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Impact of the COVID-19 pandemic on the number of births in Pernambuco Brazil

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Abstract

This study aimed at analysing the potential effects of the COVID-19 pandemic on the time series and spatial patterns of live births in the state of Pernambuco, Brazil, from 2010 to 2021. This is an ecological study that applied intervention analysis in time series, with the goal to identify how projected data behaved in relation to observed data in the months December 2020 to November 2021, *i.e.* months representing conceptions from March 2020 to April 2021. For the state of Pernambuco, a discrepancy up to +5.7% was found between the observed and projected data, while the respective difference for the São Francisco mesoregion showed the opposite trend with maximum discrepancy of –9%. The results did not indicate a clear change in the number of live births but supported the expected continuation of the downward trend of the previous years. Considering the importance of the number of live births in the context of demography, economy and public health, monitoring must be maintained to analyse the possible future impact of the COVID-19 pandemic on live birth projections.

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Introduction

In December 2019, an outbreak of pneumonia of unknown origin was reported in Wuhan, Hubei Province, China (Shereen *et al*., 2020). This was later understood to due to infections by a new human virus, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the syndrome was named coronavirus disease 2019 (COVID-19) (Ciotti *et al*., 2020). The emergence of this coronavirus resulted in a rapidly expanding epidemic that became one of the most significant threats to public health in recent history (Chen *et al*., 2020; Zhu *et al*., 2020). The World Health Organization (WHO) declared COVID-19 a public health emergency of international concern in January 2020 and a pandemic on March 11 the same year. At the time this manuscript was written, over 280,320,346 cases had already been confirmed infected worldwide, with 5,416,667 deaths (WHO, 2021).

The rapid spread of the virus and the lack of specific treatment or validated vaccines at the beginning made non-pharmacological measures the only approach escapable of reducing transmission and impact on the population's health. Preventive strategies such as lockdown, social distancing and quarantines were adopted by several countries, limiting spatial mobility to varying degrees, together with the use of facemasks, hand sanitization, ventilation and sunlight exposure, including routine cleaning of confined spaces and surfaces (Bhardwaj, 2020; Garcia and Duarte, 2020). Lockdown is a governmental last resort measure to confine citizens to their homes in order to reduce the rate of dissemination (Garcia and Duarte, 2020). Although other factors that also could have an impact on the mortality rate must be considered, lockdown proved to be one of the most efficient measures to reduce the number of cases (and deaths). It contributed to prevent a collapse of the health systems (Góis *et al*., 2020) but generated social, economic and emotional effects on individuals and communities (Pfefferbaum and North, 2020).

The pandemic created a series of uncertainties, causing people to suspend or change their plans in several areas. In this sense, it is probable that the population even had to rethink its planning in terms of having or not having children (Marteleto *et al*., 2021). Therefore, the pandemic has had demographic consequences, influencing fertility, conception, pregnancy and birth (Ullah *et al*., 2020). With the lockdown measures, couples spent less time in contact with the outside environment and more time together, which could lead to increased birth rates. It was argued that the ongoing pandemic could result in a 'baby boom' one the one hand (Aassve *et al*., 2020) while on the other, pregnant women and their newborns were considered a risk group in the current COVID-19 environment (Nakamura-Pereira *et al*., 2020; Takemoto *et al*., 2020). Supposedly, fear of the disease and its repercussions on the health of pregnant and postpartum women, as well as on the health of newborns, may have reduced the number of births. In addition, social and economic factors, such as the rise in unemployment and lower household income could impact reproductive plans (Coutinho *et al*., 2020).

Epidemics, environmental disasters and economic crises can affect demographic dynamics and lead to both a reduction and increase in the number of births (Coutinho *et al*., 2020). The 1918-1920 Spanish influenza pandemic had a high mortality with an impact on reproductive behaviour and a reduction in the number of births (Chandra *et al*., 2015; Coutinho *et al*., 2020; Aassve *et al*., 2020). In the United States, the monthly data on births during this severe influenza showed a decline in the three months after peak mortality, regression in birth numbers to normal levels between five and seven months after peak mortality and finally a sharp decrease in births between nine and ten months after peak mortality (Chandra *et al*., 2018). The analysis of the time series of births in other countries, *e.g*., Taiwan, also showed a significant reduction in births nine months after mortality had peaked (Chandra and Yang-Liang, 2015).

It is important to register that Pernambuco was the epicentre of the Zika virus epidemic in Brazil in 2016 (Araújo *et al*., 2016; Vargas *et al*. 2016), which presented the greatest reduction in the number of births accounted for at the national level (Castro *et al*., 2018). Basically, it was due to the fear imposed by the virus in generating children with microcephaly (Castro *et al*., 2018; Marteleto *et al*., 2020; Moreira and Fusco, 2021). As a consequence of the congenital syndrome associated with the Zika virus infection, it was expected that COVID-19 could cause a reduction in fertility similar to what happened with the Zika virus epidemic (Marteleto *et al*., 2021).

This expectation may have caused births to undergo changes noticeable in their historical series; however, such differences may not be real, showing the importance of a better understanding of this behaviour. The aim of this study was to analyse the potential effects of the COVID-19 pandemic on time series and the spatial patterns of live births in the state of Pernambuco, Brazil, from 2010 to 2021.

Materials and methods

Study area

This ecological study was focused on the state of Pernambuco, which is located in the Northeast of Brazil. The state has a territorial extension of 98,067,880 km², comprising 184 municipalities and the state district of Fernando de Noronha, distributed in five meso-regions: Agreste (71 municipalities), Mata (43 municipalities), the state capital Recife and surroundings (15 municipalities), São Francisco (15 municipalities) and Sertão (41 municipalities). In 2020, the estimated population of the state was of 9,616,610 inhabitants; 4,990,400 women, 3,187,854 (63.9%) of whom in child-bearing age (between 10 and 49 years old). Most of them live in the metropolitan meso-region of Recife followed by the meso-region of Agreste, which has the second largest population in the state (Pernambuco, 2022). In 2015, the total fertility rate was of 1.88 births per woman (Carmo and Camargo, 2018).

