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Trends in HIV Status and Treatment Outcomes among Patients with Tuberculosis in Indonesia, 2022–2025: An Analysis of National Surveillance Data

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Abstract

Background

Tuberculosis (TB) and HIV coinfection remain important public health challenges in Indonesia. This study examined demographic characteristics, temporal trends, HIV-status documentation, mortality associations, and provincial spatial patterns among TB registrations during 2022–2025 to inform integrated TB–HIV services.

Methods

A retrospective analysis used routine surveillance data from Indonesia's Tuberculosis Information System (SITB). Descriptive analyses assessed demographic and clinical characteristics, treatment outcomes, and annual changes in HIV-status documentation. HIV positivity was calculated among registrations with documented positive or negative HIV status. Logistic regression assessed factors associated with death among eligible registrations from 2022–2024. Sensitivity analyses included modified Poisson regression with robust standard errors, restriction to death versus treatment success, and complete-case analysis. Provincial spatial associations were assessed using Global Moran's I and local indicators of spatial association, with false discovery rate adjustment for local tests.

Results

The dataset comprised 2,988,098 TB registrations. Annual registrations increased from 638,646 in 2022 to 827,174 in 2025. The median age was 39 years (interquartile range: 21–55), and 57.6% were male. HIV-status documentation increased from 21.7% to 33.6%, while HIV positivity among registrations with known status declined from 6.3% to 4.7%. Nevertheless, documented HIV-positive registrations increased from 8,735 to 12,980. HIV-positive status was associated with higher odds of death (adjusted odds ratio: 5.06; 95% confidence interval: 4.86–5.26), with a consistent association across sensitivity analyses. Modified Poisson regression yielded an adjusted risk ratio of 4.27 (95% confidence interval: 4.13–4.41). Pooled provincial HIV positivity exhibited significant positive global spatial autocorrelation (Moran's I = 0.275; P = 0.0029). Annual global associations were significant overall during 2023–2025, but no local associations remained significant after false discovery rate adjustment.

Conclusions

Increasing TB notifications and documented HIV-positive registrations, persistent gaps in HIV-status documentation, and higher mortality among HIV-positive patients highlight priorities for integrated TB–HIV care. Declining documented positivity should be interpreted cautiously. Strengthening HIV testing,

result documentation, coordinated care, and outcome monitoring is essential for informed programme planning.

Background

Tuberculosis (TB) remains a major global public health challenge despite the availability of effective preventive measures and treatment. According to the World Health Organization (WHO) Global Tuberculosis Report 2025, an estimated 10.7 million people developed TB in 2024, and approximately 1.23 million died from the disease, including 150,000 people living with HIV [1]. TB remains the leading cause of death from a single infectious agent and a leading cause of death among people living with HIV. Indonesia is among the countries contributing the largest numbers of incident TB cases worldwide [1]. Previous analyses of Indonesia's national surveillance data have documented substantial variation in notified cases, treatment outcomes, and economic burden across provinces [2]. The national TB programme review conducted in 2025 further identified persistent gaps in diagnosis, treatment completion, and continuity of care, underscoring the need for evidence to guide more targeted programme responses [3].

HIV infection adds considerable complexity to TB prevention, diagnosis, and treatment. HIV-associated immunosuppression increases vulnerability to active TB and contributes to poor treatment outcomes, making coordinated management of both diseases essential [4]. Diagnosing TB in people living with HIV can also be challenging, requiring diagnostic approaches that account for pulmonary and extrapulmonary disease. WHO's updated diagnostic guidelines and operational handbook recommend strategies that include concurrent testing of respiratory and non-respiratory specimens in relevant populations living with HIV [5, 6]. These challenges highlight the importance of examining HIV status alongside disease site and diagnostic classification when evaluating outcomes among patients receiving TB treatment.

Recent observational evidence demonstrates that HIV remains an important marker of adverse outcomes among patients with TB. A retrospective cohort study in Kenya found that HIV infection and unknown HIV status were associated with mortality and loss to follow-up during TB treatment [7]. A multicentre European cohort similarly identified TB as an important predictor of mortality among people living with HIV, alongside immunological, virological, and social factors [8]. In Indonesia, the INA-PROACTIVE prospective cohort documented TB among the reported causes of death in people living with HIV [9]. Although these studies involve different populations and healthcare settings, they reinforce the importance of evaluating the relationship between HIV status and mortality within the Indonesian TB treatment programme.

Reducing adverse outcomes requires an integrated approach that extends beyond prescribing anti-TB medication. Current WHO guidance addresses effective treatment regimens, patient care, and support for treatment completion [10]. TB preventive treatment is also a central component of reducing the burden of disease among eligible people living with HIV after active TB has been excluded [11]. Reliable

HIV testing and linkage to care are necessary to identify patients who require coordinated TB–HIV management [12]. In Indonesia, the 2023 technical guidance on collaborative TB–HIV activities provides a national framework for screening, diagnosis, treatment, referral, and recording and reporting across the two programmes [13]. Evaluating outcomes by recorded HIV status can therefore provide evidence relevant to the implementation and monitoring of these collaborative activities.

Existing Indonesian studies provide an important foundation but address different aspects of the TB care continuum. A multicentre study of adults with bacteriologically confirmed pulmonary TB documented substantial unfavourable treatment outcomes, including death and loss to follow-up [14]. A national retrospective cohort of more than one million drug-susceptible TB cases registered during 2020–2022 identified differences in treatment outcomes across patient characteristics and regions [15]. A subsequent surveillance-based study examined factors associated with loss to follow-up, highlighting the importance of care coordination and treatment continuity [16]. More directly, an analysis of the 2023 national TB registry investigated demographic, clinical, and health-service factors associated with TB–HIV coinfection [17]. Building on this evidence, a multiyear analysis can examine changes in recorded HIV status and treatment outcomes while assessing the association between HIV status and death during TB treatment.

Incomplete HIV-status documentation is an important consideration in interpreting routine surveillance data. An unknown HIV status cannot be assumed to indicate the absence of HIV infection or to demonstrate that testing was not performed. Changes in the proportion of patients recorded as HIV-positive may reflect changes in testing, documentation, or the composition of patients entering care, as well as changes in underlying coinfection patterns. WHO's updated TB surveillance guidance emphasizes standardized case-based recording and reporting to improve the quality and usefulness of programme data [18]. Accordingly, analyses of TB–HIV outcomes should distinguish positive, negative, and unknown HIV status and explicitly assess the implications of incomplete documentation. Recorded deaths during treatment should also be distinguished from deaths specifically attributable to TB or HIV.

This study aimed to examine trends in recorded HIV status, epidemiological characteristics, and treatment outcomes among patients with TB registered in Indonesia's national Tuberculosis Information System (Sistem Informasi Tuberkulosis; SITB) during 2022–2025. It further assessed the association between HIV status and death during TB treatment, accounting for available demographic and clinical characteristics, geographic region, and registration year. By evaluating both patient outcomes and the completeness of HIV-status documentation, the study seeks to inform targeted TB–HIV service integration, strengthen surveillance, and identify patient groups requiring closer clinical and programme follow-up.

Methods

Study design and setting

This study used routinely collected data from SITB to examine epidemiological characteristics, recorded HIV status, and treatment outcomes among patients registered during 2022–2025. A retrospective cohort approach was used to assess outcomes recorded after treatment initiation, with descriptive comparisons across annual registration cohorts. Reporting will follow the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement and its extension for studies using routinely collected health data, the RECORD statement [19, 20].

Data source and study population

Data were obtained from SITB, Indonesia's national information system for recording and reporting TB programme data. The analytical dataset comprised 2,988,098 TB registration records from 1 January 2022 to 31 December 2025. It covered all age groups and both pulmonary and extrapulmonary disease. Records with unknown HIV status were retained to assess the completeness of HIV-status documentation. The unit of analysis was an individual TB registration record, and all supplied records were included in the descriptive analysis without sampling. Case characteristics and treatment outcomes were interpreted using standardized TB surveillance definitions [21].

Treatment outcomes were assessed using the information recorded in the supplied SITB extract. Records with missing or not evaluated outcomes were retained in the descriptive summaries. For the proposed mortality analysis, these records will be excluded because their vital status during treatment cannot be established from the recorded outcome. The extraction date and outcome ascertainment cutoff must be specified to assess follow-up completeness, particularly for patients registered in 2025.

Data collection and management

Variables extracted from SITB included age, sex, occupation, geographic location, TB anatomical site, diagnostic classification, HIV status, diabetes mellitus status, registration year, and treatment outcome. These variables were used to describe patient characteristics across registration years and assess the association between recorded HIV status and death during TB treatment.

Data management procedures comprised merging the annual SITB datasets for 2022–2025, harmonizing variable names and category coding across years, grouping occupation entries into standardized categories, and recoding geographic location, TB anatomical site, diagnostic classification, HIV status, diabetes mellitus status, and treatment outcomes for analysis. Missing and undocumented values were identified and distinguished from explicitly recorded negative results.

Category mappings for occupation, geographic region, diagnostic classification, and treatment outcomes were documented to support reproducibility. Missing or undocumented values were distinguished from explicitly negative clinical results.

The study population, exclusion process, and number of records entering each analysis will be presented in a flow diagram. Where repeated treatment episodes occurred, their handling will be described explicitly rather than assuming that every record represented a different individual.

Variable definitions

HIV status

The principal exposure was recorded HIV status, classified as positive, negative, or unknown. Positive and negative statuses were based on the corresponding SITB entries; laboratory verification outside the surveillance dataset was unavailable unless otherwise specified. Unknown status included records without a documented positive or negative result according to the final recoding rules. Unknown HIV status was not interpreted as HIV-negative or as definitive evidence that HIV testing had not been performed. National guidance on collaborative TB-HIV activities provided the programmatic context for interpreting HIV screening, diagnosis, referral, and documentation [22].

