Report

The Potential Impact of COVID-19 Pandemic on Tuberculosis Epidemic

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The potential impact of COVID-19 pandemic on tuberculosis epidemic

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Contents

Summary

Tuberculosis (TB) and Coronavirus Disease-19 (COVID-19) infection are two respiratory diseases that are of particular concern epidemiologically. TB is estimated that approximately one quarter of the world's population is infected with latent Mycobacterium tuberculosis (LTBI). India has one of the largest numbers of people with latent TB infection and the large burden of active TB case. Moreover many areas of public health, including tuberculosis prevention and response activities has been affected during the impact of COVID-19 pandemic. In our current study, we aimed to assess how COVID-19 pandemic have a potential impact on TB incidence and prevalence in Tamil Nadu. This study was carried out among adult population (people who are 18 years of age or older) in the Indian state of Tamil Nadu. The secondary data was collected from the published literatures and reports. The two mathematical models are designed to estimate the prevalence, and incidence of TB before and during COVID-19 pandemic in Tamil Nadu. This modelling is used for a detailed view of determining the prevalence and incidence on TB during the spread of COVID-19 pandemic. The time series models were used to find the notification trend on pulmonary TB before and during COVID-19 pandemic in Tamil Nadu. Data analysis was performed using R package. This model represents the impact of disruptions on TB incidence, prevalence and notification, also to curtail this impact for potential interventions. We calculated the overall prevalence and incidence with 95% CI before and during COVID-19. The rate of reduction presented in percentage for the previous year and current year in an aspect of with/without COVID-19. An average reduction rate of prevalence and incidence of without the impact of COVID-19 is 1.320 and 1.307. An average reduction rate of prevalence and incidence of with the impact of COVID-19 is 1.475 and 1.454. The difference rate is calculated for with/without COVID-19 and different scenario analysis. The results of our study shows that there was an annual decline in the trend of the prevalence and incidence during COVID-19 pandemic (2020 to 2025) when compared to before COVID-19 pandemic (2017 to 2025). Therefore it is noted that there is a reduction in the TB prevalence, incidence, and notification on TB in Tamil Nadu during COVID-19 pandemic. Additionally, our results indicate that there was an interruption in the reduction of TB notification due to the first and second wave of the COVID-19 pandemic lockdown from March 2020 to April 2021. This study highlights the importance of monitoring the impact of COVID-19 pandemic on TB and implementing effective control measures and prevention strategies in Tamil Nadu. The results of this study can help in better understanding and managing the impact of COVID-19 on TB and in improving TB control and prevention efforts in the region.

I. Introduction

The coronavirus disease (COVID-19) pandemic had been affected many areas of public health, including tuberculosis (TB) prevention and response activities. The novel coronavirus (COVID-19) pandemic is a major source of disaster in the 21st century and it has caused enormous health, demographic, social and economic impacts.[1] The disease is primarily spread through respiratory droplets and contact with contaminated surfaces, and symptoms range from mild to severe, including fever, cough, shortness of breath, and in severe cases, pneumonia, acute respiratory distress syndrome, and multi-organ failure. The global spread of COVID-19 has led to an unprecedented response from public health officials, governments, and individuals around the world, with measures such as travel restrictions, quarantine, social distancing, and vaccination campaigns being implemented in an attempt to slow down and control the spread of the virus. With the rise of COVID-19 cases in India, the country now has the fourth highest number of reported cases.[2] In March 2020, the first COVID-19 case reported and had the highest percentage of positive COVID-19 samples among total samples tested in the country. This has caused a shift in economic and political priorities towards COVID-19 containment, leading to a potential decrease in efforts to tackle TB. India has a significant number of people with latent TB infection and a large burden of active TB cases, making it a major concern for public health. TB epidemiology is closely connected with social and economic conditions which make its prevention, care, and control more challenging.[3] The mathematical modelling is used to estimate the prevalence, and incidence of TB before and during COVID-19 pandemic in Tamil Nadu. This modelling is used for a detailed view of determining the prevalence and incidence on TB during the spread of COVID-19 pandemic. Several analyses using mathematical models to predict the number of cases and fatalities resulting from COVID-19 in India. These analyses are likely to have been conducted by experts in the field of epidemiology, using various data and statistical models to simulate the spread of the virus.[4] The COVID-19 pandemic has resulted in a health shock and economic shock, which can have an impact on TB incidence. The lockdowns in response to the pandemic and its related events may worsen poverty and undernutrition, leading to under-detection of active TB cases. Furthermore, the key transient changes that may affect TB epidemiology include lockdown induced worsening of poverty and undernutrition in the poor as well pushing those who live a fragile economic life into poverty, and lockdown induced under detection of active TB.[5]

The other issue is that impacts on the provision and access to essential TB services, the number of people diagnosed with TB and notified as TB cases through national disease surveillance systems. As India faces towards the battle of coronavirus pandemic, the lockdown was leading to debilitating effects on TB services, with limited access to healthcare and anti-tuberculosis drugs as well as disruption of treatment services. The Stop TB Partnership modelling analysis has assessed the potential effects of lockdown on TB incidence and mortality over the next 5 years in high-burden settings. In the case of India, lockdown has resulted in a striking 80% reduction in TB notification rates.[6] Moreover, the COVID-19 pandemic has resulted in lifestyle changes, including encouraging masking, handwashing and social distancing. This implementation of preventative measures against the transmission of SARS-CoV-2 may have had a significant impact on reducing respiratory infections in many cases.

India bears the largest share of the tuberculosis (TB) burden globally, accounting for 26% of the estimated new cases in 2019. Prior to the outbreak of the COVID-19 pandemic, the country had shown promise in decreasing the gap in TB case finding, registering a 60% increase from 2013 to 2019. However, the COVID-19 pandemic has had a detrimental effect on the efforts to control TB, causing a major disruption in the allocation of resources for the diagnosis, treatment, and prevention of the disease. The early data on case notification in India, indicating a 70% decline in case reporting between weeks 10 and 15 of 2020 when compared to the same period in 2019.[7] The detection of tuberculosis cases in public sector health facilities is typically reported through established reporting systems. However, a significant number of cases detected and treated in the private sector are not reported, due to various reasons. In Tamil Nadu, the tuberculosis notification process serves as a means to enhance the standard of care in both the public and private sector. This includes the proper diagnosis and treatment of patients, as well as follow-up care, contact tracing, chemoprophylaxis, and the provision of social support systems. The COVID-19 pandemic has presented a significant obstacle to the endeavours aimed at eradicating tuberculosis (TB) in Tamil Nadu. Evaluating the treatment outcome of TB and identifying its associated factors is an integral part of the treatment.

The World Health Organization (WHO) has provided guidance on how to address the impact of COVID-19 on TB. WHO suggests leveraging the expertise of National TB Elimination Programmes (NTEP) for rapid testing and contact tracing for COVID-19 response. The use of digital technologies for remote care and support for people with TB is also encouraged.[8] To limit the transmission of both TB and COVID-19, basic infection prevention and control measures should be implemented, including cough etiquette and patient triage. The provision of TB preventive treatment can be supported by

building synergies with COVID-19 contact tracing efforts. Simultaneous testing for both TB and COVID-19 should also be carried out when indicated. The lack of proactive planning and budgeting may result in undiagnosed and untreated cases of TB transmission rates.[9] Another report estimates that India will need to manage excess TB cases and deaths during lockdown, which is highly compared to other high-burden countries. In response to the pandemic, public health officials and governments have implemented a range of measures to try to slow down the spread of the virus and mitigate its impact. These measures include:

1. Travel restrictions: Governments have implemented travel restrictions, border closures, and quarantine requirements to limit the spread of the virus between countries.
2. Quarantine and isolation: People who have been exposed to or have tested positive for the virus have been required to self-isolate or quarantine themselves to prevent further spread of the disease.
3. Social distancing: Governments and health officials have recommended or mandated social distancing measures, such as staying at least six feet apart from others, to reduce the spread of the virus in public spaces.
4. Masks and personal protective equipment (PPE): Wearing masks and other forms of PPE have been recommended or required in public spaces to reduce the spread of the virus.
5. Testing and contact tracing: Health officials have implemented widespread testing and contact tracing efforts to identify and isolate those who have been exposed to the virus.
6. Vaccination campaigns: Vaccines have been developed and distributed worldwide in an effort to protect individuals and communities from the virus and to achieve herd immunity.

Although these measures have had significant impacts on TB reduction rate during COVID-19 pandemic, they have also been effective in slowing down the spread of the virus and reducing its impact on public health. However, the COVID-19 pandemic is an ongoing situation, and continued efforts will be necessary to control the spread of the virus and mitigate its long-term impact. This study aims to provide a comprehensive understanding of the impact of COVID-19 on tuberculosis in Tamil Nadu. The results of this study can help public health professionals and policymakers in developing effective strategies to reduce the burden of TB and ensure the continuation of TB prevention and response activities during the COVID-19 pandemic. There was a large difference between reported TB cases in India and those expected in the absence of the pandemic. This information can help inform the Indian TB program as they consider interventions to accelerate case finding and notification once the pandemic related TB service disruptions improve.[10]

II. Objectives

1. To estimate the prevalence and incidence of TB before and during COVID-19 pandemic in Tamil Nadu using mathematical modelling approaches.
2. To model the notification trend of pulmonary TB cases before and during COVID-19 pandemic in Tamil Nadu.

III. Methodology

Study Area

Our study focuses on all districts of Tamil Nadu to assess the impact of COVID-19 on tuberculosis in Tamil Nadu which is the tenth-largest state by area and the sixth-most populated state in India.

Study Population

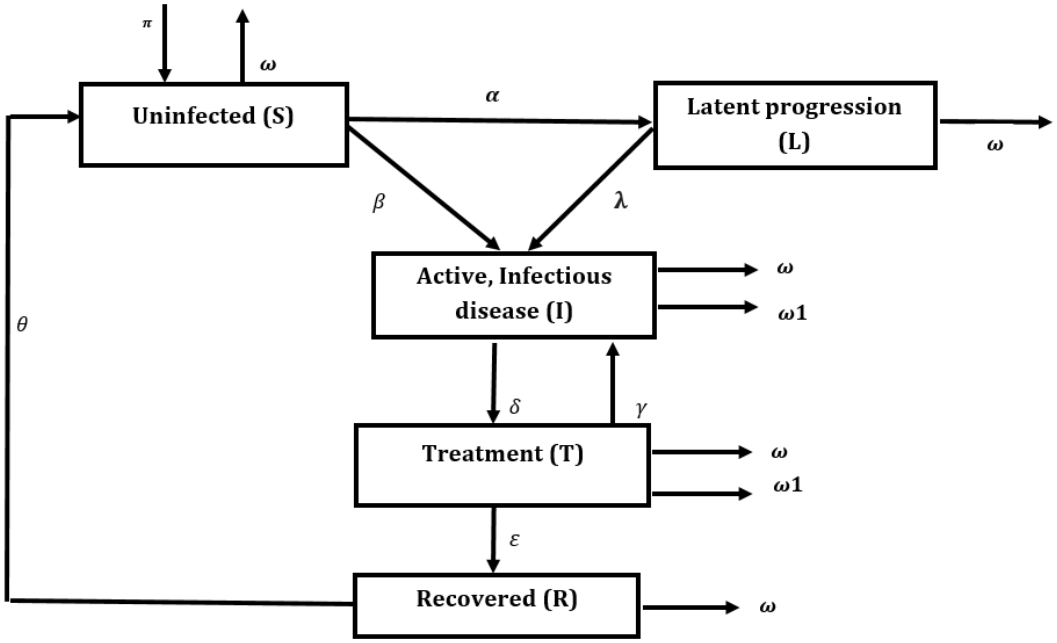
The current study focuses on the adult population (people who are 18 years of age or older) in the Indian state of Tamil Nadu.

Study Design

We used two mathematical modelling approaches to estimate the prevalence and incidence of TB before and during the COVID-19 pandemic in all districts of Tamil Nadu. The mathematical framework represents variable and their interrelationship to describe observed phenomena in the TB cascade during COVID–19 Pandemic.[11] The SIR model is a commonly used compartmental model in epidemiology that describes the transmission of infectious diseases within a population. It categorizes individuals into three compartments: susceptible, infected, and recovered.[12] The SIR model uses a set of differential equations that consider the rates of infection, recovery, and death, in order to analyze the dynamics of disease transmission. The model has widespread applications in epidemiology, as it helps to understand the spread of diseases. In the present study, we have further developed the SIR model by adding 5 compartments.

The notification of TB was calculated by three time series analyses, that is, ARIMA (Autoregressive Integrated Moving Average), TBATS (Trigonometric seasonality, Box-Cox transformation ARMA errors Trend and Seasonal components), and ESSSM (Exponential Smoothing State Space Model) to determine the trend of pulmonary TB cases before and during COVID-19 pandemic. These methods allowed to estimate the number of TB cases, providing a more comprehensive understanding of the impact of COVID-19 on TB in Tamil Nadu.

Figure 1. Model for the prevalence and incidence of TB without COVID-19 pandemic in Tamil Nadu



The compartment variables are given below.

S – Susceptible (The number of susceptible individuals and an infectious individual come into "infectious contact", the susceptible individual contacts the disease and transitions to the infectious compartment)

L – Latent (Persons with latent TB infection are not infectious and cannot spread TB infection to other)

I – Infectious (Persons with TB disease are considered as active and infectious and may spread TB bacteria to other)

T- Treatment (Person with TB disease who is diagnosed)

R – Recovered (Persons who have recovered from the TB burden)

Table 1. Input Parameter

Parameter	Transmission
α	Uninfected to Latent Progression
π	New susceptible
β	Uninfected to Active infection
λ	Latent Progression to Active infection
δ	Active infection to Treatment
γ	Treatment to Active infection
ε	Treatment to Recovered
θ	Recovered to Uninfected
ω	All-cause mortality
ω_1	TB mortality

Based on these assumptions and concepts, the variables following the system of Ordinary Differential Equations, which represents the SEIR model without the impact of COVID-19 used in this study,

$$\frac{dS}{dt} = -(\alpha * S) - (\beta * S) + (\theta * R) + (\pi * N) - (\omega * S)$$

$$\frac{dL}{dt} = (\alpha * S) - (\lambda * L) - (\omega * L)$$

$$\frac{dI}{dt} = (\beta * S) + (\lambda * L) - (\delta * I) + (\gamma * T) - (\omega * I) - (\omega_1 * I)$$

$$\frac{dT}{dt} = (\delta * I) - (\omega * T) - (\omega_1 * T) - (\gamma * T) - (\varepsilon * T)$$

$$\frac{dR}{dt} = (\varepsilon * T) - (\theta * R) - (\omega * R)$$

Figure 2. Model for the prevalence and incidence of TB with COVID-19 pandemic in Tamil Nadu

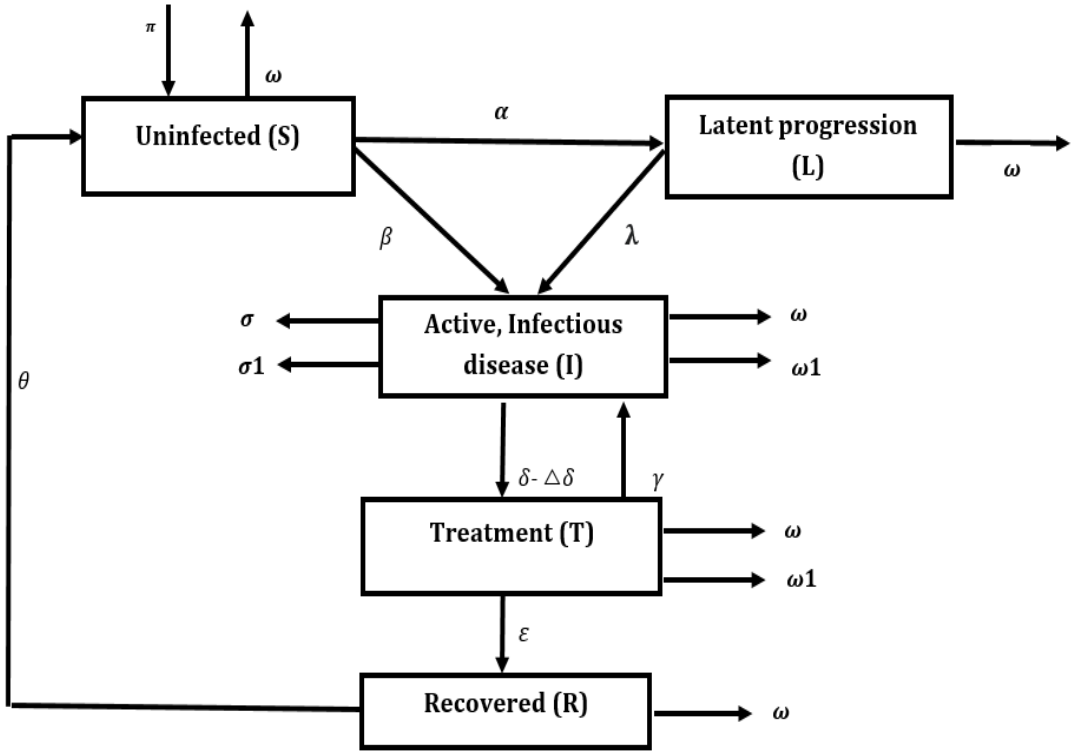


Table 2. Input Parameter

Parameter	Transmission
α	Uninfected to Latent Progression
π	New susceptible
β	Uninfected to Active infection
λ	Latent Progression to Active infection
$\Delta\delta$	Delay in diagnosis and treatment
δ	Active infection to Treatment
γ	Treatment to Active infection
ε	Treatment to Recovered
θ	Recovered to Uninfected
ω	All-cause mortality
ω_1	TB mortality
σ	Social distancing
σ1	Mask Utilization

Based on these assumptions and concepts, the variables following the system of Ordinary Differential Equations, which represents the SEIR model with the impact of COVID-19 used in this study,

$$\frac{dS}{dt} = -(\alpha * S) - (\beta * S) + (\theta * R) + (\pi * N) - (\omega * S)$$

$$\frac{dL}{dt} = (\alpha * S) - (\lambda * L) - (\omega * L)$$

$$\frac{dI}{dt} = (\beta * S) + (\lambda * L) - ((\delta - \Delta\delta) * I) + (\gamma * T) - (\omega * I) - (\omega_1 * I) - (\sigma * I) - (\sigma 1 * I)$$

$$\frac{dT}{dt} = (\delta * I) - (\omega * T) - (\omega_1 * T) - (\gamma * T) - (\varepsilon * T)$$

$$\frac{dR}{dt} = (\varepsilon * T) - (\theta * R) - (\omega * R)$$

The two mathematical model is used to estimate the prevalence and incidence over the study period 2017-2025 (without COVID-19) and 2020-2025 (with COVID-19) using the statistical package R. This model can be modified to account for a change in the overall population over time. Here, the different frameworks are predicted to relate the epidemiologic factors and possible outcomes to evaluate epidemic spread.

Data collection

We collected data based on two factors: demography and socio-economic. Demography refers to the study of population characteristics such as age, sex, race, and migration patterns, while socio-economic refers to the study of the social and economic factors that influence the well-being of individuals and communities. The correlation between the economic growth and TB cases can help to determine the role of socio-economic factors in the spread of TB.

Population

We collected the population data from two sources: the government of Tamil Nadu census survey for the period 2001-2011 and the National Commission of Population Ministry of Health and Family welfare for the period 2017-2022.[13]The data obtained from both sources offers a thorough comprehension of the age-based distribution of the population within the region over a period of ten years. The 2016 projected population for age > 18 was used as an initial value for susceptible

compartment in the mathematical model, it is categorized into five compartments according to their respective proportions.

Latent TB infection

In 2017, a study was conducted to collect data on latent tuberculosis infection among household contacts in South India, with a sample size 359.[14] The following year, in 2018, latent TB infection data was collected from household contacts in Chennai and Pune, with a sample size 869.[15] In 2020, latent infection data was collected from household contacts in South India with a sample size 220[16] and in Vellore with a sample size 1000.[17] In 2021, a study was conducted on latent infection among household contacts in South India, with a sample size 1523.[18] However, it should be noted that the aforementioned studies have certain limitations concerning the size of the sample. This factor impedes the ability to develop comprehensive conclusions to the wider population of Tamil Nadu, which includes individuals over 18 years of age, therefore we implemented a latent infection rate of 33% in the present modeling analysis.[19]

TB prevalence

The prevalence of Tuberculosis (TB) has been collected over the period 2017 to 2021. The data was collected with a focus on various factors including the study area (rural/urban), study setting (national survey, community survey, and household survey), sample size, and the method used to diagnose TB (culture/smear). [20] [21] [22] [23]Here TB period prevalence (301 per lakh) is considered to the total number of people in a population who have active tuberculosis (TB) during a specific time period.[24]

TB Incidence

The incidence of Tamil Nadu were collected from various literatures published. The data was collected with a focus on the study area, study design (prospective cohort, community survey, household survey, and national survey), and sample size. The incidence of an outcome refers to the number of new cases that occur over a certain period of time in a specific population.[25] [26] [27]

TB notification

We collected data on notified Tuberculosis (TB) cases in 31 districts of Tamil Nadu over the period from January 2017 to December 2022. The data was obtained from the NIKSHAY Dashboard portal, which provides information on TB cases notified to the government.[28] For the Chennai district, the notified TB cases were combined based on five different regions: central Chennai, south Chennai,

north Chennai, west Chennai, and east Chennai. This approach provides more understanding of the distribution of TB cases within the Chennai district.[28]

Treatment outcome

Evaluating the treatment outcome of tuberculosis and identifying the associated factors should be an integral part of tuberculosis treatment. We collected data on the treatment outcomes of Tuberculosis (TB) cases and it is categorized as successful (cured, treatment completed) or unsuccessful (non-adherent, treatment failure, or death). There is concern that coinfection with TB and COVID-19 may lead to unfavourable treatment outcomes, especially if TB treatment is interrupted, and the spread of infection in the state. To address this issue, we collected data on the treatment success rate, defined as the percentage of active TB cases that have been cured or completed treatment, from the recent National Tuberculosis Elimination Programme (NTEP) report 2022.[29]

Delay in Diagnosis

The data for delay in diagnosis were collected as per the study area (urban/rural), sample size, patient delay, diagnostic delay, and treatment delay for the period 2017 to 2022.[30] [31] Reductions in TB patient notifications in 2020 compared to pre-2020 trends were due to delayed diagnosis and treatment, likely caused by COVID-19-related restrictions and the allocation of healthcare staff to pandemic response.[29] Despite efforts by the Tamil Nadu government to maintain the TB program during the pandemic, some delay in diagnosis and treatment were inevitable. Various scenarios were observed in this study to determine the effects of 5%, 10%, and 15% delays in identifying active cases and treatment initiation.

Poverty

The various study conducted to determine the factors of tuberculosis in the state of Tamil Nadu is significantly influenced by the levels of poverty and literacy. [32] [33] [34]To gather relevant data, the percentage of poverty rates (both rural and urban) was obtained from the Ministry of Finance, Government of India, and the literacy rate from Tamil Nadu for the period 2017 to 2022.[35] However, these parameters were not used in the model of this study.

GDP (Gross state Domestic Product)

Moreover, we gathered the GDP (Gross State Domestic Product) per lakh from the Ministry of statistics and program implementation, the Government of India, and the Economy of Tamil Nadu over the period 2017 to 2022.[36]

Life expectancy

In our study, data was collected on life expectancy in the state of Tamil Nadu, with a focus on the urban and rural location, as well as age groups, over the period of 2017 to 2022.[37]

Inflation

We gathered the inflation rate for India over the period 1991-2021 can provide valuable insights into the changes in the price level and its impact on the economy of Tamil Nadu.[38]

COVID-19

Data on confirmed, recovered, and deceased COVID-19 cases in Tamil Nadu from March 2020 to November 2022 was collected from the Health and Family Welfare Department, Government of Tamil Nadu, Stop Corona TN (Media Bulletin).[39] This data was analyzed to understand the impact of COVID-19 on the state of Tamil Nadu and its possible relationship with the incidence of tuberculosis.