The average human development index (HDI) of the state is of 0.673, but more than half of the municipalities are in the low HDI range (0.500 to 0.599) as shown in Figure 1. Metropolitan Recife is the only meso-region that has municipalities with a high HDI (0.700 to 0.799), with a fertility rate in 2020 of 1.74 children per woman. The other meso-regions have the following characteristics: Agreste: 77.4% of the municipalities with low HDIs; Mata: 55.8% of the municipalities with average HDIs between 0.600 and 0.699; São Francisco: 53.3% of municipalities with low HDIs; Sertão: 58.5% of the municipalities with low HDIs, one of which with a value below 0.500.

Data source

All live births to mothers residing in Pernambuco registered in the Information System on Live Births managed by the Secretariat of Health Surveillance, Ministry of Health (Sinasc) in Brazil from January 2010 to November 2021 were included, with the data updated in February 2022 when they became available on the website of the Department of Informatics of the Unified Health System (DATASUS) in Brazil (DATASUS, 2022). Due to the computational methods used to estimate the parameters of the statistical models, it is significant to have a large number of observations. Because of this significance, the total number starting from 2010 amounted to 143 registers per time series in analysis. This helps in the convergence of parameter estimates for both trend/seasonality and time series models.

Sinasc gathers the national epidemiological information on live births based on Live Birth Certificates. The digital mesh used is available on the website of the Brazilian Institute of Geography and Statistics (IBGE) that uses the Sirgas 2000/UTM zone 25S coordinate reference system.

Data analysis

To assess the COVID-19 impact, the time series analysis of intervention methodology was used (Morettin and Toloi, 2018). Intervention analysis is a method of statistical analysis designed to prove possible causes and effects of events over time (Feng and Xin, 2021). This technique seeks counterfactual evidence that indicates that the occurrence of a certain event X allowing the occurrence/non-occurrence of another event Y, or simply, the change in behaviour of Y in some of its time series characteristics (trend, stage or seasonality) (Morettin and Toloi, 2018).

A two-step time series modelling was conducted (Figure 2). The first consisted of decomposing the series in terms of seasonality/trend and noise from a regression model generating an additive decomposition, where models were tested strictly for positive data (characteristic of the variable under analysis). The seasonality and trend of the series was checked for location and variability (or shape) of the evaluated distributions. The tested distributions were: Gamma, Inverse Normal, Pareto, Log-Normal, Inverse Gamma and Weibull. These distributions were chosen because they have the two parameters - location and variability - (Rigby *et al*., 2019), which provide more accurate results. Furthermore, the trend was estimated by the non-parametric method of cubic splines (Hastie and Tibshirani, 1993) to ensure a better fit of the temporal trend. It should be noted that this technique is subject to overfitting and worse predictions; however, these aspects are minimized by the size of the sample used and by the reasonably short projection (12 months). The regression models were chosen based on the lowest Generalized Akaike Information Criteria (GAIC) metric (Burnhamand Anderson, 2002).

After removing the trend and seasonality of the series, the noise was adjusted by the following modelling techniques for time series: autoregressive integrated moving average (ARIMA) (Box and Jenkins, 1970); autoregressive fractionally integrated moving average (ARFIMA) (Haslett and Raftery, 1989); exponential smoothing state space model using error, trend and seasonal components (ETS) (Hyndman *et al*., 2008); and exponential smoothing state space model with Box-Cox transformation, ARMA errors, trend and seasonal components (BATS and TBATS) (De Livera *et al*., 2011). To choose the best model to adjust the noise of the series, the mean squared error (MSE) performance metric was evaluated in the year 2020 adjustment for the January to November months:

$$MSE = \sum_{t=1}^{n} \frac{(Y_t - \hat{Y}_t)^2}{n} \quad (1)$$

where Y_t is the observed time series; $\hat{Y}_t$ the adjusted values of the series; n the total of observed values; and t the period of the evaluated series. The series had a monthly frequency starting in January 2010 and ending in April 2021. The projection of the series was made by adding the trend/seasonality and noise projected for the periods of interest (from December 2020 to April 2021), months in which COVID-19 could already be capable of presenting impacts on women's reproductive behaviour and, consequently, on the number of live births, given that we had to consider the nine-month-time of pregnancy. The time series study considered the state of Pernambuco as a whole as well as a breakdown into meso-regions.

To assess the goodness-of-fit of the statistical model, we used the mean relative absolute error (MRAE) expressed as the percentage calculated during the periods from January 2010 to November 2020 (the months in which no projections were made):