Two descriptive measures will be reported separately, the proportion recorded as HIV-positive among all included TB records and the proportion recorded as HIV-positive among records with known HIV status. The latter will be described as HIV positivity among patients with documented status, rather than as an unbiased estimate of HIV prevalence among all patients with TB.

TB anatomical site and diagnostic classification

TB anatomical site was classified as pulmonary (coded as 0) or extrapulmonary (coded as 1) based on the SITB entry. Patients with both pulmonary and extrapulmonary involvement were classified as pulmonary TB. Pulmonary TB was used as the reference category in regression analyses.

Diagnostic classification comprised bacteriologically confirmed and clinically diagnosed TB. Bacteriologically confirmed TB refers to disease with a biological specimen positive by smear microscopy, culture, or a WHO-recommended rapid diagnostic test. Clinically diagnosed TB refers to disease diagnosed by a clinician without meeting the bacteriological-confirmation criteria [21, 23]. Clinically diagnosed TB was not treated as synonymous with a documented negative bacteriological test.

Treatment outcomes

Treatment outcomes were grouped as treatment success, death, loss to follow-up, treatment failure, not evaluated, or missing. Treatment success combined the recorded categories of cured and treatment completed. Death referred to death from any cause during TB treatment and was not interpreted as confirmed TB-attributable or HIV-attributable mortality. Loss to follow-up, treatment failure, and not evaluated were interpreted in accordance with the applicable surveillance definitions and the original SITB coding [21, 24]. “Not evaluated” represented an explicitly recorded outcome category, whereas

“missing” represented the absence of a usable outcome entry. The two categories were retained separately in descriptive analyses.

For the proposed binary mortality analysis, death will be coded as 1. Patients with a documented non-death treatment outcome will be coded as 0. Records with missing or not-evaluated outcomes will be excluded from this binary analysis. This comparison will estimate the odds of recorded death relative to another documented outcome; it will not establish complete ascertainment of survival for patients lost to follow-up.

Other variables

Age was summarized continuously and categorized as < 15, 15–24, 25–44, 45–64, and ≥ 65 years. Sex was classified as female or male. Occupation was grouped into not working/child, housewife, student, farmer/livestock worker/fisherman, laborer/manual worker, private employee, self-employed/trader, government/military/educator, health professional, other, or unknown. Geographic location was categorized as Western, Central, or Eastern Indonesia. The province-to-region mapping used in the analysis will be provided in a supplementary table. Diabetes mellitus status was categorized as positive, negative, or unknown using the recorded SITB status. The registration year was treated as a categorical variable in the adjusted mortality model.

Statistical analysis

Descriptive analysis and annual comparisons

Categorical variables will be summarized as frequencies and percentages, and age will be summarized as the median and interquartile range. Characteristics will be presented for the overall population and separately for each registration year. The Kruskal–Wallis test will be used to compare age distributions across years [25]. Pearson’s chi-square test will be used for categorical comparisons where expected cell counts are adequate [26]. Categories with very sparse counts will be handled separately and will not be used to justify unreliable asymptotic comparisons.

Annual outcome proportions will be reported with their denominators explicitly stated. HIV-status documentation will be summarized as the percentage of records with a positive or negative HIV entry. Where interval estimates are presented for proportions, 95% confidence intervals will be calculated using the Wilson method [27]. Changes between 2022 and 2025 will be expressed as absolute percentage-point differences and, where informative, relative percentage changes. These comparisons describe changes in registered records and recorded outcomes; they will not be interpreted as changes in population TB incidence. Population-based incidence rates and age-standardized incidence rates will not be calculated without appropriate population denominators.

Association between HIV status and recorded death

Univariable logistic regression will estimate crude odds ratios for recorded death. Multivariable logistic regression will estimate adjusted odds ratios and 95% confidence intervals, using HIV-negative status as the reference category. The initial adjusted model will include HIV status, age group, sex, geographic region, TB anatomical site, diagnostic classification, diabetes mellitus status, and registration year. Occupation will be considered in an additional model if category validity and completeness support its inclusion. Covariates will be selected using substantive knowledge and the study objective rather than solely on univariable statistical significance [28, 29].

Because diagnostic classification and anatomical site may partly reflect manifestations of HIV-associated TB, adjustment for these variables will be interpreted as estimating an association conditional on recorded clinical characteristics rather than necessarily the total causal effect of HIV. Model specifications and reference categories will be reported explicitly. Model convergence, sparse categories, and potentially redundant predictors will be assessed. If facility identifiers are available, the need to account for clustering within reporting facilities will be evaluated. Results will be interpreted as associations with recorded death during treatment, without assuming that residual confounding or differential outcome ascertainment has been eliminated.

Missing data and sensitivity analyses

The extent of missing or unknown information will be reported for each variable and registration year. Unknown HIV status will be retained as a separate category in descriptive analyses and in a model examining recorded HIV-status categories. Its coefficient will describe the association of undocumented status with recorded mortality, rather than the biological effect of HIV infection. Retaining unknown categories does not, by itself, correct bias due to missing covariate information [28]. Consequently, a sensitivity analysis will restrict the model to records with known HIV status, and the characteristics of included and excluded records will be compared. A further analysis will exclude the 2025 registration cohort to assess whether incomplete outcome ascertainment in the most recent cohort materially changes the results.

Multiple imputation will not be assumed to resolve the substantial proportion of unknown HIV status. Its suitability will be considered only after evaluating available predictors of missingness, auxiliary information, and the plausibility of the missing-at-random assumption [28]. If implemented, the imputation model, variables, number of imputations, diagnostics, and pooling procedure will be reported separately. An additional sensitivity analysis may estimate adjusted risk ratios using modified Poisson regression with robust variance, provided that outcome ascertainment and the analytic cohort support a risk interpretation [29]. This analysis will be included only if actually performed.

Spatial distribution and spatial autocorrelation analysis

TB registration records were aggregated by province for each year from 2022 to 2025 and for the overall study period. Records with missing or unidentifiable province information were excluded from spatial analyses but retained in the national descriptive summaries. Provincial identifiers were harmonized with

level-1 administrative boundaries obtained from the Global Administrative Areas (GADM) database through the R package geodata. Boundary names were standardized to match SITB province labels, including Jakarta Raya to DKI Jakarta, Yogyakarta to DI Yogyakarta, and Bangka Belitung to Kepulauan Bangka Belitung. Records from Papua Tengah, Papua Selatan, and Papua Pegunungan were aggregated with Papua, while records from Papua Barat Daya were aggregated with Papua Barat, to align with the boundaries used.

Choropleth maps were constructed to display the geographic distribution of registered TB cases, HIV positivity among patients with documented HIV status, and HIV-status documentation completeness. Provincial HIV positivity was calculated as the number of HIV-positive TB records divided by the total number of HIV-positive and HIV-negative TB records, multiplied by 100. HIV-status documentation completeness was calculated as the percentage of all TB records with a documented positive or negative HIV result. HIV positivity was examined overall and separately for male and female patients, using the corresponding sex-specific denominators.

These indicators described the distribution of registered cases and documented HIV status rather than population-based TB incidence or HIV prevalence in the general population. Provinces with no records with known HIV status were assigned missing values rather than zero HIV positivity. Consistent map scales were used for comparisons across years, and provincial denominators were reported to support interpretation.

Spatial autocorrelation

Global Moran's I was used to evaluate whether provincial HIV positivity exhibited spatial autocorrelation. Positive values indicated spatial similarity between neighbouring provinces, whereas negative values indicated spatial dissimilarity. Statistical evidence of clustering or dispersion was evaluated against the permutation-based null distribution rather than by interpreting the sign or magnitude of the statistic alone.

Spatial relationships were represented by a spatial weights matrix constructed using four nearest neighbours (k = 4), identified using great-circle distances between representative points located within provincial polygons. The matrix was initially row-standardized and subsequently symmetrized using listw2U() for the Global Moran's I and annual local spatial autocorrelation analyses. The nearest-neighbor definition assigned neighbors to every province, including island provinces, thereby avoiding isolated provinces that could arise under a contiguity-based definition. Spatial weights and autocorrelation statistics were implemented using the spdep package in R [30].

Local Moran's I was used to identify local indicators of spatial association (LISA) [30]. Statistically significant patterns were classified as high–high or low–low clusters and high–low or low–high spatial outliers, based on provincial HIV positivity and the corresponding spatial lag. High–high clusters represented provinces with relatively high HIV positivity, surrounded by provinces with relatively high HIV

positivity; low–low clusters represented the converse. High–low and low–high categories identified provinces whose values differed from those of their neighbours.

Statistical significance was evaluated using 999 conditional permutations. Local P values were adjusted for multiple comparisons using the Benjamini–Hochberg false discovery rate (FDR) procedure within each population group and year, with adjusted $P < 0.05$ considered statistically significant. Local associations were classified as high–high, low–low, high–low, or low–high when significant; otherwise, they were classified as non-significant. HIV-status documentation completeness and the number of records with known HIV status were considered when interpreting spatial patterns, because differences in testing or recording practices could influence observed provincial HIV positivity. All spatial analyses and mapping were performed using R version 4.6.1, (R Foundation for Statistical Computing, Vienna, Austria), with relevant packages and their versions documented to support reproducibility [31, 32, 33].

Ethics approval and data protection

Ethical approval

was obtained from the Ethical Clearance Committee of the Faculty of Medicine, University of Tanjungpura, approval number 8029/UN22.9/PT.01.04/2026, dated 8 September 2026. The data used in this study were obtained from the Ministry of Health of the Republic of Indonesia through the SITB. Only aggregate results are reported, without disclosure of individual patient information.

