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Disease Burden Analysis of Cervical Cancer in Indonesia: A Secondary Analysis of Global Burden of Disease Study 2023

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Abstract

Background: In 2023, cervical cancer (CC) accounted for approximately 13.26 million Disability-Adjusted Life Years (DALYs) globally (95% UI: 10.12–17.36 million), exceeding the combined burden of uterine and ovarian cancers (9.38 million; 95% UI: 7.93–11.04 million). Understanding CC burden, including Years Lived with Disability (YLD), Years of Life Lost (YLL), and DALY, is foundational to CC elimination programs.
Methods: This secondary analysis of CC burden estimates from the Global Burden of Disease (GBD) 2023 Study by the Institute for Health Metrics and Evaluation assessed temporal trends, spatial distribution, autocorrelation, and forecast CC burden in Indonesia. Age-standardized rates of YLD, YLL, and DALY from 1990 to 2023 were analyzed using joinpoint regression, Global and Local Moran's I, and Holt's Double Exponential Smoothing.
Result: In 1990–2023, the Average Annual Percent Change (AAPC) indicated increasing CC burden nationally and provincially, although segment-specific Annual Percent Change (APC) values varied, with some declines. The highest national APC for YLD occurred in 2007–2011, and for YLL and DALY in 2018–2021. Riau Islands had the highest AAPC for YLD; Maluku had the highest for YLL and DALY. Global Moran's I indicated a nonsignificant tendency toward a dispersed spatial pattern. Local Moran's I identified local spatial autocorrelation in East Kalimantan and Gorontalo. YLD, YLL, and DALY are projected to increase from 2024 to 2028.
Conclusion: CC remains a substantial public health burden in Indonesia, requiring prevention and control efforts.

Keywords: Cervical cancer ; YLD ; YLL ; DALY

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Introduction

Evaluating a population's health status cannot rely solely on absolute mortality rate calculations. This is supported by Sullivan's statement, which was reaffirmed by WHO, that as the epidemiological transition occurred and survival rates for all causes of death increased, nonfatal health outcomes are becoming increasingly dominant.[1] As a result, individuals whose deaths could have been prevented tend to spend their remaining years in suboptimal health. Therefore, a Burden of Disease (BoD) study was conducted in 1991 to systematically assess global health status using standardized methods, with the results published in the *World Development Report 1993: Investing in Health*.[2,3] The first Global Burden of Disease (GBD) study was conducted by the Harvard School of Public Health and the World Health Organization (WHO) using Disability-Adjusted Life Years (DALY) as a metric.[4] DALY is the sum of Years Lived with Disability (YLD), which represents years lived with suboptimal health, and Years of Life Lost (YLL), which represents years lost due to premature death. In other words, DALY measures the number of healthy life years lost. It was designed to assess the burden of all types of diseases, including cancer.

Cancer is a major global health concern. In 2023, cancer was the second leading cause of death among noncommunicable diseases, accounting for 271 million DALYs (95% UI: 255–285), excluding non-melanoma skin cancer.[5] Of all types of cancer, gynecological cancers account for a significant portion of the BoD among women. Among gynecological cancers, whose DALYs increased from 2019 to 2023, cervical cancer (CC) had by far the highest burden. In 2023, it reached 13,261,257.47 DALYs (95% UI: 10,118,488.54–17,360,952.99), exceeding the combined total of uterine and ovarian cancers (9,377,899.65; 95% UI: 7,927,867.65–11,037,488.05).[6] In ASEAN, CC accounted for 1,136,448.207 DALYs (95% UI: 808,783.91–1,678,212.08). Meanwhile, Indonesia's DALYs stand at 437,696.43 (95% UI: 259,890.16–699,707.89). This number increased compared to 2019 [379,329.25 (95% UI: 231,695.48 – 600,177.02).[6] The Global Cancer Observatory (GCO) reported 662,301 CC cases globally in 2022, 60% of which occurred in Asia.[7] In the South-East Asia Region, Indonesia is the second highest after India, with 36,633 new cases in 2020 and 36,964 in 2022, and over 41,000 deaths across those two years.[8–10] This situation makes CC one of the primary contributors to the high disease burden among Indonesian women.

The Burden of Disease has serious consequences for individuals, families, the healthcare system, and socioeconomic development. A high BoD reduces life expectancy and causes long-term suffering. The phase of caring for cancer patients also gives rise to caregiver burden.[11] The economic challenges include limited insurance coverage, out-of-pocket costs, negative income, and lost productivity.[12,13] Indonesia's national health insurance, BPJS Kesehatan, reported that CC can cost up to Rp120 million per patient, with total projected costs of Rp12.67–15.04 trillion in 2035.[14] Vaccination, screening, and optimized cancer management can reduce this burden. However, national Visual Inspection with Acetic Acid (VIA) screening coverage was only 14.6% (2023) and 23.59% (2024), against a 70% target.[15,16] Meanwhile, Human Papillomavirus Deoxyribonucleic Acid (HPV DNA) screening in pilot areas (35 districts/cities across 16 provinces) reached only 12%.[14] As a result, CC is often diagnosed at an advanced stage, with low survival. In fact, the five-year survival rate for CC reaches 91% when it is properly managed and diagnosed early.[17]

A global analysis of CC burden from 1990 to 2021 found that the age-standardized rate (ASR) of DALY decreased, although the pace varied across Socio-demographic Index regions.[18] Studies in China (1990–2019) and Taiwan (2020–2021) showed similar results at the national level, and a global projection study estimated a decline in the age-standardized incidence rate (ASIR) through 2050.[19–21] In contrast, a study in Indonesia shows an increasing CC burden from 1990 to 2017.[22] Previous studies have generally examined temporal trends, spatial distribution, and future projections separately, mostly in

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global or non-Indonesian settings. Their findings may not apply to local conditions because health evidence is context-specific.[23,24] Indonesia has established the National Action Plan for CC Elimination, 2023–2030 (Rencana Aksi Nasional Eliminasi Kanker Leher Rahim di Indonesia Tahun 2023–2030), but integrated evidence to support its implementation remains limited. Local data analysis is still needed to capture context-specific patterns and support evidence-based policy.

Evidence-based policies are essential because, without clear data and analysis, interventions risk being ineffective and inadequately targeted. The "WHO Guide for Evidence-Informed Decision-Making" emphasizes that using data improves effectiveness, efficiency, and helps ensure the equitable distribution of health interventions. Indonesia's Ministry of Health Strategic Plan for 2025–2029 (Regulation of the Minister of Health No. 12 of 2025) uses DALY as one basis for health program formulation.[25] A comprehensive understanding of BoD dynamics cannot be obtained from a single analytical approach. Integrating temporal, spatial, and forecasting approaches provides a more comprehensive understanding of the CC burden by linking changes over time, geographic variation across provinces, and future burden. Therefore, this study is important. The findings are expected to provide policymakers with data-driven evidence to formulate and implement strategies to eliminate CC, in line with the WHO target of reducing the incidence to 4 cases per 100,000 women per year, and ultimately improve women's health.