Mortality

Our study involved collecting data on the tuberculosis mortality rate in Tamil Nadu, over a 12 year period from 2009 to 2021. The data was sourced from the sources such as Statista and Rural and Urban death rates of India by states. The data collection process involved analyzing the TB mortality rate in both rural and urban areas.[40] Data on TB mortality was gathered from the NTEP report of 2021.[47]

Mask utilization

Several studies have found that the use of masks can significantly reduce the transmission of tuberculosis. The implementation of mask-wearing during the COVID-19 pandemic has resulted in a decrease in transmission within the community.[29] However, it should be noted that it cannot be assumed that all household contacts wear masks at all times.[41]As a result, this study has considered a marginal impact on transmission of 0.005%.

Lockdown

The outbreak of COVID-19 led to a worldwide lockdown which seemingly resulted in a decrease in the transmission of tuberculosis in the general population. [42,43] However, the restriction on mobility and social distancing measures also had an adverse effect on households where transmission rates increased.[44] According to a recent mathematical modelling analysis, the application of social distancing measures has resulted in a 50% reduction in TB transmission[11]. Therefore, it is believed that the decrease in TB transmission is partly due to the implementation of social distancing measures.

Though the recommended public health interventions centred on social distancing based on these predictions, are sensible, the assumptions underlying these may not be accurate.[45] In order to incorporate this fact, our model has included a marginal of 0.005%. This adjustment was made to ensure that the potential impact of social distancing on TB transmission was accounted for in our model.

Data Analysis

In this study, mathematical modeling was used to estimate the prevalence and incidence of TB before and during the COVID-19 pandemic. The model was developed from the basic framework of the SIR model to reflect the epidemiological conditions and respective care cascades in Tamil Nadu, both before and during the COVID-19 pandemic. Additionally, ARIMA, TBATS, and ESSSM models were used to assess the notification trend of pulmonary TB cases before and during the COVID-19 pandemic.

SEIR Model for TB Prevalence

Based on actual data, we estimated the period prevalence over the period from 2017 to 2025 before and during the COVID-19 pandemic. By comparing the prevalence rates between these two time periods, the difference in prevalence was quantified. Additionally, the prevalence have been predicted for all districts of Tamil Nadu in the same period. The following formula is used to calculate the prevalence,

$$\text{Prevalence of } n^{th} \text{ year} = \frac{\text{Infection of nth year} + \text{Infection of } (n-1)\text{th year}}{\text{Total Population of nth year}} * 100000$$

We have derived six ordinary differential equations (ODEs) for the SEIR model that can be implemented to present the impact of before and during COVID-19 on TB. The prevalence rate was calculated as cases per lakh population from the above output table for SEIR model.

Table 3. Input parameter and values used for the SEIR model

Parameter	Transmission	Values	Sources
α	Uninfected to Latent Progression	0.33	S. Saha et al. Current status of treatment of latent tuberculosis infection in India. Indian J Med Sci. 2019;71(2):54-9.
π	New susceptible	0.0123	Tamil Nadu, Birth-rate https://knoema.com/atlas/India/Tamil-Nadu/Birth-rate
β	Uninfected to Active infection	0.00301	National TB prevalence Survey (2019-2021)
λ	Latent Progression to Active infection	0.005	S. Saha et al. Current status of treatment of latent tuberculosis infection in India. Indian J Med Sci. 2019;71(2):54-9.
δ	Active infection to Treatment	0.96	NTEP Annual Report (2022)
γ	Treatment to Active infection	0.102	Estimated from NTEP Annual Report (2021)
ε	Treatment to Recovered	0.83	NTEP Annual Report (2021), https://data.worldbank.org/indicator
θ	Recovered to Uninfected	0.99	Assumption
ω	All-cause mortality	0.009	Tamil Nadu Death-rate https://knoema.com/atlas/India/Tamil-Nadu/Death-rate
ω_1	TB mortality	0.059	NTEP Annual Report (2021)
σ	Lockdown	0.005	Assumption
σ_1	Mask Utilization	0.005	Assumption

SEIR Model for TB Incidence

Using SEIR model, we estimated the incidence with Covid for the period from 2017 to 2025 and without COVID-19 for the period from 2020 to 2025. The calculated incidence rate was derived from the model output. It was measured as the number of cases per lakh population. The below formula is used to calculate TB Incidence by using SEIR model.

$$\text{Incidence of } n^{th} \text{ year} = \frac{\text{Infection of nth year}}{\text{Total Population of nth year}} * 100000$$

Impact of COVID-19 on Prevalence and Incidence

To find the impact of COVID-19 on TB prevalence and incidence in Tamil Nadu, we included marginal presumption of mask utilisation, social distance and different delay scenarios in diagnosis and treatment initiation as an intervention of COVID-19 in this model during the year 2020 to 2025.

TB Notification

To assess the trend in pulmonary TB, we compiled the monthly notified TB cases from both the public and private sectors in Tamil Nadu from January 2017 to December 2022. These data were exported as Excel spreadsheets and compiled. We also interpreted the district-wise private and public TB notification trends in Tamil Nadu for the same period. The overall notified public and private TB cases from Nikshay were plotted from January 2017 to February 2020 to assess the real-time notification trend. The overall TB notification trend for the public and private sectors was assessed for both seasonal and random variation using the additive seasonal decomposition method. To test for independence in the residuals, the Ljung Box test for independence was used. The Augmented Dickey-Fuller (ADF) unit root test was used to check for stationarity. Time series analysis based forecasting models were implemented using the R programming software (version 4.2.0).

ARIMA model for TB Notification

To predict the notification trend in TB, three different models, ARIMA, TBATS, and ESSSM are used. These models were compared to assess their fit with the real-time notification trend. For the ARIMA model, we used an order of (1 0 0) and a seasonality of (1 1 0) with a frequency of the month 12. We estimated the trend of notified TB using AIC (Akaike information criterion) and BIC (Bayesian information criterion). These seasonality patterns were used to estimate future values and address uncertainty about the future. We compared the observed and estimated rates, which were calculated using the Seasonal ARIMA model.

Exponential smoothing State Space model for TB Notification

Here, exponential smoothing is used to estimate the notification trend in TB using AIC (Akaike information criterion) and BIC (Bayesian information criterion) over the period from January 2017 to February 2020. We compared the estimated values with the observed values of notified TB cases in Nikshay to determine the best fit.

TBATS (Trigonometric seasonality Box-Cox transformation ARIMA errors Trend Seasonal components)

To identify the best fit, the TBATS model is used to forecast the time series with complex seasonal patterns using exponential smoothing. By using this method, AIC (Akaike information criterion) value and BIC (Bayesian information criterion) value were found to compare with the other two time series models to determine the best fit.

Impact of COVID-19 on TB Notification

To assess the trend on TB notification in Tamil Nadu during COVID-19 over the period March 2020 to November 2022, we compared the observed value of TB notification and an estimated value of Seasonal ARIMA (1,0,0)*(1,1,0)[12] to find the difference of the estimated rate during COVID-19. Further, we showed the trend of the percentage of month-wise TB notifications in Tamil Nadu with the impact of COVID-19 over the period March 2020 to November 2022. In addition, we correlated the observed and expected TB notifications during the COVID-19 pandemic lockdown period from April 2020 to October 2021. To interpret the interruption of COVID-19 pandemics (both first and second wave) explicitly, Interrupted Time Series (ITS) analysis has been performed to assess the change in the significance of notified trend before COVID-19 and during COVID-19 interruption.

Latent Progression

Assumed the prevalence of latent TB infection as 33%, and the risk for these individuals to develop active tuberculosis is 5% was collected from published literature[46]. In latent TB infection, the TB bacteria remain inactive for a lifetime without causing disease, especially in people who have a weak immune system, the bacteria become active, multiply, and cause TB disease.

Treatment Outcome

In 2016, the treatment success rate for TB people was 86%. In our model, the recovered rate was calculated by using the successful cure/completed rate 83% from both the public and private sectors in TB notification in the year 2017.[47] Estimated TB mortality over the 2020 to 2025.

TB mortality

Estimates of TB mortality are based on the active infectious and treatment compartments. The period from 2017 to 2025 is used to estimate TB mortality without the influence of COVID-19, while the impact of the COVID-19 pandemic is factored in for the years 2020 to 2025.

IV. Results

Table 4. SEIR model values for without the impact of COVID-19

Year	Total Population >15	Susceptible	Latent Progression	Active/ Infectious	Treatment	Recovery	TB Mortality
2017	57068340	39677931	17138298	85543	91614	74954	10440
2018	57342263	40097166	16993397	84842	91262	75596	10390
2019	57616352	40516263	16849722	84132	90671	75565	10313
2020	57890625	40934751	16707262	83423	89980	75209	10231
2021	58165093	41352415	16566006	82718	89251	74703	10146
2022	58439764	41769162	16425945	82019	88510	74129	10061
2023	58714646	42184958	16287068	81326	87767	73528	9976
2024	58989745	42599798	16149365	80638	87027	72917	9892
2025	59265069	43013688	16012827	79956	86292	72305	9809

Table 5. SEIR model values for with the impact of COVID-19

Year	Total Population >15	Susceptible	Latent Progression	Active/ Infectious	Treatment	Recovery	TB Mortality
2020	57889810	40934731	16707232	82923	89769	75156	10242
2021	58163505	41352253	16565917	82063	88783	74490	10080
2022	58437425	41768684	16425787	81318	87884	73752	9983
2023	58711568	42184018	16286840	80614	87063	73034	9893
2024	58985937	42598300	16149067	79927	86289	72354	9807
2025	59260535	43011578	16012459	79249	85542	71707	9723

Table 6. SEIR model values for with the impact of COVID-19 and delay 5

Year	Total Population >15	Susceptible	Latent Progression	Active/ Infectious	Treatment	Recovery	TB Mortality
2020	57889777	40934440	16707384	85462	88027	74464	10392
2021	58163365	41351009	16566375	85427	87207	73346	10185
2022	58437127	41766302	16426598	84936	86671	72618	10125
2023	58711086	42180612	16288015	84297	86099	72062	10053
2024	58985258	42594039	16150606	83612	85464	71537	9975
2025	59259656	43006597	16014358	82916	84789	70996	9895

Table 7. SEIR model values for with the impact of COVID-19 and delay 10

Year	Total Population >15	Susceptible	Latent Progression	Active/ Infectious	Treatment	Recovery	TB Mortality
2020	57889743	40934142	16707541	88107	86203	73751	10548
2021	58163219	41349713	16566856	89020	85498	72133	10297
2022	58436813	41763784	16427459	88856	85327	71387	10277
2023	58710573	42176971	16289272	88315	85024	70990	10227
2024	58984531	42589451	16152261	87645	84545	70629	10159
2025	59258710	43001208	16016407	86934	83954	70208	10082

Table 8. SEIR model values for with the impact of COVID-19 and delay 15

Year	Total Population >15	Susceptible	Latent Progression	Active/ Infectious	Treatment	Recovery	TB Mortality
2020	57889708	40933837	16707702	90863	84292	73013	10710
2021	58163067	41348360	16567359	92863	83641	70843	10414
2022	58436481	41761117	16428373	93111	83833	70048	10440
2023	58710025	42173073	16290618	92711	83817	69806	10415
2024	58983751	42584500	16154044	92075	83515	69618	10360
2025	59257690	42995362	16018623	91356	83022	69327	10288

Table 9. TB Prevalence without the impact of COVID-19

The estimated prevalence of tuberculosis (TB) has been consistently decreasing from 2017 to 2025. The 95% confidence interval for the overall TB prevalence per lakh has been provided in this table for each year from 2017 to 2025.

Year	Prevalence per 100000 popn.	Rate of Reduction (%)
2017	301 (295 - 307)	-
2018	297 (291 - 303)	1.282
2019	293 (287 - 300)	1.317
2020	289 (283 - 296)	1.327
2021	286 (279 - 292)	1.329
2022	282 (276 - 288)	1.328
2023	278 (272 - 285)	1.327
2024	275 (268 - 281)	1.325
2025	271 (265 - 277)	1.323

Figure 3. Confidence Interval for TB prevalence without the impact of COVID-19

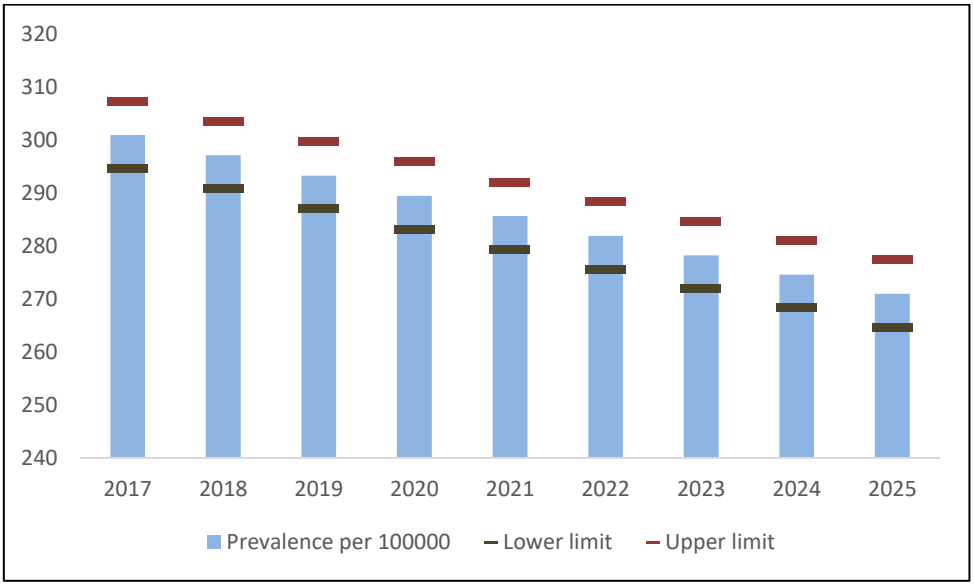


Figure 3 displays the estimated prevalence per lakh of tuberculosis (TB) without the influence of COVID-19, which is derived from the data presented in table 9.

Table 10. TB Prevalence with the impact of COVID-19

As a result of the COVID-19 pandemic on tuberculosis cases, there has been a consistent decline in the estimated prevalence of TB from 2020 to 2025. This table also includes the 95% confidence interval for the overall TB prevalence per lakh.

Year	Prevalence per 100000 popn.	Rate of Reduction (%)
2020	289 (283 - 294)	1.629
2021	284 (278 - 289)	1.732
2022	280 (274 - 285)	1.458
2023	276 (270 - 281)	1.368
2024	272 (267 - 278)	1.338
2025	269 (263 - 274)	1.327

Figure 4. Confidence Interval for TB Prevalence with the impact of COVID-19

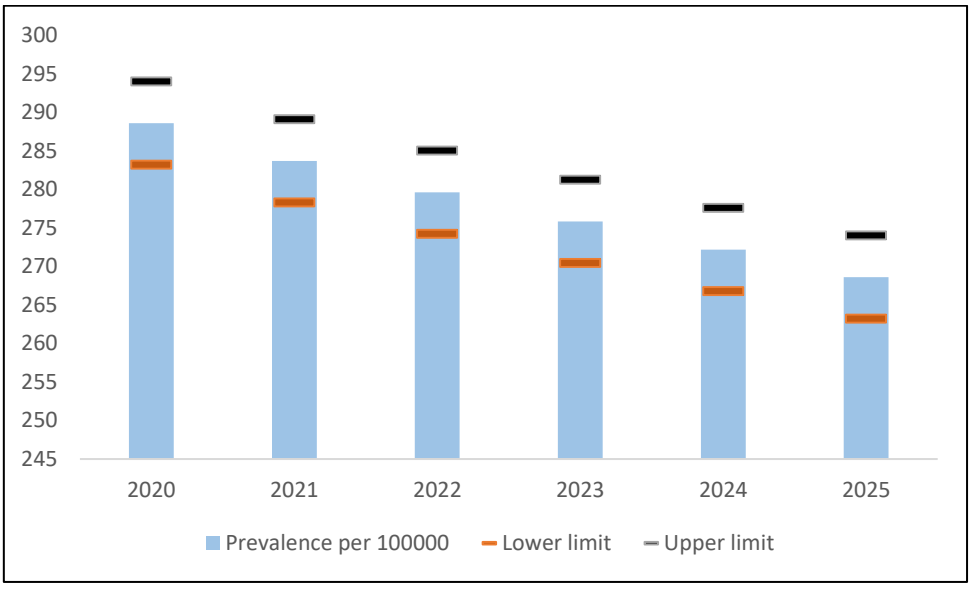


Figure 4 displays the estimated prevalence per lakh of tuberculosis (TB) with the influence of COVID-19, which is derived from the data presented in table 10.

Table 11. TB Prevalence (Without/With COVID - 19)

Prevalence of TB for with/without COVID-19 pandemic, there has been a consistent decline in the estimated prevalence of TB from 2020 to 2025. This table also includes the 95% confidence interval for the overall TB prevalence per lakh.

Year	(Without COVID-19)		(With COVID-19)	
	Prevalence per 100000 popn.	Rate of Reduction (%)	Prevalence per 100000 popn.	Rate of Reduction (%)
2020	289 (283 - 296)	1.327	289 (283 - 294)	1.629
2021	286 (279 - 292)	1.329	284 (278 - 289)	1.732
2022	282 (276 - 288)	1.328	280 (274 - 285)	1.458
2023	278 (272 - 285)	1.327	276 (270 - 281)	1.368
2024	275 (268 - 281)	1.325	272 (267 - 278)	1.338
2025	271 (265 - 277)	1.323	269 (263 - 274)	1.327

Table 12. Comparison of TB Prevalence (Without/With COVID - 19)

As a result of the COVID-19 pandemic on tuberculosis cases, there has been a consistent decline in the estimated prevalence of TB from 2020 to 2025. This table also includes 95% confidence interval for the overall TB prevalence per lakh.

Year	(Without COVID-19)	(With COVID-19)	Difference Rate (%)
2020	289	289	0.298
2021	286	284	0.697
2022	282	280	0.826
2023	278	276	0.867
2024	275	272	0.880
2025	271	269	0.884

Table 13. TB Prevalence with the impact of COVID-19 (delay in diagnosis 5%, 10% and 15%)

As a result of the COVID-19 pandemic and a 5%, 10% and 15% delay in diagnosing tuberculosis cases, there has been a consistent decline in the estimated prevalence of TB from 2020 to 2025. This table also includes the 95% confidence interval for the overall TB prevalence per lakh.

Year	Delay in Dx & Rx 5%		Delay in Dx & Rx 10%		Delay in Dx & Rx 15%	
	Prevalence per 100000 popn.	Rate of Reduction (%)	Prevalence per 100000 popn.	Rate of Reduction (%)	Prevalence per 100000 popn.	Rate of Reduction (%)
2020	293 (289 - 297)	0.108	298 (295 - 300)	-1.451	302 (298 - 307)	-3.074
2021	294 (290 - 298)	-0.290	305 (302 - 307)	-2.355	316 (312 - 320)	-4.497
2022	292 (288 - 295)	0.775	304 (301 - 307)	0.047	318 (314 - 323)	-0.750
2023	288 (285 - 292)	1.126	302 (299 - 305)	0.861	317 (312 - 321)	0.547
2024	285 (281 - 288)	1.244	298 (295 - 301)	1.145	313 (309 - 318)	1.019
2025	281 (277 - 285)	1.282	295 (292 - 298)	1.244	310 (305 - 314)	1.192

Table 14. TB Incidence without the impact of COVID-19

The estimated incidence of tuberculosis (TB) has been consistently decreasing from 2017 to 2025. The 95% confidence interval for the overall TB prevalence per lakh has been provided in a table for each year from 2017 to 2025.

Year	Incidence per 100000 popn.	Rate of Reduction (%)
2017	150 (147 - 153)	-
2018	148 (145 - 151)	1.293
2019	146 (143 - 149)	1.309
2020	144 (141 - 147)	1.312
2021	142 (139 - 145)	1.312
2022	140 (137 - 143)	1.311
2023	139 (135 - 142)	1.310
2024	137 (134 - 140)	1.308
2025	135 (132 - 138)	1.306

Figure 5. Confidence Interval for TB incidence without the impact of COVID-19

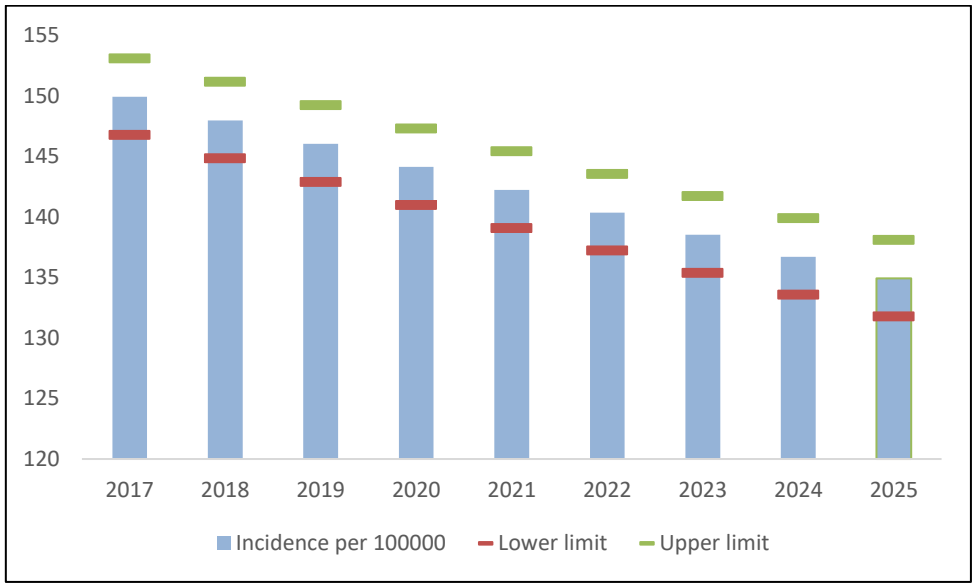


Figure 5 displays the estimated incidence per lakh of tuberculosis (TB) without the influence of COVID-19, which is derived from the data presented in table 14.

Table 15. TB Incidence with the impact of COVID-19

As a result of the COVID-19 pandemic on tuberculosis cases, there has been a consistent decline in the estimated incidence of TB from 2020to 2025. This table also includes the 95% confidence interval for the overall TB incidence per lakh.

Year	Incidence per 100000 popn.	Rate of Reduction (%)
2020	143 (141 - 146)	1.902
2021	141 (139 - 144)	1.503
2022	139 (137 - 142)	1.372
2023	137 (135 - 140)	1.329
2024	136 (133 - 138)	1.313
2025	134 (131 - 136)	1.307

Figure 6. Impact of COVID-19 on TB Incidence during the year 2020 to 2025

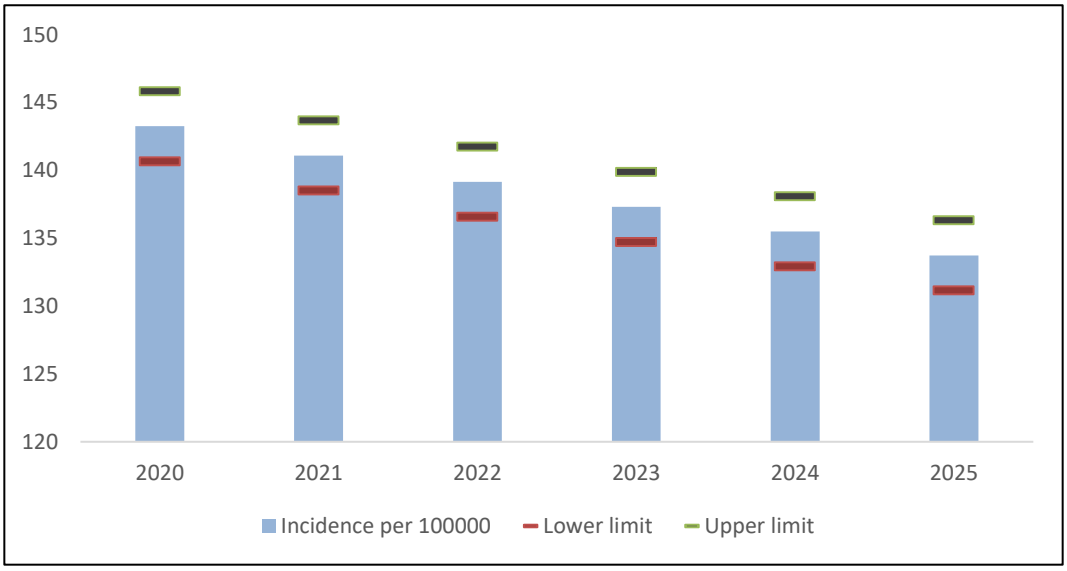


Figure 6 displays the estimated incidence per lakh of tuberculosis (TB) with the influence of COVID-19, which is derived from the data presented in table 15.