Result

Demographic and clinical characteristics

The demographic and clinical characteristics of the study population are presented in Table 1. Between 2022 and 2025, the analytical dataset comprised 2,988,098 TB registration records in Indonesia. Annual registrations increased from 638,646 in 2022 to 729,935 in 2023, 792,343 in 2024, and 827,174 in 2025, representing a 29.5% increase over the study period. The overall median age was 39 years (IQR: 21–55), increasing from 38 years (IQR: 21–54) in 2022 to 41 years (IQR: 22–57) in 2025. Patients aged 45–64 years constituted the largest age group (914,610; 31%)

Table 1
Characteristics of tuberculosis patients, Indonesia, 2022–2025

Characteristic	Overall N = 2,988,098[1]	2022 N = 638,646[1]	2023 N = 729,935[1]	2024 N = 792,343[1]	2025 N = 827,174[1]
Age, years	39 (21–55)	38 (21–54)	38 (20–54)	39 (21–55)	41 (22–57)
Age group, years					
< 15	501,670 (17%)	106,449 (17%)	130,983 (18%)	134,882 (17%)	129,356 (16%)
15–24	411,088 (14%)	91,641 (14%)	101,737 (14%)	108,239 (14%)	109,471 (13%)
25–44	828,081 (28%)	186,222 (29%)	204,229 (28%)	215,945 (27%)	221,685 (27%)
45–64	914,610 (31%)	194,804 (31%)	218,378 (30%)	242,738 (31%)	258,690 (31%)
≥65	332,649 (11%)	59,530 (9.3%)	74,608 (10%)	90,539 (11%)	107,972 (13%)
Sex					
Female	1,267,536 (42%)	272,627 (43%)	310,443 (43%)	335,997 (42%)	348,469 (42%)
Male	1,720,561 (58%)	366,019 (57%)	419,492 (57%)	456,346 (58%)	478,704 (58%)
Occupation					
Not working / child	385,070 (13%)	86,251 (14%)	96,981 (13%)	101,407 (13%)	100,431 (12%)
Housewife	458,814 (15%)	101,995 (16%)	110,080 (15%)	119,233 (15%)	127,506 (15%)
Student	236,011 (7.9%)	54,376 (8.5%)	60,267 (8.3%)	60,910 (7.7%)	60,458 (7.3%)
Farmer / livestock / fisherman	240,728 (8.1%)	54,929 (8.6%)	57,064 (7.8%)	62,389 (7.9%)	66,346 (8.0%)
Laborer / manual worker	277,646 (9.3%)	60,364 (9.5%)	66,052 (9.0%)	73,686 (9.3%)	77,544 (9.4%)
Private employee	174,845 (5.9%)	39,920 (6.3%)	43,729 (6.0%)	46,755 (5.9%)	44,441 (5.4%)

[1]Median (Q1–Q3); n (%)

Characteristic	Overall N = 2,988,098[1]	2022 N = 638,646[1]	2023 N = 729,935[1]	2024 N = 792,343[1]	2025 N = 827,174[1]
Self-employed / trader	220,306 (7.4%)	47,887 (7.5%)	51,526 (7.1%)	57,626 (7.3%)	63,267 (7.6%)
Government / military / educator	40,378 (1.4%)	9,757 (1.5%)	9,553 (1.3%)	10,266 (1.3%)	10,802 (1.3%)
Health professional	3,412 (0.1%)	815 (0.1%)	796 (0.1%)	917 (0.1%)	884 (0.1%)
Other	382,437 (13%)	68,618 (11%)	89,199 (12%)	102,949 (13%)	121,671 (15%)
Unknown	568,451 (19%)	113,734 (18%)	144,688 (20%)	156,205 (20%)	153,824 (19%)
Region					
Western Indonesia	2,483,783 (83,4%)	530,974 (82,7%)	610,001 (83,7%)	657,503 (83,1%)	685,305 (83,1%)
Central Indonesia	395,019 (13%)	83,994 (13%)	96,004 (13%)	105,335 (13%)	109,686 (13%)
Eastern Indonesia	109,296 (3.7%)	23,678 (3.7%)	23,930 (3.3%)	29,505 (3.7%)	32,183 (3.9%)
TB anatomical site					
Pulmonary	2,735,468 (92%)	586,718 (92%)	666,464 (91%)	726,297 (92%)	755,989 (91%)
Extrapulmonary	252,630 (8.5%)	51,928 (8.1%)	63,471 (8.7%)	66,046 (8.3%)	71,185 (8.6%)
Type of diagnosis					
Bacteriologically confirmed	1,437,335 (48%)	302,084 (47%)	338,947 (46%)	390,429 (49%)	405,875 (49%)
Clinically diagnosed	1,550,763 (52%)	336,562 (53%)	390,988 (54%)	401,914 (51%)	421,299 (51%)
HIV status					
Negative	745,751 (25%)	130,033 (20%)	158,247 (22%)	192,728 (24%)	264,743 (32%)
Positive	42,729 (1.4%)	8,735 (1.4%)	10,141 (1.4%)	10,873 (1.4%)	12,980 (1.6%)

[1]Median (Q1–Q3); n (%)

Characteristic	Overall N = 2,988,098[1]	2022 N = 638,646[1]	2023 N = 729,935[1]	2024 N = 792,343[1]	2025 N = 827,174[1]
Unknown	2,199,618 (74%)	499,878 (78%)	561,547 (77%)	588,742 (74%)	549,451 (66%)
Diabetes mellitus status					
Negative	1,332,422 (45%)	212,351 (33%)	312,508 (43%)	394,185 (50%)	413,378 (50%)
Positive	218,734 (7.3%)	40,592 (6.4%)	53,761 (7.4%)	61,912 (7.8%)	62,469 (7.6%)
Unknown	1,436,942 (48%)	385,703 (60%)	363,666 (50%)	336,246 (42%)	351,327 (42%)
Treatment outcome					
Treatment success	2,425,447 (81%)	552,629 (87%)	623,875 (85%)	674,538 (85%)	574,405 (69%)
Death	116,851 (3.9%)	22,999 (3.6%)	27,561 (3.8%)	32,447 (4.1%)	33,844 (4.1%)
LTFU	240,721 (8.1%)	48,940 (7.7%)	60,874 (8.3%)	70,313 (8.9%)	60,594 (7.3%)
Failure	8,186 (0.3%)	1,901 (0.3%)	2,301 (0.3%)	2,276 (0.3%)	1,708 (0.2%)
Not evaluated	7,136 (0.2%)	414 (< 0.1%)	2,971 (0.4%)	2,721 (0.3%)	1,030 (0.1%)
Missing	189,757 (6.4%)	11,763 (1.8%)	12,353 (1.7%)	10,048 (1.3%)	155,593 (19%)

[1]Median (Q1–Q3); n (%)

followed by those aged 25–44 years (828,081; 28%). The proportion aged ≥ 65 years increased from 9.3% in 2022 to 13% in 2025. Male patients accounted for 1,720,561 registrations (58%), compared with 1,267,536 female registrations (42%). The most frequently recorded occupational categories were housewives (458,814; 15%), not working/child (385,070; 13%), and other occupations (382,437; 13%). Occupation was unknown in 568,451 records (19%). The proportion of students declined from 8.5% in 2022 to 7.3% in 2025.

Western Indonesia accounted for most registrations (2,483,783; 83,4%), followed by Central Indonesia (395,019; 13%) and Eastern Indonesia (109,296; 3.7%). Pulmonary TB accounted for 2,735,468 records (92%), whereas extrapulmonary TB accounted for 252,630 (8.5%). Slightly more than half of registrations

were clinically diagnosed (1,550,763; 52%), while 1,437,335 (48%) were bacteriologically confirmed. The proportion with bacteriological confirmation increased from 47% in 2022 to 49% in 2025. Treatment success was documented in 2,425,447 records (81%), death in 116,851 (3.9%), loss to follow-up in 240,721 (8.1%), and treatment failure in 8,186 (0.3%). A further 7,136 records (0.2%) were classified as not evaluated, while 189,757 (6.4%) had missing outcomes.

The recorded death proportion increased from 3.6% in 2022 to 3.8% in 2023 and 4.1% in both 2024 and 2025. Loss to follow-up increased from 7.7% in 2022 to 8.9% in 2024, before decreasing to 7.3% in 2025. Recorded treatment success decreased from 87% in 2022 to 85% in 2023 and 2024 and 69% in 2025. The 2025 cohort also had a substantially larger proportion of missing outcomes (19%) than the preceding cohorts (1.3–1.8%).

Recorded HIV status and diabetes mellitus

Overall, 42,729 TB records were HIV-positive, 745,751 were HIV-negative, and 2,199,618 had unknown HIV status. HIV-positive records represented 1.4% of all registrations and 5.42% of the 788,480 records with documented positive or negative HIV status. The number of HIV-positive registrations increased from 8,735 in 2022 to 10,141 in 2023, 10,873 in 2024, and 12,980 in 2025, representing a 48.6% increase. However, HIV positivity among records with known status declined from 6.29% in 2022 to 6.02% in 2023, 5.34% in 2024, and 4.67% in 2025. Over the same period, HIV-status documentation increased from 21.7% to 33.6% of all registrations, while the proportion with unknown status decreased from 78.3% to 66.4%.

Diabetes mellitus was recorded as positive in 218,734 records (7.3%), negative in 1,332,422 (45%), and unknown in 1,436,942 (48%). The proportion with recorded diabetes increased from 6.4% in 2022 to 7.6% in 2025, while unknown diabetes status decreased from 60% to 42%.

