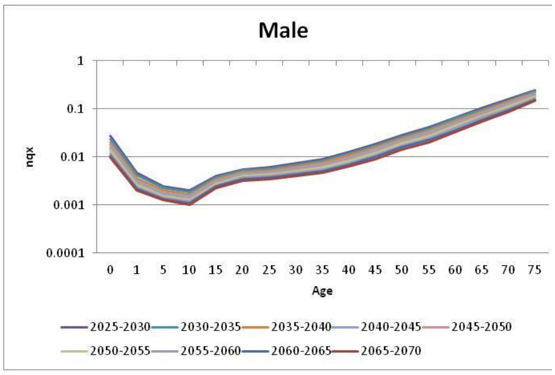


Fig 6 – Projected Age-Specific Mortality Rates, Males, São Paulo



Source: Demographic Census (IBGE, 2022); Population Projections based on IBGE, SIM, and SINASC data; IBGE Population Projections, 2024 revision.

Migration Component

Figures 7 and 8 present the migration trends for São Paulo. The net migration rate (NMR) converges toward zero, mirroring the assumption adopted by IBGE. The detailed age pattern (Figure 8) shows slightly negative NMRs for adult ages (15–45 years) in the final projection period (2065–2070), suggesting a modest net outflow of working-age adults by mid-century.

Fig 7 – Projected Net Migration Rate, São Paulo

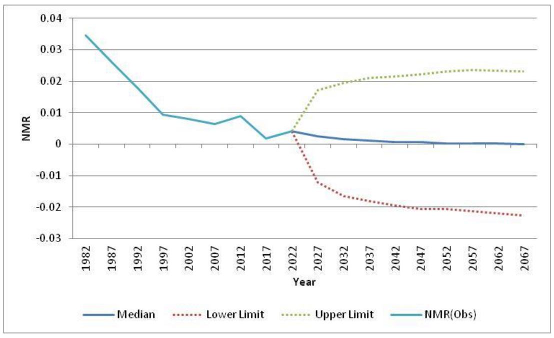
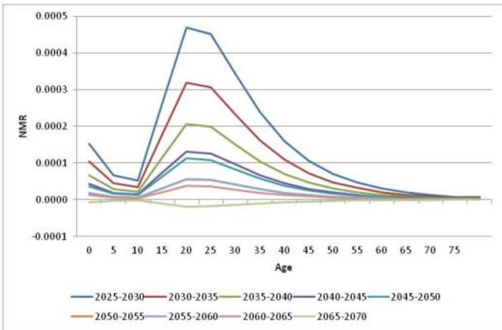


Fig 8 – Projected Age-Specific Net Migration Rates, São Paulo



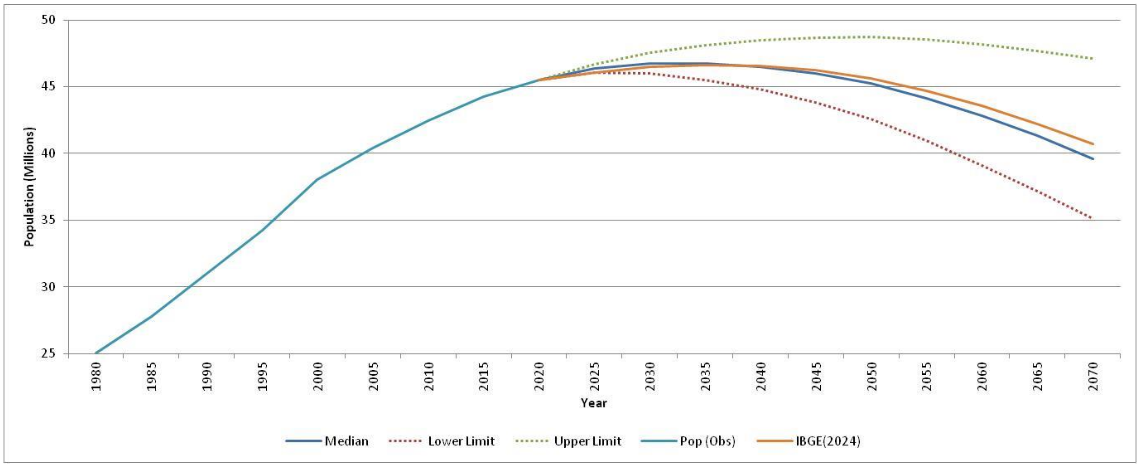
Source: Demographic Census (IBGE, 2022); IBGE Population Projections, 2024 revision.