Table 16. TB Incidence (Without/With COVID - 19)

Year	(Without COVID-19)		(With COVID-19)	
	Incidence per 100000 popn.	Rate of Reduction (%)	Incidence per 100000 popn.	Rate of Reduction (%)
2020	144 (141 - 147)	1.312	143 (141 - 146)	1.902
2021	142 (139 - 145)	1.312	141 (139 - 144)	1.503
2022	140 (137 - 143)	1.311	139 (137 - 142)	1.372
2023	139 (135 - 142)	1.310	137 (135 - 140)	1.329
2024	137 (134 - 140)	1.308	136 (133 - 138)	1.313
2025	135 (132 - 138)	1.306	134 (131 - 136)	1.307

Table 17. Comparison of TB Incidence (Without/With COVID - 19)

Year	(Without COVID-19)	(With COVID-19)	Difference Rate (%)
2020	144	143	0.598
2021	142	141	0.790
2022	140	139	0.851
2023	139	137	0.870
2024	137	136	0.876
2025	135	134	0.877

Table 18. TB Incidence with the impact of COVID-19 (with delay in diagnosis 5%, 10% and 15%)

As a result of the COVID-19 pandemic and a 5%, 10% and 15% delay in diagnosing tuberculosis cases, there has been a consistent decline in the estimated incidence of TB from 2020 to 2025. This table also includes the 95% confidence interval for the overall TB incidence per lakh.

Year	Delay in Dx & Rx 5%		Delay in Dx & Rx 10%		Delay in Dx & Rx 15%	
	Incidence per 100000 popn.	Rate of Reduction (%)	Incidence per 100000 popn.	Rate of Reduction (%)	Incidence per 100000 popn.	Rate of Reduction (%)
2020	148 (145 - 150)	-1.101	152 (150 - 155)	-4.230	157 (155 - 159)	-7.491
2021	147 (145 - 149)	0.511	153 (151 - 156)	-0.562	160 (158 - 162)	-1.721
2022	145 (143 - 148)	1.040	152 (150 - 155)	0.652	159 (158 - 162)	0.203
2023	144 (141 - 146)	1.216	150 (149 - 153)	1.072	158 (156 - 160)	0.893
2024	142 (140 - 144)	1.274	149 (147 - 151)	1.219	156 (155 - 159)	1.147
2025	140 (138 - 142)	1.292	147 (145 - 149)	1.271	154 (153 - 157)	1.240

Table 19. District wise TB Prevalence without the impact of COVID-19 from 2017 to 2025

S.No	District	2017	2018	2019
1	Ariyalur	206.76 (190.45 - 223.08)	204.23 (187.91 - 220.55)	201.66 (185.34 - 217.97)
2	Chennai	323.31 (297.81 - 348.82)	319.25 (293.74 - 344.76)	315.14 (289.63 - 340.65)
3	Coimbatore	303.27 (279.34 - 327.2)	299.48 (275.55 - 323.41)	295.63 (271.7 - 319.56)
4	Cuddalore	287.22 (264.55 - 309.89)	283.64 (260.97 - 306.31)	280.01 (257.34 - 302.68)
5	Dharmapuri	234.96 (216.41 - 253.51)	232.07 (213.52 - 250.61)	229.13 (210.58 - 247.68)
6	Dindigul	259.1 (238.65 - 279.55)	255.89 (235.44 - 276.34)	252.63 (232.18 - 273.09)
7	Erode	263.12 (242.35 - 283.89)	259.86 (239.09 - 280.63)	256.55 (235.78 - 277.32)
8	kanchipuram	311.29 (286.73 - 335.85)	307.39 (282.83 - 331.96)	303.44 (278.87 - 328)
9	kanniyakumari	247.03 (227.53 - 266.54)	243.98 (224.48 - 263.48)	240.88 (221.38 - 260.39)
10	karur	210.79 (194.15 - 227.43)	208.21 (191.57 - 224.85)	205.58 (188.95 - 222.22)
11	krishnagiri	247.03 (227.53 - 266.54)	243.98 (224.48 - 263.48)	240.89 (221.38 - 260.39)
12	Madurai	299.26 (275.64 - 322.88)	295.52 (271.91 - 319.14)	291.73 (268.11 - 315.34)
13	Namakkal	243.01 (223.83 - 262.2)	240.01 (220.83 - 259.2)	236.97 (217.78 - 256.15)
14	Nagapattinam	238.99 (220.12 - 257.85)	236.04 (217.17 - 254.91)	233.05 (214.18 - 251.91)
15	Permbalur	202.73 (186.74 - 218.72)	200.25 (184.26 - 216.24)	197.73 (181.74 - 213.72)
16	Pudukottai	238.99 (220.12 - 257.85)	236.04 (217.17 - 254.91)	233.05 (214.18 - 251.91)
17	Ramanathapuram	222.88 (205.29 - 240.48)	220.14 (202.55 - 237.74)	217.36 (199.77 - 234.96)
18	Salem	303.27 (279.34 - 327.2)	299.48 (275.55 - 323.41)	295.63 (271.7 - 319.56)
19	Sivaganga	222.88 (205.29 - 240.48)	220.14 (202.55 - 237.74)	217.36 (199.77 - 234.96)
20	Thanjavur	267.14 (246.05 - 288.23)	263.82 (242.74 - 284.91)	260.46 (239.37 - 281.55)
21	The nilgiris	206.76 (190.45 - 223.08)	204.23 (187.91 - 220.54)	201.66 (185.34 - 217.97)
22	Theni	218.85 (201.58 - 236.13)	216.16 (198.89 - 233.44)	213.44 (196.16 - 230.71)
23	Tiruchy	291.24 (268.25 - 314.22)	287.6 (264.62 - 310.59)	283.92 (260.93 - 306.9)
24	Thiruvallur	307.28 (283.03 - 331.53)	303.44 (279.19 - 327.68)	299.54 (275.29 - 323.78)
25	Thiruvarur	218.85 (201.58 - 236.13)	216.17 (198.89 - 233.44)	213.44 (196.16 - 230.71)
26	Thoothukodi	243.01 (223.83 - 262.2)	240.01 (220.83 - 259.2)	236.97 (217.78 - 256.15)
27	Tirunelveli	299.26 (275.64 - 322.88)	295.52 (271.91 - 319.14)	291.73 (268.11 - 315.34)
28	Tiruppur	283.21 (260.86 - 305.56)	279.68 (257.33 - 302.03)	276.1 (253.75 - 298.45)
29	Thiruvanamalai	275.17 (253.46 - 296.89)	271.75 (250.03 - 293.47)	268.28 (246.56 - 290)
30	Vellore	311.29 (286.73 - 335.85)	307.39 (282.83 - 331.95)	303.44 (278.87 - 328)
31	Villupuram	303.27 (279.34 - 327.2)	299.48 (275.55 - 323.41)	295.63 (271.7 - 319.56)
32	Virudhunagar	251.06 (231.24 - 270.88)	247.95 (228.13 - 267.77)	244.8 (224.98 - 264.62)

Continued...

S.No	District	2020	2021	2022
1	Ariyalur	199.1 (182.78 - 215.42)	196.57 (180.25 - 212.88)	194.07 (177.75 - 210.38)
2	Chennai	311.04 (285.53 - 336.55)	307 (281.49 - 332.51)	303.01 (277.5 - 328.52)
3	Coimbatore	291.81 (267.88 - 315.74)	288.03 (264.1 - 311.96)	284.3 (260.37 - 308.23)
4	Cuddalore	276.4 (253.73 - 299.07)	272.83 (250.16 - 295.5)	269.31 (246.64 - 291.97)
5	Dharmapuri	226.2 (207.65 - 244.75)	223.31 (204.76 - 241.86)	220.45 (201.91 - 239)
6	Dindigul	249.39 (228.94 - 269.85)	246.19 (225.74 - 266.64)	243.03 (222.57 - 263.48)
7	Erode	253.25 (232.48 - 274.02)	250 (229.23 - 270.77)	246.78 (226.01 - 267.55)
8	kanchipuram	299.51 (274.94 - 324.07)	295.62 (271.06 - 320.18)	291.79 (267.22 - 316.35)
9	kanniyakumari	237.8 (218.3 - 257.3)	234.75 (215.25 - 254.26)	231.75 (212.24 - 251.25)
10	karur	202.97 (186.33 - 219.61)	200.39 (183.75 - 217.03)	197.84 (181.2 - 214.48)
11	krishnagiri	237.8 (218.3 - 257.3)	234.75 (215.25 - 254.26)	231.75 (212.24 - 251.25)
12	Madurai	287.96 (264.34 - 311.57)	284.23 (260.61 - 307.85)	280.55 (256.94 - 304.17)
13	Namakkal	233.94 (214.75 - 253.12)	230.94 (211.76 - 250.12)	227.98 (208.8 - 247.17)
14	Nagapattinam	230.07 (211.2 - 248.94)	227.13 (208.26 - 245.99)	224.22 (205.35 - 243.09)
15	Permbalur	195.22 (179.23 - 211.21)	192.74 (176.75 - 208.73)	190.29 (174.3 - 206.28)
16	Pudukottai	230.07 (211.2 - 248.94)	227.13 (208.26 - 245.99)	224.22 (205.35 - 243.09)
17	Ramanathapuram	214.59 (197 - 232.19)	211.86 (194.26 - 229.45)	209.15 (191.56 - 226.75)
18	Salem	291.81 (267.88 - 315.74)	288.03 (264.1 - 311.96)	284.3 (260.37 - 308.23)
19	Sivaganga	214.59 (197 - 232.19)	211.85 (194.26 - 229.45)	209.15 (191.56 - 226.75)
20	Thanjavur	257.11 (236.03 - 278.2)	253.81 (232.72 - 274.89)	250.54 (229.45 - 271.63)
21	The nilgiris	199.1 (182.78 - 215.41)	196.57 (180.25 - 212.88)	194.07 (177.75 - 210.38)
22	Theni	210.72 (193.44 - 228)	208.03 (190.76 - 225.31)	205.38 (188.11 - 222.66)
23	Tiruchy	280.25 (257.27 - 303.24)	276.63 (253.65 - 299.61)	273.06 (250.07 - 296.04)
24	Thiruvallur	295.66 (271.41 - 319.91)	291.82 (267.58 - 316.07)	288.04 (263.79 - 312.29)
25	Thiruvarur	210.72 (193.44 - 228)	208.03 (190.76 - 225.31)	205.38 (188.11 - 222.66)
26	Thoothukodi	233.94 (214.75 - 253.12)	230.94 (211.76 - 250.12)	227.98 (208.8 - 247.17)
27	Tirunelveli	287.96 (264.34 - 311.57)	284.23 (260.61 - 307.85)	280.55 (256.94 - 304.17)
28	Tiruppur	272.54 (250.19 - 294.9)	269.03 (246.68 - 291.38)	265.56 (243.2 - 287.91)
29	Thiruvanamalai	264.83 (243.11 - 286.55)	261.42 (239.7 - 283.14)	258.05 (236.33 - 279.77)
30	Vellore	299.51 (274.94 - 324.07)	295.62 (271.06 - 320.18)	291.79 (267.22 - 316.35)
31	Villupuram	291.81 (267.88 - 315.74)	288.03 (264.1 - 311.96)	284.3 (260.36 - 308.23)
32	Virudhunagar	241.67 (221.85 - 261.49)	238.57 (218.75 - 258.39)	235.51 (215.69 - 255.33)

Continued...

S.No	District	2023	2024	2025
1	Ariyalur	191.6 (175.28 - 207.92)	189.17 (172.85 - 205.48)	186.77 (170.45 - 203.08)
2	Chennai	299.07 (273.57 - 324.58)	295.2 (269.69 - 320.71)	291.38 (265.87 - 316.88)
3	Coimbatore	280.62 (256.69 - 304.55)	276.99 (253.06 - 300.93)	273.42 (249.49 - 297.35)
4	Cuddalore	265.83 (243.17 - 288.5)	262.41 (239.74 - 285.08)	259.03 (236.36 - 281.7)
5	Dharmapuri	217.64 (199.09 - 236.19)	214.86 (196.31 - 233.41)	212.12 (193.57 - 230.67)
6	Dindigul	239.91 (219.45 - 260.36)	236.83 (216.38 - 257.28)	233.8 (213.35 - 254.25)
7	Erode	243.61 (222.85 - 264.38)	240.49 (219.72 - 261.26)	237.41 (216.64 - 258.18)
8	kanchipuram	288.01 (263.44 - 312.57)	284.28 (259.72 - 308.84)	280.61 (256.04 - 305.17)
9	kanniyakumari	228.78 (209.28 - 248.28)	225.85 (206.35 - 245.35)	222.97 (203.46 - 242.47)
10	karur	195.32 (178.68 - 211.96)	192.84 (176.2 - 209.48)	190.39 (173.75 - 207.03)
11	krishnagiri	228.78 (209.28 - 248.28)	225.85 (206.35 - 245.35)	222.97 (203.46 - 242.47)
12	Madurai	276.92 (253.31 - 300.54)	273.35 (249.73 - 296.96)	269.82 (246.21 - 293.44)
13	Namakkal	225.07 (205.88 - 244.25)	222.19 (203.01 - 241.37)	219.35 (200.17 - 238.54)
14	Nagapattinam	221.35 (202.49 - 240.22)	218.52 (199.66 - 237.39)	215.74 (196.87 - 234.6)
15	Permbalur	187.88 (171.89 - 203.87)	185.49 (169.5 - 201.48)	183.14 (167.15 - 199.13)
16	Pudukottai	221.35 (202.49 - 240.22)	218.52 (199.66 - 237.39)	215.74 (196.87 - 234.6)
17	Ramanathapuram	206.49 (188.89 - 224.08)	203.86 (186.26 - 221.45)	201.26 (183.67 - 218.86)
18	Salem	280.62 (256.69 - 304.55)	276.99 (253.06 - 300.93)	273.42 (249.49 - 297.35)
19	Sivaganga	206.49 (188.89 - 224.08)	203.86 (186.26 - 221.45)	201.26 (183.67 - 218.86)
20	Thanjavur	247.32 (226.23 - 268.41)	244.15 (223.06 - 265.23)	241.02 (219.93 - 262.1)
21	The nilgiris	191.6 (175.28 - 207.91)	189.17 (172.85 - 205.48)	186.77 (170.45 - 203.08)
22	Theni	202.77 (185.49 - 220.04)	200.18 (182.91 - 217.46)	197.64 (180.36 - 214.92)
23	Tiruchy	269.53 (246.55 - 292.51)	266.06 (243.07 - 289.04)	262.63 (239.65 - 285.61)
24	Thiruvallur	284.31 (260.07 - 308.56)	280.64 (256.39 - 304.88)	277.01 (252.77 - 301.26)
25	Thiruvarur	202.77 (185.49 - 220.04)	200.19 (182.91 - 217.46)	197.64 (180.36 - 214.92)
26	Thoothukodi	225.07 (205.88 - 244.25)	222.19 (203.01 - 241.37)	219.35 (200.17 - 238.54)
27	Tirunelveli	276.92 (253.31 - 300.54)	273.35 (249.73 - 296.97)	269.82 (246.21 - 293.44)
28	Tiruppur	262.13 (239.78 - 284.48)	258.76 (236.41 - 281.11)	255.43 (233.08 - 277.78)
29	Thiruvanamalai	254.73 (233.01 - 276.45)	251.45 (229.74 - 273.17)	248.23 (226.51 - 269.94)
30	Vellore	288 (263.44 - 312.57)	284.28 (259.72 - 308.84)	280.61 (256.04 - 305.17)
31	Villupuram	280.62 (256.69 - 304.55)	276.99 (253.06 - 300.93)	273.42 (249.49 - 297.35)
32	Virudhunagar	232.49 (212.67 - 252.31)	229.51 (209.69 - 249.33)	226.58 (206.76 - 246.4)

Table 20. District wise TB Prevalence with the impact of COVID-19 from 2020 to 2025

S.No	District	2020	2021	2022
1	Ariyalur	197.35 (181.22 - 213.48)	194.84 (178.71 - 210.97)	192.36 (176.24 - 208.49)
2	Chennai	308.32 (283.11 - 333.54)	304.32 (279.1 - 329.54)	300.36 (275.14 - 325.58)
3	Coimbatore	289.25 (265.6 - 312.91)	285.51 (261.85 - 309.17)	281.81 (258.15 - 305.47)
4	Cuddalore	273.98 (251.57 - 296.39)	270.44 (248.03 - 292.85)	266.95 (244.54 - 289.36)
5	Dharmapuri	224.22 (205.88 - 242.56)	221.35 (203.02 - 239.69)	218.52 (200.19 - 236.86)
6	Dindigul	247.21 (226.99 - 267.43)	244.03 (223.81 - 264.25)	240.9 (220.68 - 261.12)
7	Erode	251.04 (230.5 - 271.57)	247.81 (227.28 - 268.34)	244.62 (224.09 - 265.16)
8	kanchipuram	296.89 (272.6 - 321.17)	293.03 (268.75 - 317.32)	289.24 (264.95 - 313.52)
9	kanniyakumari	235.72 (216.44 - 255)	232.7 (213.42 - 251.98)	229.72 (210.44 - 249)
10	karur	201.19 (184.74 - 217.64)	198.63 (182.18 - 215.08)	196.1 (179.65 - 212.55)
11	krishnagiri	235.72 (216.44 - 255)	232.7 (213.42 - 251.98)	229.72 (210.44 - 249)
12	Madurai	285.44 (262.09 - 308.78)	281.74 (258.4 - 305.09)	278.1 (254.75 - 301.45)
13	Namakkal	228.05 (209.4 - 246.7)	225.13 (206.48 - 243.79)	222.25 (203.6 - 240.91)
14	Nagapattinam	231.89 (212.92 - 250.85)	228.92 (209.95 - 247.88)	225.99 (207.02 - 244.95)
15	Permbalur	193.51 (177.7 - 209.32)	191.05 (175.24 - 206.86)	188.62 (172.82 - 204.43)
16	Pudukottai	228.05 (209.4 - 246.7)	225.13 (206.48 - 243.79)	222.25 (203.6 - 240.91)
17	Ramanathapuram	212.71 (195.32 - 230.1)	210 (192.6 - 227.39)	207.32 (189.92 - 224.71)
18	Salem	289.25 (265.6 - 312.91)	285.51 (261.85 - 309.17)	281.81 (258.15 - 305.47)
19	Sivaganga	212.71 (195.32 - 230.1)	210 (192.6 - 227.39)	207.32 (189.92 - 224.71)
20	Thanjavur	254.86 (234.02 - 275.71)	251.58 (230.74 - 272.43)	248.35 (227.5 - 269.19)
21	The nilgiris	185.79 (170.37 - 201.21)	182.13 (166.71 - 197.55)	178.54 (163.12 - 193.96)
22	Theni	208.87 (191.79 - 225.95)	206.21 (189.13 - 223.29)	203.58 (186.5 - 220.66)
23	Tiruchy	196.64 (180.31 - 212.97)	192.76 (176.43 - 209.09)	188.95 (172.62 - 205.29)
24	Thiruvallur	208.87 (191.79 - 225.95)	206.21 (189.13 - 223.29)	203.58 (186.5 - 220.66)
25	Thiruvarur	208.87 (191.79 - 225.95)	206.21 (189.13 - 223.29)	203.58 (186.5 - 220.66)
26	Thoothukodi	231.89 (212.92 - 250.85)	228.92 (209.95 - 247.88)	225.99 (207.02 - 244.95)
27	Tirunelveli	285.44 (262.09 - 308.78)	281.74 (258.4 - 305.09)	278.1 (254.75 - 301.45)
28	Tiruppur	270.16 (248.06 - 292.26)	266.67 (244.58 - 288.77)	263.23 (241.14 - 285.33)
29	Thiruvanamalai	262.51 (241.04 - 283.98)	259.13 (237.66 - 280.6)	255.79 (234.32 - 277.26)
30	Vellore	296.89 (272.6 - 321.17)	293.03 (268.75 - 317.32)	289.24 (264.95 - 313.52)
31	Villupuram	289.25 (265.6 - 312.91)	285.51 (261.85 - 309.17)	281.81 (258.15 - 305.47)
32	Virudhunagar	239.55 (219.96 - 259.14)	236.48 (216.88 - 256.07)	233.44 (213.85 - 253.04)

Continued...