Age- and sex-specific patterns of TB–HIV

Age- and sex-specific patterns among HIV-positive TB records are shown in Fig. 1. Case counts increased sharply from late adolescence and peaked in the late twenties, followed by a progressive decline at older ages (Fig. 1A). Male case counts exceeded female counts across most adult ages, with the largest absolute difference occurring in the late twenties and early thirties (Fig. 1B).

In both sexes, patients aged 25–44 years accounted for the largest number of HIV-positive TB registrations throughout the study period. Annual case counts increased among both male and female patients, while the contribution of patients aged ≥ 65 years remained small (Fig. 1C). HIV positivity among patients with known HIV status was highest in the 25–44-year age group for both sexes and was consistently higher among males than females in this age group. Positivity declined between 2022 and 2025 among patients aged 25–44 years in both sexes. Lower positivity was observed among children aged < 15 years and adults aged ≥ 65 years (Fig. 1D).

Temporal patterns

Regional temporal patterns are presented in Fig. 2. Western Indonesia consistently contributed the largest number of HIV-positive TB registrations, whereas Eastern Indonesia had the highest HIV positivity among patients with documented status. HIV-positive case counts increased across the three regions between 2022 and 2025, while positivity declined overall (Fig. 2A). Monthly HIV positivity varied within and between years. Eastern Indonesia maintained higher monthly positivity than Western and Central Indonesia throughout the study period. The timing of monthly peaks and troughs varied across regions and years, with no consistent nationwide seasonal pattern apparent in the plotted series (Fig. 2B).

The fitted trends shown in Fig. 2 indicated declining annual HIV positivity in Western Indonesia (APC: −11.19%; P = 0.011) and Eastern Indonesia (APC: −9.36%; P = 0.033). Central Indonesia also showed a negative estimated trend, but the evidence did not reach the conventional significance threshold (APC: −5.04%; P = 0.215) (Fig. 2C–E).

Geographic distribution of HIV positivity

Annual provincial maps showed geographic variation in HIV positivity among patients with documented status (Fig. 3). The highest mapped values were concentrated in Papua throughout the study period, whereas most provinces in Sumatra, Java, and Kalimantan showed lower values. This east–west contrast was visible in the overall maps and in the male- and female-specific maps. The mapped values in the Papua area decreased between 2022 and 2025 but remained relatively high compared with much of western Indonesia. The sex-specific maps showed broadly similar geographic patterns, with elevated positivity in the Papua area among both males and females.

Geographic distribution of TB registrations and HIV indicators

The provincial distributions of TB registrations, HIV positivity, and HIV-status ascertainment during 2022–2025 are shown in Fig. 4. TB registrations were concentrated on Java, particularly in West Java, whereas most provinces outside Java recorded fewer cases (Fig. 4A). In contrast, HIV positivity among patients with known HIV status was highest in the Papua area, with comparatively lower values across most provinces in Sumatra, Java, and Kalimantan (Fig. 4B).

HIV-status ascertainment also varied geographically, with relatively higher proportions of documented status in parts of Kalimantan and western Papua (Fig. 4C). The areas with the largest numbers of TB registrations did not coincide with those showing the highest HIV positivity. These maps describe HIV positivity among patients with documented status alongside provincial differences in the completeness of HIV-status recording.

Local spatial autocorrelation

Global spatial autocorrelation analysis showed significant positive spatial autocorrelation in provincial HIV positivity among TB patients over the pooled 2022–2025 period (Moran's I = 0.275, Z = 2.980, P = 0.0029; Table 2). Annual Moran's I values increased from 0.167 in 2022 to 0.325 in 2025. Spatial autocorrelation was statistically significant in 2023–2025, whereas the association in 2022 did not reach statistical significance (P = 0.0524).

Among male patients, the pooled analysis also indicated significant positive spatial autocorrelation (Moran's I = 0.263, Z = 2.812, P = 0.0049). Annual Moran's I increased from 0.112 in 2022 to 0.344 in 2025, with significant spatial autocorrelation observed from 2023 onwards. Among female patients, positive spatial autocorrelation was significant both over the pooled period (Moran's I = 0.264, Z = 3.042, P = 0.0024) and in every individual year. Annual values ranged from 0.236 in 2022 to 0.269 in 2025, showing less variation than those observed among male patients.

Table 2
Global spatial autocorrelation of HIV positivity among TB patients, Indonesia, 2022–2025

Population group	Period	Moran's I	Moran's Z-score	P-value
Overall	2022–2025	0.275	2.980	0.0029
	2022	0.167	1.940	0.0524
	2023	0.252	2.740	0.0061
	2024	0.294	3.126	0.0018
	2025	0.325	3.540	0.0004
Male	2022–2025	0.263	2.812	0.0049
	2022	0.112	1.366	0.1720
	2023	0.226	2.449	0.0143
	2024	0.275	2.938	0.0033
	2025	0.344	3.624	0.0003
Female	2022–2025	0.264	3.042	0.0024
	2022	0.236	2.767	0.0057
	2023	0.237	2.756	0.0059
	2024	0.265	2.966	0.0030
	2025	0.269	3.159	0.0016

The pooled local Moran's I analysis for 2022–2025 identified a high–high cluster in the area mapped as Papua, indicating relatively high HIV positivity accompanied by high values in neighbouring spatial units

(Fig. 5). Low–low clusters were visible in Jambi, South Sumatra, and Bengkulu. Most other provinces were classified as not significant in the supplied LISA map.

Factors associated with death during TB treatment

Crude and adjusted associations with recorded death during TB treatment for 2022–2024 are presented in Table 3. Compared with HIV-negative patients, HIV-positive patients had higher crude odds of death (cOR: 4.27; 95% CI: 4.12–4.42). The association remained after adjustment for the variables included in the model (aOR: 5.06; 95% CI: 4.86–5.26; P < 0.001). Compared with patients aged 25–44 years, adjusted odds of death were higher among those aged 45–64 years (aOR: 1.81; 95% CI: 1.74–1.87) and ≥ 65 years (aOR: 3.25; 95% CI: 3.12–3.38). Lower odds were observed among patients aged < 15 years (aOR: 0.19; 95% CI: 0.17–0.21) and 15–24 years (aOR: 0.67; 95% CI: 0.63–0.71). Male patients had higher adjusted odds of death than female patients (aOR: 1.17; 95% CI: 1.13–1.22).

Table 3
Factors associated with mortality during tuberculosis treatment, Indonesia, 2022–2024

Characteristic	Crude analysis				Adjusted analysis			
	cOR	95% CI	95% CI	p-value	aOR	95% CI	95% CI	p-value
HIV status								
Negative	—	—	—		—	—	—	
Positive	4.27	4.12, 4.42	4.12, 4.42	< 0.001	5.26	5.06, 5.47	5.06, 5.47	< 0.001
Age group, years								
25–44	—	—	—		—	—	—	
< 15	0.19	0.17, 0.21	0.17, 0.21	< 0.001	0.21	0.19, 0.23	0.19, 0.23	< 0.001
15–24	0.61	0.58, 0.64	0.58, 0.64	< 0.001	0.67	0.63, 0.71	0.63, 0.71	< 0.001
45–64	1.43	1.39, 1.48	1.39, 1.48	< 0.001	1.83	1.77, 1.89	1.77, 1.89	< 0.001
≥ 65	2.56	2.46, 2.65	2.46, 2.65	< 0.001	3.37	3.24, 3.51	3.24, 3.51	< 0.001
Sex								
Female	—	—	—		—	—	—	
Male	1.38	1.34, 1.41	1.34, 1.41	< 0.001	1.16	1.12, 1.20	1.12, 1.20	< 0.001
Occupation								
Private employee	—	—	—		—	—	—	
Not working / child	1.15	1.07, 1.23	1.07, 1.23	< 0.001	1.84	1.72, 1.97	1.72, 1.97	< 0.001
Housewife	1.11	1.05, 1.19	1.05, 1.19	< 0.001	1.22	1.14, 1.31	1.14, 1.31	< 0.001
Student	0.46	0.42, 0.50	0.42, 0.50	< 0.001	1.31	1.19, 1.44	1.19, 1.44	< 0.001
Farmer / livestock / fisherman	1.42	1.33, 1.51	1.33, 1.51	< 0.001	1.17	1.10, 1.26	1.10, 1.26	< 0.001
Laborer / manual worker	0.98	0.92, 1.05	0.92, 1.05	0.618	0.99	0.92, 1.07	0.92, 1.07	0.825

Abbreviations: CI = Confidence Interval, OR = Odds Ratio

Characteristic	Crude analysis				Adjusted analysis			
	cOR	95% CI	95% CI	p-value	aOR	95% CI	95% CI	p-value
HIV status								
Self-employed / trader	1.16	1.08, 1.24	1.08, 1.24	< 0.001	1.08	1.00, 1.15	1.00, 1.15	0.044
Government / military / educator	1.20	1.07, 1.34	1.07, 1.34	0.002	1.01	0.90, 1.13	0.90, 1.13	0.888
Health professional	0.46	0.26, 0.73	0.26, 0.73	0.003	0.60	0.34, 0.96	0.34, 0.96	0.050
Other	1.15	1.08, 1.23	1.08, 1.23	< 0.001	1.39	1.30, 1.49	1.30, 1.49	< 0.001
Unknown	1.48	1.39, 1.58	1.39, 1.58	< 0.001	1.43	1.34, 1.52	1.34, 1.52	< 0.001
Region								
Western Indonesia	—	—	—		—	—	—	
Central Indonesia	1.81	1.76, 1.87	1.76, 1.87	< 0.001	1.58	1.53, 1.64	1.53, 1.64	< 0.001
Eastern Indonesia	1.54	1.45, 1.63	1.45, 1.63	< 0.001	1.22	1.14, 1.29	1.14, 1.29	< 0.001
Unknown	1.13	0.93, 1.36	0.93, 1.36	0.213	1.15	0.94, 1.39	0.94, 1.39	0.165
TB anatomical site								
Pulmonary	—	—	—		—	—	—	
Extrapulmonary	0.70	0.66, 0.74	0.66, 0.74	< 0.001	0.92	0.87, 0.97	0.87, 0.97	0.001
Diabetes mellitus status								
Negative	—	—	—		—	—	—	
Positive	1.52	1.45, 1.59	1.45, 1.59	< 0.001	1.21	1.16, 1.27	1.16, 1.27	< 0.001
Unknown	1.17	1.14, 1.20	1.14, 1.20	< 0.001	1.09	1.06, 1.12	1.06, 1.12	< 0.001
Year								
Abbreviations: CI = Confidence Interval, OR = Odds Ratio								