4.2. Population Projection for São Paulo

The combined trends of fertility decline, mortality improvement, and migration stabilization produce a population trajectory that enters negative growth between 2035 and 2040, marking the onset of population decline in São Paulo. The state's population will also become substantially older, as shown in Table 1.

The median Bayesian projection closely matches IBGE's point projection up to approximately 2045, diverging only slightly thereafter. As expected, prediction intervals widen with increasing temporal distance.

Fig 9 – Observed and Projected Total Population, São Paulo



Source: Demographic Census (IBGE, 2022); Population Projections based on IBGE, SIM, and SINASC data; IBGE Population Projections, 2024 revision.

Table 1 presents the projected evolution of dependency ratios and the aging index for São Paulo between 2020 and 2070. These indicators clearly reflect the process of demographic aging: the share of the population aged 65 and over increases markedly, while the share of children under 15 declines steadily.

By 2070, the total dependency ratio (the number of individuals aged under 15 or over 65 per 100 persons aged 15–64) will nearly double, rising from just over 40 dependents per 100 working-age persons in 2020 to about 80 in 2070. IBGE's deterministic projection yields a similar figure of 75 (IBGE, 2024).

This increase is driven primarily by the old-age dependency ratio, which rises from 15 elderly persons per 100 working-age persons in 2020 to 61 per 100 by 2070. The youth dependency ratio stabilizes around 19 after 2040, slightly below the IBGE projection of 21.

The aging index—the ratio of persons aged 65 and over to those under 15—provides further evidence of the structural shift. According to the median projection, São Paulo will have 94 elderly per 100 young people by 2030, and by 2070, the elderly population will be more than three times larger, reaching 315 elderly per 100 young persons. IBGE's 2024 projection estimates 266 for the same year, confirming the general direction of the trend.

Table 1 – Dependency Ratios and Aging Index: Census 2020 and Projected Populations, São Paulo, Brazil**.**

dependency ratio	Sex	2020	2030			2040			2050			2060			2070		
		Census	M	Low	Upp	M	Low	Upp	M	Low	Upp	M	Low	Upp	M	Low	Upp
young	Male	26	24	21	26	20	15	25	20	14	26	20	14	27	19	14	28
	Female	25	22	20	25	19	14	24	19	13	26	19	13	26	19	14	27
	Total	25	23	21	26	19	15	25	20	14	26	19	13	27	19	14	28
elderly	Male	13	18	18	19	24	23	25	34	34	35	44	44	43	53	57	49
	Female	17	25	25	25	34	33	34	47	47	47	59	61	56	68	76	61
	Total	15	22	21	22	29	28	30	41	40	41	51	53	49	61	67	55
Total	Male	39	42	39	45	44	38	50	54	47	61	64	58	70	73	71	76
	Female	42	47	45	50	53	47	59	66	60	73	78	74	82	88	90	88
	Total	41	45	42	48	48	43	55	60	54	67	71	66	76	80	81	82
aging index	Male	49	77	84	71	123	156	100	174	241	133	226	328	161	274	402	174
	Female	71	112	122	102	176	227	140	243	346	181	305	460	212	358	548	224
	Total	60	94	103	86	149	191	120	208	293	157	265	393	186	315	473	199

Source: Demographic Census (IBGE, 2022); Population Projections based on IBGE, SIM, and SINASC data; IBGE Population Projections, 2024 revision.
M - Median; Low – Lower limit; Upp – Upper Limit

4.3. Demographic Component Projections for Rio Grande do Norte (RN)

Fertility Component

Figure 10 shows the projected trend of the Total Fertility Rate (TFR) for the state of Rio Grande do Norte. The median estimate of the probabilistic projection indicates a lower fertility level than that projected by IBGE (2024), reaching a TFR of 1.34 between 2065 and 2070, compared to IBGE's projected 1.5.