S.No	District	2023	2024	2025
1	Ariyalur	189.92 (173.79 - 206.05)	187.51 (171.38 - 203.64)	185.13 (169 - 201.26)
2	Chennai	296.47 (271.25 - 321.68)	292.62 (267.4 - 317.84)	288.84 (263.62 - 314.06)
3	Coimbatore	278.17 (254.51 - 301.83)	274.58 (250.92 - 298.24)	271.04 (247.38 - 294.69)
4	Cuddalore	263.51 (241.1 - 285.92)	260.12 (237.71 - 282.53)	256.77 (234.36 - 279.18)
5	Dharmapuri	215.73 (197.4 - 234.07)	212.98 (194.64 - 231.32)	210.26 (191.93 - 228.6)
6	Dindigul	237.81 (217.59 - 258.03)	234.76 (214.54 - 254.98)	231.76 (211.54 - 251.98)
7	Erode	241.48 (220.95 - 262.02)	238.39 (217.85 - 258.92)	235.33 (214.8 - 255.87)
8	kanchipuram	285.49 (261.21 - 309.77)	281.8 (257.52 - 306.08)	278.16 (253.88 - 302.44)
9	kanniyakumari	226.78 (207.5 - 246.05)	223.88 (204.6 - 243.15)	221.02 (201.74 - 240.3)
10	karur	193.61 (177.16 - 210.06)	191.15 (174.7 - 207.6)	188.72 (172.28 - 205.17)
11	krishnagiri	226.78 (207.5 - 246.05)	223.88 (204.6 - 243.15)	221.02 (201.74 - 240.3)
12	Madurai	274.51 (251.16 - 297.85)	270.96 (247.62 - 294.31)	267.47 (244.12 - 290.82)
13	Namakkal	219.41 (200.76 - 238.06)	216.61 (197.96 - 235.26)	213.85 (195.2 - 232.5)
14	Nagapattinam	223.1 (204.13 - 242.06)	220.25 (201.28 - 239.21)	217.43 (198.47 - 236.4)
15	Permbalur	186.23 (170.42 - 202.04)	183.87 (168.06 - 199.67)	181.54 (165.73 - 197.34)
16	Pudukottai	219.41 (200.76 - 238.06)	216.61 (197.96 - 235.26)	213.85 (195.2 - 232.5)
17	Ramanathapuram	204.68 (187.28 - 222.07)	202.07 (184.68 - 219.47)	199.5 (182.11 - 216.89)
18	Salem	278.17 (254.51 - 301.83)	274.58 (250.92 - 298.24)	271.04 (247.38 - 294.69)
19	Sivaganga	204.68 (187.28 - 222.07)	202.07 (184.68 - 219.46)	199.5 (182.11 - 216.89)
20	Thanjavur	245.16 (224.31 - 266)	242.01 (221.17 - 262.86)	238.91 (218.06 - 259.76)
21	The nilgiris	175.01 (159.59 - 190.43)	171.55 (156.13 - 186.97)	168.16 (152.74 - 183.58)
22	Theni	200.99 (183.91 - 218.07)	198.43 (181.35 - 215.51)	195.91 (178.83 - 212.99)
23	Tiruchy	185.22 (168.89 - 201.55)	181.55 (165.22 - 197.88)	177.96 (161.63 - 194.29)
24	Thiruvallur	200.99 (183.91 - 218.07)	198.43 (181.35 - 215.51)	195.91 (178.83 - 212.99)
25	Thiruvarur	200.99 (183.91 - 218.07)	198.43 (181.35 - 215.51)	195.91 (178.83 - 212.99)
26	Thoothukodi	223.1 (204.13 - 242.06)	220.24 (201.28 - 239.21)	217.43 (198.47 - 236.4)
27	Tirunelveli	274.51 (251.16 - 297.85)	270.96 (247.62 - 294.31)	267.47 (244.12 - 290.82)
28	Tiruppur	259.84 (237.75 - 281.94)	256.5 (234.4 - 278.59)	253.2 (231.1 - 275.3)
29	Thiruvanamalai	252.5 (231.03 - 273.97)	249.26 (227.79 - 270.73)	246.06 (224.59 - 267.53)
30	Vellore	285.49 (261.21 - 309.77)	281.8 (257.52 - 306.08)	278.16 (253.88 - 302.44)
31	Villupuram	278.17 (254.51 - 301.83)	274.58 (250.92 - 298.24)	271.04 (247.38 - 294.69)
32	Virudhunagar	230.45 (210.86 - 250.05)	227.51 (207.91 - 247.1)	224.6 (205.01 - 244.19)

Table 21. District wise TB Incidence without the impact of COVID-19 from 2017 to 2025

S.No	District	2017	2018	2019
1	Ariyalur	102.98 (99.25 - 106.71)	101.69 (97.96 - 105.42)	100.4 (96.67 - 104.13)
2	Chennai	161.05 (155.21 - 166.9)	158.99 (153.14 - 164.83)	156.92 (151.08 - 162.77)
3	Coimbatore	151.07 (145.58 - 156.55)	149.14 (143.65 - 154.62)	147.21 (141.72 - 152.69)
4	Cuddalore	143.07 (137.87 - 148.26)	141.25 (136.05 - 146.44)	139.43 (134.23 - 144.62)
5	Dharmapuri	117.03 (112.78 - 121.28)	115.56 (111.31 - 119.8)	114.08 (109.84 - 118.33)
6	Dindigul	129.06 (124.37 - 133.74)	127.42 (122.74 - 132.11)	125.79 (121.11 - 130.47)
7	Erode	131.06 (126.3 - 135.82)	129.4 (124.64 - 134.16)	127.74 (122.98 - 132.5)
8	kanchipuram	155.06 (149.43 - 160.69)	153.08 (147.45 - 158.71)	151.1 (145.46 - 156.73)
9	kanniyakumari	123.05 (118.58 - 127.51)	121.49 (117.03 - 125.96)	119.94 (115.47 - 124.4)
10	karur	104.99 (101.18 - 108.8)	103.67 (99.87 - 107.48)	102.36 (98.55 - 106.17)
11	krishnagiri	123.05 (118.58 - 127.51)	121.49 (117.03 - 125.96)	119.94 (115.47 - 124.4)
12	Madurai	149.07 (143.65 - 154.48)	147.16 (141.75 - 152.58)	145.26 (139.85 - 150.68)
13	Namakkal	121.04 (116.65 - 125.43)	119.51 (115.12 - 123.91)	117.99 (113.6 - 122.38)
14	Nagapattinam	119.04 (114.72 - 123.35)	117.54 (113.22 - 121.85)	116.04 (111.72 - 120.35)
15	Permbalur	100.97 (97.31 - 104.63)	99.71 (96.05 - 103.37)	98.45 (94.79 - 102.11)
16	Pudukottai	119.04 (114.72 - 123.35)	117.54 (113.22 - 121.85)	116.04 (111.72 - 120.35)
17	Ramanathapuram	111.01 (106.99 - 115.04)	109.62 (105.59 - 113.64)	108.22 (104.2 - 112.25)
18	Salem	151.07 (145.58 - 156.55)	149.14 (143.65 - 154.62)	147.21 (141.72 - 152.69)
19	Sivaganga	111.01 (106.99 - 115.04)	109.62 (105.59 - 113.64)	108.22 (104.2 - 112.25)
20	Thanjavur	133.06 (128.23 - 137.89)	131.38 (126.55 - 136.2)	129.69 (124.86 - 134.52)
21	The nilgiris	102.98 (99.25 - 106.71)	101.69 (97.96 - 105.43)	100.4 (96.67 - 104.14)
22	Theni	109 (105.05 - 112.96)	107.64 (103.68 - 111.59)	106.27 (102.32 - 110.22)
23	Tiruchy	145.07 (139.8 - 150.34)	143.22 (137.95 - 148.49)	141.37 (136.11 - 146.64)
24	Thiruvallur	153.06 (147.51 - 158.62)	151.11 (145.55 - 156.67)	149.15 (143.59 - 154.71)
25	Thiruvarur	109 (105.05 - 112.96)	107.64 (103.68 - 111.59)	106.27 (102.32 - 110.22)
26	Thoothukodi	121.04 (116.65 - 125.43)	119.51 (115.12 - 123.91)	117.99 (113.6 - 122.38)
27	Tirunelveli	149.07 (143.65 - 154.48)	147.16 (141.75 - 152.58)	145.26 (139.85 - 150.68)
28	Tiruppur	141.07 (135.95 - 146.19)	139.27 (134.15 - 144.39)	137.48 (132.36 - 142.6)
29	Thiruvanamalai	137.07 (132.09 - 142.04)	135.33 (130.35 - 140.3)	133.59 (128.61 - 138.56)
30	Vellore	155.06 (149.43 - 160.69)	153.08 (147.45 - 158.71)	151.1 (145.46 - 156.73)
31	Villupuram	151.07 (145.58 - 156.55)	149.14 (143.65 - 154.62)	147.21 (141.72 - 152.69)
32	Virudhunagar	125.05 (120.51 - 129.59)	123.47 (118.93 - 128.01)	121.89 (117.35 - 126.43)

Continued...

S.No	District	2020	2021	2022
1	Ariyalur	99.13 (95.4 - 102.86)	97.86 (94.13 - 101.59)	96.62 (92.89 - 100.35)
2	Chennai	154.88 (149.04 - 160.73)	152.87 (147.02 - 158.71)	150.88 (145.03 - 156.72)
3	Coimbatore	145.3 (139.81 - 150.79)	143.42 (137.93 - 148.9)	141.56 (136.07 - 147.04)
4	Cuddalore	137.62 (132.43 - 142.82)	135.85 (130.65 - 141.04)	134.09 (128.9 - 139.29)
5	Dharmapuri	112.62 (108.38 - 116.87)	111.18 (106.94 - 115.43)	109.76 (105.51 - 114.01)
6	Dindigul	124.17 (119.49 - 128.86)	122.58 (117.89 - 127.26)	121 (116.32 - 125.69)
7	Erode	126.1 (121.34 - 130.85)	124.47 (119.72 - 129.23)	122.87 (118.12 - 127.63)
8	kanchipuram	149.13 (143.5 - 154.76)	147.2 (141.57 - 152.83)	145.29 (139.66 - 150.92)
9	kanniyakumari	118.4 (113.94 - 122.87)	116.88 (112.42 - 121.35)	115.38 (110.92 - 119.85)
10	karur	101.06 (97.25 - 104.86)	99.77 (95.96 - 103.58)	98.5 (94.69 - 102.31)
11	krishnagiri	118.4 (113.94 - 122.87)	116.88 (112.42 - 121.35)	115.38 (110.92 - 119.85)
12	Madurai	143.38 (137.97 - 148.79)	141.52 (136.11 - 146.94)	139.69 (134.28 - 145.1)
13	Namakkal	116.48 (112.08 - 120.87)	114.98 (110.59 - 119.37)	113.51 (109.12 - 117.9)
14	Nagapattinam	114.55 (110.23 - 118.87)	113.08 (108.76 - 117.4)	111.64 (107.32 - 115.95)
15	Permbalur	97.2 (93.54 - 100.85)	95.96 (92.3 - 99.62)	94.74 (91.08 - 98.4)
16	Pudukottai	114.55 (110.23 - 118.87)	113.08 (108.76 - 117.4)	111.64 (107.32 - 115.95)
17	Ramanathapuram	106.84 (102.82 - 110.87)	105.48 (101.45 - 109.5)	104.13 (100.11 - 108.16)
18	Salem	145.3 (139.81 - 150.79)	143.42 (137.93 - 148.9)	141.56 (136.07 - 147.04)
19	Sivaganga	106.84 (102.82 - 110.87)	105.48 (101.45 - 109.5)	104.13 (100.11 - 108.16)
20	Thanjavur	128.02 (123.19 - 132.85)	126.37 (121.54 - 131.2)	124.74 (119.91 - 129.57)
21	The nilgiris	99.13 (95.39 - 102.86)	97.86 (94.13 - 101.6)	96.62 (92.89 - 100.35)
22	Theni	104.91 (100.96 - 108.87)	103.57 (99.62 - 107.53)	102.25 (98.3 - 106.21)
23	Tiruchy	139.54 (134.28 - 144.81)	137.74 (132.47 - 143.01)	135.96 (130.69 - 141.23)
24	Thiruvallur	147.22 (141.66 - 152.78)	145.31 (139.75 - 150.87)	143.42 (137.86 - 148.98)
25	Thiruvarur	104.91 (100.96 - 108.87)	103.58 (99.62 - 107.53)	102.25 (98.3 - 106.21)
26	Thoothukodi	116.48 (112.08 - 120.87)	114.98 (110.59 - 119.37)	113.51 (109.12 - 117.9)
27	Tirunelveli	143.38 (137.97 - 148.79)	141.52 (136.11 - 146.94)	139.69 (134.28 - 145.1)
28	Tiruppur	135.7 (130.58 - 140.83)	133.95 (128.83 - 139.07)	132.22 (127.1 - 137.34)
29	Thiruvanamalai	131.86 (126.89 - 136.84)	130.16 (125.19 - 135.14)	128.48 (123.51 - 133.46)
30	Vellore	149.13 (143.5 - 154.76)	147.2 (141.57 - 152.83)	145.29 (139.66 - 150.92)
31	Villupuram	145.3 (139.81 - 150.78)	143.42 (137.93 - 148.9)	141.56 (136.07 - 147.04)
32	Virudhunagar	120.33 (115.79 - 124.86)	118.78 (114.24 - 123.32)	117.26 (112.72 - 121.8)

Continued...

S.No	District	2023	2024	2025
1	Ariyalur	95.39 (91.66 - 99.12)	94.18 (90.45 - 97.91)	92.99 (89.26 - 96.71)
2	Chennai	148.92 (143.07 - 154.76)	146.99 (141.14 - 152.83)	145.09 (139.24 - 150.93)
3	Coimbatore	139.73 (134.24 - 145.21)	137.92 (132.44 - 143.41)	136.14 (130.66 - 141.63)
4	Cuddalore	132.36 (127.17 - 137.56)	130.66 (125.46 - 135.85)	128.97 (123.78 - 134.17)
5	Dharmapuri	108.36 (104.11 - 112.6)	106.97 (102.73 - 111.22)	105.61 (101.36 - 109.86)
6	Dindigul	119.45 (114.76 - 124.13)	117.92 (113.23 - 122.6)	116.41 (111.72 - 121.09)
7	Erode	121.3 (116.54 - 126.05)	119.74 (114.98 - 124.5)	118.21 (113.45 - 122.96)
8	kanchipuram	143.41 (137.77 - 149.04)	141.55 (135.92 - 147.18)	139.72 (134.09 - 145.35)
9	kanniyakumari	113.91 (109.44 - 118.37)	112.45 (107.98 - 116.91)	111.01 (106.55 - 115.48)
10	karur	97.24 (93.44 - 101.05)	96.01 (92.2 - 99.82)	94.79 (90.98 - 98.6)
11	krishnagiri	113.91 (109.44 - 118.37)	112.45 (107.98 - 116.91)	111.01 (106.55 - 115.48)
12	Madurai	137.89 (132.47 - 143.3)	136.11 (130.69 - 141.52)	134.35 (128.94 - 139.76)
13	Namakkal	112.06 (107.67 - 116.45)	110.63 (106.23 - 115.02)	109.21 (104.82 - 113.6)
14	Nagapattinam	110.21 (105.89 - 114.53)	108.8 (104.48 - 113.12)	107.41 (103.09 - 111.73)
15	Permbalur	93.54 (89.88 - 97.2)	92.35 (88.69 - 96.01)	91.18 (87.52 - 94.84)
16	Pudukottai	110.21 (105.89 - 114.53)	108.8 (104.48 - 113.12)	107.41 (103.09 - 111.73)
17	Ramanathapuram	102.8 (98.78 - 106.83)	101.49 (97.47 - 105.52)	100.2 (96.18 - 104.23)
18	Salem	139.73 (134.24 - 145.21)	137.92 (132.44 - 143.41)	136.14 (130.66 - 141.63)
19	Sivaganga	102.8 (98.78 - 106.83)	101.49 (97.47 - 105.52)	100.2 (96.18 - 104.23)
20	Thanjavur	123.14 (118.31 - 127.97)	121.56 (116.73 - 126.39)	120 (115.17 - 124.83)
21	The nilgiris	95.39 (91.66 - 99.12)	94.18 (90.45 - 97.91)	92.98 (89.25 - 96.72)
22	Theni	100.95 (97 - 104.91)	99.67 (95.71 - 103.62)	98.4 (94.45 - 102.35)
23	Tiruchy	134.2 (128.94 - 139.47)	132.47 (127.21 - 137.74)	130.77 (125.5 - 136.03)
24	Thiruvallur	141.57 (136.01 - 147.12)	139.74 (134.18 - 145.29)	137.93 (132.37 - 143.49)
25	Thiruvarur	100.95 (97 - 104.91)	99.67 (95.71 - 103.62)	98.4 (94.45 - 102.35)
26	Thoothukodi	112.06 (107.67 - 116.45)	110.62 (106.23 - 115.02)	109.21 (104.82 - 113.6)
27	Tirunelveli	137.89 (132.47 - 143.3)	136.11 (130.69 - 141.52)	134.35 (128.94 - 139.76)
28	Tiruppur	130.52 (125.4 - 135.64)	128.84 (123.72 - 133.96)	127.18 (122.06 - 132.3)
29	Thiruvanamalai	126.83 (121.86 - 131.81)	125.2 (120.22 - 130.18)	123.59 (118.62 - 128.57)
30	Vellore	143.4 (137.77 - 149.04)	141.55 (135.92 - 147.18)	139.72 (134.09 - 145.35)
31	Villupuram	139.73 (134.24 - 145.21)	137.92 (132.44 - 143.41)	136.14 (130.66 - 141.63)
32	Virudhunagar	115.75 (111.22 - 120.29)	114.27 (109.73 - 118.81)	112.81 (108.27 - 117.35)

Table 22. District wise TB Incidence with the impact of COVID-19 from 2020 to 2025

S.No	District	2020	2021	2022
1	Ariyalur	98.26 (94.59 - 101.92)	97.01 (93.34 - 100.67)	95.77 (92.1 - 99.44)
2	Chennai	153.53 (147.78 - 159.28)	151.53 (145.78 - 157.28)	149.56 (143.81 - 155.31)
3	Coimbatore	144.03 (138.64 - 149.42)	142.16 (136.77 - 147.55)	140.32 (134.93 - 145.71)
4	Cuddalore	136.42 (131.31 - 141.52)	134.66 (129.55 - 139.76)	132.92 (127.81 - 138.02)
5	Dharmapuri	111.64 (107.46 - 115.81)	110.21 (106.04 - 114.38)	108.8 (104.63 - 112.97)
6	Dindigul	123.08 (118.48 - 127.69)	121.5 (116.9 - 126.11)	119.94 (115.34 - 124.55)
7	Erode	124.99 (120.32 - 129.67)	123.38 (118.71 - 128.06)	121.8 (117.12 - 126.47)
8	kanchipuram	147.83 (142.29 - 153.36)	145.91 (140.38 - 151.44)	144.02 (138.48 - 149.55)
9	kanniyakumari	117.36 (112.97 - 121.75)	115.86 (111.47 - 120.25)	114.37 (109.99 - 118.76)
10	karur	100.17 (96.43 - 103.91)	98.89 (95.15 - 102.63)	97.63 (93.89 - 101.37)
11	krishnagiri	117.36 (112.98 - 121.75)	115.86 (111.47 - 120.25)	114.37 (109.99 - 118.76)
12	Madurai	142.13 (136.81 - 147.45)	140.29 (134.97 - 145.6)	138.47 (133.15 - 143.79)
13	Namakkal	113.55 (109.3 - 117.79)	112.09 (107.85 - 116.34)	110.66 (106.41 - 114.9)
14	Nagapattinam	115.45 (111.14 - 119.77)	113.97 (109.66 - 118.29)	112.52 (108.2 - 116.83)
15	Permbalur	96.34 (92.75 - 99.94)	95.12 (91.52 - 98.71)	93.91 (90.31 - 97.5)
16	Pudukottai	113.55 (109.3 - 117.79)	112.09 (107.85 - 116.34)	110.66 (106.41 - 114.9)
17	Ramanathapuram	105.9 (101.95 - 109.86)	104.55 (100.6 - 108.51)	103.22 (99.26 - 107.18)
18	Salem	144.03 (138.64 - 149.42)	142.16 (136.77 - 147.55)	140.32 (134.93 - 145.71)
19	Sivaganga	105.9 (101.95 - 109.86)	104.55 (100.6 - 108.51)	103.22 (99.26 - 107.18)
20	Thanjavur	126.9 (122.15 - 131.64)	125.26 (120.52 - 130.01)	123.65 (118.91 - 128.4)
21	The nilgiris	92.5 (88.55 - 96.45)	90.68 (86.73 - 94.62)	88.89 (84.94 - 92.84)
22	Theni	103.99 (100.11 - 107.88)	102.67 (98.78 - 106.55)	101.36 (97.47 - 105.24)
23	Tiruchy	97.9 (93.72 - 102.09)	95.97 (91.79 - 100.15)	94.08 (89.89 - 98.26)
24	Thiruvallur	103.99 (100.11 - 107.88)	102.67 (98.78 - 106.55)	101.36 (97.47 - 105.24)
25	Thiruvarur	103.99 (100.11 - 107.88)	102.67 (98.78 - 106.55)	101.36 (97.47 - 105.24)
26	Thoothukodi	115.45 (111.14 - 119.77)	113.97 (109.66 - 118.29)	112.52 (108.2 - 116.83)
27	Tirunelveli	142.13 (136.81 - 147.45)	140.29 (134.97 - 145.6)	138.47 (133.15 - 143.79)
28	Tiruppur	134.52 (129.48 - 139.55)	132.78 (127.75 - 137.81)	131.07 (126.03 - 136.1)
29	Thiruvanamalai	130.71 (125.82 - 135.6)	129.02 (124.13 - 133.91)	127.36 (122.47 - 132.25)
30	Vellore	147.83 (142.29 - 153.36)	145.91 (140.38 - 151.44)	144.02 (138.48 - 149.55)
31	Villupuram	144.03 (138.64 - 149.42)	142.16 (136.77 - 147.55)	140.32 (134.93 - 145.71)
32	Virudhunagar	119.27 (114.81 - 123.73)	117.74 (113.28 - 122.2)	116.23 (111.77 - 120.69)

Continued...

S.No	District	2023	2024	2025
1	Ariyalur	94.55 (90.89 - 98.22)	93.35 (89.69 - 97.02)	92.17 (88.5 - 95.84)
2	Chennai	147.62 (141.87 - 153.37)	145.71 (139.96 - 151.46)	143.82 (138.07 - 149.57)
3	Coimbatore	138.51 (133.11 - 143.9)	136.72 (131.33 - 142.11)	134.95 (129.56 - 140.34)
4	Cuddalore	131.2 (126.1 - 136.31)	129.51 (124.41 - 134.62)	127.85 (122.74 - 132.95)
5	Dharmapuri	107.41 (103.24 - 111.58)	106.04 (101.87 - 110.21)	104.69 (100.51 - 108.86)
6	Dindigul	118.4 (113.8 - 123.01)	116.89 (112.28 - 121.49)	115.39 (110.79 - 119.99)
7	Erode	120.23 (115.56 - 124.91)	118.69 (114.02 - 123.37)	117.17 (112.5 - 121.85)
8	kanchipuram	142.15 (136.62 - 147.69)	140.31 (134.78 - 145.85)	138.5 (132.97 - 144.04)
9	kanniyakumari	112.91 (108.52 - 117.3)	111.47 (107.08 - 115.85)	110.04 (105.65 - 114.43)
10	karur	96.39 (92.65 - 100.13)	95.17 (91.43 - 98.91)	93.96 (90.22 - 97.7)
11	krishnagiri	112.91 (108.52 - 117.3)	111.47 (107.08 - 115.85)	110.04 (105.65 - 114.43)
12	Madurai	136.68 (131.36 - 142)	134.92 (129.6 - 140.24)	133.18 (127.86 - 138.5)
13	Namakkal	109.24 (105 - 113.49)	107.85 (103.6 - 112.09)	106.47 (102.23 - 110.72)
14	Nagapattinam	111.08 (106.76 - 115.39)	109.66 (105.34 - 113.97)	108.26 (103.94 - 112.57)
15	Permbalur	92.72 (89.12 - 96.31)	91.54 (87.95 - 95.13)	90.38 (86.79 - 93.97)
16	Pudukottai	109.24 (105 - 113.49)	107.85 (103.6 - 112.09)	106.47 (102.23 - 110.72)
17	Ramanathapuram	101.9 (97.95 - 105.86)	100.61 (96.65 - 104.56)	99.33 (95.37 - 103.28)
18	Salem	138.51 (133.11 - 143.9)	136.72 (131.33 - 142.11)	134.95 (129.56 - 140.34)
19	Sivaganga	101.9 (97.95 - 105.86)	100.61 (96.65 - 104.56)	99.33 (95.37 - 103.28)
20	Thanjavur	122.06 (117.32 - 126.81)	120.5 (115.75 - 125.24)	118.95 (114.21 - 123.7)
21	The nilgiris	87.13 (83.18 - 91.08)	85.41 (81.46 - 89.36)	83.72 (79.77 - 87.67)
22	Theni	100.07 (96.18 - 103.95)	98.79 (94.91 - 102.68)	97.54 (93.65 - 101.42)
23	Tiruchy	92.22 (88.03 - 96.4)	90.39 (86.21 - 94.57)	88.6 (84.42 - 92.78)
24	Thiruvallur	100.07 (96.18 - 103.95)	98.79 (94.91 - 102.68)	97.54 (93.65 - 101.42)
25	Thiruvarur	100.07 (96.18 - 103.95)	98.79 (94.91 - 102.68)	97.54 (93.65 - 101.42)
26	Thoothukodi	111.08 (106.76 - 115.39)	109.66 (105.34 - 113.97)	108.26 (103.94 - 112.57)
27	Tirunelveli	136.68 (131.36 - 142)	134.92 (129.6 - 140.24)	133.18 (127.86 - 138.5)
28	Tiruppur	129.38 (124.34 - 134.41)	127.71 (122.68 - 132.75)	126.07 (121.04 - 131.1)
29	Thiruvanamalai	125.72 (120.83 - 130.61)	124.11 (119.22 - 129)	122.51 (117.62 - 127.4)
30	Vellore	142.15 (136.62 - 147.69)	140.31 (134.78 - 145.85)	138.5 (132.97 - 144.04)
31	Villupuram	138.51 (133.11 - 143.9)	136.72 (131.33 - 142.11)	134.95 (129.56 - 140.34)
32	Virudhunagar	114.74 (110.28 - 119.2)	113.27 (108.81 - 117.73)	111.82 (107.37 - 116.28)

Table 23. Comparison of Observed and Estimated TB notification rate from March 2020 to December 2022

Comparison of Observed vs Estimated				
Month	**Observed Rate**	**Estimated**		**Difference in Rate (%)**
		Rate	**Confidence Interval (95%)**	
Mar-20	9.80	12.9	(10.8 - 14.9)	-23.88
Apr-20	3.68	12.8	(10.1 - 15.5)	**-71.29**
May-20	5.74	13.5	(10.3 - 16.6)	-57.33
Jun-20	6.62	12.5	(9.1 - 16)	-47.23
Jul-20	5.04	12.5	(8.9 - 16.2)	-59.73
Aug-20	5.18	11.3	(7.5 - 15.1)	-54.30
Sep-20	7.10	11.0	(7.1 - 14.9)	-35.34
Oct-20	7.84	11.1	(7.1 - 15.1)	-29.51
Nov-20	7.75	11.6	(7.5 - 15.6)	-32.99
Dec-20	9.91	12.2	(8.1 - 16.3)	-18.71
Jan-21	9.12	12.4	(8.3 - 16.6)	-26.59
Feb-21	10.06	13.1	(8.9 - 17.2)	-22.94
Mar-21	10.90	13.4	(9 - 17.8)	-18.45
Apr-21	8.00	12.8	(8.3 - 17.4)	-37.65
May-21	4.15	13.3	(8.6 - 18)	**-68.72**
Jun-21	6.68	12.1	(7.3 - 16.9)	-44.83
Jul-21	10.04	12.5	(7.7 - 17.4)	-19.82
Aug-21	9.84	11.5	(6.6 - 16.4)	-14.52
Sep-21	10.26	11.1	(6.1 - 16)	-7.43
Oct-21	9.67	10.9	(5.9 - 15.9)	-11.55
Nov-21	9.03	11.8	(6.8 - 16.8)	-23.61
Dec-21	10.79	12.3	(7.3 - 17.4)	-12.46
Jan-22	8.82	12.1	(7.1 - 17.2)	-27.21
Feb-22	9.95	12.7	(7.7 - 17.8)	-21.84
Mar-22	11.29	13.2	(7.8 - 18.5)	-14.22
Apr-22	10.47	12.9	(7.3 - 18.5)	-18.66
May-22	10.56	13.4	(7.6 - 19.2)	-21.25
Jun-22	10.05	12.4	(6.5 - 18.3)	-18.75
Jul-22	5.72	12.5	(6.5 - 18.6)	-54.38
Aug-22	9.69	11.4	(5.4 - 17.5)	-15.36
Sep-22	10.13	11.1	(4.9 - 17.2)	- 8.33
Oct-22	9.23	11.1	(4.9 - 17.2)	-16.47
Nov-22	9.85	11.7	(5.5 - 17.9)	-15.80
Dec-22	9.5	12.2	(5.9 - 18.5)	-22.08

From table 23, the comparison of observed and estimated TB notification rate from March 2020 to December 2022 is observed that there is a decrease in the difference rate of observed rate of TB notification and estimated rate of Seasonal ARIMA (1,0,0)*(1,1,0)[12] in the month April 2020 i.e., -71.29%, and again it is decreasing in the month May 2021 i.e., -68.72%. The estimated rate was calculated using the ARIMA model (1,0,0)*(1,1,0)[12].