Characteristic	Crude analysis				Adjusted analysis			
	cOR	95% CI	95% CI	p-value	aOR	95% CI	95% CI	p-value
HIV status								
2022	—	—	—		—	—	—	
2023	1.05	1.01, 1.08	1.01, 1.08	0.009	1.04	1.01, 1.08	1.01, 1.08	0.022
2024	1.12	1.09, 1.16	1.09, 1.16	< 0.001	1.12	1.08, 1.16	1.08, 1.16	< 0.001
Abbreviations: CI = Confidence Interval, OR = Odds Ratio								

Relative to Western Indonesia, adjusted odds of death were higher in Central Indonesia (aOR: 1.62; 95% CI: 1.57–1.68) and Eastern Indonesia (aOR: 1.22; 95% CI: 1.15–1.30). Extrapulmonary TB was associated with lower odds than pulmonary TB (aOR: 0.82; 95% CI: 0.78–0.87), whereas clinically diagnosed TB was associated with higher odds than bacteriologically confirmed disease (aOR: 1.27; 95% CI: 1.23–1.30). Recorded diabetes mellitus was also associated with higher odds of death (aOR: 1.24; 95% CI: 1.18–1.30). Compared with private employees, higher adjusted odds of death were observed among patients classified as not working/child (aOR: 1.86; 95% CI: 1.74–2.00), housewives (aOR: 1.24; 95% CI: 1.15–1.33), students (aOR: 1.32; 95% CI: 1.20–1.45), farmers/livestock workers/fishermen (aOR: 1.20; 95% CI: 1.12–1.29), and self-employed patients/traders (aOR: 1.09; 95% CI: 1.01–1.17). Health professionals had lower adjusted odds (aOR: 0.59; 95% CI: 0.34–0.96; P = 0.047). Associations for laborers/manual workers and government/military/educator occupations were not statistically significant after adjustment. Compared with 2022, adjusted odds of recorded death were slightly higher in 2023 (aOR: 1.04; 95% CI: 1.00–1.07; P = 0.046) and in 2024 (aOR: 1.12; 95% CI: 1.08–1.15; P < 0.001).

Table 4
Modified Poisson regression with robust standard errors for TB mortality, Indonesia, 2022–2024

Variable	aRR (95% CI)	p-value
HIV Status	4.27 (4.13–4.41)	< 0.001
Positive		
Age group, years	0.20 (0.18–0.22)	< 0.001
<15		
15–24	0.69 (0.65–0.72)	< 0.001
45–64	1.72 (1.67–1.78)	< 0.001
≥65	2.96 (2.85–3.07)	< 0.001
Sex	1.16 (1.12–1.20)	< 0.001
Male		
Occupation	1.75 (1.65–1.87)	< 0.001
Not working / child		
Housewife	1.22 (1.14–1.30)	< 0.001
Student	1.28 (1.16–1.40)	< 0.001
Farmer / livestock / fisherman	1.19 (1.11–1.26)	< 0.001
Laborer / manual worker	1.01 (0.94–1.08)	0.804
Self-employed / trader	1.08 (1.01–1.15)	0.022
Government / military / educator	1.01 (0.91–1.13)	0.803
Health professional	0.60 (0.37–0.99)	0.043
Other	1.35 (1.27–1.44)	< 0.001
Unknown	1.39 (1.32–1.48)	< 0.001
Geographic Region	1.55 (1.50–1.60)	< 0.001
Central		
Eastern	1.21 (1.14–1.28)	< 0.001
TB anatomical site	0.84 (0.79–0.88)	< 0.001
Extrapulmonary		

Variable	aRR (95% CI)	p-value
Diagnostic Clasification Clinically diagnosed	1.24 (1.21–1.28)	< 0.001
Diabetes Mellitus status Positive	1.22 (1.17–1.28)	< 0.001
Unknown	1.07 (1.04–1.10)	< 0.001
Registration Year 2023	1.03 (1.00–1.07)	0.045
2024	1.11 (1.07–1.14)	< 0.001

Modified Poisson regression with robust standard errors showed that HIV-positive status was associated with a higher risk of death among TB patients registered during 2022–2024 (adjusted risk ratio [aRR] = 4.27, 95% CI: 4.13–4.41; P < 0.001). Compared with patients aged 25–44 years, mortality risk was higher among those aged 45–64 years (aRR = 1.72, 95% CI: 1.67–1.78) and ≥ 65 years (aRR = 2.96, 95% CI: 2.85–3.07), and lower among those aged < 15 years (aRR = 0.20, 95% CI: 0.18–0.22) and 15–24 years (aRR = 0.69, 95% CI: 0.65–0.72). Higher mortality risk was also observed among male patients, patients in Central and Eastern Indonesia, those with clinically diagnosed TB, and those with documented diabetes mellitus. Extrapulmonary TB was associated with a lower mortality risk than pulmonary TB (aRR = 0.84, 95% CI: 0.79–0.88). Detailed estimates are presented in Table 4.

Table 5
Sensitivity analyses of the association between HIV status and TB mortality

Analysis	Effect measure	Estimate (95% CI)	p-value
Main logistic model	aOR	5.06 (4.86–5.26)	< 0.001
Modified Poisson robust	aRR	4.27 (4.13–4.41)	< 0.001
Death vs treatment success	aOR	5.38 (5.17–5.60)	< 0.001
Complete-case analysis	aOR	5.33 (5.02–5.67)	< 0.001

The association between HIV-positive status and mortality remained statistically significant across all sensitivity analyses (Table 5). The main logistic regression model yielded an adjusted odds ratio (aOR) of 5.06 (95% CI: 4.86–5.26). When the outcome comparison was restricted to death versus treatment success, the aOR was 5.38 (95% CI: 5.17–5.60). Complete-case analysis yielded a similar estimate (aOR = 5.33, 95% CI: 5.02–5.67). All analyses had P < 0.001, indicating a consistent association across model specifications and analytical restrictions.

Discussion

This study analysed 2,988,098 TB registrations in Indonesia during 2022–2025 and identified a divergence between recorded case volume, HIV positivity, and documentation completeness. TB notifications and documented HIV-positive registrations increased, while HIV positivity among registrations with known status declined. HIV-positive status was strongly associated with recorded death in the 2022–2024 analyses, and provincial positivity exhibited significant global spatial autocorrelation but no significant local associations after FDR adjustment. The contribution of these findings is the combined assessment of who entered the surveillance system, whose HIV status was documented, and which registered groups experienced adverse outcomes. This approach helps distinguish changes in surveillance ascertainment from changes that might reflect disease burden, while identifying priorities for integrated TB–HIV care [34–38].

The increase in annual TB registrations should be interpreted in light of prior Indonesian research on case detection and reporting. Lestari et al. observed an increase in notifications during service strengthening in Mimika, including expanded primary-care involvement and diagnostic capacity, followed by a disruption during the COVID-19 pandemic [39]. In contrast, Widoyo et al. linked laboratory and treatment registers in North and West Sumatra and found that approximately one-quarter of bacteriologically confirmed cases were absent from treatment notification databases [40]. These studies demonstrate that recorded case volume is sensitive to both service activity and registration completeness. Our 29.5% increase in notifications is therefore compatible with improved capture of diagnosed disease, but it does not establish that ascertainment improved or that population incidence increased. Distinguishing these explanations requires information on reporting facilities, diagnostic activity, and registration practices. The increase represents a larger recorded demand for care regardless of its underlying cause.

The demographic findings also have parallels in previous studies, but their interpretation depends on the denominator. Males accounted for 57.6% of registrations, while HIV-positive records were concentrated among working-age adults. Horton et al.'s meta-analysis of prevalence surveys found substantially higher TB prevalence among men and evidence that notification data can understate sex differences in disease burden [41]. Our male predominance is consistent with that direction, although a registration proportion cannot quantify a sex-specific incidence or prevalence ratio. Age and sex also matter for service design: the concentration of documented TB–HIV among adults aged 25–44 years identifies a substantial demand for coordinated care during working life. Occupational associations should be interpreted with caution because categories such as housewife, not working/child, and farmer encompass different social circumstances, and occupation was undocumented in 19% of records. Appointment flexibility and continuity of care are reasonable priorities to investigate; the dataset does not establish that occupational exposure or inability to attend services caused the observed differences.

Incomplete HIV-status documentation is a central finding rather than a secondary data-quality concern. Documentation increased from 21.7% to 33.6%, yet approximately two-thirds of registrations in 2025 still lacked a positive or negative entry. Previous Indonesian research illustrates why testing, attendance, and documentation must be separated. In Jogjakarta, Mahendradhata et al. found substantial acceptance of

unlinked anonymous testing but much lower uptake of voluntary counselling and testing services [42]. That historical study used a different testing model and cannot benchmark current coverage; its relevance is that different steps in the testing pathway need separate measurement. Lestari et al. subsequently reported improving comorbidity screening within a district TB programme [39], demonstrating that local improvements can coexist with incomplete national records. Our unknown-status category cannot distinguish testing that was not undertaken from results that were not transferred or entered. Reconciliation between TB and HIV service records is therefore necessary before undocumented status is interpreted as a clinical service failure.