This difference arises because the IBGE model imposes a deterministic lower bound of 1.5 on TFR values, while the Bayesian model used here allows fertility to evolve freely based on the posterior distribution without predefining a minimum.

As in São Paulo, Figure 11 illustrates the projected age pattern of fertility, showing a relative decline among younger women (ages 15–24) and an increase in the contribution of women aged 25–34, indicating a continued postponement of childbearing.

Fig 10 – Projection of Total Fertility Rate, Rio Grande do Norte.

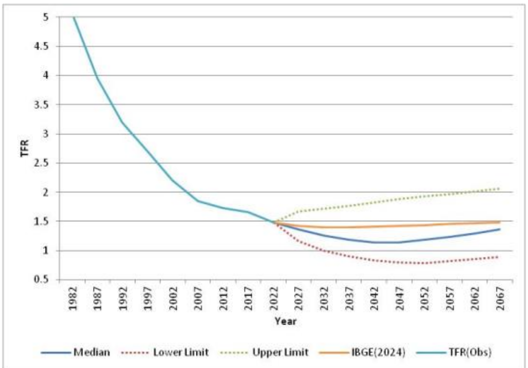
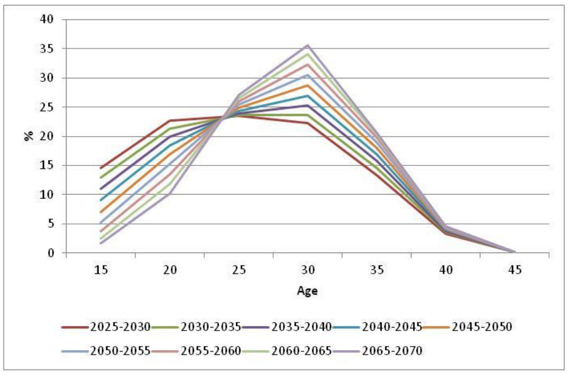


Fig 11 – Projection of Age-Specific Fertility Rates, Rio Grande do Norte



Source: Demographic Census (IBGE, 2022); Population Projections based on IBGE, SIM, and SINASC data; IBGE Population Projections, 2024 revision.

Mortality Component

Figures 12 through 15 display the projected levels and patterns of mortality by sex for Rio Grande do Norte. According to Figures 12 and 13, female life expectancy at birth will reach 88 years between 2065 and 2070, while male life expectancy will be 81.6 years. The IBGE projection yields slightly lower values for females (86.3 years) and similar ones for males (81.9 years) by 2070 (IBGE, 2024).

Unlike São Paulo, which exhibited a temporary decline in life expectancy during the COVID-19 pandemic (2017–2022), Rio Grande do Norte shows relative stability over this period.

As observed previously, Figures 14 and 15 indicate that the age pattern of mortality is expected to remain largely unchanged, with mortality levels decreasing gradually across all age groups.

Fig 12 – Observed and Projected Female Life Expectancy at Birth, Rio Grande do Norte

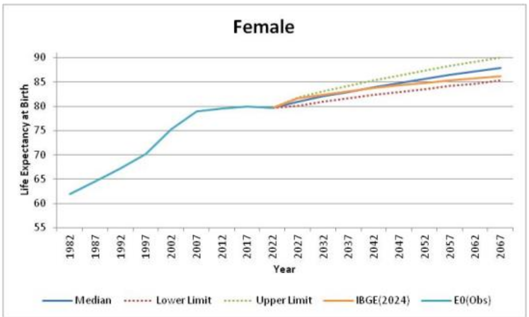


Fig 13 – Observed and Projected Male Life Expectancy at Birth, Rio Grande do Norte.

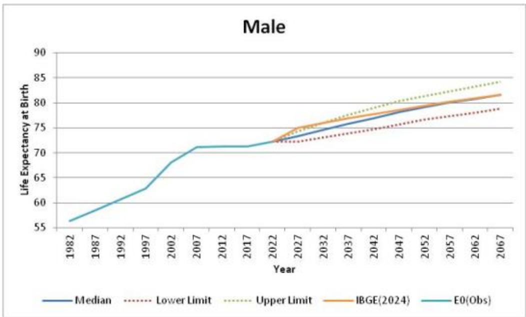


Fig 14 – Projected Age-Specific Mortality Rates, Females, Rio Grande do Norte.