Methods

A. Research Design and Data Sources

This study employed a secondary ecological time-series and spatial analysis of modeled GBD estimates (DisMod-MR 2.1), with a forecasting component. CC data were extracted from the GBD 2023 database via the Global Health Data Exchange (GHDx) query tool (https://vizhub.healthdata.org/gbd-results/) on 6 March 2026. The query was restricted to YLD, YLL, and DALY, reported as age-standardized rates per 100,000 population with 95% uncertainty intervals (UI).

Location filters were set to Indonesia and its 34 provinces for 1990–2023. Although several provinces (Gorontalo, the Riau Islands, and North Kalimantan) did not exist as separate administrative units in 1990, GBD adjusted the data to current boundaries across the entire period, following its standard subnational estimation approach.[26] In this study, CC was defined according to the GBD 2023 cause hierarchy (All causes → Non-communicable diseases → Neoplasms → Cervical cancer). The extracted dataset was downloaded as a CSV file containing the following fields: population group id, population group name, measure id, measure name, location id, location name, sex id, sex name, age id, age name, cause id, cause name, metric id, metric name, year, val, upper, lower. We obtained the base map from INA-Geoportal. We conducted the analysis in Malang, Indonesia, from March to May 2026.

B. Joinpoint Regression Analysis

Temporal trends were analyzed using Joinpoint Regression Software version 6.0.1 (Surveillance Research Program, National Cancer Institute). Joinpoint regression detects statistically significant changes in trend direction and magnitude by dividing the time series into segments with different slopes connected at joinpoints, rather than assuming a single linear trend throughout the study period, as in simple linear regression. It provides Annual Percent Change (APC) and Average Annual Percent Change (AAPC), which enable comparison of trends across provinces; positive values indicate an increasing trend and negative values a decreasing trend. APC is calculated using $APC_i = (e^{bi} - 1) \times 100$ %. The AAPC is computed as a weighted average of the APCs from the joinpoint model, with the weights equal to the length of the APC intervals included: $AAPC = (e^{\Sigma wi\ bi\ /\ \Sigma wi} - 1) \times 100$.

We estimated the confidence interval (CI) using the empirical quantile method, with statistical significance assessed at the 95%

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confidence level. To ensure comparability across provinces, we specified a first-order autocorrelated error model (estimated from the data) because the Durbin-Watson test showed $d < dL$ or $d > 4 - dL$ in 33 provinces for YLD and 31 provinces for YLL and DALY (Appendix 1). We used the Weighted Bayesian Information Criterion (WBIC) for model selection.

C. Spatial Analysis

Spatial analysis was performed using GeoDa version 1.22.0.21 by Luc Anselin. CC burden was visualized in percentile choropleth maps with six categories (<1%, 1-10%, 10-50%, 50-90%, 90-99%, and >99%) for 1990 (pre-intervention), 2007 (formalization of the national CC control program), and 2023 (end of the observation period). We assessed spatial autocorrelation using Global Moran's I, which provides a single summary value for the entire study area, and Local Moran's I (Local Indicator of Spatial Association, LISA), which identifies clusters (high-high, low-low) and outliers (high-low, low-high). Moran's I ranges from $-1 \leq I \leq 1$. Values of $0 < I \leq 1$ indicate positive autocorrelation, while $-1 \leq I < 0$ indicate negative spatial autocorrelation. The spatial weights matrix combined Queen's contiguity with K-Nearest Neighbor (KNN = 1), because Queen's contiguity alone left several island provinces (Bali, West Nusa Tenggara, East Nusa Tenggara, Bangka Belitung Islands, Riau Islands, North Maluku, and Maluku) without neighbors. KNN = 1 ensured that every province had at least one neighbor while minimizing artificial connections.

D. Forecasting

We forecasted CC burden in Indonesia using Holt's Double Exponential Smoothing (DES), which suits trend-based data, with parameters α (level) and γ (trend). For each indicator, we tested 81 combinations of α and γ (0.1–0.9, in increments of 0.1) and selected optimal values independently based on the lowest Mean Absolute Percentage Error (MAPE) and Mean Absolute Deviation (MAD). YLD, YLL, and DALY were forecasted using three independent models rather than deriving DALY as the sum of forecasted YLD and YLL The selected parameters were $\alpha = 0.9$ and $\gamma = 0.5$ for YLD (MAPE = 2.23480%, MAD = 0.11194), $\alpha = 0.9$ and $\gamma = 0.3$ for YLL (MAPE = 2.847%, MAD = 6.328), $\alpha = 0.9$ and $\gamma = 0.3$ for DALY (MAPE = 2.827%, MAD = 6.426). Appendix 6 provides the complete results of all iterations. The analysis was performed using Minitab version 22.1.

Ethical approval for this study was obtained from the Research Ethics Committee of Universitas Negeri Malang (Ethical Clearance No. 27.02.08/UN32.14.2.8/LT2026).

Result

A. Trends of Cervical Cancer Burden at the National and Provincial Levels, 1990–2023

Joinpoint regression showed the highest APC for YLD in Central Java (2007–2010) and the largest decrease in Papua (2021–2023). For YLL and DALY, South Kalimantan had both the highest and lowest APCs. The Riau Islands had the highest AAPC of YLD, while Yogyakarta recorded the lowest. For YLL and DALY, Maluku had the highest AAPC, while Yogyakarta again recorded the lowest. Figures 1, 2, and 3 present graphs and APC values for the national level and representative provinces, and Appendix 2 provides those for all provinces. Table 1 shows AAPC values for representative provinces, with province-specific details in Appendix 3.

B. Trends in Years Lived with Disability (YLD), 1990–2023

The YLD trend for CC increased overall throughout the observation period. Nationally, the rate of change increased significantly three times, with four joinpoints.