The simultaneous decline in documented HIV positivity and increase in HIV-positive registrations requires a more precise interpretation than an improvement in the TB–HIV epidemic. Positive registrations increased from 8,735 to 12,980, while positivity among records with known status declined from 6.29% to 4.67%. The denominator with known status expanded faster than the numerator, so these findings are mathematically compatible. Previous research in Jogjakarta found that HIV positivity varied by facility type and prior testing history [42], illustrating how the composition of tested patients can influence observed positivity. If documentation expanded to groups with lower HIV probability, the recorded proportion could fall without a corresponding reduction in underlying coinfection. Conversely, preferential recording among clinically vulnerable patients could elevate it. These are plausible selection mechanisms, not effects demonstrated by this study. Consequently, trends should be interpreted alongside documentation completeness within age, sex, facility, and provincial strata rather than using aggregate positivity alone as evidence of programme impact.

The association between HIV-positive status and recorded death is consistent with previous cohort evidence. Ngari et al.'s surveillance cohort in Meru County, Kenya, found higher mortality among patients with HIV, including those recorded as receiving or not receiving antiretroviral therapy, relative to HIV-negative patients [7]. In Indonesia, Fitriangga et al.'s national analysis of drug-susceptible TB registrations during 2020–2022 found lower odds of treatment success among HIV-positive patients [15]. Our mortality-specific aOR of 5.06 extends this evidence to a later registration period and a different outcome. However, it cannot be directly compared with an odds ratio for treatment success or a hazard ratio from a survival model. The Kenyan cohort accounted for time and competing events, whereas our analysis compared recorded binary outcomes. Moreover, the Indonesian studies overlap in 2022 and share SITB as their source; their consistency is supportive but does not constitute an entirely independent replication.

Clinical cohort research provides context for the HIV association without proving its mechanism in our data. Merati et al.'s INA-PROACTIVE study measured immunological and virological characteristics alongside mortality among people living with HIV in Indonesia [9]. Such information is important because a binary HIV-status field cannot distinguish well-controlled infection from advanced disease. Our models did not incorporate verified CD4 counts, viral load, ART initiation, adherence, nutritional status, or other opportunistic infections. The observed association may therefore combine differences in immune function, clinical presentation, access to care, and unmeasured severity. It identifies a group

requiring closer assessment and follow-up, but it does not estimate the mortality attributable to HIV itself or the preventable fraction under an integrated-care intervention. Future linkage of SITB with clinical HIV information would help distinguish these pathways and identify which components of care are most strongly associated with survival.

The sensitivity analyses support consistency of the HIV–mortality association while clarifying the measure being estimated. The association persisted when comparison was restricted to death versus treatment success and when complete cases were analysed. Modified Poisson regression yielded an aRR of 4.27, which provides a different interpretation than the aOR of 5.06. Zou's methodological study supports the use of robust Poisson regression for estimating relative risks in binary outcomes [33]. Accordingly, the logistic result should be described as approximately a fivefold higher odds ratio, rather than a fivefold higher risk. Similar estimates across analytical restrictions reduce concerns that the result depends entirely on a single outcome definition, but the models share the same underlying surveillance limitations. Excluding individuals with unknown HIV status and missing outcomes can yield a clinically different population, and complete-case analysis adds another selection step. These checks, therefore, support robustness to the examined specifications rather than eliminating bias or establishing causality.

Age and comorbidity findings reinforce the need to assess vulnerability beyond HIV status. Older age was associated with higher mortality, consistent with Sugiyono et al.'s prospective multicentre Indonesian study, in which age ≥ 50 years was associated with unfavourable treatment outcomes [14]. That study also identified underweight as a relevant factor, which our analysis could not address. The diabetes association is consistent with the earlier Indonesian national study, which reported poorer treatment success among patients with diabetes [15]. However, previous studies have not uniformly demonstrated statistically significant effects: Kumar et al.'s prospective cohort of 412 adults in India found numerically higher mortality among patients with diabetes, but the difference was not statistically significant [43]. Differences in precision, eligibility, diabetes management, and outcome definitions may contribute to this contrast; it does not demonstrate a statistically significant difference between study effects. Our large sample improves precision but cannot establish that poor glycaemic control explains the association. Older adults and patients with documented diabetes warrant coordinated assessment, while unknown diabetes status must remain distinct from a verified negative result.

Diagnostic classification also showed a mortality pattern consistent with previous surveillance research. Clinically diagnosed TB was associated with higher adjusted odds of death than bacteriologically confirmed disease. Abdullahi et al. similarly reported higher mortality among clinically diagnosed patients in a Kenyan cohort [44], and Ngari et al. found clinical diagnosis associated with mortality in Meru [7]. These parallels strengthen the case for examining diagnostic pathways, but they do not show that clinical diagnosis causes death or that the diagnosis was incorrect. Clinical classification may identify patients who cannot produce specimens, have less readily detectable disease, or present with complex illness. Conversely, bacteriological confirmation may depend on diagnostic availability and the opportunity to complete testing. The lower mortality association for extrapulmonary TB also requires

caution because this category combines anatomically and prognostically different conditions. Without site-specific information and severity measures, neither diagnostic category should be treated as a direct measure of disease severity or quality of care.

Comparison with previous treatment-outcome studies highlights the importance of eligibility and follow-up. Our overall recorded treatment success was approximately 81%, whereas Fitriangga et al. reported 92.1% among drug-susceptible registrations with complete outcomes [15]. Sugiyono et al. reported 72.3% in a smaller multicentre cohort combining drug-susceptible and multidrug-resistant pulmonary TB [14]. These differences should not be interpreted as evidence of improving or worsening national performance: the populations, resistance profiles, and availability of outcomes differ. In our 2025 cohort, success was recorded for 69% and outcomes were missing for 19%, so an incomplete observation period could substantially affect the apparent decline. Restricting mortality analyses to 2022–2024 reduces the most immediate concern about recent registrations, but does not verify adequate observation for every episode. Cohort comparisons require an explicit extraction date, outcome cutoff, and sufficient time for treatment completion and reporting.

The geographical findings distinguish areas with high notification volume from those with high documented HIV positivity. Java contributed large numbers of TB registrations, whereas the Papua area showed comparatively elevated positivity among records with known HIV status. Previous research supports the relevance of the Papua signal. Pontororing et al.'s prospective study in Timika documented TB–HIV coinfection and increased hospitalization or death among coinfected participants [45]. That study involved a local smear-positive pulmonary TB population and predates the current registration period; it provides historical clinical context rather than confirmation of current provincial prevalence. District programme research in Mimika also found that improved detection did not automatically translate into substantial improvement in treatment outcomes [38]. Taken together with our findings, this suggests that service planning should distinguish diagnostic and reporting demand from the need for integrated HIV care. Provincial priorities should combine absolute positive counts, positivity denominators, documentation completeness, and observed outcomes, rather than ranking provinces by a single mapped percentage.

Global spatial autocorrelation provides evidence of an overall provincial pattern, but not sufficient evidence to designate individual intervention clusters. Pooled positivity showed a positive Moran's I of 0.275, and annual overall associations were significant during 2023–2025. Nevertheless, no local associations remained significant after FDR adjustment. The apparent high–high Papua and low–low Sumatran classifications in the unadjusted LISA display should therefore be treated as exploratory. This distinction matters when relating our maps to previous local studies: clinical evidence of TB–HIV in Timika [39] does not, on its own, validate a statistically significant provincial cluster in our spatial model. Nearest-neighbor weights, aggregation of new Papua provinces, and unequal denominators can influence the observed pattern. The increase in annual Moran's I was descriptive and was not formally tested as a change in clustering strength. Provincial patterns justify more detailed investigation, but do not establish cross-provincial transmission or locate outbreaks.

The practical implications are supported by both intervention evidence and observational comparisons. In the CAMELIA trial, Blanc et al. found that earlier initiation of ART improved survival among adults with TB and marked immunosuppression [46]. Peter et al.'s multicountry trial found that urine LAM-guided diagnosis and treatment initiation reduced short-term mortality among hospitalised HIV-positive adults with suspected TB [47]. These trials support timely HIV treatment and diagnostic pathways responsive to severe illness, although their eligibility criteria limit direct extrapolation to all SITB registrations. Our data do not measure ART timing or evaluate a diagnostic intervention. A proportionate response is to strengthen documentation of HIV testing and results, referral completion, ART status, and outcomes, with closer clinical follow-up for patients with TB–HIV and other documented vulnerabilities. Local implementation should evaluate whether these steps improve linkage and survival rather than assuming that more complete data alone will reduce mortality.

This study has several limitations. Registration data do not capture all TB cases, and previous Indonesian record-linkage research demonstrates that diagnosed cases may be absent from treatment registers [39]. An extensive unknown HIV status may affect both positivity and selection into mortality models; the direction of bias depends on whether undocumented records differ in HIV probability and mortality. Missing outcomes and LTFU can further obscure vital status, while recorded death does not establish a TB- or HIV-attributable cause. Repeat registrations may represent multiple episodes rather than unique patients, and their handling requires verified identifiers. Unmeasured ART, immune status, nutrition, resistance, treatment history, and clinical severity constrain interpretation of adjusted associations. Agreement across sensitivity analyses cannot remove these limitations. Finally, provincial aggregation conceals local variation, and the exclusion of 2,470 records with unknown province status, including 224 positive records, could affect geographical estimates if the exclusions were patterned. The findings are most directly applicable to the supplied registrations and eligible analytical subsets; generalisation to all Indonesian patients with TB requires better ascertainment and linked clinical information.