Figure 7. Impact of COVID on decline in TB Notification March 2020 to November 2022

The notified TB cases remains undetected, it is observed that the percentage of decline in TB notification is high, which is shown in the figure 7.

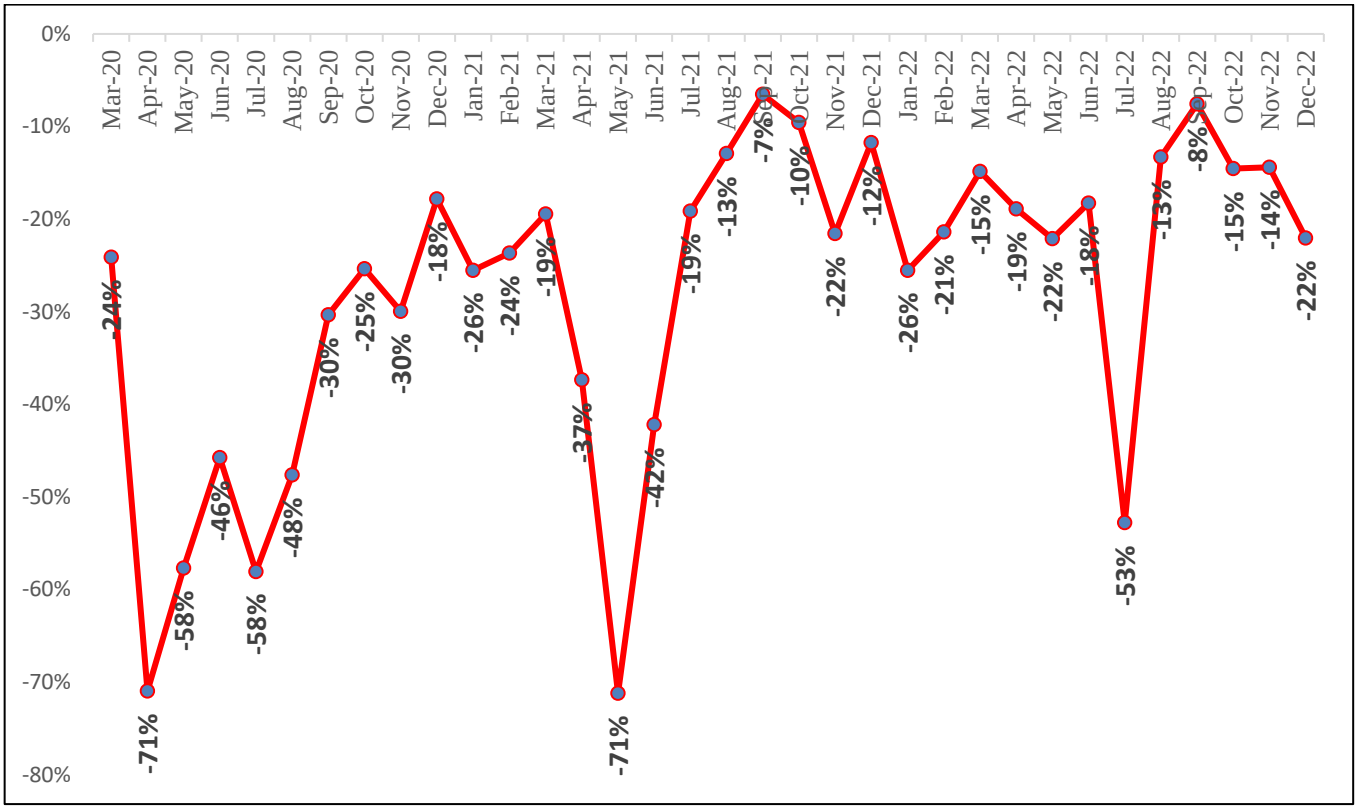


Table 24. Month wise TB notification rate from January 2017 to November 2022

TB notified rate						
Month	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
January	10.8	8.6	12.4	11.7	9.1	8.9
February	11.0	8.6	**13.2**	12.3	10.1	10.0
March	**13.3**	8.7	**13.3**	9.8	10.9	11.4
April	13.3	10.0	12.4	3.7	8.0	10.5
May	12.0	11.0	12.7	5.8	4.2	10.6
June	8.6	12.3	11.4	6.6	6.7	10.1
July	8.7	11.9	12.2	5.0	10.1	5.8
August	7.4	11.3	11.4	5.2	9.9	9.7
September	6.8	10.0	11.0	7.1	10.3	10.2
October	7.6	9.9	10.6	7.8	9.7	9.3
November	8.3	10.6	11.9	7.8	9.0	9.9
December	7.9	10.4	12.3	9.9	10.8	9.5

From table 24, it describes the month wise notified TB cases for public sector, private sector and overall (public + private) from January 2017 to December 2022. The notified TB rate were reported high in the month of March (13.3) followed by April (13.3) and May (12) in 2017. Further, the notified TB rate is reported high in the month of February and March in 2019.

Figure 8. TB Notification trend

The overall trend of observed rate of month wise notification from the period January 2017 to February 2020.

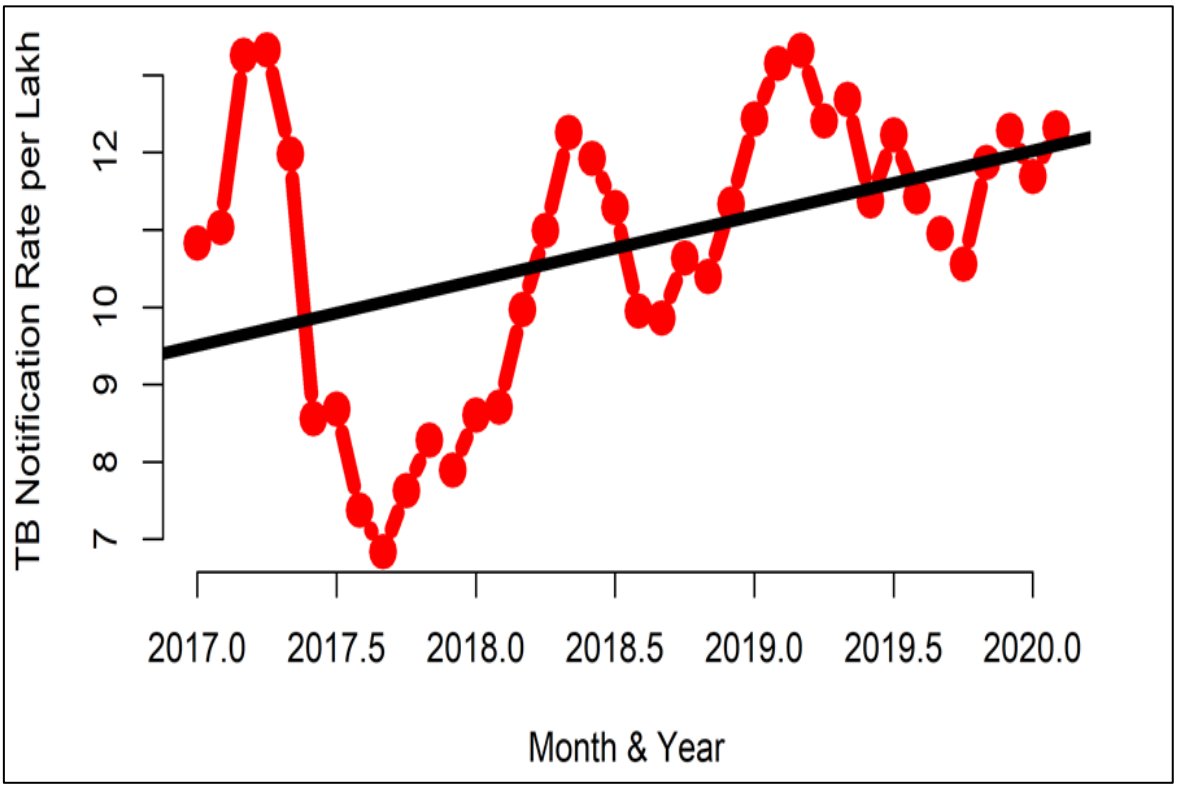
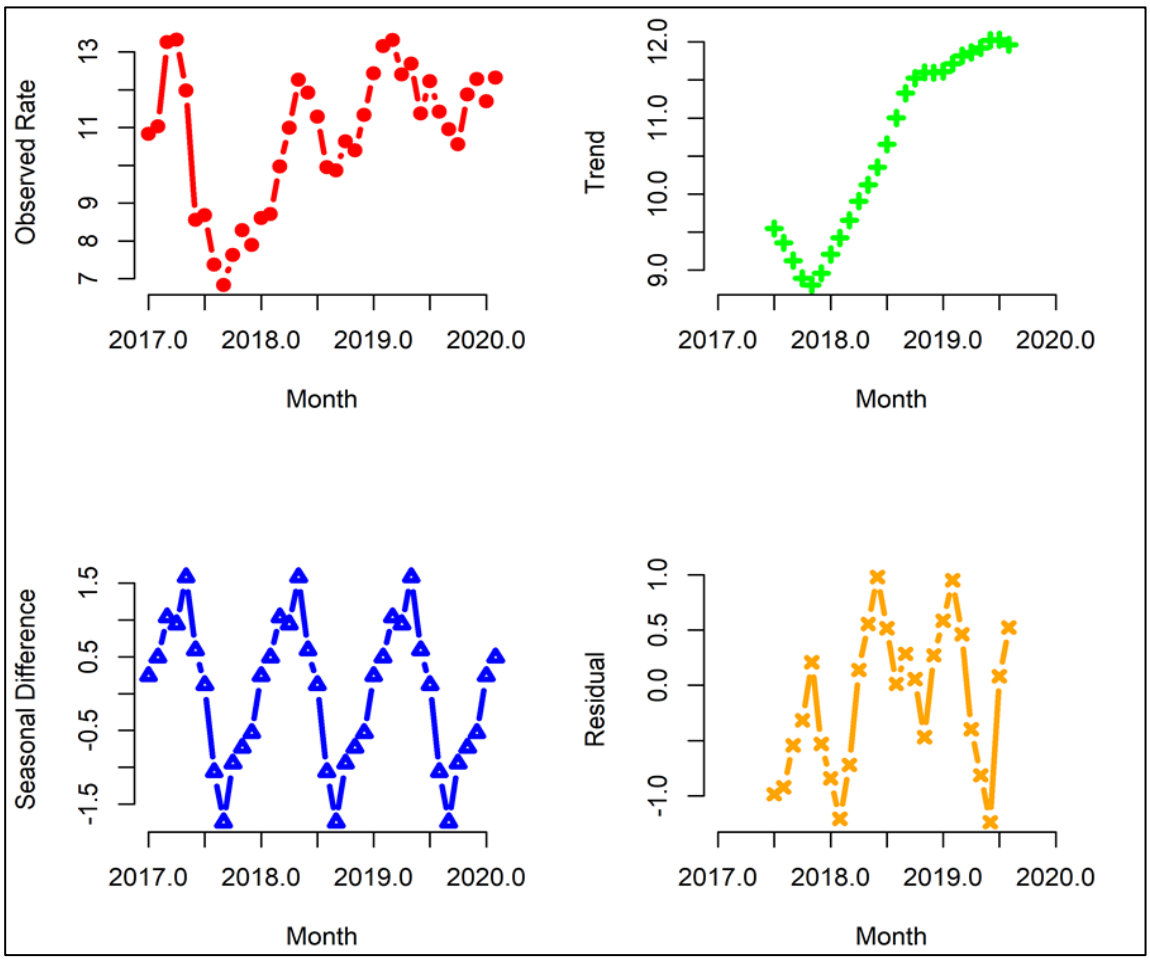


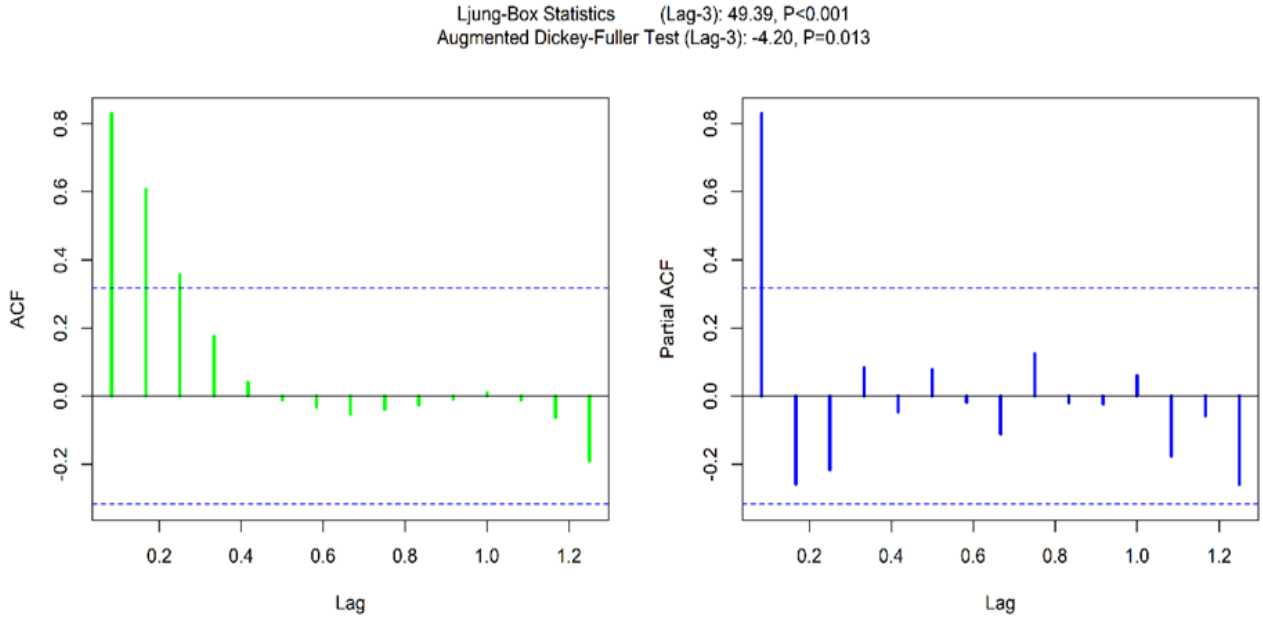
Figure 9. Decomposition of Additive Time Series for Overall Notified TB Cases



We observed the notification trend of moving average for the period 2017 to 2020. Further the month wise seasonal difference has been shown for the period January 2017 to February 2020 to show the fluctuations in the month wise difference in the notification trend for the period January 2017 to February 2020. We found the difference between the observed and predicted values of month wise notification trend for the same period.

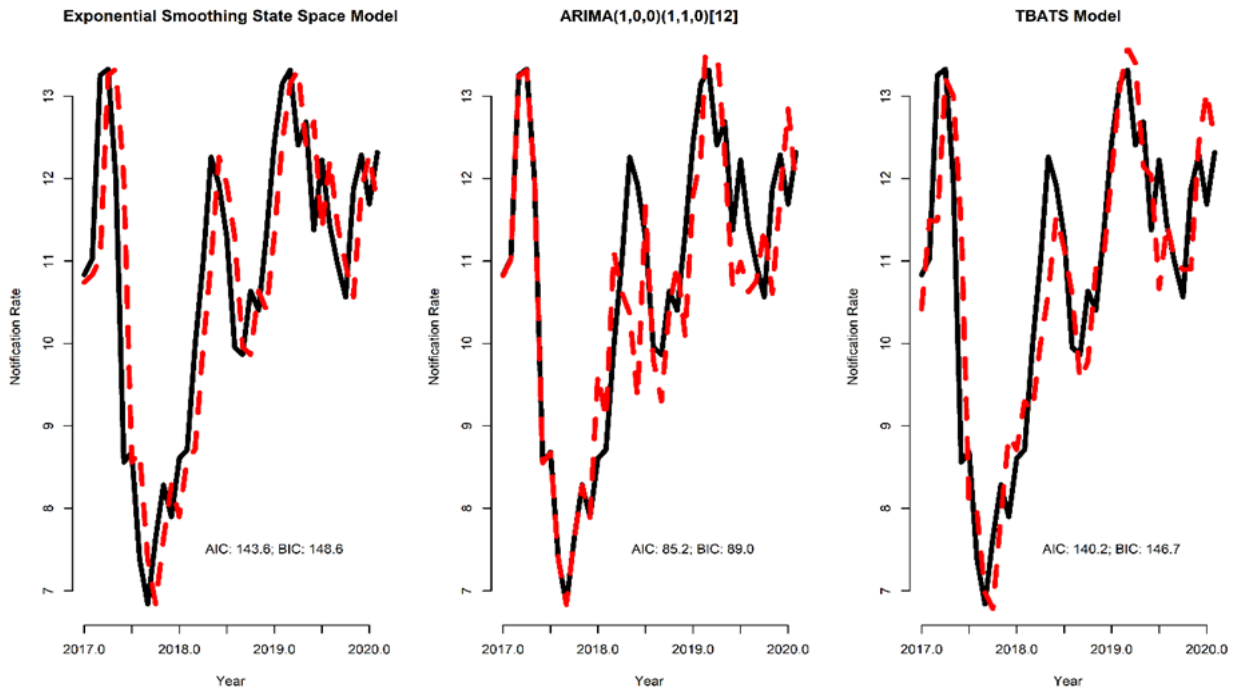
Figure 10. Ljung box Test

The ACF/PACF plot and Ljung Box statistic are used to assess the residuals of the ARIMA model, which indicate if the model accurately fits the data. The ADF test checks for stationarity, which is a necessary condition for the ARIMA model. It is observed from the results that the residuals are independently and identically distributed, and the time series is stationary, indicating that the ARIMA model is a suitable model for predicting the TB notification trend.



ARIMA model had the best fit for the prediction of TB notification trend in Tamil Nadu from 2017-2020, based on the AIC (Akaike Information Criteria) and BIC (Bayesian Information Criteria) values. The AIC value of 85.2 and BIC value of 89 for the ARIMA model suggest that it has a good fit for the observed data. The TBATS and ESSS models also showed a change in the trend of TB notification but with higher AIC (140.2 and 143.8) and BIC (146.7 and 148.6) values. This suggests that the ARIMA model is the best model to use for predicting TB notification in Tamil Nadu.

Figure 11. Model Prediction based on Exponential Smoothing State Space Model, ARIMA Model and TBATS Model



The minimum value of AIC is 85.2, therefore we conclude that ARIMA is a best suitable forecast model for the TB notification trend.

Figure 12. Model Forecast for Notified TB based on Seasonal ARIMA Model

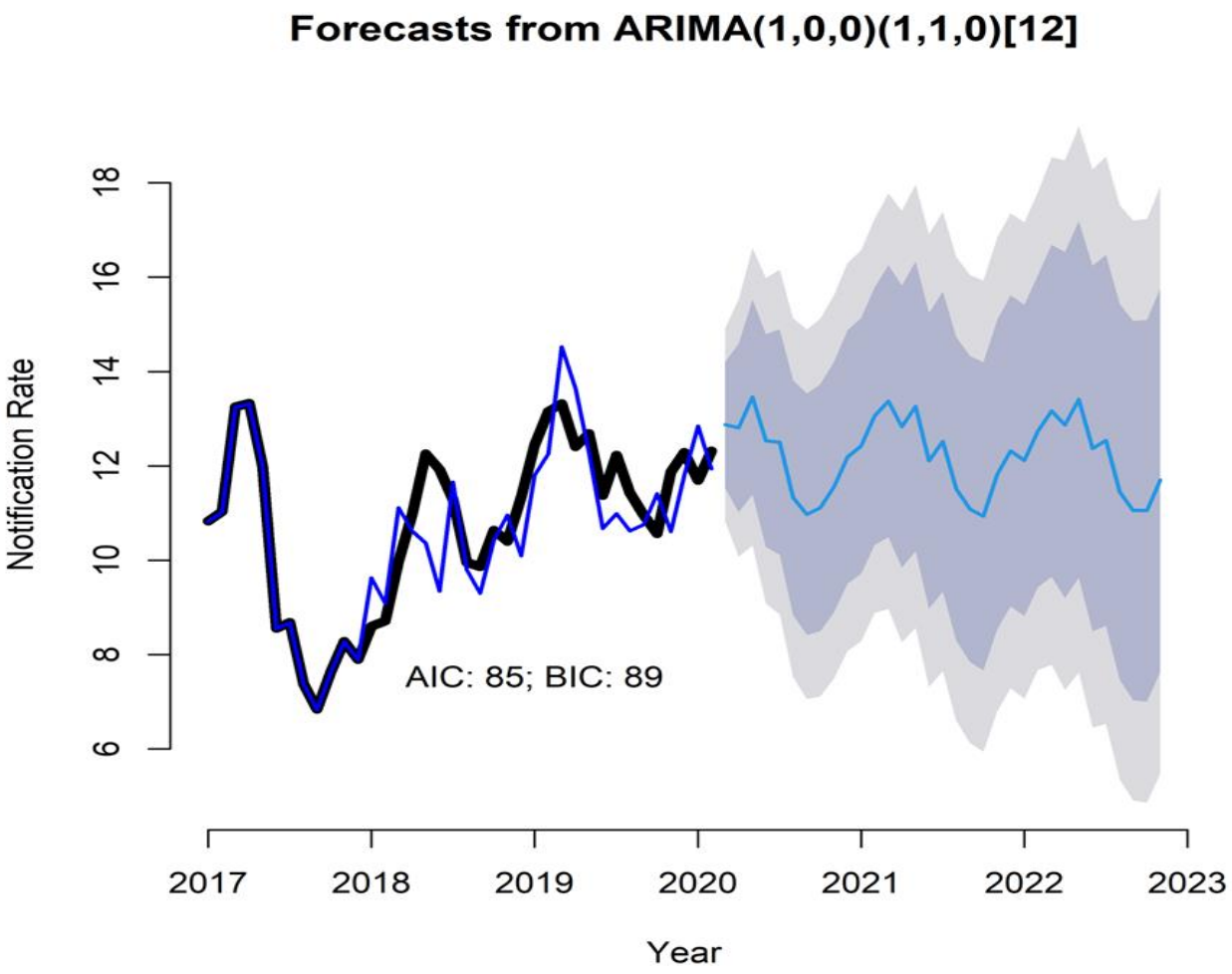


Figure 12 illustrates the model forecast for notified TB rate for the period from March 2020 to December 2022 using a Seasonal ARIMA Model, which was estimated based on data from January 2017 to February 2020. The black line represents the observed notified TB rate, while the blue line represents the estimated notified TB rate. The shaded region represents the estimated lower and upper confidence intervals for the years 2020 to 2022.