$$MRAE = \sum_{t=1}^{n} \frac{|RAE_t|}{n} \quad (2)$$

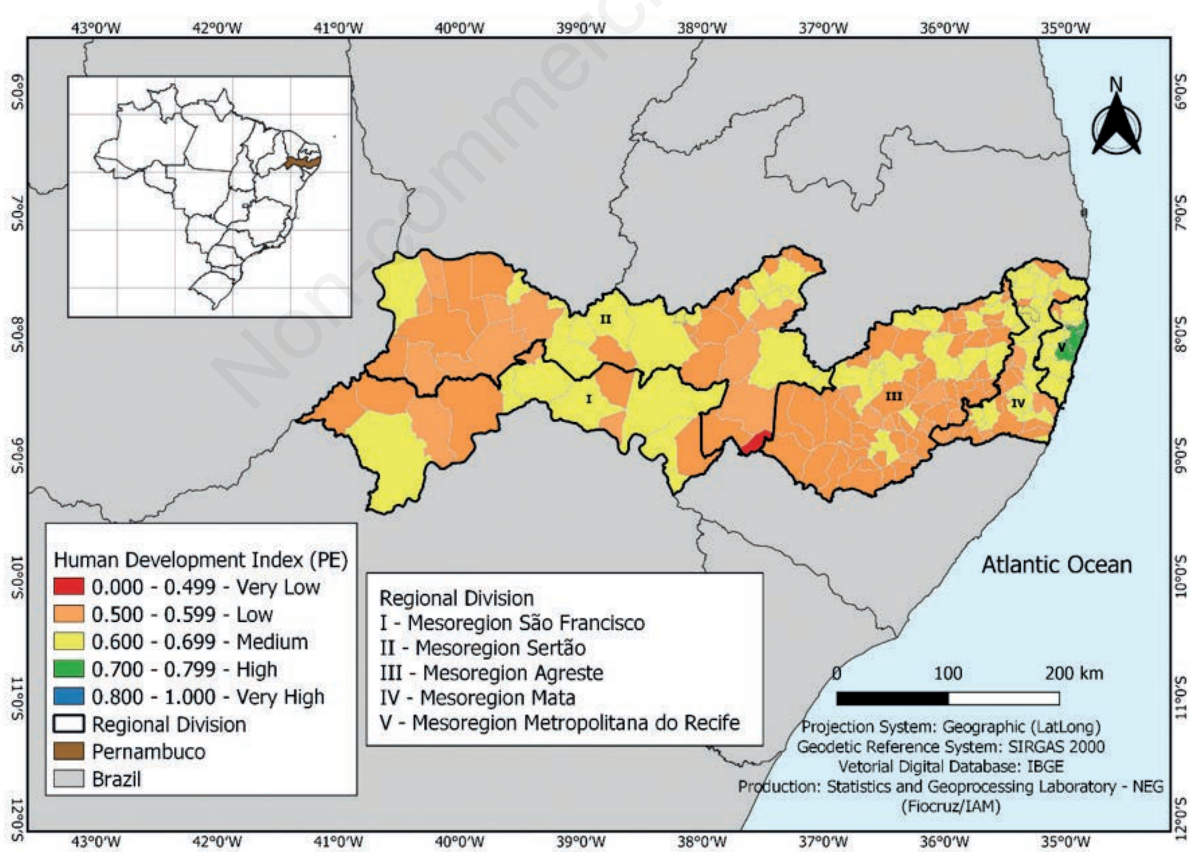

Figure 1. Geographical location of Pernambuco and its mesoregions and human development index of municipalities.

where RAE_t is $\frac{|Projected_t - Observed_t|}{Observed_t}$; and t the month/year of the evaluated series.

All calculations and graphs were performed using R statistical programming, version 4.0.1 (https://cran.r-project.org/bin/windows/base/old/4.0.1/NEWS.R-4.0.1.html). The stipulated level of significance was 5%. For the first phase of the modelling (trend/seasonality removal), functions from the gamlss package, version 5.3-4 (https://www.rdocumentation.org/packages/gamlss/versions/5.3-4) were used, as for the second stage, functions from the forecast package, version 8.15 were used.

Results

Figure 3 shows the total numbers of live births and Figure 4 the gross rate of live births per 1000 people in Pernambuco and its meso-regions in the 2010-2021 period. In general, a downward trend was observed, both in the number of live births and the gross rate. This was mainly influenced by the metropolitan meso-region of Recife, which includes about 40% of all live births in the state. The years 2014 and 2015 had the highest number of live births, with the exception of the Sertão and Agreste meso-regions (only in 2015). Even though 2014-2015 were the years with highest total number of births, the highest rates did not occur then, except in metropolitan Recife. In 2016, there was a reduction in live births and in the gross rate of live births in all meso-regions, which showed a downward trend for both indicators, with the exception of the number of live births in São Francisco that had an average growth of +8 live births per year, however, with many fluctuations.

The temporal evolution of the gross rate of live births per thousand inhabitants by municipality during the study period (Figure 5) points to a concentration of the lowest rates in the eastern portion of the state: metropolitan Recife (13.3 in 2010 and 11.1 in 2021); Mata (13.9 in 2010 and 10.8 in 2021); and Agreste (14.7 in 2010 and 12.5 in 2021), while most municipalities in the western part of the state had higher gross rates of live births: São Francisco (17.1 in 2010 and 14.9 in 2021); Sertão (16.3 in 2010 and 13.5 in 2021). Over the years, the gross rate of live births continued to decrease in almost all municipalities of the state, following a trajectory propagating from the municipalities of the state capital and its surroundings towards the interior.