Conclusion

This analysis of TB registrations in Indonesia during 2022–2025 identified increasing TB notifications and documented HIV-positive registrations, alongside declining HIV positivity among registrations with known HIV status. HIV-status documentation improved but remained incomplete for most registrations, limiting interpretation of temporal and geographical differences. The decline in documented positivity therefore cannot be assumed to represent a reduction in the national TB–HIV burden.

HIV-positive status was strongly associated with mortality in the 2022–2024 analyses, with consistent findings across sensitivity analyses. Provincial HIV positivity exhibited significant positive global spatial autocorrelation over the pooled period, although no local associations remained statistically significant after false discovery rate adjustment. These findings support strengthening HIV testing and result documentation within TB services, coordinating TB–HIV care, and improving follow-up and outcome ascertainment. Geographical resource allocation should consider TB notification volume, HIV positivity,

and documentation completeness together. More complete surveillance and linked clinical information are needed to distinguish changes in recorded patterns from changes in disease burden and to guide targeted programme responses.

Abbreviations

TB	Tuberculosis
HIV	Human immunodeficiency virus
TB–HIV	Tuberculosis and HIV coinfection
WHO	World Health Organization
SITB	Sistem Informasi Tuberkulosis (Indonesia's Tuberculosis Information System)
ART	Antiretroviral therapy
DM	Diabetes mellitus
IQR	Interquartile range
CI	Confidence interval
cOR	Crude odds ratio
aOR	Adjusted odds ratio
aRR	Adjusted risk ratio
APC	Annual percent change
LTFU	Loss to follow-up
GADM	Global Administrative Areas
LISA	Local indicators of spatial association
FDR	False discovery rate

Declarations

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Authors' contributions

IFEM, RA, AF, and IWGAEP contributed to the study conceptualization and methodology. AF conducted the data management and statistical analyses. IFEM, RA, AF, and IWGAEP contributed to the interpretation of the findings. IFEM and AF prepared the initial draft of the manuscript. All authors critically revised the manuscript, approved the final version, and agreed to be accountable for the work.

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Data availability

The data used in this study were supplied by the Ministry of Health of the Republic of Indonesia. Access to the underlying registration-level data is subject to the Ministry's authorization and applicable data-sharing requirements. Requests for data access should be directed to the Ministry of Health.

Ethics approval and consent to participate

This study analysed secondary TB surveillance data supplied by the Ministry of Health of the Republic of Indonesia. Ethical approval was obtained from **Ethical Clearance Committee of Faculty of Medicine University of Tanjungpura**, approval number **No: 8029/UN22.9/PT.01.04/2026,** dated **8 September 2026.**

Human Ethics and Consent to Participate declarations

Not applicable

Competing interests

The authors declare that they have no competing interests.

Clinical trial number

Not applicable.