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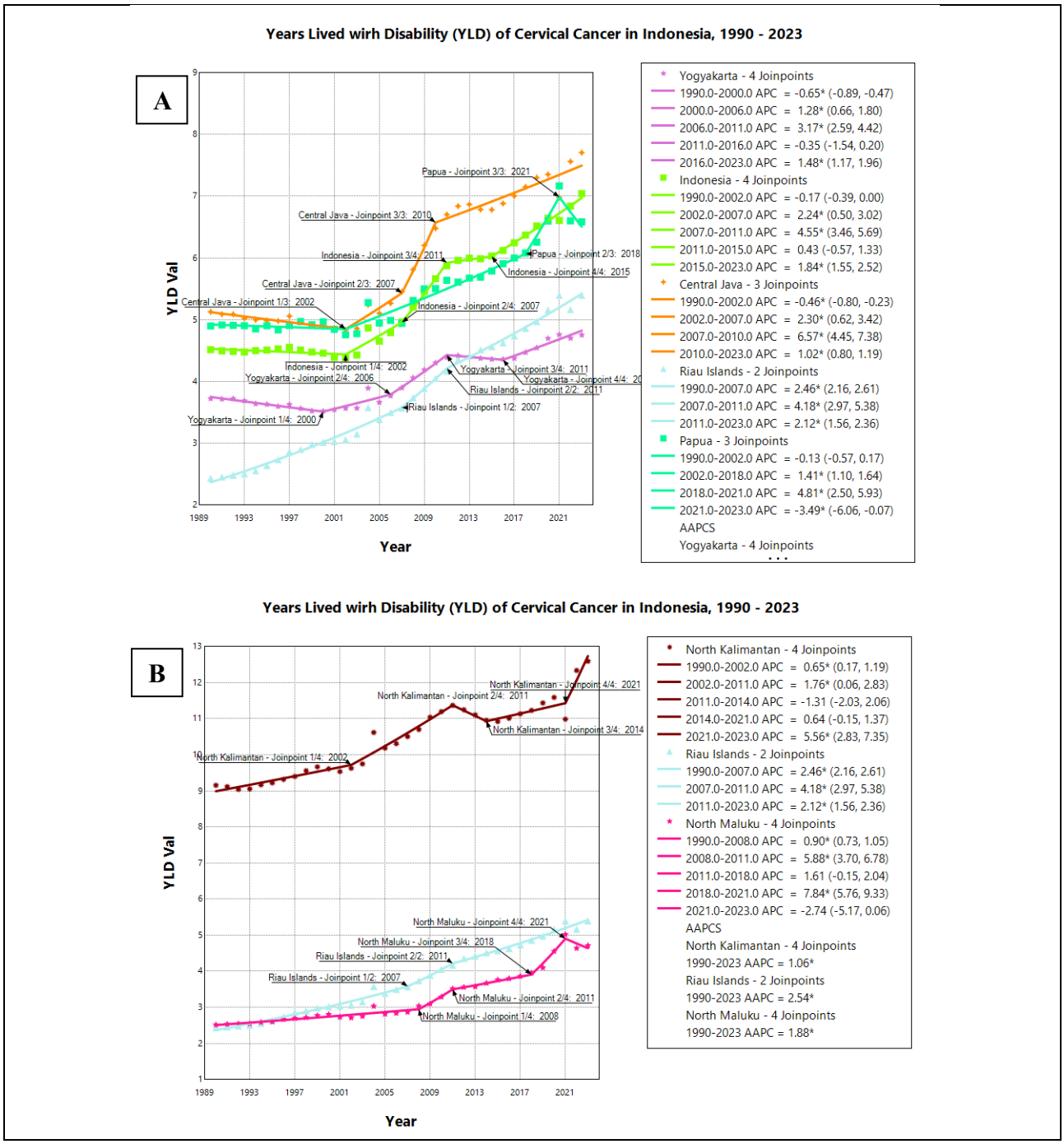


Figure 1. Trends in YLD for CC, 1990–2023: a) national level and the provinces with the highest and lowest APC and AAPC; b) provinces with the highest and lowest Age-Standardized Rate value of YLD at the beginning and end of the observation period. *Statistically significant at α = 0.05

North Kalimantan consistently had the highest ASR of YLD, while the lowest shifted from the Riau Islands (1990) to North Maluku (2023). The national APC was highest in 2007-2011. Provincially, Central Java had the largest increase in 2007–2010 [APC: 6.57% (95% CI: 4.45–7.38%)], Papua the lowest [2021–2023; APC: -3.49% (95% CI: -6.06 – -0.07%)].

C. Trends in Years of Life Lost (YLL), 1990–2023

The national YLL trend peaked in 2021, as did those of 18 other provinces (Appendix 2).

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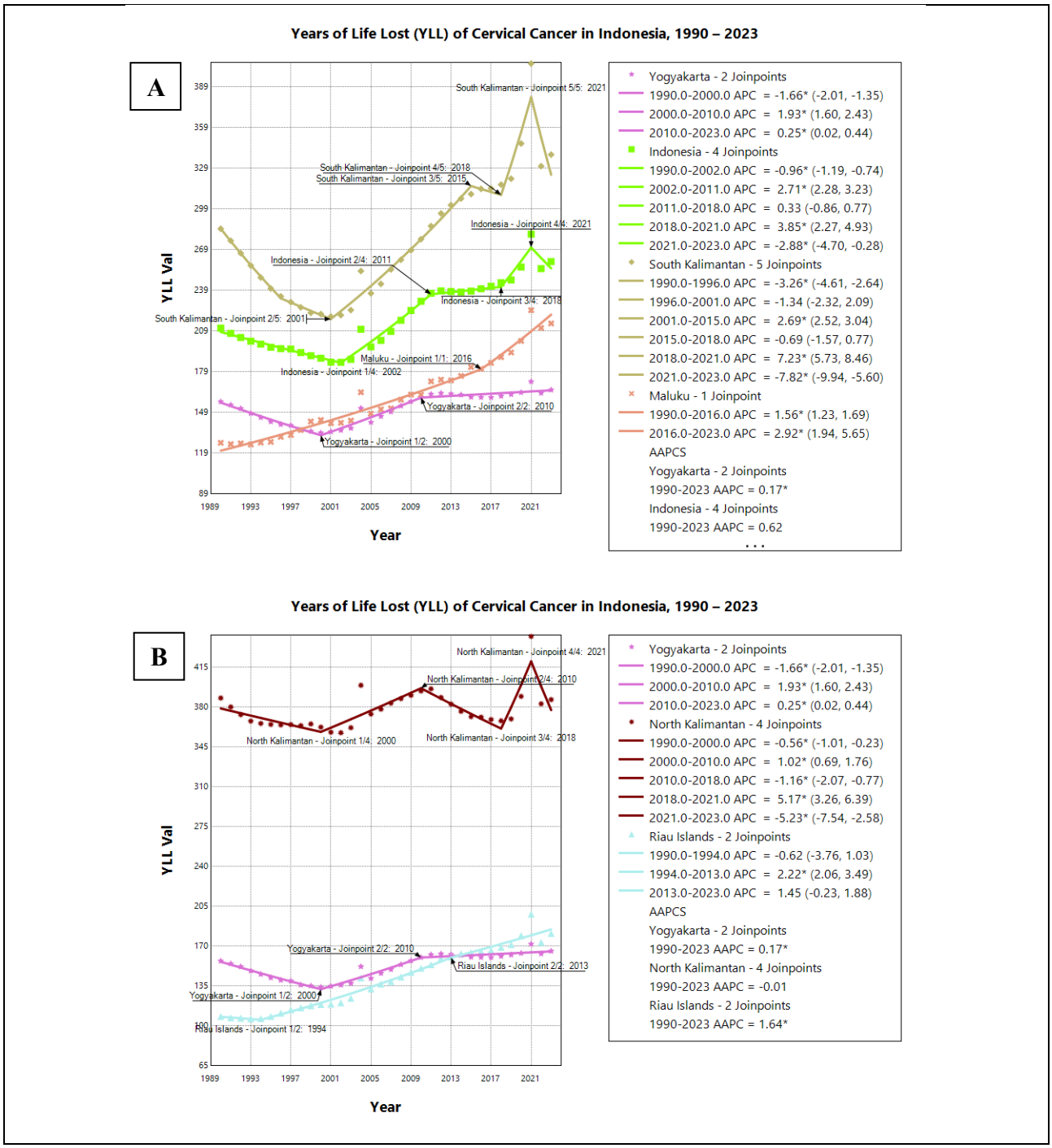


Figure 2. Trends in YLL for CC, 1990–2023: a) national level and the provinces with the highest and lowest APC and AAPC; b) provinces with the highest and lowest Age-Standardized Rate value of YLL at the beginning and end of the observation period. *Statistically significant at α = 0.05

Across all provinces, South Kalimantan had both the highest [2018-2021: 7.23% (95% CI: 5.73–8.46%)] and lowest [2021-2023: -7.82% (95% CI: -9.94 – -5.60%)] APC of YLL. North Kalimantan consistently had the highest ASR of YLL in 1990 and 2023, while the lowest ASR shifted from the Riau Islands (1990) to Yogyakarta (2023).