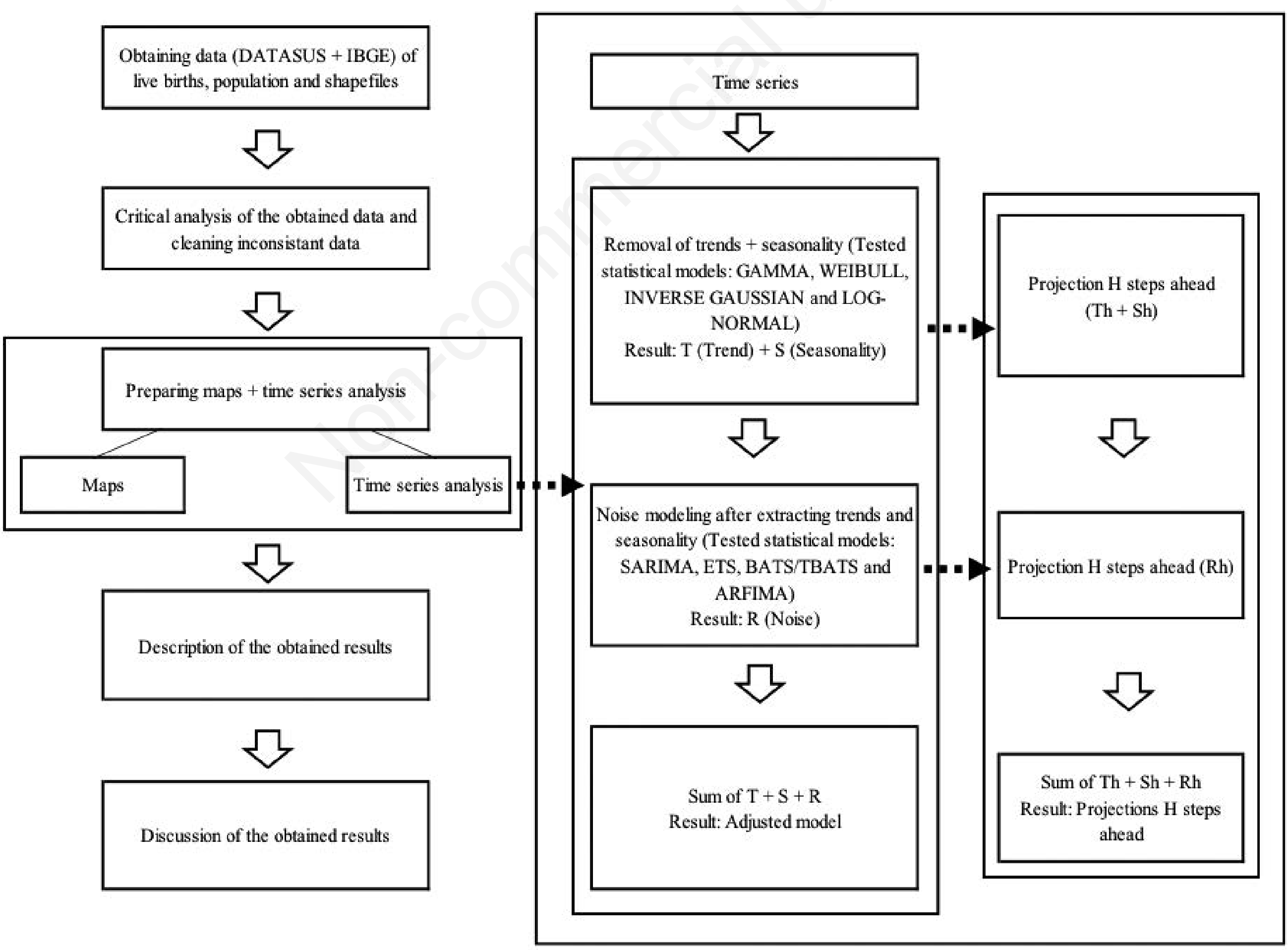

Figure 2. Flow chart of the activities performed during the data analysis of the study.

Figure 6 shows the results of the adjusted/projected *vis-à-vis* observed values of the total number of live births in Pernambuco confirming that the series followed the projected trajectory. In September, October and November of 2021, the differences were more than, 2.9%, 3% and 5.7%, respectively, compared to those projected. Such differences are within the estimated projection ranges. The MRAE of the series fit was ±2%.