Figure 13. Impact of COVID on TB Notification

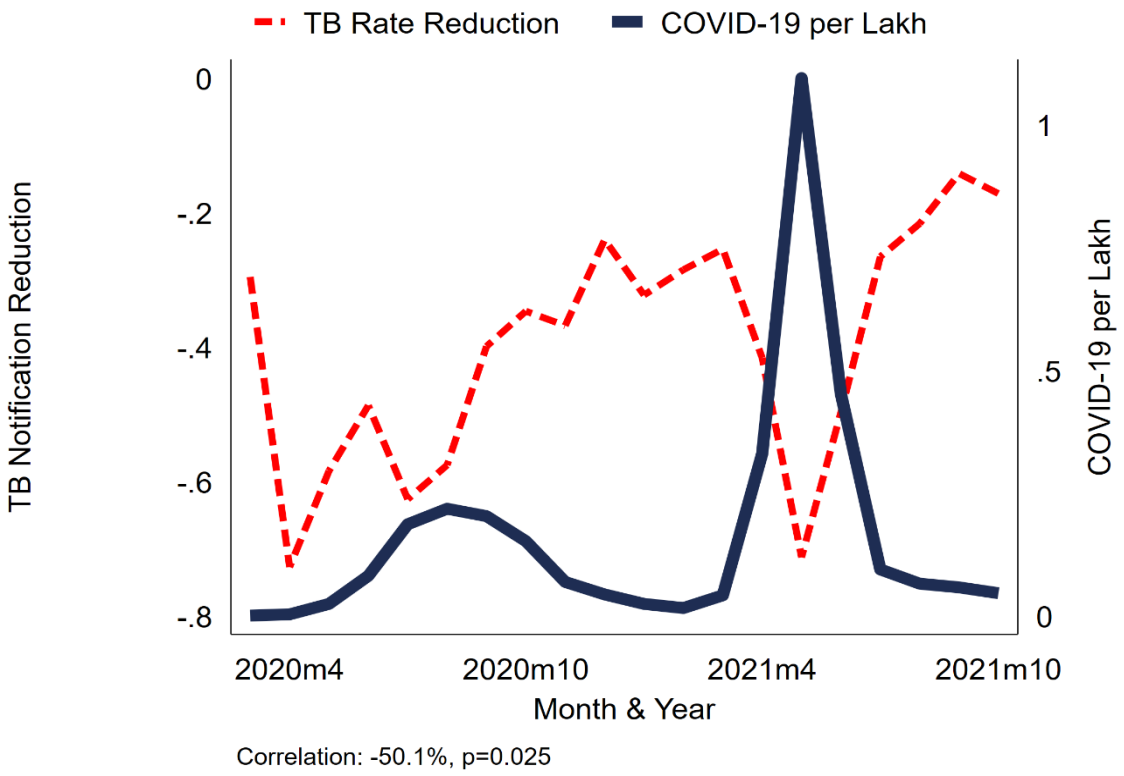
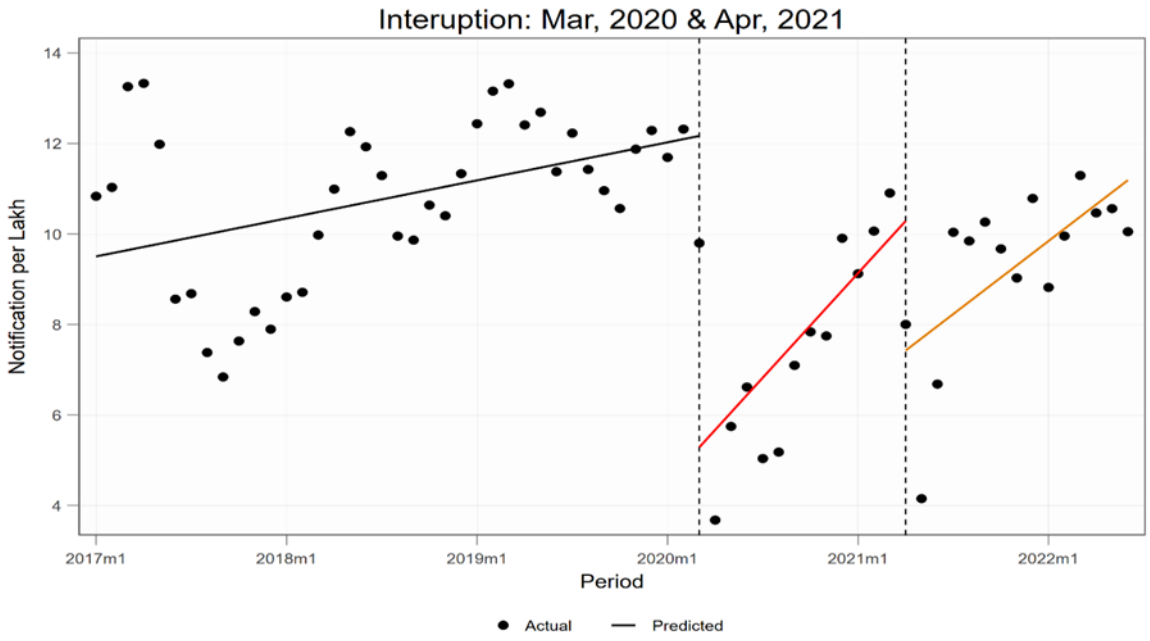


Figure 13 indicates that there is a significant association between the reduction in notified TB rate and the number of COVID-19 cases per lakh during the lockdown period from April 2020 to October 2021, ($P \leq 0.05$). There is a significant association between the reduction of notified TB rate and COVID-19 cases per lakh during the COVID-19 pandemic lockdown period.

Figure 14. Interrupted Time Series (ITS)

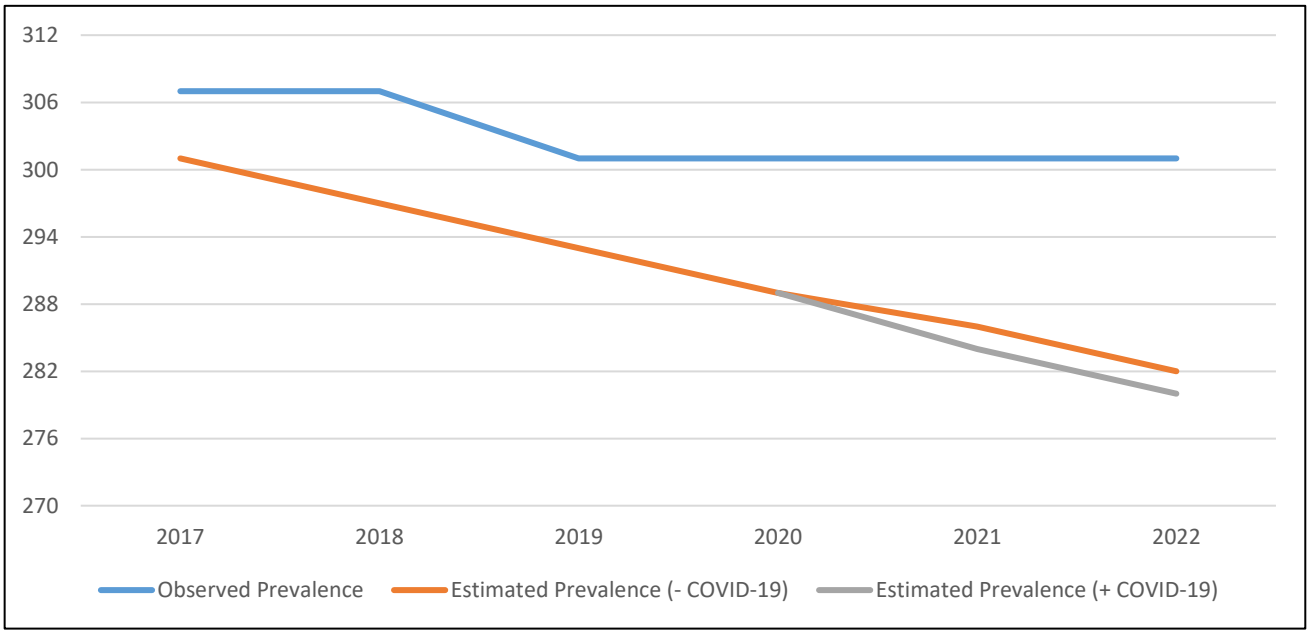
It is observed that there is an interruption in the TB notification reduction because of the first and second wave of COVID-19 pandemic. During the first (p=0.012) and second (p=0.010) wave, there is an associate between the reduction of notified TB Rate and COVID-19 cases per Lakh Population.



The interruption result shows that the Interrupted Time Series (ITS) analysis has been performed to assess the change in the significance of notified trend between before COVID-19 and during COVID-19 interruption.

Observed Prevalence Rate and estimated Prevalence Rate on TB (without/with COVID-19) in Tamil Nadu from the year 2017-2022

Year	Observed Prevalence	Estimated Prevalence (without COVID-19)	Estimated Prevalence (with COVID-19)
2017	307	301	-
2018	307	297	-
2019	301	293	-
2020	301	289	289
2021	301	286	284
2022	301	282	280



V. Discussion

The possibility of bringing down tuberculosis (TB) incidence to pre-elimination levels in Tamil Nadu is a multifaceted issue. In 2019 strategic document for TB free Tamil Nadu reported that the state faced various challenges. One of the critical challenges is on-the-job migration, particularly among labourers from North-eastern parts of the country.[48] Due to high infection rates in their states of origin, many migrants have acquired TB infection, leading to an increased risk of developing active TB disease. Vulnerable groups, such as the poor, homeless[49], migrants, and tribal people[50,51,52] are also at risk of TB infection and progression due to factors such as increased exposure and infection risks.[48] Additionally, the state is witnessing an increasing trend of diabetes, which plays a significant role in the development of TB disease. Industrial workers, particularly those in the cotton industry, are also at risk of developing TB due to non-usage of proper personal protection. The state has a high prevalence of HIV compared to other states, but the sustained intervention of the state has helped to reduce it. However, 5% to 10% of diagnosed TB cases are also HIV positive, prompting the initiation of INH preventive therapy to all HIV positive individuals without any evidence of the disease.[48]

The state facing a significant TB risk due to a considerable number of people reporting contact with TB cases during their childhood, when chemoprophylaxis was not available, in addition to high co-morbidity rates of HIV and diabetes among TB patients. However, TB remains common among chronic smokers[53], habitual alcoholics[54], and people with a history of chronic respiratory illness.[55] Despite these challenges, it is expected that the incidence of TB will significantly drop in the coming years, as the current younger cohort with a low prevalence of latent TB infection (LTBI) becomes older. Early detection of TB cases through household contact tracing and active case finding, as well as screening for and treating LTBI in suitable settings, could accelerate the declined.[48]

Moreover in 2020 Coronavirus disease (COVID-19) is an infectious disease emerged in India and it brought more additional challenges for the TB elimination program. In Tamil Nadu, tuberculosis (TB) case findings that were hit in the midst of the COVID-19 pandemic have improved with targeted interventions. Now, to reduce the TB burden to 44 per one lakh population by 2025, Tamil Nadu is aiming at testing more for TB along the same lines of COVID-19 to detect more cases.[56] The following measures taken in Tamil Nadu for COVID-19 Pandemic, that includes geographic quarantine, social distancing measures, enhanced active surveillance, testing all suspected cases, isolation of cases, and home quarantine of contacts, advocacy and social mobilization to follow preventive public health

measures. However, in order to increase active case finding and case detection, the services for tuberculosis can be followed in a right way.[57]

The present study is the TB prevalence amongst all districts of population from across the state of Tamil Nadu. The results provide vital information on the TB disease situation amongst this population and can serve as baseline data for future evaluation of the impact of disease control measures and epidemiological trends. From the SEIR model, we estimated the TB prevalence and TB incidence from 2017 to 2021 in Tamil Nadu. This may be mainly attributed to a series of stringent measures taken during COVID-19 pandemic, as well as the increased awareness of self-protection and protective measures taken by people, which also reduced the chance of TB infection. The global incidence of TB has been decreasing by approximately 2% annually, and from 2015 to 2020, the overall reduction amounted to 11%. This progress represents more than 50% of the targeted 20% reduction set forth in the End TB Strategy for the 2015-2020 period.[58] This was over half way to the End TB Strategy milestone of 20% reduction between 2015 and 2020[59]. Further, the COVID-19 pandemic brought about lifestyle changes, including encouragement to wear masks, wash hands, and maintain social distance. This implementation of preventative measures against the transmission of SARS-CoV-2 may have had a significant impact on reducing respiratory infections in many cases. The impact of lockdown can also be perceived as only 34,566 TB patients were notified nationwide during the past 3 weeks in comparison to 1,14,460 patients in early March 2020 (pre-lockdown phase).[60] These preventive measures against transmission of diseases may have contributed to the decline in many types of respiratory infectious diseases, especially Tuberculosis.

TB notification play vital role in improving the standard of care for TB patients in Tamil Nadu. The notification of TB cases is essential as it helps both private and public health sectors to provide better care for patients. However, the private health sector has not been notifying TB cases as effectively as the public sector, which is concerning because over 40% of TB cases are caused by the private sector and many of these cases go unreported. [61] This has led to a lower cure rate in 2020 compared to 2019, due to delays in diagnosis and reduced screening for TB during the COVID-19 pandemic. COVID-19 and tuberculosis (TB) can occur simultaneously in a patient, and individuals with active pulmonary TB are at higher risk for worse outcomes if they contract COVID-19. Few studies found that low income and poverty to be a risk factor for diagnostic delay.[62,63] The symptoms of the two diseases can be similar, making it challenging to diagnose. However, the widespread use of imaging techniques such as chest radiography and computerized tomography may facilitate the early detection of TB in individuals who have contracted COVID-19, as these tests can reveal pre-existing TB infections.[64]

In general, the co-infection of COVID-19 and tuberculosis by the viral respiratory infections and TB impair the host's immune responses. TB patients often live in crowded conditions with poor hygiene, which increases their risk of getting COVID-19. From the study conducted in China and India among the co-infected population, TB plays a role in the development of COVID-19 infection and exacerbation of the course of the disease.[65] There is a possibility of the reduction of TB incidence among persons who did not receive the intervention like an ecological fallacy. A study conducted in 1999-2005 demonstrated the benefits of implementing a tuberculosis control program based on DOTS. It is clear that reducing TB infection over this partial period will be beneficial for this period in infection control.[66] Social distancing is one of the important preventive measures for COVID-19. The findings also suggest that promoting better health, such as reducing body mass index and lowering smoking rates, may help prevent illnesses and deaths during future pandemics. The available evidence on the other sources like reports and published literature suggests that COVID-19 happens regardless of TB occurrence either before, during or after an active TB diagnosis. But still more evidence is required to determine if COVID-19 may reactivate or worsen active TB disease.

The COVID-19 pandemic has highlighted the importance of public health measures, such as testing and contact tracing, in controlling the spread of infectious diseases. By applying similar approaches to other diseases, such as TB, it is possible to improve detection and reduce the burden of illness in the population. It is important for health systems to remain vigilant and adaptable in the face of emerging threats, to ensure the best possible outcomes for patients and communities.

VI. Conclusion

This study has reflected the substantial changes in TB that resulted from the COVID-19 pandemic. During the COVID-19 pandemic, there was a higher incidence of mortality within the group affected by COVID-19 compared to the pre-pandemic period. The TB prevalence, TB incidence, and TB notification in Tamil Nadu were impacted effectively by the pandemic of COVID-19. The study analysed the changes in TB prevalence, incidence, and notification and found that these were significantly affected by the COVID-19 pandemic. The findings were based on various aspects of TB, including latent TB, active/infectious TB, treatment outcome, prevalence, incidence, and notification. We estimated TB prevalence and incidence in all the districts of Tamil Nadu and made predictions for both till the year 2025. Furthermore, we demonstrated without considering the influence of COVID-19 on the TB prevalence and incidence between 2017 and 2025, as well as the TB prevalence and incidence estimates for 2020 to 2025 considering the impact of COVID-19. If the COVID-19 pandemic had not occurred, the estimated TB prevalence and incidence in Tamil Nadu would have shown a decreasing trend from 2017 to 2025. However, taking into account the impact of the COVID-19 pandemic, the estimated TB prevalence and incidence in Tamil Nadu are higher, but still follow the same decreasing trend from 2020 to 2025. The results provide a reliable estimate of the trend of pulmonary TB in Tamil Nadu. The changes in lifestyle brought about by the COVID-19 pandemic, including increased mask-wearing, handwashing, and social distancing, have played a role in reducing the number of TB cases. However, the delay in diagnosing for initiating TB treatment has contributed to an increase in TB cases. The implementation of preventative measures to reduce the transmission of SARS-CoV-2 may have significantly contributed to the reduction of respiratory infections, and this may have affected the estimated TB prevalence in the population of Tamil Nadu from 2017 to 2025.

From the results, it is observed that there is an annual decline in the TB notification for the year 2020 to 2022. The results of this study can help in understanding the impact of COVID-19 on the trend of notified TB cases in Tamil Nadu and can be used to design effective strategies to address this issue. Moreover, we have found that there is an interruption in the TB notification reduction because of the first and second wave of the COVID-19 pandemic lockdown from the period March 2020 to April 2021. It may be mainly attributed to a series of strict measures taken during the COVID-19 pandemic, as well as the increased awareness of self-protection and protective measures taken by people, which also reduced the chance of TB infection. Our findings can help to improve the control measures and

prevention of TB in Tamil Nadu. By understanding the impact of COVID-19 on TB, public health professionals can develop effective strategies to reduce the burden of TB and ensure the continuation of TB prevention and response activities during the COVID-19 pandemic.

VII. Limitation

This analysis had several limitations. As this study was carried out among adults (≥18 years of age), our focus was only on the TB Prevalence, Incidence and Notification who got notified by the private and public sector and their routinely recorded data was used to represent the prevalence of tuberculosis. In 2017, TB notification data was extracted from the Nikshay portal in 31 districts of Tamil Nadu, even though the state had officially been divided into 38 districts following that year. This study model assumes constant parameter values, and limited factors affecting disease transmission. However, in reality, populations are not uniformly mixed, can grow or decline, and have various factors influencing disease transmission. The model only considers susceptibility, infectiousness, and recovery, ignoring factors such as age, immunity, and genetics. Additionally, the model is short-term and not suitable for predicting long-term epidemic evolution. People with tuberculosis are not more likely to get COVID-19, but pre-existing tuberculosis has a higher chance of developing serious complications from COVID-19. More high-quality studies from different countries are needed to better understand the association between tuberculosis and COVID-19 prognosis.[67] Strengthening the governmental policies toward rapid adoption of TB control measures in times of newer challenges like COVID-19 must be an immediate priority in mitigating the disease burden.[68]

The impact of COVID-19 on the tourism, hospitality, and recreation industries has been unprecedented, with a 75% decline in quarterly revenues observed in the accommodation and lodging sectors. It is difficult to estimate the impact of social distancing and overall decline of economic activity. Because of India's vast population and diversity, it may be difficult to obtain accurate prevalence data, and the process would require a significant investment of resources and time. However, despite these logistical challenges, analyzing reliable data on COVID-19 deaths over time can provide valuable information about the trajectory of the epidemic and the impact of public health measures.[45] The purpose of these analyses is not to predict future outcomes, but to provide possible scenarios of how the pandemic may progress, based on potential state and actions taken. The Indian government is working hard to resolve TB issues through revised plans and their implementation throughout the country. Our model does not incorporate the impact of age, which appears to have a significant effect on disease transmission and mortality. Other models have conducted analyses at the state level, to show potential interactions before and during COVID-19. While these more sophisticated methods may offer some advantages, the results of this analysis are generally consistent

with these analyses, and we believe a simpler analysis may be more accessible to help understand the broad effects of different types of available interventions. Despite this, much work remains to achieve a significant reduction in the high incidence and prevalence of TB in India.[69]

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Database

The Potential Impact of COVID-19 Pandemic on Tuberculosis Epidemic

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Content

I. Demography

I.1. Population

Table I.1.1 Total population of Tamil Nadu (2001 and 2011)

Age-group	2001			2011		
	Total	Males	Females	Total	Males	Females
0-4	66229	33853	32376	5278701	2714578	2564123
5-9	75877	39365	36512	5551255	2851293	2699962
10-14	68790	35985	32805	6177547	3188990	2988557
15-19	60595	31068	29527	6253792	3229838	3023954
20-24	56623	25929	30694	6411543	3154804	3256739
25-29	59703	28500	31203	6663746	3237374	3426372
30-34	46699	22674	24025	5815560	2908749	2906811
35-39	52409	25159	27250	5836456	2815205	3021251
40-44	39128	20824	18304	5064209	2549846	2514363
45-49	36052	19267	16785	4713056	2374915	2338141
50-54	25415	13619	11796	3703460	1875563	1827897
55-59	18583	9316	9267	3101142	1540924	1560218
60-64	17759	9118	8641	2782608	1378039	1404569
65-69	10030	4858	5172	1868370	896412	971958
70-74	7620	4128	3492	1406529	693167	713362
75-79	2959	1586	1373	710241	353746	356495
80+	3680	2024	1656	742010	339862	402148
Others	3170	1644	1526	66805	34670	32135
TOTAL	**651321**	**328917**	**322404**	**72147030**	**36137975**	**36009055**

Source: Government of Tamil Nadu, Census and Survey (tn.data.gov)

Table I.1.2. Population of Tamil Nadu over a period

Year	Population. (Lakhs)
2011	721
2012	732
2013	742
2014	752
2015	765
2016	771
2017	783
2018	793
2019	804
2020	814
2021	824
2022	834

Source: Central Tuberculosis Division, Government of India, NTEP Reports 2018 to 2022

Table I.1.3. Population of Tamil Nadu

Sl.No	Year	Total Population.	Males	Females
1	2017	7,49,88,000	3,75,06,000	3,74,82,000
2	2018	7,53,42,000	3,76,71,000	3,76,71,000
3	2019	7,56,96,000	3,78,36,000	3,78,60,000
4	2020	7,60,49,000	3,80,00,000	3,80,49,000
5	2021	7,64,02,000	3,81,65,000	3,82,37,000
6	2022	7,66,31,000	3,82,63,000	3,83,68,000

Source: National Commission on Population Ministry of Health & Family Welfare, New Delhi. Census of India 2011. Population projections for India and states 2011-2036

