Fuzzy Logic–Based Time Series Forecasting for Tuberculosis Cases in Sabah

Suriana Binti Lasaraiya
http://orcid.org/0000-0002-9119-2858
Universiti Malaysia Sabah, Malaysia

Suzelawati Binti Zenian
Universiti Malaysia Sabah, Malaysia

Risman Mat Hasim
http://orcid.org/0000-0002-5358-587X
Universiti Putra Malaysia, Malaysia

Azmirul Ashaari
http://orcid.org/0000-0002-4405-4890
Universiti Teknologi Malaysia, Malaysia

Lorna Uden
http://orcid.org/0000-0002-8598-7355
University of Staffordshire, UK

ABSTRACT

This article explores the application of fuzzy logic in predicting tuberculosis cases within Sabah, Malaysia. TB is a pressing public health concern, and accurate forecasting is vital for managing its spread. The article outlines fuzzy logic principles, contrasting them with traditional logic, and demonstrates their effectiveness in addressing data uncertainties. It describes the fuzzy time series forecasting methodology, including data collection, fuzzification, rule formation, defuzzification, and the use of triangular membership functions. These functions are analyzed for their strengths, limitations, and mathematical representation, supported by case studies that highlight their practical application in TB forecasting and their impact on public health strategies. Challenges in implementing these models are discussed alongside recommendations for future research. The article concludes by summarizing key findings and emphasizing the potential of fuzzy logic to enhance TB management efforts.

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A. INTRODUCTION

Tuberculosis (TB) is a communicable disease that is a major cause of ill health and one of the leading causes of death worldwide. Until the coronavirus (CO VID-19) pandemic, TB was the leading cause of death from a single infectious agent, ranking above HIV/AI DS, Global Tuberculosis Report, (2022). TB is caused by the bacillus Mycobacterium tuberculosis, which is spread when people who are sick with TB expel bacteria into the air (e.g. by coughing). Tuberculosis (TB) remains a significant global health challenge despite the availability of effective treatments. The World Health Organization (WHO) estimates that nearly a quarter of the global population is at risk of developing TB, with higher susceptibility observed among immunocompromised individuals, such as those living with diabetes, HIV, or those who smoke (Lönnroth et al., 2010; WHO, 2019). In 2019 alone, TB accounted for 10 million new cases and 1.4 million deaths, making it one of the top 10 causes of mortality worldwide (WHO, 2020).

In Malaysia, TB incidence has shown a concerning upward trend, with reported new and relapse cases increasing from 18,000 in 2010 to 25,000 in 2019 (WHO, 2020). Projections indicate that TB cases in Malaysia will continue to rise by 2030 (Ministry of Health Malaysia, 2016). While efforts have been made to reduce mortality rates, they remain relatively stagnant, ranging from 4.5 to 5.5 deaths per 100,000 population between 1990 and 2015. As of 2019, TB mortality among HIV-negative individuals was 3.8 per 100,000 population, with an estimated 1,200 deaths reported (WHO, 2020). From a disability perspective, the Global Burden of Disease (GBD) study in 2015 ranked TB as the 14th leading cause of Disability-Adjusted Life Years (DALYs) worldwide (Institute for Health Metrics and Evaluation, 2017). Similarly, the Malaysian Burden of Disease and Injury Study (MBOD) highlighted an 18.8% increase in DALYs associated with TB between 2009 and 2014, positioning the disease as the 16th leading cause of DALYs in 2014 (Institute of Public Health, 2017).

In response to this public health threat, global and national strategies have been developed. The WHO's End TB Strategy and Malaysia's National Strategic Plan for Tuberculosis Control aim to eliminate TB by 2035. The year 2015 serves as a critical benchmark for evaluating progress in this endeavor (Ministry of Health Malaysia, 2016; WHO, 2015; WHO, 2019). These comprehensive frameworks underscore the need for continued surveillance, innovative interventions, and strengthened healthcare systems to combat the TB epidemic effectively. The World Health Organization (WHO) has published a global TB report every year since 1997. The purpose of the report is to provide a comprehensive and up to date assessment of the status of the TB epidemic and progress in the response at global, regional and national levels, in the context of global commitments, strategies and targets.

Malaysia has made notable progress in its efforts to combat tuberculosis (TB), achieving considerable milestones in reducing its prevalence and mortality rates. However, TB remains a significant public health challenge, particularly in the state of Sabah. This region consistently reports a higher prevalence of TB compared to other states in Malaysia, a disparity that can be attributed to several interconnected factors. Sabah's unique demographic composition is one of the primary contributors to its elevated TB burden. The state is home to a large and diverse population, including indigenous communities and a significant proportion of migrant workers from neighbouring countries. These groups often face systemic barriers to accessing healthcare services, including geographical remoteness, economic constraints, and language or cultural differences. For indigenous populations, limited infrastructure and healthcare facilities in rural areas can impede timely diagnosis and treatment of TB. Similarly, migrant workers may encounter additional challenges, such as lack of legal documentation, fear of deportation, and limited health literacy, further complicating their ability to seek and receive adequate medical care.