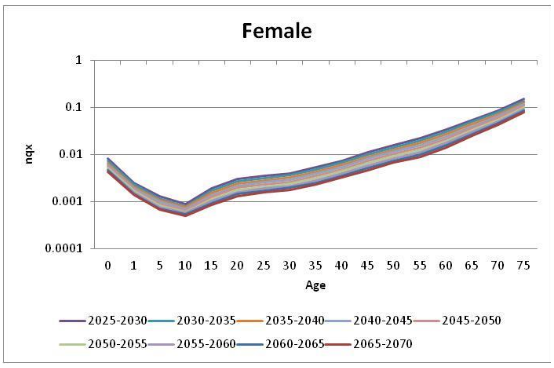
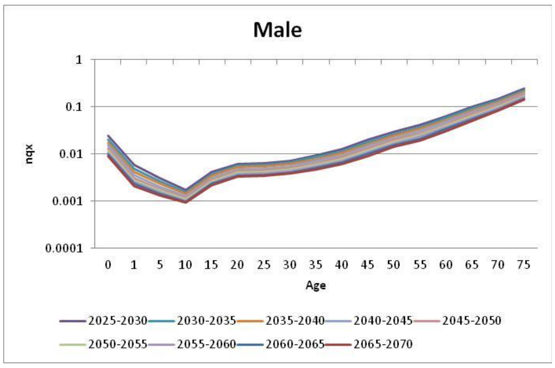


Fig 15 – Projected Age-Specific Mortality Rates, Males, Rio Grande do Norte



Source: Demographic Census (IBGE, 2022); Population Projections based on IBGE, SIM, and SINASC data; IBGE Population Projections, 2024 revision.

Migration Component

Figures 16 and 17 present the projected migration trends for Rio Grande do Norte. The net migration rates (NMRs) remain close to zero throughout the entire projection period. Figure 17 shows a minor inversion after 2035, when the NMRs for adult ages become slightly negative, indicating a weak net outflow, though values remain negligible across all age groups.

Fig 16 – Projected Net Migration Rate, Rio Grande do Norte.

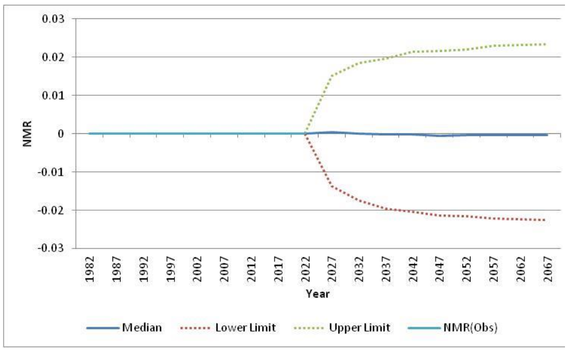
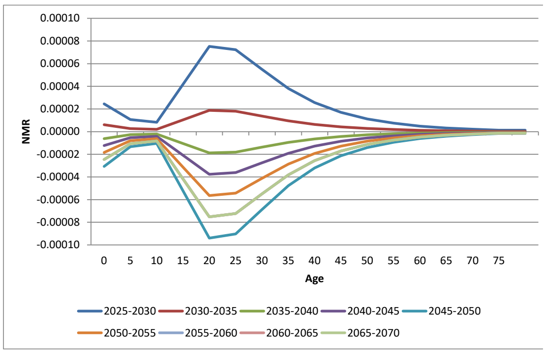


Fig 17 – Projected Age-Specific Net Migration Rates, Rio Grande do Norte.