Table I.1.4. District wise population

District	2017	2018	2019	2020	2021	2022
Chennai	4852444	4881607	4910946	4940461	4970153	5000023
Coimbatore	3599696	3621330	3643094	3664989	3687016	3709175
Cuddalore	2696088	2712292	2728593	2744991	2761489	2778085
Dharmapuri	1557915	1567279	1576698	1586174	1595707	1605297
Dindigul	2240487	2253952	2267498	2281126	2294836	2308628
Erode	2342324	2356401	2370563	2384810	2399143	2413561
Kancheepuram	4136988	4161852	4186864	4212028	4237342	4262809
Kanniyakumari	1931378	1942985	1954663	1966410	1978228	1990117
Karur	1115998	1122705	1129452	1136240	1143069	1149939
Krishnagiri	1952687	1964423	1976229	1988106	2000055	2012075
Madurai	3152359	3171305	3190364	3209538	3228828	3248233
Nagapatinam	1673154	1683210	1693326	1703503	1713741	1724040
Namakkal	1784185	1794908	1805695	1816547	1827465	1838448
Perambalur	1365202	1373407	1381661	1389965	1398319	1406723
Pudukkottai	1677980	1688065	1698210	1708416	1718684	1729013
Ramanathapuram	1386523	1394856	1403239	1411673	1420157	1428692
Salem	3607398	3629078	3650889	3672831	3694905	3717111
Sivaganga	1390348	1398704	1407110	1415567	1424075	1432633
Thanjavur	2490738	2505707	2520766	2535916	2551157	2566489
The Nilgiris	761979	766559	771166	775800	780463	785153
Theni	1289211	1296959	1304753	1312595	1320484	1328420
Thiruvallur	3862081	3885292	3908642	3932133	3955765	3979539
Thiruvarur	1314514	1322414	1330362	1338358	1346401	1354493
Thoothukudi	1802011	1812841	1823737	1834697	1845724	1856816
Tiruchirappalli	2813202	2830109	2847118	2864230	2881444	2898761
Tirunelveli	3185367	3204511	3223770	3243144	3262636	3282244
Tiruppur	2561684	2577080	2592568	2608149	2623824	2639593
Tiruvannamalai	2559345	2574727	2590201	2605768	2621428	2637183
Vellore	4071899	4096371	4120990	4145758	4170674	4195739
Viluppuram	3590062	3611638	3633344	3655180	3677148	3699248
Virudhunagar	2014446	2026553	2038733	2050985	2063312	2075712

Source: Estimated with growth rate 0.68% based on National Commission on Population Ministry of Health & Family Welfare, New Delhi. Census of India 2011 data

I.2. Migration

Table I.2. Migration

	Year	Total population			Rural			Urban		
		Total	Male	Female	Total	Male	Female	Total	Male	Female
Based on Census[1]	1991	13430472	4622136	8808336	8032560	2144684	5887876	5397912	2477452	2920460
	2001	15824383	6671234	9153149	8073309	2918171	5155138	8073309	2918171	5155138
	2011	31274107	12784326	18489781	14560394	5073538	9486856	16713713	7710788	9002925
Average										
Arithmetic method[2]	2016	35735016	14824874	20910142	16192353	5805752	10386601	19542663	9019122	10523541
	2017	36627198	15232983	21394215	16518744	5952194	10566550	20108453	9280789	10827665
	2018	37519379	15641093	21878287	16845136	6098637	10746499	20674243	9542456	11131788
	2019	38411561	16049202	22362359	17171528	6245080	10926448	21240033	9804122	11435911
	2020	39303743	16457312	22846431	17497919	6391522	11106397	21805823	10065789	11740034
	2021	40195925	16865421	23330504	17824311	6537965	11286346	22371614	10327456	12044158
	2022	41088106	17273531	23814576	18150703	6684408	11466295	22937404	10589123	12348281
Geometric growth rate[3]	2016	41405288	17762309	23932624	17751579	6629741	11310540	24364570	11919148	12959703
	2017	43795551	18969842	25200086	18469271	6994130	11715357	26272168	13003926	13939184
	2018	46323799	20259468	26534673	19215979	7378546	12134663	28329120	14187431	14992692
	2019	48998000	21636766	27939939	19992877	7784092	12568977	30547118	15478649	16125824
	2020	51826578	23107697	29419627	20801184	8211927	13018836	32938772	16887383	17344597
	2021	54818445	24678626	30977679	21642172	8663277	13484795	35517678	18424327	18655483
	2022	57983028	26356352	32618244	22517160	9139435	13967431	38298497	20101151	20065444

Source: [1]National Commission on Population Ministry of Health & Family Welfare, New Delhi. Census of India 1991, 2001 & 2011
[2]Estimated with reference 1 by Arithmetic method
[3]Estimated with reference 1 by Geometric growth method

II. Tuberculosis

II.1. Latent TB

Table II.1.1: Latent TB Infection

S.No.	Reference	Year	Study area	Population	Sample size	LTBI (%, 95% CI)
Tamil Nadu						
1.	Chandrasekaran et al.	2018	Pune & Chennai	Household contacts	869	646 (74.3, 71.3 - 77.1)
2.	Praveen et al.	2020	South India	Household contacts	220	96 (43.6, 37.3 – 50.2)
3.	Krishnamoorthy et al.	2021	South India	Household contacts	1523	801 (52.6, 50.1 – 55.1)
4.	Narasimhan et al.	2017	South India	Household contacts	359	143 (44.1, 38.8 – 49.6)
5.	Paradkar et al.	2020	Pune & Chennai	Household contacts	997	707 (70.9, 68.0 – 73.7)
6.	A N Karthik et al	2020	Madurai	Children contact with TB patient	140	31 (29.8 %)
7.	Pradipkumar A. Dabh et al	2020	Vellore	NIDDM patient	1000	103(10.3 %)
8.	Natasha S,Hoghberg et al	2017	Puducherry	Household contacts	1259	906 (77.1%)
Others						
9.	Chauhan et al.	2013	Northern India	Household contacts	240	78 (39.0, 32.5 - 45.9)
10.	Sharma et al.	2017	Delhi	Household contacts	1511	917 (60.7, 58.2 – 63.1)
11.	Sanjay k jane	2013	Pune	Children	223	27 (12%)
12.	Purushottam A Giri et al	2013	Maharashtra	HIV patients	1012	172 (16.9%)

II.2. Prevalence of tuberculosis

Table: II.2.1 Prevalence of tuberculosis

S. No	Published Year	Author	Year of study	Location	Urban/ Rural	Study setting	Methodology
Tamil Nadu							
1	2022	ICMR, New Delhi	2019-2021	Tamil Nadu	Both	National survey	Screening with tuberculosis symptoms, followed by X-ray sputum smear examination and culture
2	2021	Chandra Kumar Dolla et al	2015-2018	Thiruvallur	Rural	Household community	Screened with X-Ray, followed by sputum smear examination and culture
3	2015	Dhanaraj et al	2010-2012	Chennai, Tamil Nadu	Urban	Community Survey	Screening with tuberculosis symptoms and mass miniature radiography, followed by sputum smear examination and culture
4	2013	Kolappan et al	1999-2001	Tiruvallur, Tamil Nadu	Rural	Community Survey	Screening with tuberculosis symptoms and/or radiographic examination, followed by sputum smear examination and culture
5	2013	Kolappan et al.	2001-2003	Tiruvallur, Tamil Nadu	Rural	Community Survey	Screening with tuberculosis symptoms and/or radiographic examination, followed by sputum smear examination and culture
6	2013	Kolappan et al.	2004-2006	Tiruvallur, Tamil Nadu	Rural	Community Survey	Screening with tuberculosis symptoms and/or radiographic examination, followed by sputum smear examination and culture
7	2013	Kolappan et al.	2006-2008	Tiruvallur, Tamil Nadu	Rural	Community Survey	Screening with tuberculosis symptoms and/or radiographic examination, followed by sputum smear examination and culture
8	2003	Gopi et al.	1999-2001	Tiruvallur, Tamil Nadu	Both	Community Survey	Screening with tuberculosis symptoms and/or radiographic examination, followed by sputum smear examination and culture
9	2019	Mazumdar S et al	2014-2015	Tamil Nadu	Both	Community Survey	Self-reported cumulative TB
10	2017	IIPS, Mumbai	2015-2016	Tamil Nadu	Both	Community Survey	Self-reported cumulative TB

S. No	Published Year	Author	Year of study	Location	Urban/ Rural	Study setting	Methodology
11	2022	IIPS, Mumbai	2019-2021	Tamil Nadu	Both	Community Survey	Self-reported cumulative TB
Others							
12	2015	Aggarwal et al	2008-2010	Punjab	Both	Community Survey	Sputum smear examination and culture
13	2015	sharma et al	2008-2009	Haryana	Rural	Community Survey	Sputum smear examination and culture
14	2015	Narang et al	2007-2009	Maharastra	Both	Community Survey	X-ray, sputum smear examination and culture
15	2012	Rao et al	2009-2010	Jabalpur	Rural	Community Survey	Sputum smear examination and culture
16	2012	Chandha et al	2008-2010	Nelamangala, Karnataka	Rural	Community Survey	Sputum smear examination and culture
17	2009	Bhat et al	2007-2008	Madhya Pradesh	Rural	Community Survey	Sputum smear examination and culture
18	2004	Murhekar et al	2001-2002	Nicobars, Andaman and Nicobar	Rural	Community Survey	X-ray, sputum smear examination and culture
19	2009	Rao et al	2007 - 2008	Madhya Pradesh	Rural	Community Survey	Sputum smear examination
20	2010	Rao et al	2007-2008	Sheopur,Madhya Pradesh	Both	Community Survey	Sputum smear examination and culture
Tribal							
21	2010	Rao et al	2008	Chhindwara	Rural	Household contact	Sputum smear examination and culture
22	2010	Yadav et al	2011-2012	Dindori, Madhya Pradesh	Rural	Community Survey	Sputum smear examination and culture
23	2022	Rao et al	2012-2013	Madhya Pradesh	Rural	Community Survey	Screened with X-Ray, followed by sputum smear examination and culture
24	2020	Alex Joseph et al	2020	Nilgiri, Namakkal, Villupuram	Rural	Community Survey	Screened with X-Ray, followed by sputum smear examination and culture
25	2021	Beena E thomas et al	2015-2020	India (88 Villages)	Rural	Community Survey	Sputum smear examination and culture

Table: II.2.2 Prevalence of tuberculosis

S. No	Published Year	Author	Year of study	Location	Sample Characteristic	Sample size	culture	smear	Total Prevalence
Tamil Nadu									
1	2022	ICMR, New Delhi	2019- 2021	Tamil Nadu	Above 15	27,529	276	189	284
2	2021	Chandra Kumar Dolla et al	2015-2018	Thiruvallur	Above 15	62494	277	130	307
3	2015	Dhanaraj et al	2010-2012	Chennai, Tamil Nadu	Above 15	59,957	259	228	349
4	2013	Kolappan et al	1999-2001	Tiruvallur, Tamil Nadu	Above 15	83,425	548	294	548
5	2013	Kolappan et al.	2001-2003	Tiruvallur, Tamil Nadu	Above 15	85,474	402	229	402
6	2013	Kolappan et al.	2004-2006	Tiruvallur, Tamil Nadu	Above 15	89,413	283	152	283
7	2013	Kolappan et al.	2006-2008	Tiruvallur, Tamil Nadu	Above 15	92,255	360	168	360
8	2003	Gopi et al.	1999-2001	Tiruvallur, Tamil Nadu	Above 15	83,390	605	323	685
9	2019	Mazumdar S et al	2014-2015	Tamil Nadu	Above 15	NR	NA	NA	348
10	2017	IIPS, Mumbai	2015-2016	Tamil Nadu	Above 15	26,033	NA	NA	1245
11	2022	IIPS, Mumbai	2019-2021	Tamil Nadu	Above 15	27,929	NA	NA	569
Others									
12	2015	Aggarwal et al	2008-2010	Punjab	Above 15	91030	23.1	4.7	24.5
13	2015	sharma et al	2008-2009	Haryana	Above 15	105202	77.9	77	117.9

S. No	Published Year	Author	Year of study	Location	Sample Characteristic	Sample size	culture	smear	Total Prevalence
14	2015	Narang et al	2007-2009	Maharastra	Above 15	55096	149.4	121.1	188.7
15	2012	Rao et al	2009-2010	Jabalpur	Above 15	99918	207.1	171.9	255.3
16	2012	Chandha et al	2008-2010	Nelamangala, Karnataka	Above 15	71874	152	83	196
17	2009	Bhat et al	2007-2008	Madhya Pradesh	Above15	22270	NR	NR	554
18	2004	Murhekar et al	2001-2002	Nicobars, Andaman and Nicobar	Below 15	11032	NR	728.5	NR
19	2009	Rao et al	2007 -2008	Madhya Pradesh	Above15	23411	NR	NR	387
20	2010	Rao et al	2007-2008	Sheopur,Madhya Pradesh	Above 15	11116	NR	NR	1518
Tribal									
21	2010	Rao et al	2008	Chhindwara	Above 15	2586	NR	NR	432
22	2010	Yadav et al	2011-2012	Dindori, Madhya Pradesh	Above 15	2359	NR	146	NR
23	2022	Rao et al	2012-2013	Madhya Pradesh	Above15	9756	1084	1106	686

S. No	Published Year	Author	Year of study	Location	Sample Characteristic	Sample size	culture	smear	Total Prevalence
24	2020	Alex Joseph et al	2020	Nilgiri, Namakkal, Villupuram	Above15	2400	NR	NR	589
25	2021	Beena E thomas et al	2015-2020	India (88 Villages)	Above 15	92038	357	234	432

II.3.Incidence of tuberculosis

Table: II.3.1 Incidence of Tuberculosis

S. No	published Year	Author	Study Period	Region	Urban/ Rural	Age	Study Design	Sample	Incidence (percentage)
Tamil Nadu									
1	2000	Dr S Radhakrishna, et al	1968-2000	Tamil Nadu	Both	Above 15	prospective cohort	100000	113 (smear positive) 189 (culture positive)
2	2019	Mazumdar.S et.al	2014-2015	Tamil Nadu	Both	Above 15	Community Survey	26033	244
3	2006	Gopi PG et al	2001-2003	Tiruvallur, Tamil Nadu	Both	Above 15	Community Survey	100000	82
4	2021	Kathiresan Jeyashree et.al	2020 2020 2015	Tiruvanammalai	Both	Above 15	Household	NR	64 (indirect method) 66 (direct method) 135 (Baseline incidence)

S. No	published Year	Author	Study Period	Region	Urban/ Rural	Age	Study Design	Sample	Incidence (percentage)
5	2002	Sujatha Narayanan et al	1999-2000	Tiruvallur , Tamil Nadu	Both	Above 15	PHC's under RNTCP	580000	76
6	1994	D. Ray et.al	1981-1983	North Arcot Ambedkar Tamil Nadu	Both	Above 15	prospective cohort	22847	46
7	2016	R.Subramani et al	2001-2003	Chennai, Tamil Nadu	Urban	Above 15	Community Survey	74342	112
			2004-2006					75961	80
			2006-2008					79434	76
Others									
8	2013	Jitendra Singh et.al	2007-2009	South Delhi	Urban	Above 15	prospective cohort study	1608	31
9	2011	R. Joshi et al	2004	India	Both	Above 15	cohort study	726	350
10	2008	Philip C. Hill et al	2002-2004	Gambian, Africa	Both	Above 15	cohort study	4312	603
11	2022	TBAnnaulReport2022	2017	India	Both	All age group	National Survey	NR	204
			2018						199
			2019						193
			2020						188
Tribal									
12	2022	Jyothi Bha et al	2012-2013	Madhya Pradesh, central India	Rural	Above 15	prospective cohort study	9756	1504

II.4 TB notification

Table: II.4.1 TB notification

Months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2017	**Public**	7269	7551	9075	9239	8197	5693	5798	4746	4483	5016	5551	5197	**77815**
	Private	832	697	838	728	763	708	694	772	631	692	644	707	**8706**
	Total	8101	8248	9913	9967	8960	6401	6492	5518	5114	5708	6195	5904	**86521**
2018	**Public**	5495	5616	6336	6647	7050	6719	6484	5837	5965	6250	6164	6829	**75392**
	Private	979	937	1168	1621	2174	2253	2010	1651	1456	1752	1661	1697	**19359**
	Total	6474	6553	7504	8268	9224	8972	8494	7488	7421	8002	7825	8526	**94751**
2019	**Public**	6912	7502	7643	6944	7218	6383	6967	6441	6274	5962	6772	7277	**82295**
	Private	2500	2455	2437	2447	2386	2227	2288	2206	2019	2032	2215	2023	**27235**
	Total	9412	9957	10080	9391	9604	8610	9255	8647	8293	7994	8987	9300	**109530**
2020	**Public**	6741	7198	5820	2220	3497	3884	2792	2820	4083	4546	4430	5979	**54010**
	Private	2161	2180	1640	579	877	1153	1042	1122	1320	1420	1467	1563	**16524**
	Total	8902	9378	7460	2799	4374	5037	3834	3942	5403	5966	5897	7542	**70534**
2021	**Public**	5357	6023	6598	4744	2324	3797	5989	5850	6222	5849	5352	6443	**64548**
	Private	1630	1685	1754	1384	854	1321	1699	1690	1639	1558	1562	1818	**18594**
	Total	6987	7708	8352	6128	3178	5118	7688	7540	7861	7407	6914	8261	**83142**
2022	**Public**	5195	6029	6863	6166	6269	6043	3584	NR	NR	NR	NR	NR	**40149**
	Private	1600	1641	1839	1898	1868	1701	825	NR	NR	NR	NR	NR	**11372**
	Total	6795	7670	8702	8064	8137	7744	4409	NR	NR	NR	NR	NR	**51521**

Source: Ministry of Health and Family Welfare. Government of India. Nikshay Dashboard 2017 to 2022

Table: II.4.2 Active Case Finding

Year	Population screened	Presumptive TB cases tested out	TB cases diagnosed among tested
2017	49,67,754	33,43,099	6,580
2018	29,72,314	3,57,667	1,528
2019	26,80,756	40,703	2,542
2020	281122	NR	395
2021	1397431	55852	1887

Source: Central Tuberculosis Division, Government of India, NTEP Reports 2018 to 2022

Table: II.4.3 District wise TB notification

S. No	District	2017			2018			2019			2020			2021		
		Public	Private	Total	Public	Private	Total	Public	Private	Total	Public	Private	Total	Public	Private	Total
1	Chennai	7318	1911	9229	8865	4922	13787	10142	7260	17402	6567	4423	10990	9101	4374	13475
2	Coimbatore	3211	969	4180	3325	791	4116	3419	1304	4723	2127	1372	3499	2538	1360	3898
3	Cuddalore	2112	59	2171	2645	301	2946	2709	434	3143	1817	176	1993	2154	281	2435
4	Dharmapuri	1541	165	1706	1434	337	1771	1506	329	1835	909	422	1331	994	448	1442
5	Dindigul	3076	303	3379	2553	334	2887	2876	508	3384	2032	348	2380	2514	449	2963
6	Erode	2948	279	3227	3276	671	3947	3631	870	4501	1857	532	2389	2167	646	2813
7	Kancheepuram	3632	318	3950	5427	334	5761	6133	585	6718	4324	173	4497	5340	317	5657
8	Kanniyakumari	1774	127	1901	1231	198	1429	1442	312	1754	811	269	1080	953	304	1257
9	Karur	1067	16	1083	849	111	960	859	360	1219	625	93	718	727	161	888
10	Krishnagiri	1711	62	1773	1406	473	1879	1325	389	1714	962	305	1267	906	381	1287
11	Madurai	4312	639	4951	4731	1739	6470	4847	1871	6718	3413	601	4014	3759	1153	4912
12	Nagapattinam	1872	151	2023	1513	284	1797	1657	151	1808	946	250	1196	1048	243	1291
13	Namakkal	1767	77	1844	1573	280	1853	1680	308	1988	1049	258	1307	1206	262	1468
14	Perambalur	1164	4	1168	1252	222	1474	1393	453	1846	1062	149	1211	1371	181	1552
15	Pudukkottai	1533	63	1596	1296	107	1403	1425	394	1819	946	89	1035	1281	130	1411
16	Ramanathapuram	1274	80	1354	1399	570	1969	1478	794	2272	1035	391	1426	1028	480	1508

S. No	District	2017			2018			2019			2020			2021		
		Public	Private	Total	Public	Private	Total	Public	Private	Total	Public	Private	Total	Public	Private	Total
17	Salem	3859	341	4200	3067	822	3889	3445	1515	4960	2308	659	2967	2711	868	3579
18	Sivaganga	1012	77	1089	1299	266	1565	1700	537	2237	1009	461	1470	1169	369	1538
19	Thanjavur	3044	95	3139	2635	859	3494	2766	1121	3887	1921	577	2498	2388	472	2860
20	The Nilgiris	392	6	398	287	12	299	286	24	310	176	13	189	182	7	189
21	Theni	1657	2	1659	1660	153	1813	2057	299	2356	1300	86	1386	1526	175	1701
22	Thiruvallur	3575	56	3631	2299	122	2421	1911	186	2097	1199	98	1297	1525	143	1668
23	Thiruvarur	1672	98	1770	1292	93	1385	1286	198	1484	973	70	1043	1054	119	1173
24	Thoothukudi	1952	405	2357	1795	597	2392	2026	695	2721	1504	299	1803	1637	347	1984
25	Tiruchirappalli	2707	706	3413	3129	1088	4217	3525	1629	5154	2040	719	2759	2323	799	3122
26	Tirunelveli	3224	600	3824	3085	1013	4098	3337	1220	4557	2168	656	2824	2751	729	3480
27	Tiruppur	2111	55	2166	1828	165	1993	2128	269	2397	1503	257	1760	1779	287	2066
28	Tiruvannamalai	1821	94	1915	1975	183	2158	2137	293	2430	1417	202	1619	1497	244	1741
29	Vellore	4440	597	5037	3494	1257	4751	3820	1721	5541	2278	1935	4213	2541	2268	4809
30	Viluppuram	3187	52	3239	2287	229	2516	2893	184	3077	1989	154	2143	2402	167	2569
31	Virudhunagar	2850	300	3150	2485	826	3311	2455	1018	3473	1741	486	2227	1975	444	2419
	Total	**77815**	**8707**	**86522**	**75392**	**19359**	**94751**	**82294**	**27231**	**109525**	**54008**	**16523**	**70531**	**64547**	**18608**	**83155**

Source: Ministry of Health and Family Welfare. Government of India, Nikshay Dashboard 2017 to 2022

II.5.Delay in diagnosis

Table: II.5.1.Delay in diagnosis

S.No	Published Year	Author	Year of Study	Location	Urban/ Rural	Sample Size	Patient delay	Diagnostic delay	Treatment delay
Tamil Nadu									
1	1998	Balasangameshwara et al	1996-97	Dharmapuri	Both	673	18	35	NA
2	2003	Sudha et al	1997	Chennai, Madurai & Tamil Nadu	Both	649	10	NA	NA
3	2002	Rajeswari et al	1997-98	Chennai, Madurai, Chengalpet, Vellore	Both	531	20	23	NA
4	2004	Balasubramanian et al	1999	Tiruvallur	Rural	566	14	31	NA
5	2007	Selvam et al	2003	Tamil Nadu	Both	601	28	28	NA
6	2012	Ananthakrishnan et al	2007	Chennai	Urban	219	11.4	NA	NA
7	2010	Charles et al	2008	Chennai, Madurai & Tamil Nadu	Both	444	16	NA	NA
Others									
8	2010	Ghosh et al	2008	Patpur, Bankura, West Bengal	Both	64	7	NA	NA
9	2012	Jagadish et al	2009	Bangalore, Karnataka	Urban	468	24	18	NA
10	2013	Thakur et al	2009-10	Mandi, Himachal Pradesh	Both	234	15	33.5	1

S.No	Published Year	Author	Year of Study	Location	Urban/ Rural	Sample Size	Patient delay	Diagnostic delay	Treatment delay
11	2012	Paul et al	2010	Bardhaman, West Bengal & Nalagonda, Andhra Pradesh	Rural	2027	NA	NA	8
12	2013	Central TB Division	2011-12	Central TB evaluation done across India	NA	1644	15	4	3
13	2017	Selvam P et al	2012-13	Kozhikode, Kerela	NA	302	16	37	15
14	2017	Sibasis Das et al	2011-12	West Bengal	NA	374	25	32	5
15	2003	Grover et al	1998-00	Chandigarh, Haryana	Both	192	56.6	NA	NA
16	2002	Dhingra et al	2001	New Delhi, Delhi	Urban	301	18.8	NA	NA
17	2012	Tamhane et al	2002	Maharashtra	Urban	150	15	31	2
18	2006	Tobgay et al	2003	Eastern Sikkim	Rural	323	21	7	NA
19	2009	Pantoja et al	2005	Bangalore, Karnataka	Urban	658	7	35	NA
20	2010	Pradhan et al	2005-06	Maharashtra	Urban	266	6	31	4
21	2012	Goel et al	2006-07	Udupi, Karnataka	Both	98	30	54.5	2
22	2010	Bawankule et al	2007	Wardha, Maharashtra	Rural	53	95	47	NA
23	2009	Dhanvij et al	2007	Wardha, Maharashtra	Rural	39	47.2	25	1.8