Figure 7 presents the historical series that combined the total

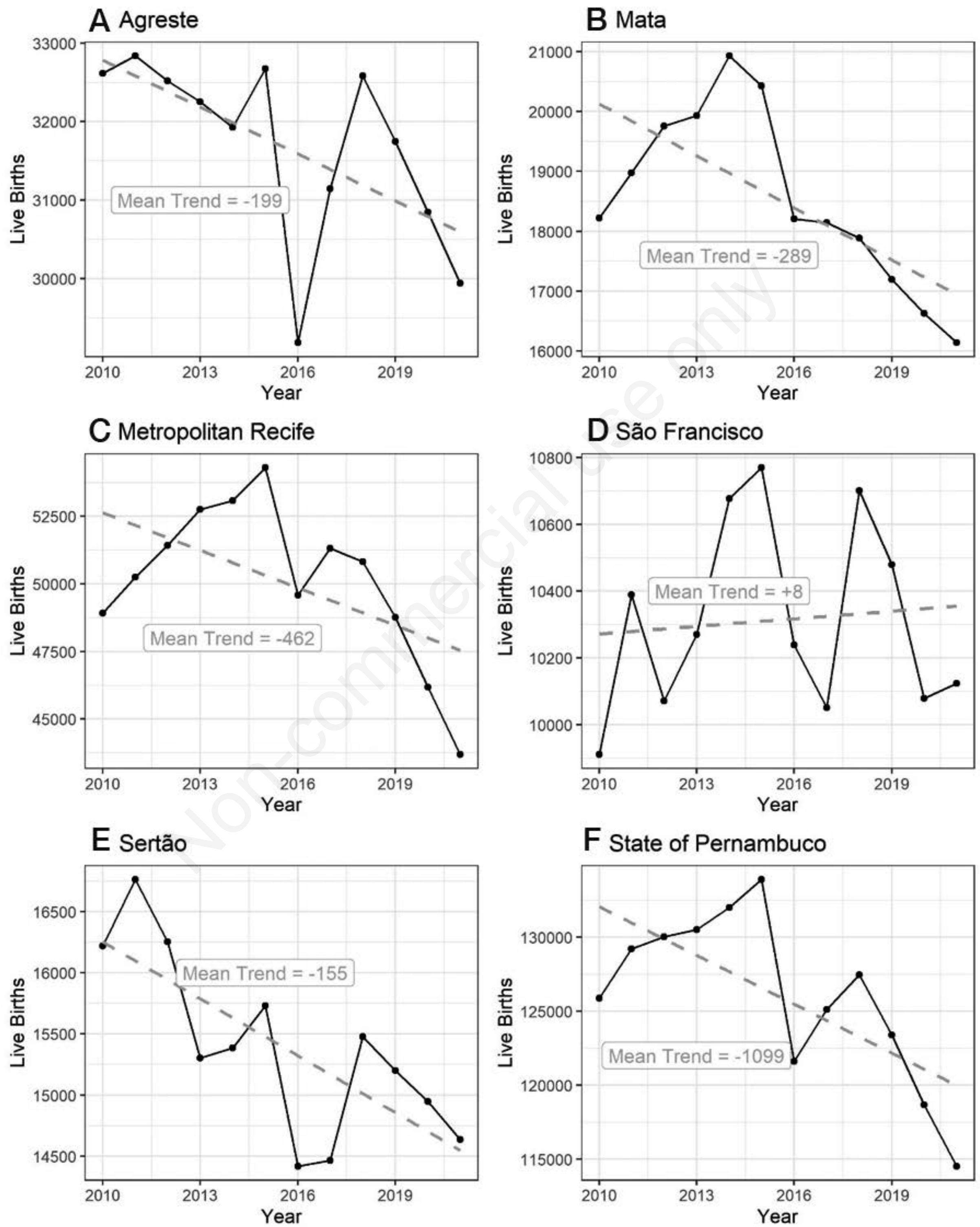

Figure 3. Number of live births by year of occurrence according to mesoregion, Pernambuco, Brazil, from 2010 to 2021. A) Agreste; B) Mata; C) Metropolitan Recife; D) São Francisco; E) Sertão; F) State of Pernambuco.

number of live births by meso-region. There were no differences that could show significant impacts in the time series, with the exception of the São Francisco series, where the observed number was 9% lower than that projected (947 to 1041) in March 2021, and the observed being lower than the inferior limit of the projection range for 95% for that month. The goodness of fit of the series was ±2.5% for Agreste; ±3.4% for Mata; ±3.5% for São Francisco; ±3.2% for Sertão; and ±2.3% for metropolitan Recife.

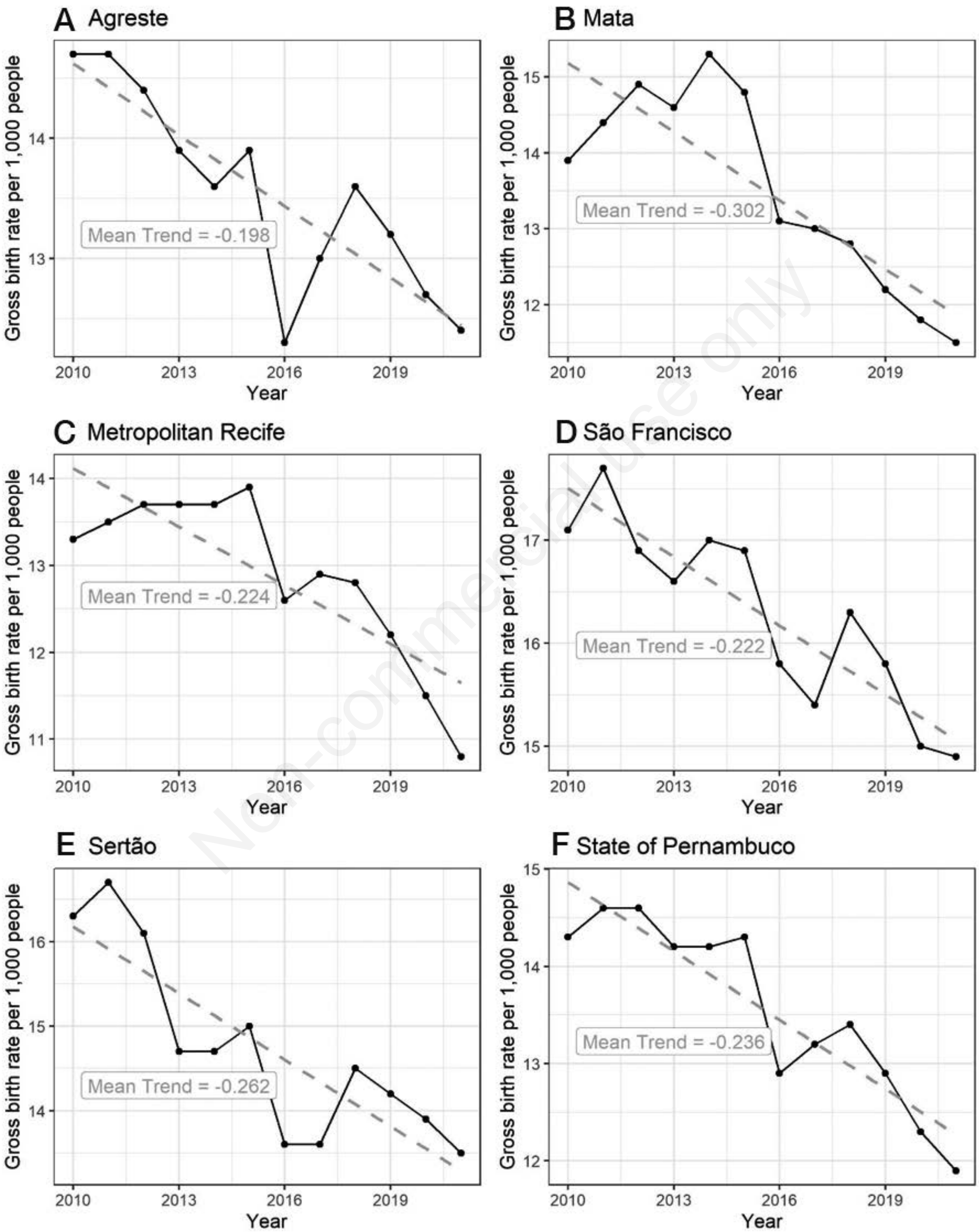

Figure 4. Gross rate of live births (per 1000 people) per year of occurrence by mesoregion, Pernambuco, Brazil, from 2010 to 2021. A) Agreste; B) Mata; C) Metropolitan Recife; D) São Francisco; E) Sertão; F) State of Pernambuco.