D. Trends in Disability-Adjusted Life Years (DALY), 1990–2023

Theoretically, DALY equals YLD plus YLL, with YLL contributing the most. Consequently, changes in each DALY segment tend to follow YLL dynamics.

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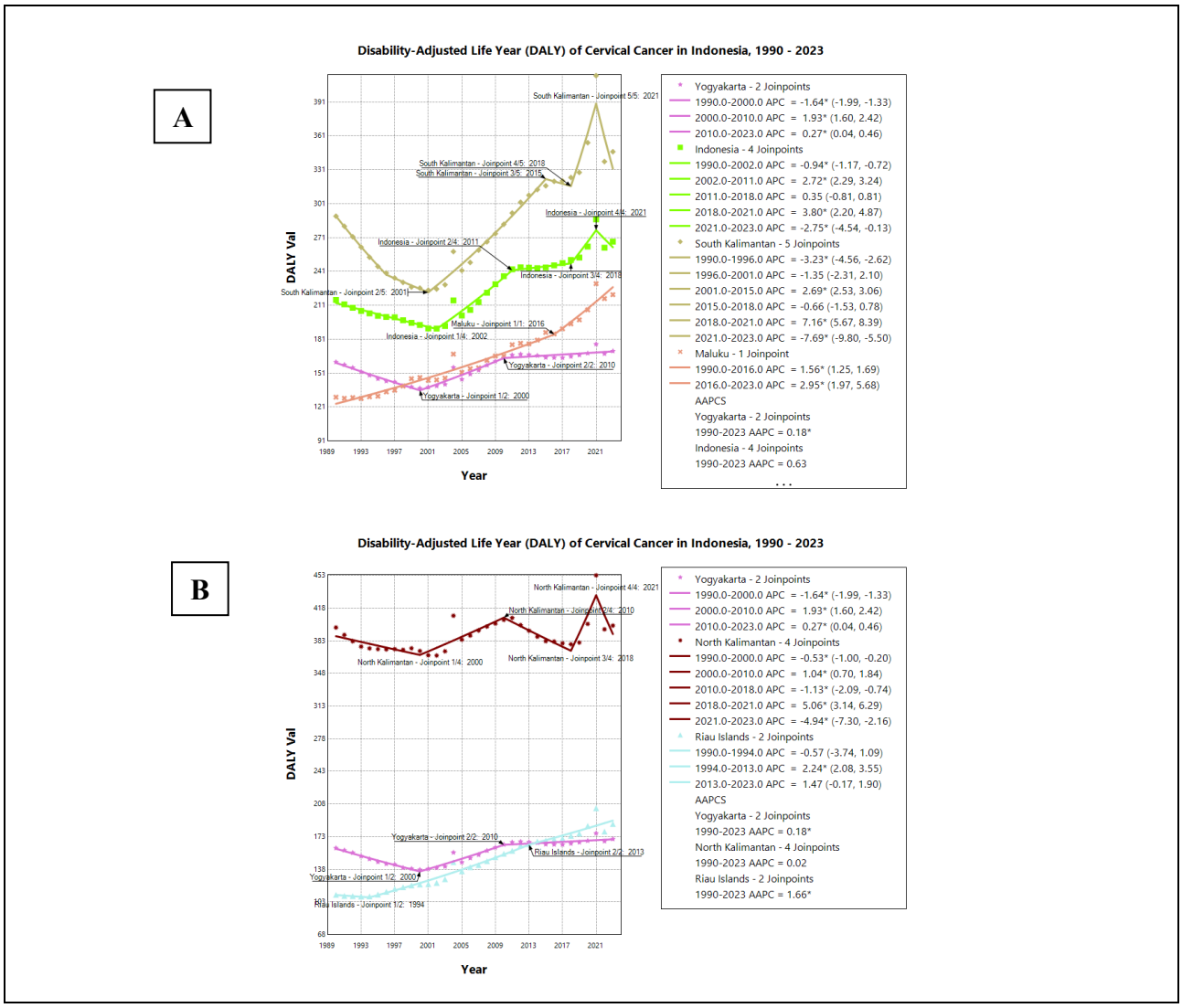


Figure 3. Trends in DALY for CC, 1990–2023: a) national level and the provinces with the highest and lowest APC and AAPC; b) provinces with the highest and lowest Age-Standardized Rate value of DALY at the beginning and end of the observation period. *Statistically significant at α = 0.05

Nationally, the DALY APC was highest in 2018–2021 (3.80%; 95% CI: 2.20–4.87%). Provincially, South Kalimantan had both the highest (2018-2021: 7.16%; 95% CI: 5.67 to 8.39%) and lowest (2021-2023: -7.69%; 95% CI: -9.80 to -5.50%) APC. North Kalimantan ranked highest throughout the observation period, and Riau Islands, which initially had the lowest ASR DALY at the start of the observation (1990), was replaced by Yogyakarta at the end (2023). Table 1 shows the highest and lowest AAPC for each variable.

Table 1. National and Provincial Average Annual Percentage Change (AAPC) in Cervical Cancer Burden: Provinces with the Highest and Lowest AAPC

Province	*Average Annual Percent Change* (AAPC) (95% CI)		
	YLD	YLL	DALY
Indonesia	1.32%* (1.26 – 1.37%)	0.62%* (0.53 – 0.74%)	0.63%* (0.54 – 0.76%)
Yogyakarta[c]	0.77%* (0.71 – 0,82%)	0.17%* (0.10 – 0.24%)	0.18%* (0.12 – 0.25%)
Riau Islands[a]	2.55%* (2.45 – 2.61%)	1.64%* (1.45 – 1.78%)	1.66%* (1.47 – 1.80%)
Maluku[b]	2.18%* (2.05 – 2.33%)	1.85%* (1.67 – 2.01%)	1.85%* (1.68 – 2.01%)

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a) Province with the highest AAPC for YLD; b) Province with the highest AAPC for YLL and DALY; c) Province with the lowest AAPC for YLD, YLL, and DALY. *Statistically significant at α = 0.05

Table 1 shows that national and provincial trends in YLD, YLL, and DALY for CC during 1990-2023 had positive AAPC values, indicating upward trends over the past three decades. The highest AAPC for YLD was in the Riau Islands, while the highest AAPC for YLL and DALY was in Maluku. Yogyakarta had the lowest statistically significant AAPC for all three indicators Appendix 3 presents complete AAPC data for all provinces.