II.6.TB treatment outcomes

Table: II.6.1 Drug Susceptible TB treatment outcome (First line)

S. No	Year	New Cases				
		Cure/Completed	Failure	Death	LTF	Others
1	2016	76	1	5	5	13
2	2017	85	1	4	4	6
3	2018	87	1	5	3	4
4	2019	85	1	6	3	5
5	2020	83	2	6	1	8

Source: Ministry of Health and Family Welfare, Government of India, Nikshay Dashboard 2017 to 2022

Table: II.6.2 Drug Resistant TB treatment outcome (Second line)

S. No	Year	Cure/Completed	Died	LTF	Failure	Others
1	2017	39	23	27	2	8
2	2018	64	12	16	3	5
3	2019	57	12	17	2	11
4	2020	53	13	15	4	15

Source: Ministry of Health and Family Welfare, Government of India, Nikshay Dashboard 2017 to 2022

Table: II.6.3 previously treated TB (Recurrent TB)

S. No	Year	Previously treated TB patients				
		Cure/Completed	Failure	Death	LTF	Others
1	2016	59	4	8	12	17
2	2017	68	8	3	12	9
3	2018	76	2	7	7	8
4	2019	76	5	7	2	10
5	2020	77	4	7	2	10

Source: Ministry of Health and Family Welfare, Government of India, Nikshay Dashboard 2017 to 2022

II.7.Poverty

Table: II.7.1 Poverty rate in rural and urban in Tamil Nadu

	Year	Rural		Urban		Total	
		No.of person (in thousands)	% of poverty rate	No.of person (in thousands)	% of poverty rate	No.of person (in thousands)	% of poverty rate
RBI report[1]	2004-05	13440	37.5	5970	19.7	19410	29.4
	2008-09	7830	21.2	4350	12.8	12180	17.1
	2011-12	5923	15.83	2340	6.54	8263	11.28
Geometric growth rate[2]	2017	3,304	8.61	1,219	3.08	4,469	5.74
	2018	2,940	7.62	1,070	2.65	3,952	5.01
	2019	2,617	6.75	939	2.28	3,495	4.38
	2020	2,328	5.98	825	1.96	3,090	3.82
	2021	2,072	5.29	724	1.68	2,733	3.34
	2022	1,844	4.68	635	1.45	2,417	2.92

Source: [1] Ministry of Finance, Government of India. Reserve Bank of India, Handbook of statistics on Indian Economy

[2] Estimated with reference 1 by geometric growth rate

Table: II.7.2 Poverty

S.NO	Year	Value	Target Year	Target Value	Source
1	2015	11.28	2030	10.95	NITI Aayog- (based on NSSO Survey 2011-12)
2	2016	11.28	2030	10.95	NITI Aayog- (based on NSSO Survey 2011-12)
3	2017	11.28	2030	10.95	NITI Aayog- (based on NSSO Survey 2011-12)
4	2018	11.28	2030	10.95	NITI Aayog- (based on NSSO Survey 2011-12)
5	2019	11.28	2030	10.95	NITI Aayog- (based on NSSO Survey 2011-12)
6	2020	11.28	2030	10.95	NITI Aayog- (based on NSSO Survey 2011-12)

Source: Planning and Development Department. Government of Tamil Nadu, tnsdg.tn.gov.in

II.8.Literacy

Table: II.8.1 Literacy rate

S.No.	District Name	Population (2011)	Literates	Literacy (%)
1	Kanyakumari	18,70,374	15,48,738	**91.75**
2	Chennai	46,46,732	37,76,276	**90.18**
3	Thoothukudi	17,50,176	13,49,697	**86.16**
4	The Nilgiris	7,35,394	5,69,647	**85.2**
5	Kanchipuram	39,98,252	30,13,382	**84.49**
6	Tiruvallur	37,28,104	27,91,721	**84.03**
7	Coimbatore	34,58,045	26,35,907	**83.98**
8	Nagapattinam	16,16,450	12,13,008	**83.59**
9	Madurai	30,38,252	22,73,430	**83.45**
10	Tiruchirappalli	27,22,290	20,38,981	**83.23**
11	Tiruvarur	12,64,277	9,46,471	**82.86**
12	Thanjavur	24,05,890	17,90,998	**82.64**
13	Tirunelveli	30,77,233	22,73,457	**82.5**
14	Ramanathapuram	13,53,445	9,78,946	**80.72**
15	Virudhunagar	19,42,288	13,98,788	**80.15**
16	Sivaganga	13,39,101	9,59,744	**79.85**
17	Vellore	39,36,331	27,73,928	**79.17**
18	Tirupur	24,79,052	17,60,566	**78.68**
19	Cuddalore	26,05,914	18,15,281	**78.04**
20	Theni	12,45,899	8,70,080	**77.26**
21	Pudukkottai	16,18,345	11,10,545	**77.19**
22	Dindigul	21,59,775	14,81,834	**76.26**
23	Karur	10,64,493	7,27,044	**75.6**
24	Namakkal	17,26,601	11,76,131	**74.63**
25	Perambalur	5,65,223	3,75,823	**74.32**
26	Tiruvannamalai	24,64,875	16,26,813	**74.21**
27	Salem	34,82,056	22,85,562	**72.86**
28	Erode	22,51,744	14,92,662	**72.58**
29	Viluppuram	34,58,873	21,95,776	**71.88**
30	Krishnagiri	18,79,809	11,87,958	**71.46**
31	Ariyalur	7,54,894	4,80,604	**71.34**
32	Dharmapuri	15,06,843	9,17,709	**68.54**
Literacy rate in Tamil Nadu				**80.09**

Source: IndiaCensus.net, Tamil Nadu Literacy rate

II.9. Gross Domestic Product (GDP)

Table: II.9.1 Gross State Domestic Product (GDP)

Year	Gross State Domestic Product (in lakhs)	₹ per USD	GSDP Deflator
2014	1,07,26,780	61	119.998
2015	1,17,65,000	64.11	121.594
2016	1,30,26,390	67.2	125.645
2017	1,46,50,510	65.12	130.135
2018	1,63,02,090	68.4	135.324
2019	1,74,31,440	70.42	140.143
2020	1,80,82,390	74.1	145.171
2021	2,06,54,360	73.92	153.552

Source: Ministry of Statistics & Programme Implementation. Government of India. Economy of Tamil Nadu

Table: II.9.2 GDP of Tamil Nadu

Year	At current prices (crore INR)				At 2011-12 prices (crore INR)			
	GSDP	GSVA	NSDP	NSVA	GSDP	GSVA	NSDP	NSVA
2020-21	19,43,399	17,67,447	17,49,516	15,73,56,313	13,39,448	11,97,153	11,92,546	10,50,25,043
2019-20	18,45,853	16,80,179	16,59,210	14,93,53,624	13,12,929	11,74,779	11,67,776	10,29,62,524
2018-19	16,30,208	14,84,993	14,65,361	13,20,14,623	12,15,307	10,89,644	10,79,894	9,54,23,131
2017-18	14,65,051	13,30,537	13,17,984	11,83,47,005	11,25,793	10,14,491	10,00,308	8,89,00,548
2016-17	13,02,639	11,83,799	11,71,973	10,53,13,354	10,36,762	9,39,501	9,22,084	8,24,82,320
2015-16	11,76,500	10,76,414	10,57,084	9,56,99,811	9,67,562	8,79,071	8,62,437	7,73,94,599
2014-15	10,72,678	9,82,843	9,57,350	8,67,51,538	8,93,915	8,15,001	7,91,915	7,13,00,072
2013-14	9,68,530	8,87,784	8,58,870	7,78,12,390	8,51,976	7,76,684	7,50,416	6,75,12,409
2012-13	8,54,825	7,84,772	7,68,295	6,98,24,144	7,91,824	7,25,074	7,09,343	6,42,59,300
2011-12	7,51,486	6,93,022	6,74,478	6,16,01,471	7,51,486	6,93,022	6,74,478	6,16,01,471

Source: Ministry of Statistics & Programme Implementation. Government of India. Economy of Tamil Nadu

Table: II.9.3 GDP per capita of Tamil Nadu

Year	Per capita at current prices (INR)		Per capita at 2011-12 prices (INR)	
	GSDP	NSDP	GSDP	NSDP
2020-21	2,54,856	2,29,430	1,75,654	1,56,389
2019-20	2,43,189	2,18,599	1,72,977	1,53,853
2018-19	2,15,784	1,93,964	1,60,865	1,42,941
2017-18	1,94,834	1,75,276	1,49,717	1,33,029
2016-17	1,74,054	1,56,595	1,38,529	1,23,206
2015-16	1,58,073	1,42,028	1,29,999	1,15,875
2014-15	1,45,094	1,29,494	1,20,914	1,07,117
2013-14	1,31,893	1,16,960	1,16,021	1,02,191
2012-13	1,17,204	1,05,340	1,08,566	97,257
2011-12	1,03,743	93,112	1,03,743	93,112

Source: Ministry of Statistics & Programme Implementation. Government of India. Economy of Tamil Nadu

Table: II.9.4 GDP Growth of Tamil Nadu

Year	Growth (%) at current prices (INR)		Growth (%) at 2011-12 prices (INR)	
	GSDP	NSDP	GSDP	NSDP
2020-21	5.28	5.44	2.02	2.12
2019-20	13.23	13.23	8.03	8.14
2018-19	11.27	11.18	7.95	7.96
2017-18	12.47	12.46	8.59	8.48
2016-17	10.72	10.87	7.15	6.92
2015-16	9.68	10.42	8.24	8.91
2014-15	10.75	11.47	4.92	5.53
2013-14	13.3	11.79	7.6	5.79
2012-13	13.75	13.91	5.37	5.17

Source: Ministry of Statistics & Programme Implementation. Government of India. Economy of Tamil Nadu

Table: II.9.5 Sector wise GDP of Tamil Nadu

S.No	Sector	GVA (Rupees in Lakh) at current prices		GVA (Rupees in Lakh) at 2011-12 prices	
		2020-21	% share	2020-21	% share
1	Primary Sector	2,36,08,421	13.36	1,40,63,097	11.75
1.1	Agriculture, forestry & fishing	2,30,57,017	13.05	1,35,36,660	11.31
1.11	Crops	1,13,44,330	6.42	53,66,852	4.48
1.12	Livestock	97,54,118	5.52	71,79,034	6
1.13	Forestry & logging	6,89,307	0.39	4,02,517	0.34
1.14	Fishing and aquaculture	12,69,261	0.72	5,88,256	0.49
1.2	Mining & quarrying	5,51,404	0.31	5,26,437	0.44
2	Secondary Sector	5,72,39,011	32.39	4,46,42,744	37.29
2.1	Manufacturing	3,53,53,305	20	2,99,62,902	25.03
2.2	Electricity, gas, water supply & other utility services	31,09,506	1.76	10,48,893	0.88
2.3	Construction	1,87,76,200	10.62	1,36,30,949	11.39
3	Tertiary Sector	9,58,97,231	54.26	6,10,09,431	50.96
3.1	Trade, repair, hotels and restaurants	2,14,45,978	12.13	1,34,00,277	11.19
3.11	Trade & repair services	1,94,35,369	11	1,21,49,071	10.15
3.12	Hotels & restaurants	20,10,608	1.14	12,51,206	1.05
3.2	Transport, storage, communication & services related to broadcasting	99,91,385	5.65	67,17,738	5.61
3.21	Railways	6,33,147	0.36	4,81,545	0.4

S. No	Sector	GVA (Rupees in Lakh) at current prices		GVA (Rupees in Lakh) at 2011-12 prices	
		2020-21	% share	2020-21	% share
3.22	Road transport	50,48,547	2.86	33,65,369	2.81
3.23	Water transport	95,453	0.05	63,629	0.05
3.24	Air transport	66,853	0.04	44,565	0.04
3.25	Services incidental to transport	11,99,640	0.68	7,99,681	0.67
3.26	Storage	50,921	0.03	32,091	0.03
3.27	Communication & services related to broadcasting	28,96,824	1.64	19,30,857	1.61
3.3	Financial services	95,93,899	5.43	76,92,561	6.43
3.4	Real estate, ownership of dwelling & professional services	3,18,60,608	18.03	1,95,18,266	16.3
3.5	Public administration & defence	56,46,119	3.19	34,81,116	2.91
3.6	Other services	1,73,59,243	9.82	1,01,99,472	8.52
3.7	GVA at basic prices	17,67,44,663		11,97,15,271	

Source: Ministry of Statistics & Programme Implementation, Government of India, Economy of Tamil Nadu

Table: II.9.6 Inflation rate of India

S. No	Year	Inflation Rate (%)	Annual Change	S. No	Year	Inflation Rate (%)	Annual Change
1	2021	5.13%	-1.49%	**32**	1990	8.97%	1.90%
2	2020	6.62%	2.89%	**33**	1989	7.07%	-2.31%
3	2019	3.73%	-0.21%	**34**	1988	9.38%	0.58%
4	2018	3.94%	0.61%	**35**	1987	8.80%	0.07%
5	2017	3.33%	-1.62%	**36**	1986	8.73%	3.17%
6	2016	4.95%	0.04%	**37**	1985	5.56%	-2.76%
7	2015	4.91%	-1.76%	**38**	1984	8.32%	-3.55%
8	2014	6.67%	-3.35%	**39**	1983	11.87%	3.98%
9	2013	10.02%	0.54%	**40**	1982	7.89%	-5.22%
10	2012	9.48%	0.57%	**41**	1981	13.11%	1.77%
11	2011	8.91%	-3.08%	**42**	1980	11.35%	5.07%
12	2010	11.99%	1.11%	**43**	1979	6.28%	3.75%
13	2009	10.88%	2.53%	**44**	1978	2.52%	-5.78%
14	2008	8.35%	1.98%	**45**	1977	8.31%	15.94%
15	2007	6.37%	0.58%	**46**	1976	-7.63%	-13.38%
16	2006	5.80%	1.55%	**47**	1975	5.75%	-22.85%

S. No	Year	Inflation Rate (%)	Annual Change	S. No	Year	Inflation Rate (%)	Annual Change
17	2005	4.25%	0.48%	**48**	1974	28.60%	11.66%
18	2004	3.77%	-0.04%	**49**	1973	16.94%	10.50%
19	2003	3.81%	-0.49%	**50**	1972	6.44%	3.36%
20	2002	4.30%	0.52%	**51**	1971	3.08%	-2.01%
21	2001	3.78%	-0.23%	**52**	1970	5.09%	5.68%
22	2000	4.01%	-0.66%	**53**	1969	-0.58%	-3.82%
23	1999	4.67%	-8.56%	**54**	1968	3.24%	-9.82%
24	1998	13.23%	6.07%	**55**	1967	13.06%	2.26%
25	1997	7.16%	-1.81%	**56**	1966	10.80%	1.33%
26	1996	8.98%	-1.25%	**57**	1965	9.47%	-3.88%
27	1995	10.22%	-0.02%	**58**	1964	13.36%	10.41%
28	1994	10.25%	3.92%	**59**	1963	2.95%	-0.69%
29	1993	6.33%	-5.46%	**60**	1962	3.63%	1.94%
30	1992	11.79%	-2.08%	**61**	1961	1.70%	-0.08%
31	1991	13.87%	4.90%	**62**	1960	1.78%	-0.08%

Source: Macrotrends, India Inflation Rate 1960-2022 (https://www.macrotrends.net/countries/IND/india/inflation-rate-cpi#google_vignette)

III.COVID-19

III. 1.Prevalence of COVID-19

Table: III.1.1 Prevalence of COVID-19 of Tamil Nadu (Per 100000 Population)

S. No	Month	2020	2021
1	January	-	24.7
2	February	-	16.0
3	March	0.15	42.6
4	April	2.70	339.9
5	May	24.58	1128.3
6	June	83.33	465.0
7	July	191.27	97.0
8	August	223.81	67.1
9	September	208.31	59.4
10	October	155.92	47.1
11	November	70.51	-
12	December	44.35	-

Source: Estimation based on JHU CSSE COVID Repository (covid19india.org)

III. 2. COVID-19 Confirmed, Recovered and Deceased

Table: III.2.1 Confirmed COVID-19 Cases

S. No	Month	2020	2021	2022
1	January	-	20326	597175
2	February	-	13202	104153
3	March	124	35131	3452
4	April	2199	280083	1107
5	May	20010	929760	1542
6	June	67834	383180	19711
7	July	155692	79901	69061
8	August	182182	55275	24411
9	September	169561	48917	-
10	October	126920	38834	-
11	November	57393	24294	-
12	December	36099	21128	-

Source: [1]Health and Family welfare Department, Government of Tamil Nadu, Stop Corona TN (Media Bulletin) [2]JHU CSSE COVID Repository (covid19india.org)

Table: III.2.2 Recovered COVID-19 Cases

S. No	Month	2020	2021	2022
1	January	-	20326	596387
2	February	-	13202	103713
3	March	123	35131	3431
4	April	2173	280083	1107
5	May	19861	929760	1542
6	June	66809	383180	19710
7	July	152958	79901	69055
8	August	178795	55275	24408
9	September	167363	48917	-
10	October	125318	38834	-
11	November	56803	23929	-
12	December	35689	20833	-

Source: [1]Health and Family welfare Department, Government of Tamil Nadu, Stop Corona TN (Media Bulletin) [2]JHU CSSE COVID Repository (covid19india.org)

Table: III.2.3 Deceased COVID-19 Cases

S. No	Month	2020	2021	2022
1	January	-	234	788
2	February	-	140	440
3	March	1	223	21
4	April	26	1327	0
5	May	149	10186	0
6	June	1025	8387	1
7	July	2734	1457	6
8	August	3387	845	3
9	September	2198	657	-
10	October	1602	538	-
11	November	590	365	-
12	December	410	295	-

Source: [1]Health and Family welfare Department, Government of Tamil Nadu, Stop Corona TN (Media Bulletin) [2]JHU CSSE COVID Repository (covid19india.org)

IV. Others

IV. 1.Mortality

Table: IV.1.1.All-cause mortality

S. No	year	Total Mortality rate	Mortality rate Rural	Mortality rate Urban
1	2009	7.6	8.5	6.6
2	2010	7.6	8.2	6.9
3	2011	7.4	8.1	6.4
4	2012	7.4	8.2	6.4
5	2013	7.3	8.1	6.3
6	2014	7	8.1	6.3
1	2015	6.7	7.6	6
8	2016	6.4	7.1	5.6
9	2017	6.7	7.6	5.9
10	2018	6.5	7.8	5.3
11	2019	6.1	7.4	4.9
12	2020	6.1	7.2	5.1
13	2021	6.1	7.2	5.1

Source: [1]Statista. Rural and urban death rates of India by states (https://www.statista.com/statistics)
[2]Lewnard JA et al_2022. All-cause mortality during the COVID-19 pandemic in Chennai

IV. 2.Life Expectancy

Table: IV.2.1 Life Expectancy during 2015-19 for the state of Tamil Nadu

S. No	Age-group	Overall			Rural			Urban		
		Total	Male	Female	Total	Male	Female	Total	Male	Female
1	0-1	72.6	70.6	74.9	70.4	68.3	72.7	74.9	73	77.1
2	1-5	73.1	71	75.3	70.9	68.8	73.2	75.3	73.3	77.5
3	5-10	69.2	67.2	71.5	67.1	65	69.4	71.4	69.4	73.6
4	10-15	64.4	62.3	66.6	62.3	60.2	64.5	66.5	64.5	68.7
5	15-20	59.5	57.5	61.8	57.4	55.3	59.6	61.6	59.6	63.9
6	20-25	54.7	52.7	57	52.6	50.6	54.8	56.9	54.9	59.1
7	25-30	50	48.1	52.2	47.9	46	50.1	52.1	50.2	54.2
8	30-35	45.3	43.4	47.4	43.3	41.4	45.3	47.4	45.5	49.4
9	35-40	40.7	38.8	42.6	38.7	36.8	40.7	42.7	40.9	44.6
10	40-45	36.1	34.4	37.9	34.2	32.5	36	38	36.4	39.9
11	45-50	31.6	30.1	33.3	29.8	28.3	31.5	33.5	32	35.1
12	50-55	27.4	26	28.8	25.6	24.3	27.1	29.2	27.9	30.6
13	55-60	23.3	22.2	24.5	21.7	20.5	22.9	25	23.9	26.1
14	60-65	19.5	18.7	20.4	18	17.1	18.9	21.1	20.3	22
15	65-70	15.9	15.2	16.6	14.5	13.8	15.2	17.4	16.7	18.1
16	70-75	12.8	12.3	13.3	11.5	11.1	11.9	14.2	13.8	14.7
17	75-80	10.1	9.7	10.5	9	8.7	9.4	11.2	10.9	11.5
18	80+85	8	7.7	8.2	6.8	6.6	7	9.2	9	9.3
19	85+	6.2	6	6.4	5.2	5	5.3	7.3	7.2	7.3

Source: Lewnard JA et al_2022. All-cause mortality during the COVID-19 pandemic in Chennai

Table: IV.2.2.Life Expectancy (India)

Year	Combined			Rural			Urban		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
1973	49.7	50.5	49	48	48.9	47.1	58.9	58.8	59.2
1978	52.3	52.5	52.1	50.6	51	50.3	60.1	59.6	60.8
1983	55.4	55.4	55.7	53.7	54	53.6	62.8	61.6	64.1
1988	57.7	57.7	58.1	56.1	56.1	56.2	63.4	62	64.9
1989	58.3	58.1	58.6	56.8	56.7	56.9	63.8	62.3	65.3
1990	58.7	58.6	59	57.4	57.2	57.4	64.1	62.8	65.5
1991	59.4	59	59.7	58	57.9	58.1	64.9	63.5	66.3
1992	60	59.4	60.4	58.6	58.2	58.7	65.4	64.1	66.7
1993	60.3	59.7	60.9	58.9	58.5	59.3	65.9	64.5	67.3
1994	60.7	60.1	61.4	59.4	58.9	59.8	66.3	64.9	67.7
1995	61.1	60.4	61.8	59.9	59.3	60.2	66.6	65.1	68
1996	61.4	60.6	62.2	60.1	59.5	60.5	66.8	65.3	68.2
1997	61.5	60.8	62.3	60.3	59.7	60.9	66.4	65.1	67.9
1998	61.9	61.2	62.7	60.7	60.1	61.3	66.7	65.4	68.3
1999	62.3	61.4	63.3	61.1	60.3	61.9	67.1	65.7	68.7
2000	62.9	61.9	64	61.6	60.7	62.5	67.6	66.1	69.2
2001	63.4	62.3	64.6	62.2	61.1	63.2	68	66.5	69.7
2002	63.9	62.8	65.2	62.7	61.6	63.8	68.4	66.9	70
2003	64.3	63.1	65.6	63	61.9	64.2	68.6	67.2	70.3
2004	64.7	63.5	66.1	63.5	62.3	64.7	68.9	67.4	70.6
2005	65	63.7	66.5	63.8	62.6	65.2	69	67.5	70.7
2006	65.4	64	66.9	64.2	62.9	65.7	69	67.5	70.8
2007	65.7	64.3	67.2	64.5	63.2	66	69.2	67.6	71
2008	66.1	64.6	67.7	64.9	63.5	66.5	69.6	68	71.4
2009	66.5	64.9	68.2	65.3	63.8	67	70.1	68.4	71.9
2010	67	65.4	68.8	65.8	64.2	67.6	70.6	69	72.4
2011	67.5	65.8	69.3	66.3	64.6	68.1	71.2	69.6	73
2012	67.9	66.4	69.6	66.7	65.1	68.4	71.5	70	73.5

Source: Lewnard JA et al_2022. All-cause mortality during the COVID-19 pandemic in Chennai