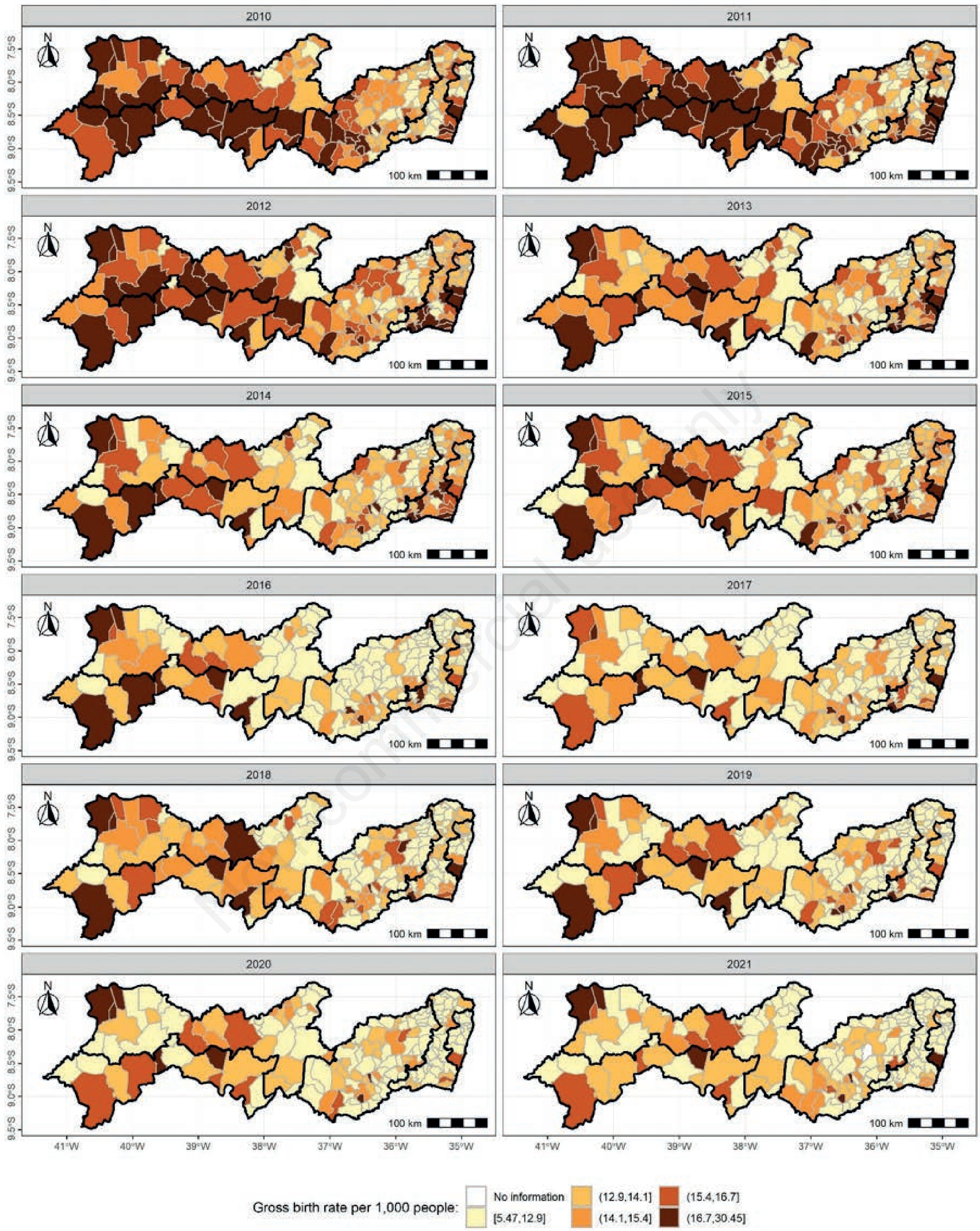

Figure 5. Gross rate of live births (per 1000 people) by year of occurrence and municipality of residence, Pernambuco, Brazil, from 2010 to 2021.

Discussion

The results of the time series analysis neither indicated a reduction in the number of live births in Pernambuco as a whole nor in the various meso-regions from December 2020 to November 2021, thereby maintaining the expected downward trend in live births. These results were expected and confirm the predictions by Moreira and Fusco (2021) of a reduction in the number of live births. However, this does not allow us to state unequivocally that the COVID-19 pandemic had an effect on this process. Although we found trends in the number of live births, the uncertainties of the preliminary information are not sufficient to firmly link these trends with the COVID-19 pandemic. However, the deleterious effects of the disease on family income may have influenced the reproductive behaviour of women, who may have decided to avoid or postpone pregnancy since March 2020, when the first case of COVID-19 was registered in the state and its rapid dissemination and potential lethality started to be widely publicized. Additionally, a study that analysed births in Brazil from 2015 to 2020 showed a significant reduction in the number of births in all regions of the country in 2020 (Moreira and Fusco, 2021), indicating that the reduction in the levels observed in 2021 is within the general range expected.