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Figures

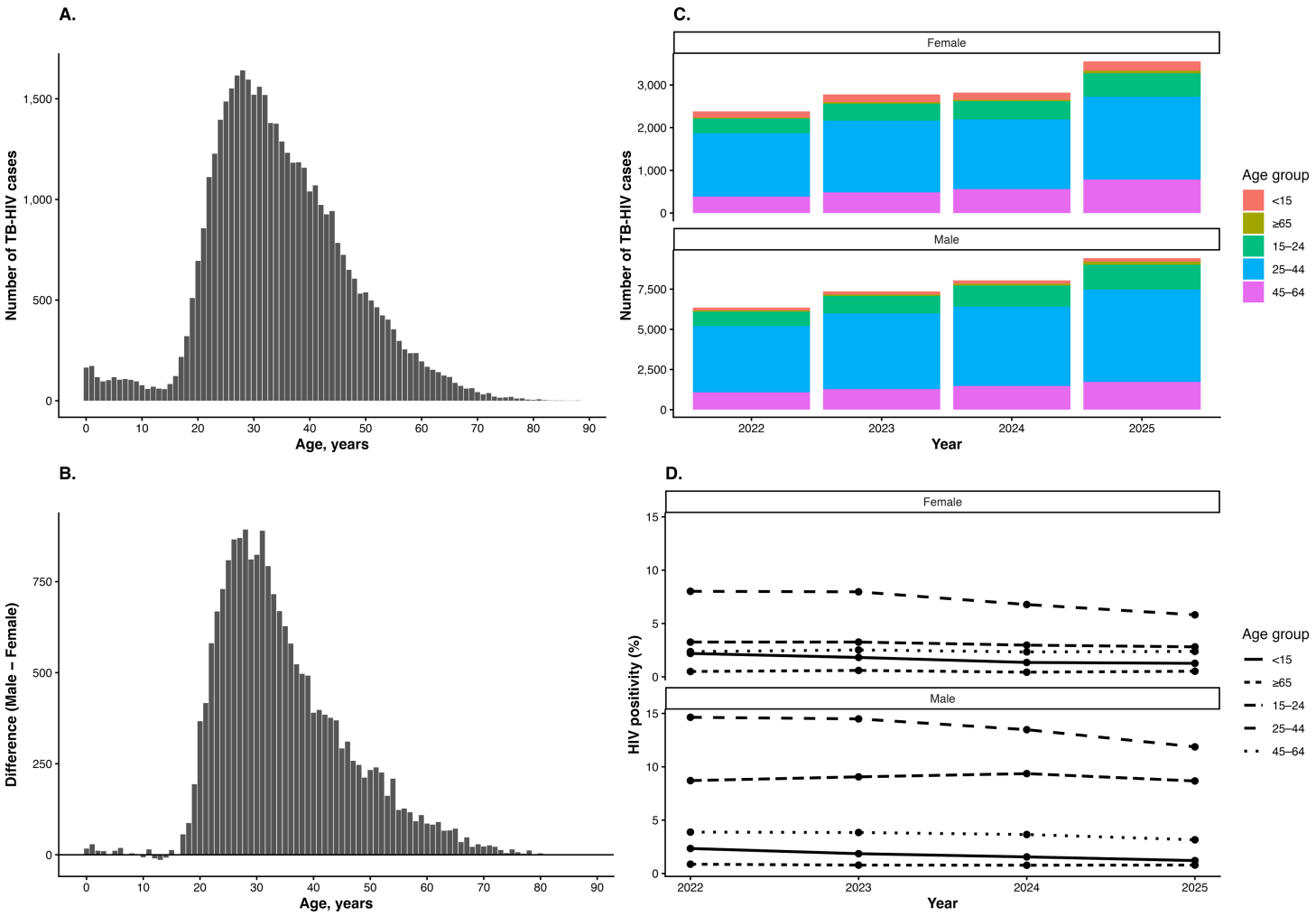


Figure 1

Age and Sex Specific Patterns of Tuberculosis-HIV Cases in Indonesia, 2022-2025

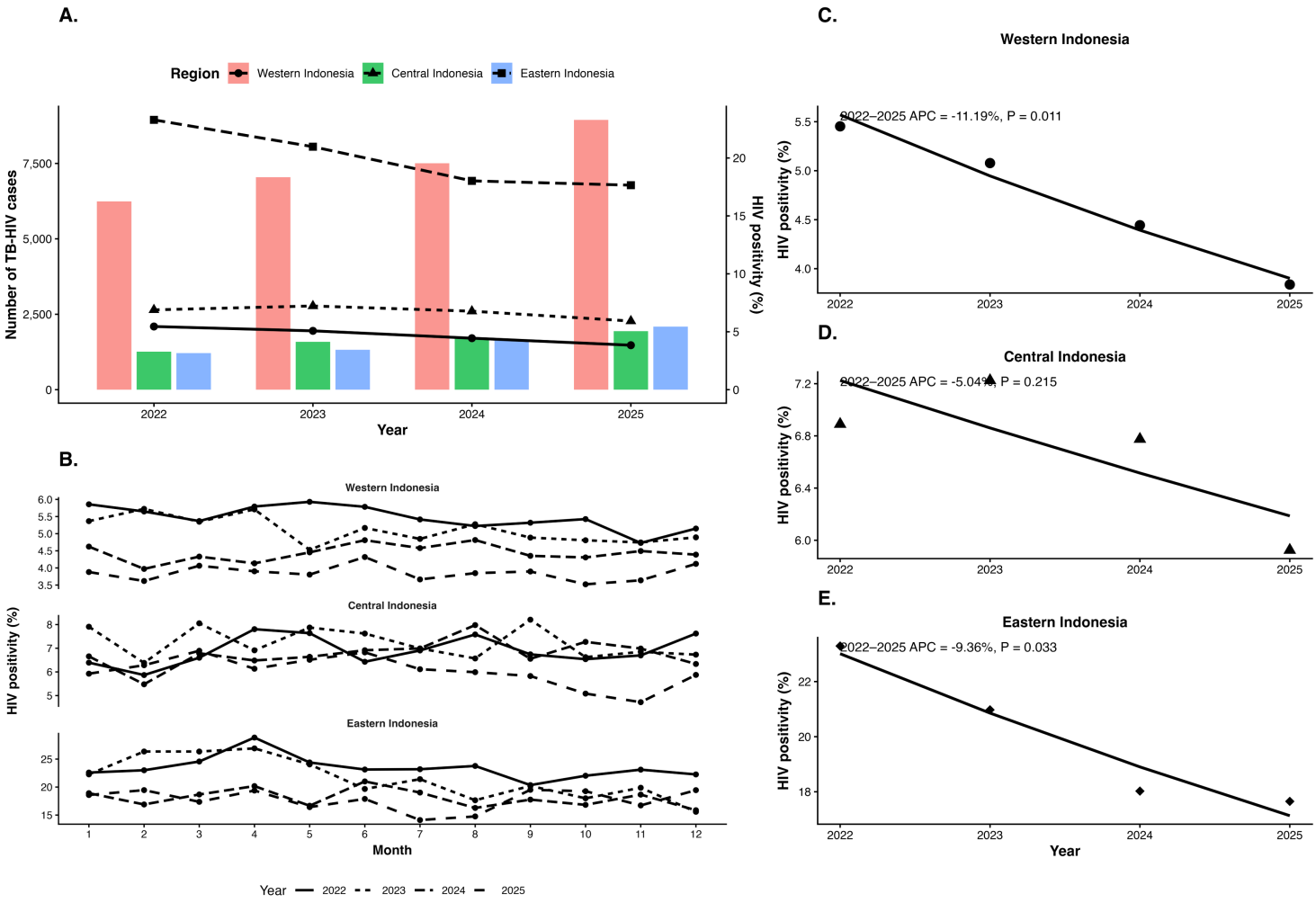


Figure 2

Temporal Patterns of Tuberculosis-HIV in Indonesia, 2022-2025

Geographic distribution of HIV positivity

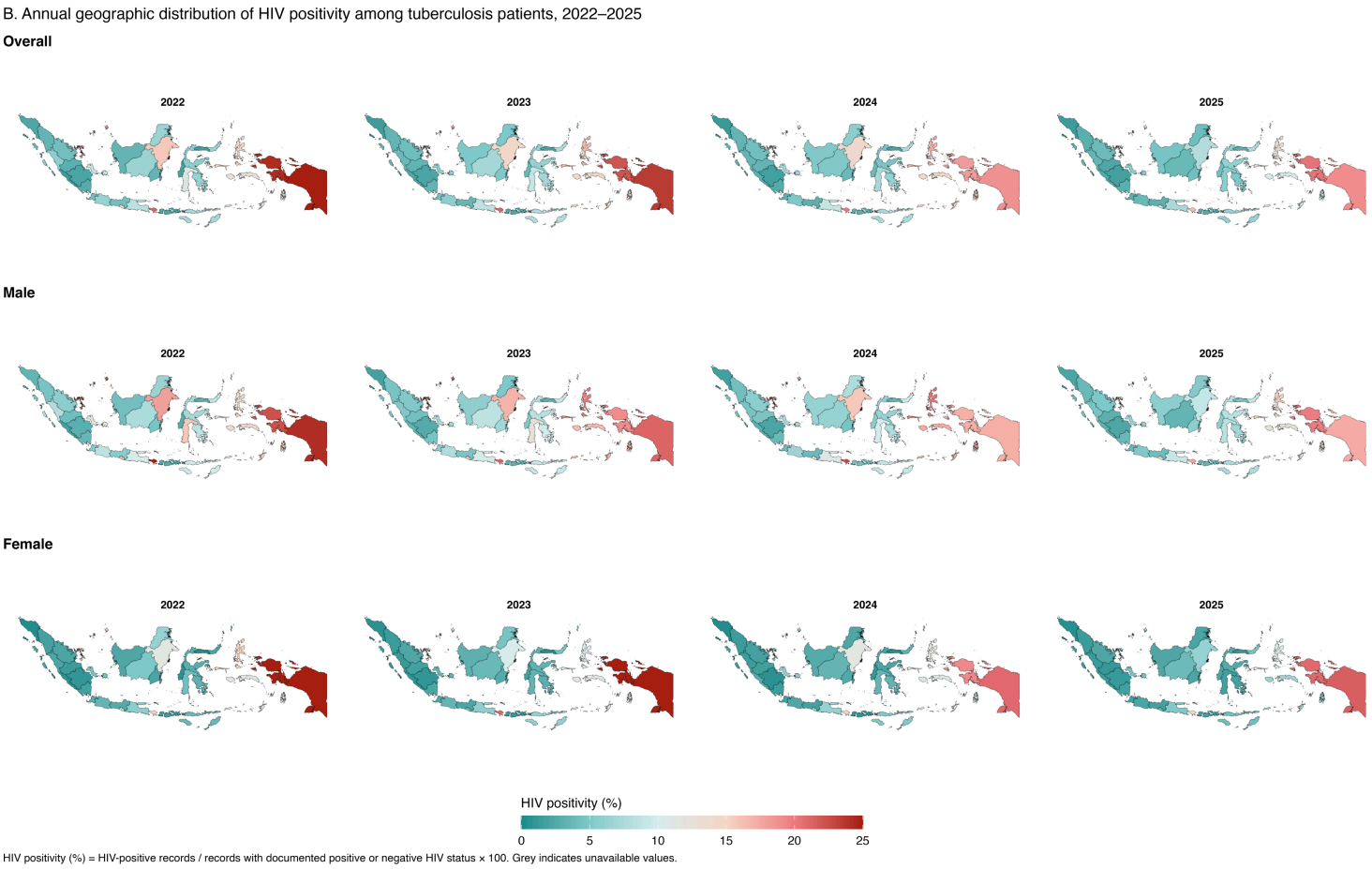


Figure 3

Annual Geographic Distribution of HIV Positivity among Tuberculosis Patients, 2022-2025

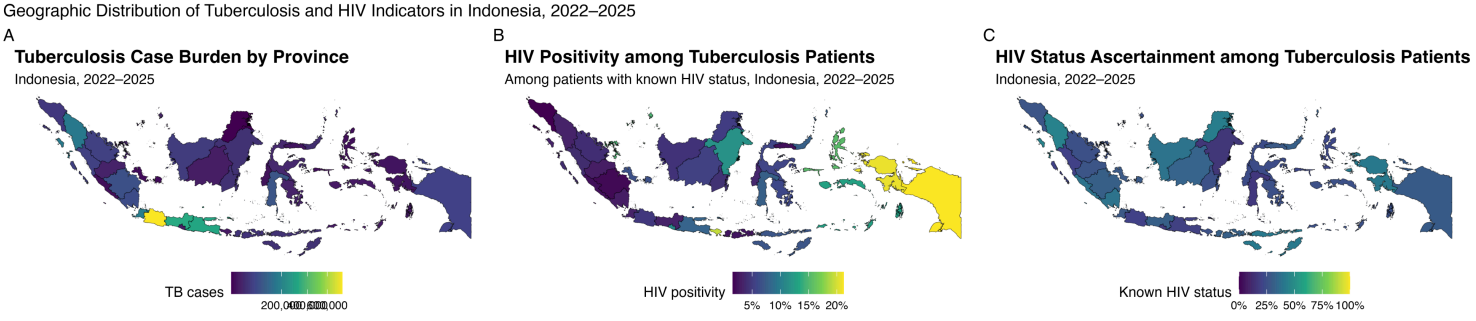


Figure 4

Geographic Distribution of Tuberculosis and HIV Indicators in Indonesia, 2022-2025

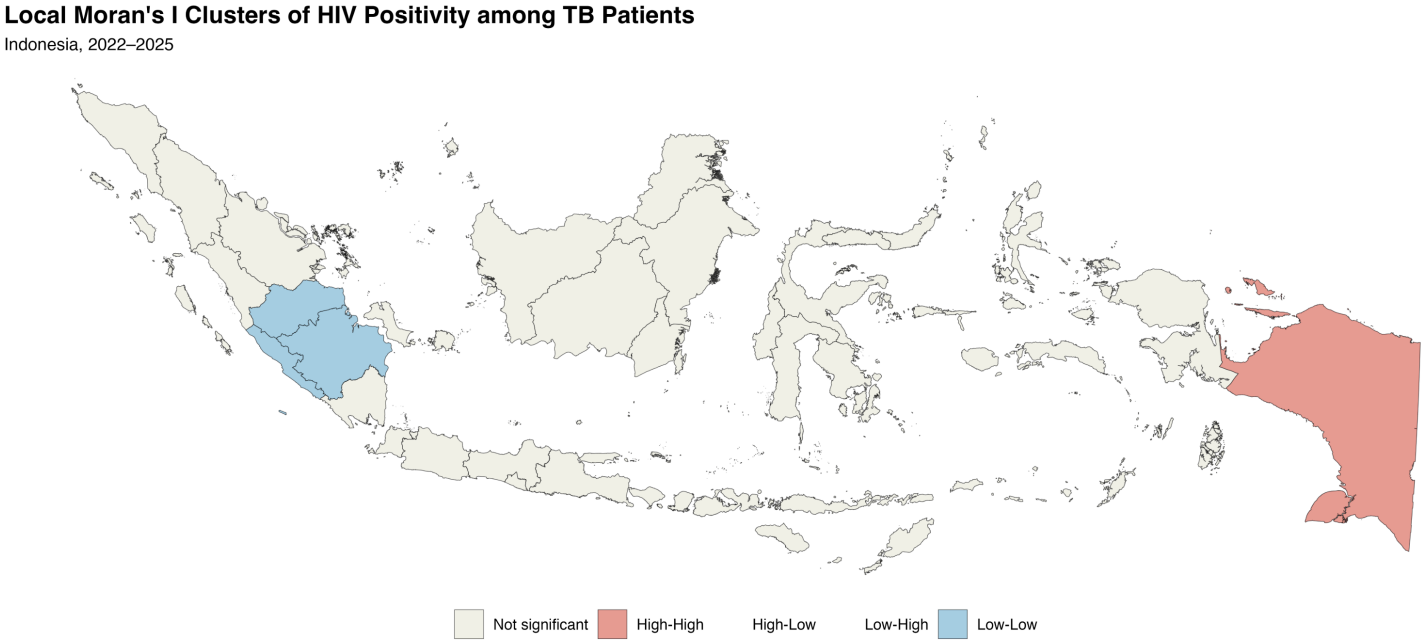


Figure 5

Local Moran’s I Clusters of HIV Positivity among TB Patients

Supplementary Files

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