E. Spatial Distribution of the Burden of Cervical Cancer in Indonesia (1990, 2007, and 2023)

Choropleth maps show that North Maluku was consistently in the low percentile (1–10%) for YLD values at all three observation points (1990, 2007, 2023). Meanwhile, West Sumatra and North Kalimantan were consistently in the high percentile (90–99%). For YLL and DALY, the Riau Islands were consistently in the low percentile, and North Kalimantan was in the high percentile (90th-99th) (Figures 4, 5, and 6).

F. Choropleth Map of Years Lived with Disability (YLD)

The YLD choropleth maps show shifts in provincial percentile categories over time, suggesting changes in the relative YLD burden across provinces.

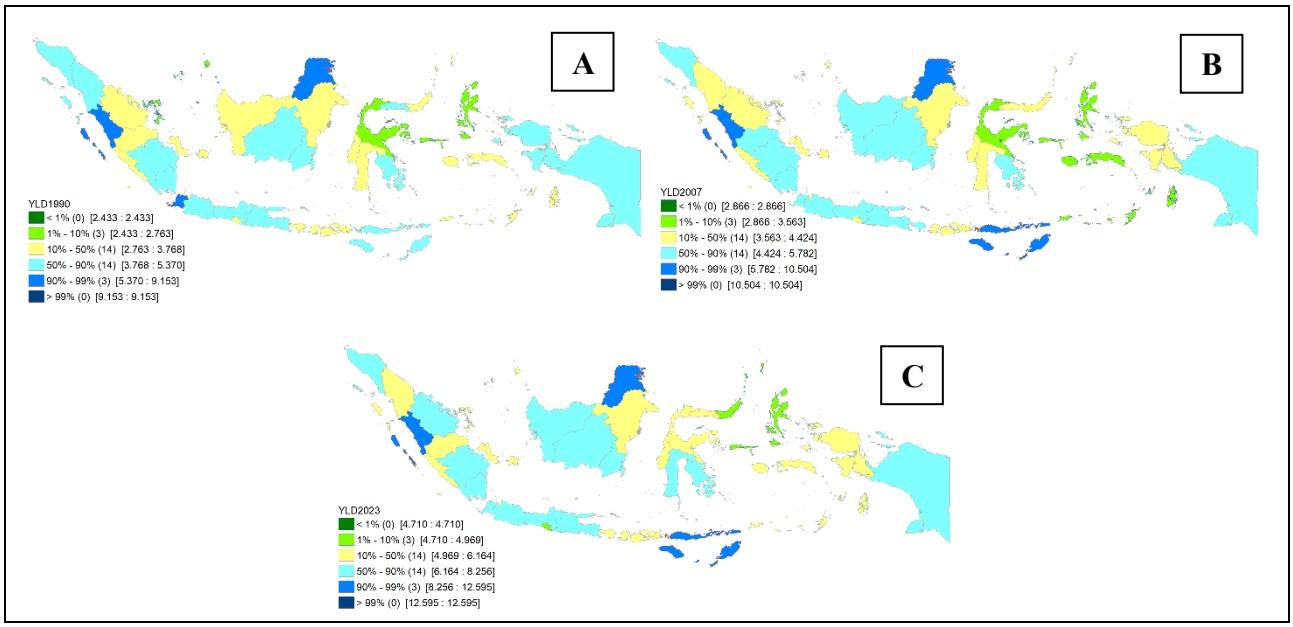


Figure 4. Percentile distribution of YLD due to CC in Indonesia in (a) 1990, (b) 2007, and (c) 2023.

Provinces located on Java were mostly in the 50–90% percentile class for YLD across all three observation years, whereas provinces on Sumatra, Kalimantan, and Sulawesi showed greater variation.

G. Choropleth Map of Years of Life Lost (YLL)

The greatest shifts in YLL percentile class occurred between 1990 and 2007, affecting 12 provinces, three of which were in Sumatra.

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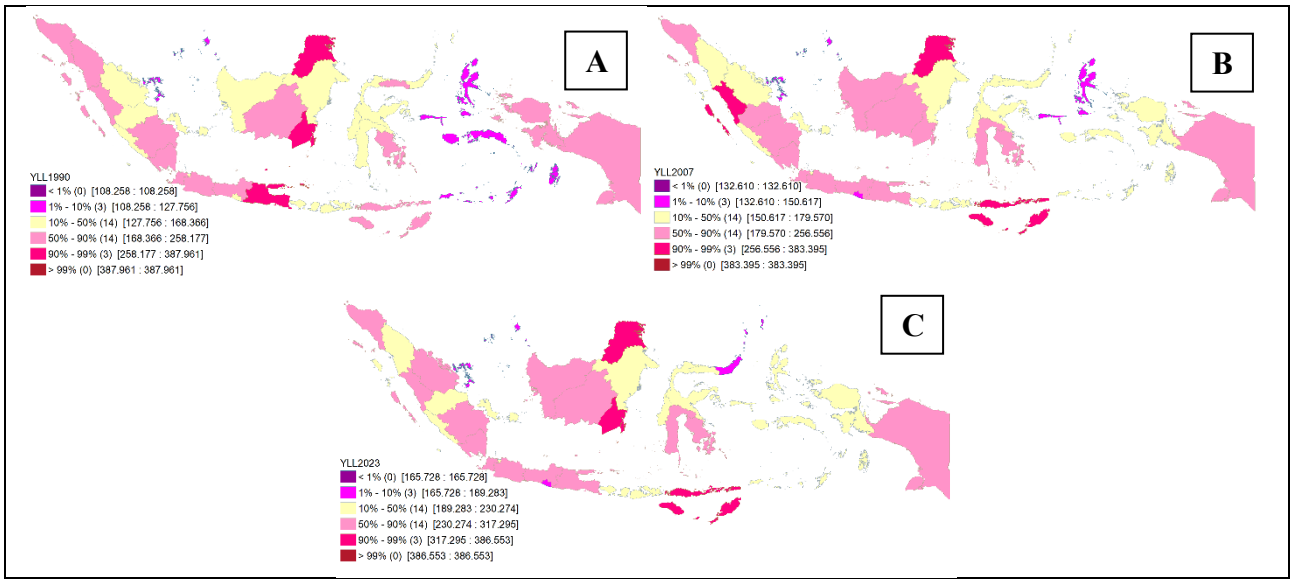


Figure 5. Percentile distribution of YLL due to CC in Indonesia in (a) 1990, (b) 2007, and (c) 2023.

The Riau Islands remained in the 1–10% percentile class for YLL across all three observation years, while North Kalimantan remained in the 90–99%. Similar to YLD, most Java provinces were in the 50-90% percentile class.

H. Choropleth Map of Disability-Adjusted Life Years (DALY)

The six-class percentile map shows that DALY distribution across the 34 provinces was identical to that of YLL over the three observation years, with comparable shifts in percentile class between years.