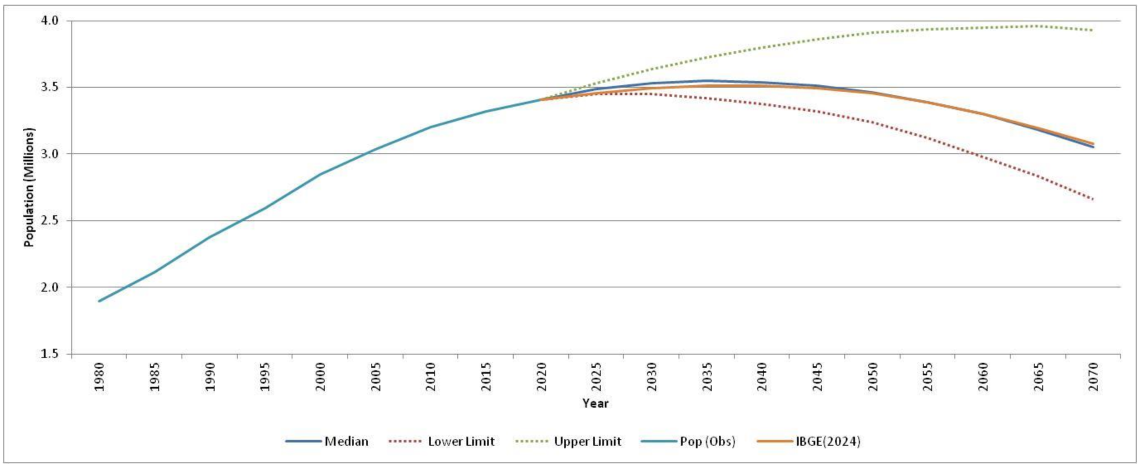


Source: Demographic Census (IBGE, 2022); IBGE Population Projections, 2024 revision.

4.4. Population Projection for Rio Grande do Norte

As a consequence of the observed component trends, the population of Rio Grande do Norte is projected to begin declining between 2035 and 2040, accompanied by a pronounced shift toward an older age structure, as shown in Table 2. As in São Paulo, the median Bayesian projection closely matches IBGE's deterministic projection across the entire period, with almost overlapping trajectories.

Fig 18 – Observed and Projected Total Population, Rio Grande do Norte



Source: Demographic Census (IBGE, 2022); Population Projections based on IBGE, SIM, and SINASC data; IBGE Population Projections, 2024 revision.

Table 2 summarizes the projected evolution of dependency ratios and the aging index for Rio Grande do Norte from 2020 to 2070. The figures reveal even more profound changes in age structure than those observed in São Paulo.

In 2020, the total dependency ratio was approximately 44 dependents per 100 working-age persons (ages 15–64). By 2070, this number is expected to rise to 85, compared to 80 projected for São Paulo in the same year (IBGE, 2024). This difference is largely attributable to the lower fertility trajectory produced by the Bayesian model, which does not constrain the TFR to a minimum of 1.5 as in IBGE's projection.

The old-age dependency ratio increases from 19 elderly per 100 working-age persons in 2020 to 68 per 100 in 2070, while the youth dependency ratio stabilizes around 17, slightly below the IBGE projection of 21.

The aging index for Rio Grande do Norte illustrates an even sharper demographic transition: by 2030, there will be 83 elderly (65+) for every 100 young persons (<15), and by 2070, the elderly population will be nearly four times larger, with 386 elderly per 100 young persons. According to IBGE, the corresponding value in 2070 will be 288.

Table 2 – Dependency Ratios and Aging Index: Census 2020 and Projected Populations, Rio Grande do Norte, Brazil.

dependency ratio	Sex	2020	2030			2040			2050			2060			2070		
		Census	M	Low	Upp	M	Low	Upp	M	Low	Upp	M	Low	Upp	M	Low	Upp
young	Male	32	24	21	26	18	14	24	17	13	24	18	13	24	18	14	24
	Female	29	22	20	25	18	14	23	17	12	23	17	12	23	17	13	24
	Total	30	23	21	26	18	14	23	17	12	24	17	12	24	17	14	24
elderly	Male	12	16	16	17	22	22	23	33	32	33	45	45	43	58	62	53
	Female	15	22	22	22	30	30	31	44	44	43	60	62	57	77	83	68
	Total	14	19	19	20	26	26	27	38	38	38	53	54	50	68	73	60
Total	Male	44	40	37	43	41	36	47	50	45	57	63	58	67	76	76	77
	Female	44	44	42	47	48	43	54	61	56	67	77	74	80	94	97	92
	Total	44	42	40	45	44	40	50	55	50	62	70	66	74	85	86	85
aging index	Male	38	69	75	63	121	153	96	187	254	137	257	363	182	330	456	218
	Female	53	99	108	90	172	220	134	261	359	186	352	509	244	445	622	286
	Total	45	83	91	76	146	186	115	223	306	161	304	435	213	386	537	251