The state of Pernambuco was the epicentre of the Zika virus epidemic associated microcephaly (Araújo *et al*., 2016). In October 2015, the Health Department of Pernambuco detected an increase in the occurrence of live births with microcephaly, which was subsequently classified as a potential public health emergency of international importance, as it was an uncommon event with a serious impact on public health. In addition to be the first to report changes in the epidemiological pattern, Pernambuco was among the states with the highest prevalence of notified, confirmed cases of microcephaly in Brazil. In consequence, the number of live births in Pernambuco fell strongly (shown in the historical series in the year 2016) mainly caused by the fear that the virus would result in babies with microcephaly (Castro *et al*., 2018; Marteleto *et al*., 2020; Moreira and Fusco, 2021). These events may have increased the effects of the COVID-19 pandemic in relation to the number of live births through the *Scar* effect, which stands for the idea a previous fatality influencing the risk fora new fatality even of the events are unconnected. By way of explanation, an experienced adverse event causes decision makers (in this case, possible mothers) to be more cautious about experiencing a new misfortune (Marteleto *et al*., 2021). However, that was not what was observed with respect to reproductive behaviour in this study, which highlights the great difference between the Zika virus epidemic and the COVID-19 pandemic.

The fact that pregnant women constitute a risk group for complications and death from COVID-19 must be taken into consideration, as it contributes to the reduction in the number of births(Collin *et al*., 2020). The anatomical and physiological changes of pregnancy with respect to the cardiovascular, respirato-

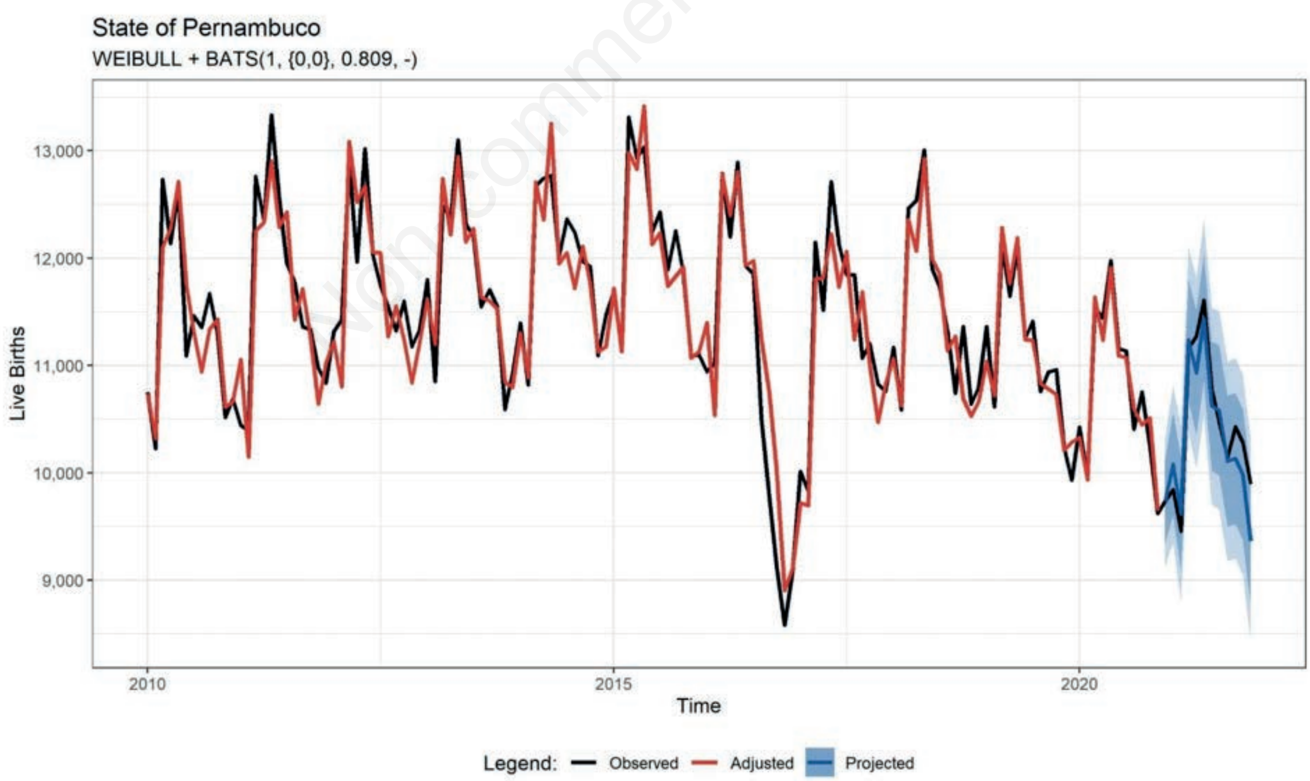

Figure 6. Historical series of total live births in Pernambuco, Brazil from January/2010 to April/2021, following the values adjusted/projected by the statistical model using WEIBULL distribution for trend/seasonality + BATS(1, {0,0}, 0.809, -) for noise.

ry, immunological systems, including blood coagulation, can lead to an increased risk for pregnant women (Souza and Amorim, 2021). This factor could have contributed to the postponement of pregnancy plans. Other factors that were expected to have contributed to the reduction of fertility are the uncertainty about the future, the heavier domestic routine due to social isolation, the fear of infection with the new virus during pregnancy and its consequences on the health of women and foetuses (Coutinho *et al*., 2020). However, our results show that the observed reduction in the number of live births was within the levels expected by the statistical method used. It is known that there may be a temporary reduction in the number of births in scenarios, such as public