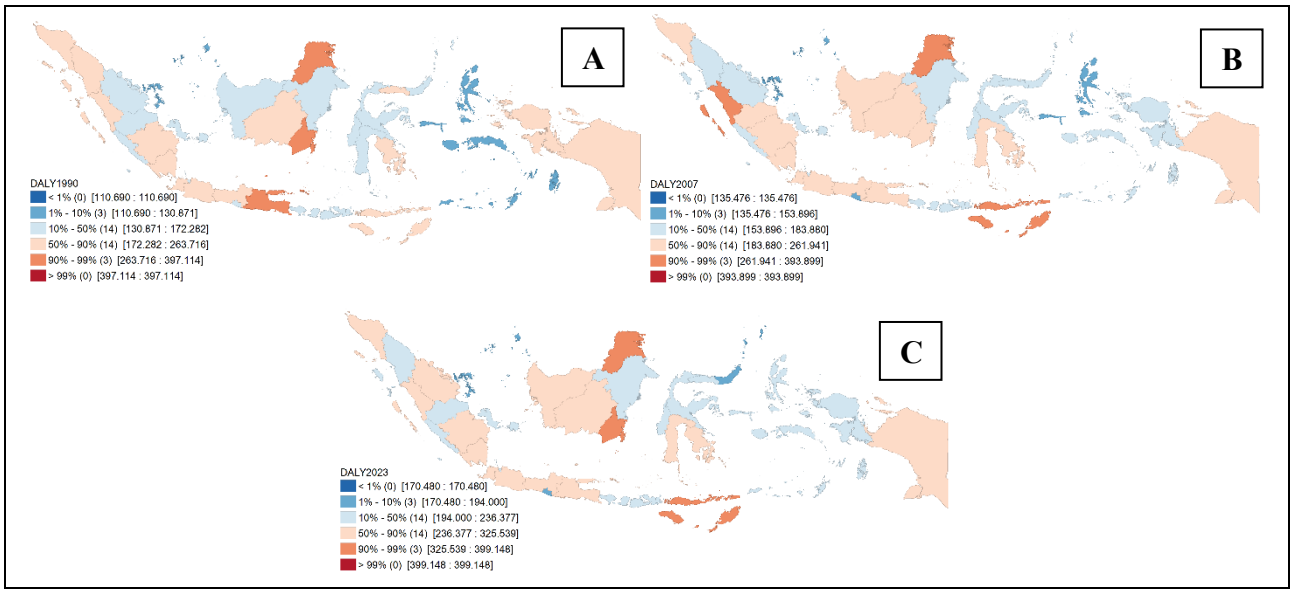


Figure 6. Percentile distribution of DALY due to CC in Indonesia in (a) 1990, (b) 2007, and (c) 2023.

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Twelve provinces, including three in Sumatra, changed DALY percentile class between 1990 and 2007. Provinces in the high YLL percentile class were also in the high DALY class, and the same applied to the low class.

J. Global Moran's I

Global Moran's I indicated a consistent tendency toward a dispersed spatial pattern for YLD, YLL, and DALY across all three observation years, although none of these results were statistically significant (Table 2).

I. Moran's I

Global Moran's I revealed no significant spatial autocorrelation in YLD, YLL, or DALY of CC in 1990, 2007, or 2023. Local Moran's I identified spatial clusters or outliers in only a few provinces.

Table 2. Global Spatial Autocorrelation Analysis Result

Year	Moran's I (I)	E(I)	Z-value	P-value
YLD				
1990	-0.0865	-0.0303	-0.3769	0.359
2007	-0.0596	-0.0303	-0.2022	0.438
2023	-0.1063	-0.0303	-0.5372	0.311
YLL				
1990	-0.1368	-0.0303	-0.6294	0.264
2007	-0.1417	-0.0303	-0.6937	0.243
2023	-0.2185	-0.0303	-1.1172	0.121
DALY				
1990	-0.1360	-0.0303	-0.7161	0.239
2007	-0.1397	-0.0303	-0.6721	0.251
2023	-0.2160	-0.0303	-1.0802	0.141

Statistically significant at 5% level (0.05)

Table 2 summarizes the Global Moran's I test results for CC burden in Indonesia in 1990 (pre-intervention), 2007 (formalization of CC control at the national level), and 2023 (end of the observation period). Consistently, Moran's I value (I) is smaller than its expected value, E(I). When $I < E(I)$, or in this study $I < -0.0303$, it indicates negative spatial autocorrelation, suggesting a global tendency toward a dispersed spatial pattern. However, the Z(I) values, which range from -1.1172 to -0.2022, along with p-values > 0.05, indicate that the analysis results are not statistically significant. Thus, although the observed I values pointed toward a dispersed pattern, there was insufficient statistical evidence to confirm a definitive global spatial pattern for YLD, YLL, and DALY due to CC in Indonesia in 1990, 2007, and 2023.

K. Local Indicators of Spatial Association (LISA), Local Moran's I

East Kalimantan was the only province that consistently identified as a Low-High (LH) outlier for YLD, YLL, DALY in 1990, 2007, and 2023. No statistically significant clusters or outliers were detected outside Kalimantan and Sulawesi in any year (Figures 7-9).

L. Local Indicators of Spatial Association (LISA), Local Moran's I of YLD

Only two types of significant local spatial autocorrelation patterns were identified at each observation point.

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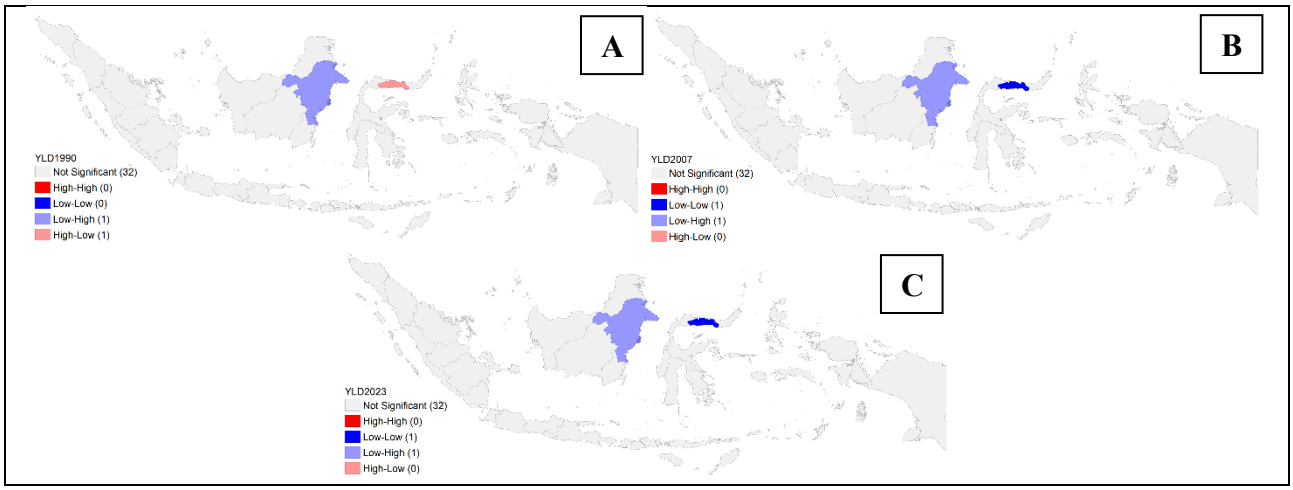


Figure 7. LISA Cluster Maps of YLD due to CC in Indonesia in (a) 1990, (b) 2007, and (c) 2023

In 1990, East Kalimantan was an L-H outlier and Gorontalo an H-L outlier. In 2007 and 2023, the only patterns were an L-L cluster in Gorontalo and an L-H outlier in East Kalimantan. No H-H cluster (hot spot) was found in any year.