Source: Demographic Census (IBGE, 2022); Population Projections based on IBGE, SIM, and SINASC data; IBGE Population Projections, 2024 revision
M - Median; Low – Lower limit; Upper limit

These indicators underscore the rapid pace of demographic aging in this small northeastern state, comparable in direction—but more intense in magnitude—to that observed in São Paulo, Brazil's most populous state.

5. Acknowledgments

The research was developed with the support of the National Council for Scientific and Technological Development (CNPq in Portuguese) and the São Paulo Research Foundation (Fapesp in Portuguese).

6. References

ALKEMA, L.; RAFTERY, A. E.; GERLAND, P. (2011). **Probabilistic projections of the total fertility rate for all countries**. Demography, v. 48, n. 3, p. 815-839.

AZOSE, J. RAFTERY, A. E. Bayesian Probabilistic Projection of International Migration. Demography. 2015. Disponível em: https://link.springer.com/article/10.1007/s13524-015-0415-0#citeas

IBGE (2024). Projeções da População: Brasil e Unidades da Federação – Estimativas e projeções. Revisão 2024. Notas metodológicas 01/2024. Rio de Janeiro.

IBGE (2022). Estudo Complementar à Aplicação da Técnica de Captura-Recaptura. Rio de Janeiro. https://www.ibge.gov.br/estatisticas/sociais/populacao/26176-estimativa-do-sub-registro.html?edicao=39639

IBGE (2018). Projeções da População: Brasil e Unidades da Federação. Revisão 2018. Série Relatórios Metodológicos. Rio de Janeiro.

JANNUZZI, P. M.; BORGES, A. S.; BRITO, L. P. G.; SILVA, V. R. L.; MARQUES, C. S. **Projeções Populacionais no Brasil: subsídios para seu aprimoramento.** In: XV Encontro Nacional de Estudos Populacionais, 2006, Caxambu.

PRESTON, S. H.; HEUVELINE, P. & GUILLOT, M. **Demography: measuring and modeling population processes**. Blackwell, 2001.

Queiroz, B. L.; Freire, F. H. M. D. A; Gonzaga, M. R.; Lima, E. E. C. D. (2017). Completeness of death count coverage and adult mortality (45q15) for Brazilian states from 1980 to 2010. Revista Brasileira de Epidemiologia, v. 20, supl. 1, p. 21-33. https://bit.ly/46P5BBQ

RAFTERY, A. E.; ALKEMA, L.; GERLAND, P. **Bayesian Population Projections for the United Nations**. Statistical Science. 2014.vol. 29, No. 1, pp. 58-68. https://projecteuclid.org/download/pdfview_1/euclid.ss/1399645729.

Raftery AE, Chunn JL, Gerland P, Sevčíková H. Bayesian probabilistic projections of life expectancy for all countries. Demography. 2013 Jun;50(3):777-801. doi: 10.1007/s13524-012-0193-x. PMID: 23494599; PMCID: PMC3904289.

RAFTERY, A. E.; LI, N.; SEVCIKOVA, H.; GERLAND, P.; HEILIG, G. K. Bayesian probabilistic population projections for all countries. Proceedings of the National Academy of Sciences, v. 109, n. 35, p. 13915-13921, 2012.

UNITED NATIONS (2024). **Department of Economic and Social Affairs, Population Division**. World Population Prospects 2024: Methodology of the United Nations population estimates and projections. New York: United Nations, 2014.
https://population.un.org/wpp/Publications/Files/WPP2024_Methodology_Advance_Unedited.pdf.

UNITED NATIONS (2019). **Department of Economic and Social Affairs, Population Division**. World Population Prospects: The 2019 Revision, Methodology of the United Nations Population Estimates and Projections. New York.