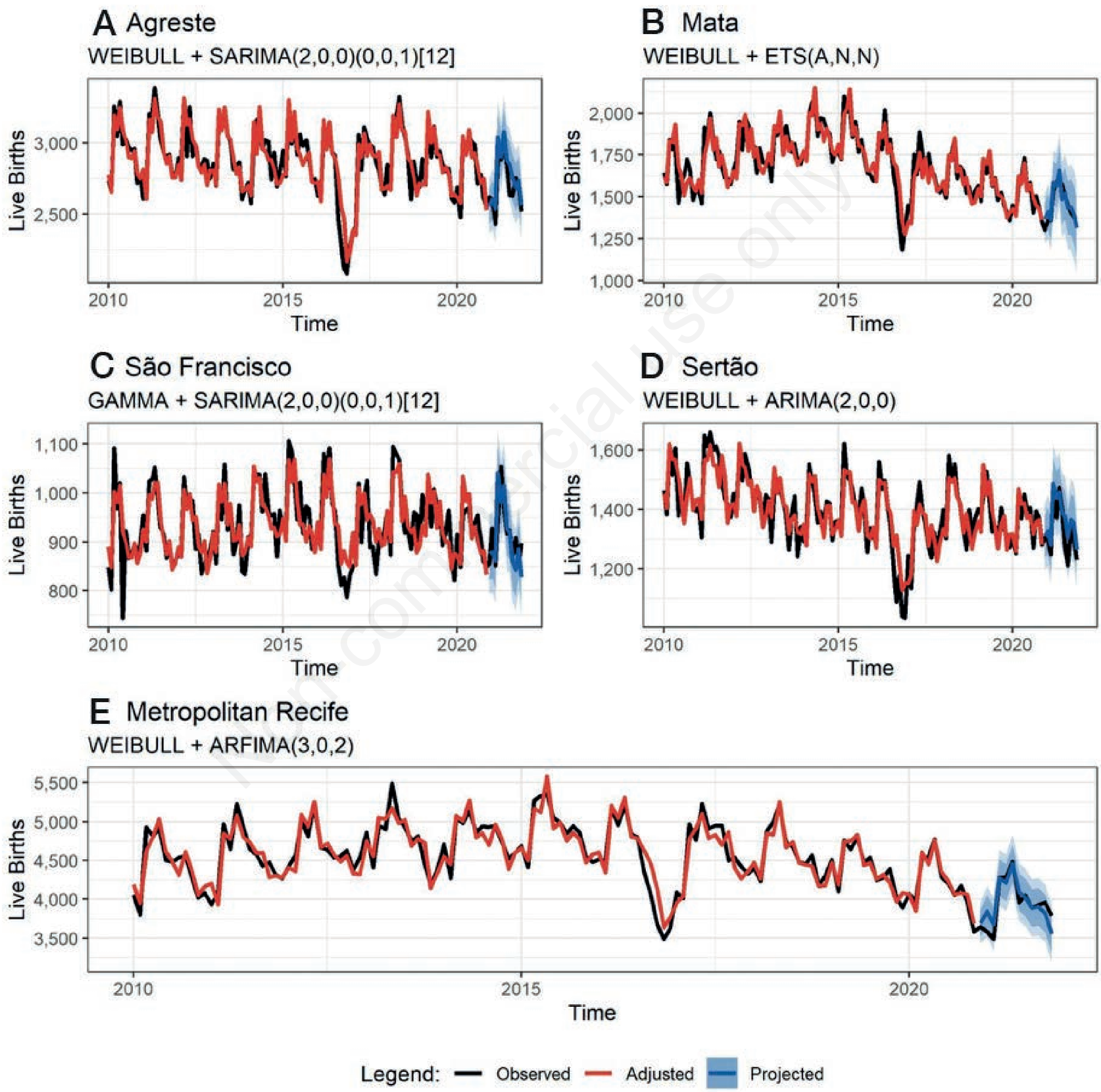

Figure 7. Historical series of total live births by mesoregion of Pernambuco, Brazil from January/2010 to April/2021, following the values adjusted/projected by the statistical model. A) Agreste using WEIBULL for trend/seasonality + SARIMA (2,0,0)(0,0,1) for noise; B) Mata using WEIBULL for trend/seasonality + ETS(A,N,N) for noise; C) São Francisco using GAMMA for trend/seasonality + SARIMA (2,0,0)(0,0,1) for noise; D) Sertão using WEIBULL for trend/seasonality + ARIMA (2,0,0) for noise; E) Metropolitan Recife using WEIBULL for trend/seasonality + ARFIMA (3,0,2) for noise.

health crises and natural disasters followed by a recovery during the following five years, that is, an increase in fertility in response to the improvement in the economic, social and public health scenarios (Stone, 2020). The reduction in the number of births in critical periods is something to be expected, however it does not mean that it will continue. The epidemic of microcephaly associated with the Zika virus and the decrease in live births, a fact not substantiated in this study, is one of these events. The resumption of plans to have children after the pandemic period may depend on public policies that promote greater financial stability for families, gender equity policies, access to prenatal services and the line of maternal and child care.

The prediction that there could eventually be an increase in the number of births with the lockdown and the resulting decrease in access to contraceptives for a significant portion of the population (Guedes *et al*., 2021; Bailey *et al*., 2022; Berrington *et al*., 2022) was quickly discarded after observing the evolution of the number of births in Brazil. Even with the economic and social impacts (IPEA, 2021) the number of births was not reduced. Thus, even in a context of losses caused by the pandemic, there is no reliable evidence that COVID-19 had an effect on the reduction of fertility levels in Brazil beyond what was expected. In this sense, Brazil was classified to be among '*countries with stable trends in monthly births, with no evident impact of COVID-19*' (UNFPA, 2022).

This study has some limitations with reference to: i) the data used are preliminary and may change, though the most recent update occurred in the month of March 2022; and ii) the meso-region is a spatial unit that contains inequalities; the analysis by smaller units (municipalities) were subject to random fluctuations due to the low number of live births in smaller cities, which could return biased inferences.

Conclusions

From this study it was not possible to verify that COVID-19 had significant impacts on the reproductive pattern of women in the state of Pernambuco, Brazil. As for the spatial pattern, no changes due to COVID-19 were identified. It is necessary to maintain the monitoring of these time series in Pernambuco and its meso-regions in order to verify the medium and long-term impacts of the COVID-19 on the projections of live births. Research on this situation Brazil and other states of the federation should be encouraged, considering the importance of live births in the context of demography, economy and public health.

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