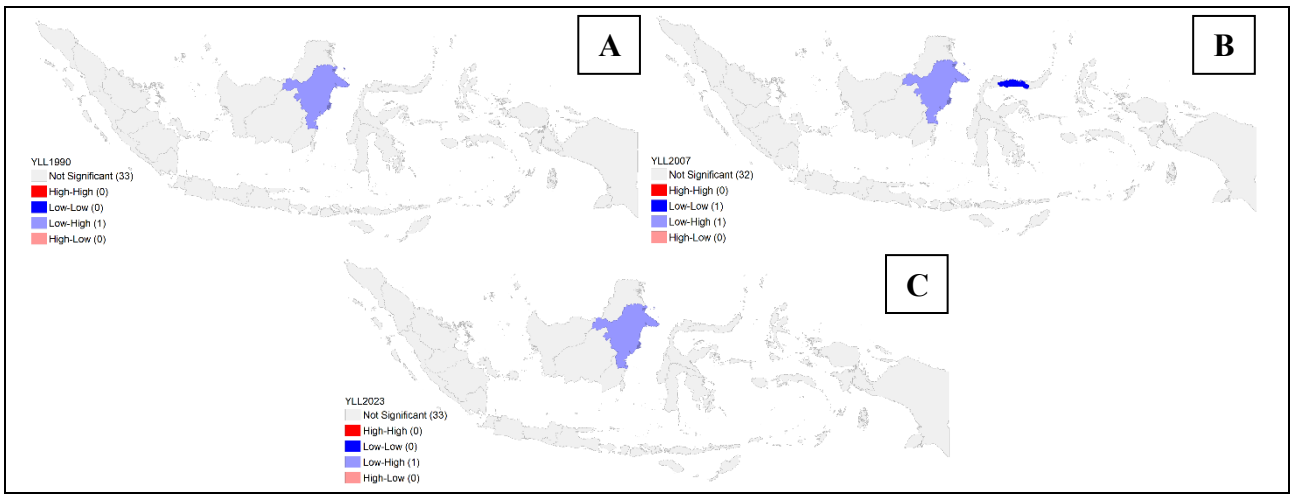


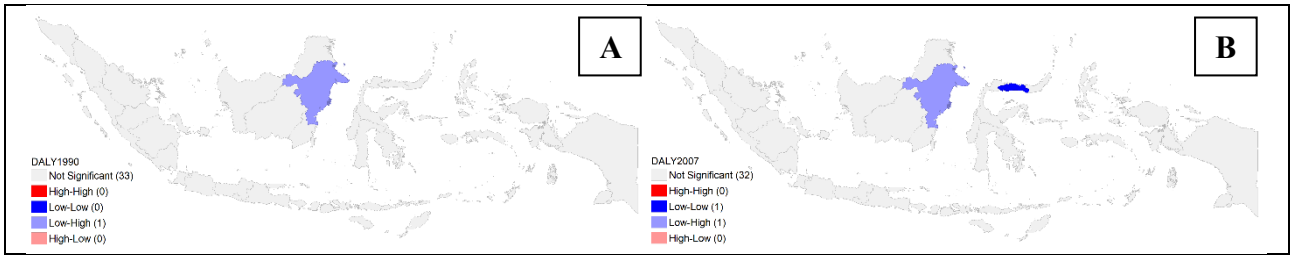
Figure 8. LISA Cluster Maps of YLL due to CC in Indonesia in (a) 1990, (b) 2007, and (c) 2023.

M. Local Indicators of Spatial Association (LISA), Local Moran's I of YLL

Local spatial autocorrelation patterns for YLL were identified only in East Kalimantan (L-H: 1990, 2007, and 2023) and Gorontalo (L-L: 2007).

N. Local Indicators of Spatial Association (LISA), Local Moran's I of DALY

The LISA patterns for DALY were identical to those for YLL in all years, in both cluster location and type.



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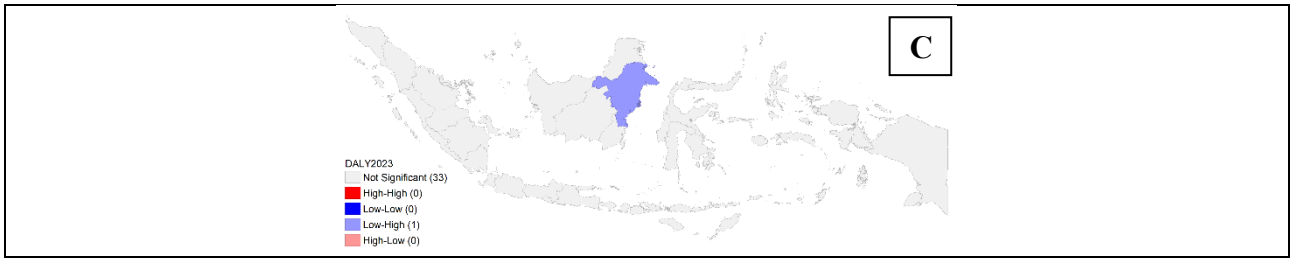


Figure 9. LISA Cluster Maps of DALY due to CC in Indonesia in (a) 1990, (b) 2007, and (c) 2023.

Figure 9 shows that clusters and outliers were confined to East Kalimantan and Gorontalo. Gorontalo was a cold spot only in 2007, whereas East Kalimantan was consistently an L-H outlier in 1990, 2007, and 2023.

O. Forecasting for YLD, YLL, and DALY of Cervical Cancer in Indonesia

Holt's DES model projected that the ASR of YLD, YLL, and DALY for CC in Indonesia would increase between 2024 and 2028.

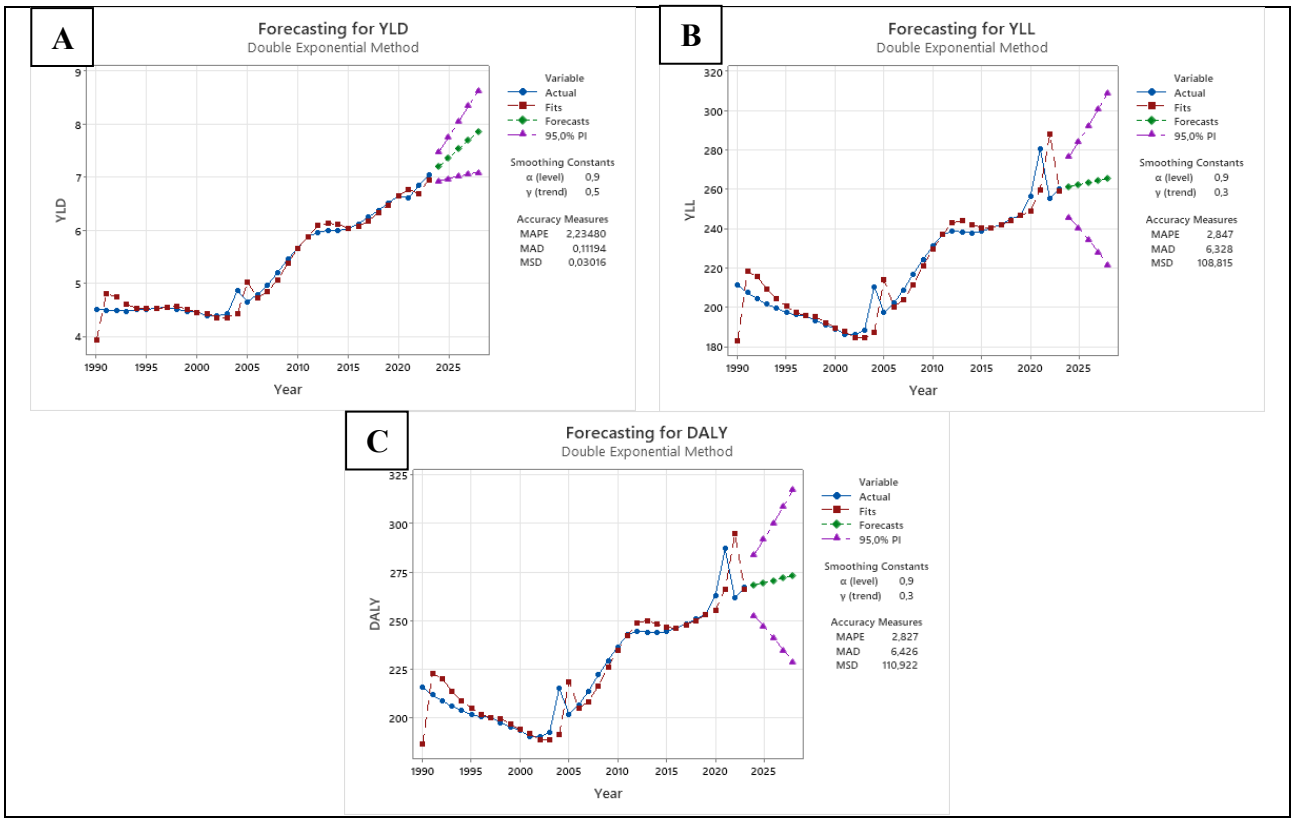


Figure 10. Forecasted Age-Standardized Rates of YLD, YLL, and DALY due to CC in Indonesia, 2024–2028 (per 100,000 population).

The GBD 2023 study, published by IHME in 2025, provides the latest burden estimates at the global, regional, and subnational levels. Therefore, the five-year burden estimates for CC in Indonesia are based on the most recent year of observation (2023). Based on these data, CC burden in Indonesia is expected to rise during 2024–2028.

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Table 3. Forecasted Age-Standardized Rates of YLD, YLL, and DALY for Cervical Cancer in Indonesia, 2024–2028

Year	Forecasting Result [95% Prediction Interval (PI)]		
	ASR YLD per 100,000	ASR YLL per 100,000	ASR DALY per 100,000
2024	7.20067 (6.92641 – 7.47492)	261.218 (245.715 – 276.720)	268.392 (252.649 – 284.134)
2025	7.36824 (6.97603 – 7.76045)	262.284 (240.114 – 284.454)	269.600 (247.087 – 292.113)
2026	7.53581 (7.01830 – 8.05332)	263.351 (234.098 – 292.603)	270.809 (241.104 – 300.514)
2027	7.70338 (7.05748 – 8.34928)	264.417 (227.908 – 300.927)	272.017 (234.943 – 309.093)
2028	7.87095 (7.09512 – 8.64679)	265.484 (221.630 – 309.339)	273.226 (228.693 – 317.759)

YLD, YLL, and DALY were obtained independently from the GBD Result Tools and forecasted using separate models with independently optimized parameters. Forecasted DALY may not exactly equal the sum of forecasted YLD and YLL.

Table 3 shows that YLD is projected to increase by 9.31% during 2024-2028, YLL by 1.63%, and DALY by 1.80%. These increases are gradual and consistent with persistent year-on-year rises in historical trends. The prediction intervals widen as the forecasting horizon extends, indicating greater uncertainty in long-term projections.

Discussion

A. Years Lived with Disability (YLD) Trend, 1990 – 2023

Nationally, the AAPC of YLD in 1990–2023 was 1.31% (95% CI: 1.26–1.37%), meaning YLD increased by an average of 1.31% per year. The highest APC of YLD occurred in 2007–2011 (4.55%; 95% CI: 3.46–5.69%), which may be associated with the issuance of the Cervical and Breast Cancer Control Working Group (Minister of Health Decree No. 1163/Menkes/SK/X/2007), the launch of the national early detection program in 2008, and the enactment of the technical guidelines for breast and cervical cancer control (Minister of Health Decree No. 796/Menkes/SK/VII/2010). Theoretically, this may be explained by how YLD is calculated from the number of cases, duration, and disability weight [4], such that large-scale early detection could improve case detection by identifying previously undiagnosed CC cases, thereby increasing the number of recorded CC patients. This aligns with 2010 Hospital Information System (SIRS) data showing that CC ranked second among cancers in inpatient cases and second among the top 10 cancers, according to the Department of Anatomical Pathology (12.7%).[26,27] In addition, although life expectancy has increased because of improved CC management, patients generally experience treatment-related side effects and chronic complications.[28,29] These factors may partly explain the rising YLD. However, this interpretation is based on published studies, as we did not directly evaluate incidence, survival, and treatment outcomes.

Provincially, Central Java had the highest APC (2007–2010: 6.57%; 95% CI: 4.45–7.38%), coinciding with the national peak and possibly reflecting intensified CC control during that period. Papua had the largest decrease (2021–2023: -3.49%; 95% CI: -6.06 to -0.07%), which may reflect the gradual recovery of health services after the COVID-19 pandemic. The Riau Islands had the highest AAPC in YLD, indicating the most rapid annual increase (1990–2023). According to the 2022 Provincial Early Cancer Detection Report of the Riau Islands, 13 of every 1,000 women screened had precancerous lesions. Smoking is a risk factor for CC, and an analysis of the 2021 GBD Study reported that 5.4% of the CC burden in Southeast Asia was attributable to smoking.[21]

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The 2007 Indonesia Demographic and Health Survey (SDKI) found that the smoking percentage among women in the Riau Islands was higher (4.3%) than the national average (2.6%). According to the 2017 publication "Analysis of the National and Subnational Disease Burden in Indonesia," smoking ranked among the top five (9.46%) risk factors contributing to the disease burden among women in the Riau Islands. A previous study stated that smoking and exposure to secondhand smoke weaken the immune system and accelerate the progression of HPV infection.[30] Furthermore, according to the 2023 Riau Islands Province Health Profile, the province had no type A hospitals, and most of its hospitals (54%) were type C. Moreover, the 2025–2029 Strategic Plan of the Riau Islands Provincial Health Office reported that radiotherapy services, which are vital for cancer treatment, remain severely limited. These factors may partly explain the high YLD in Riau Islands. In contrast, Yogyakarta had the lowest AAPC of YLD, indicating the slowest increase.

For ASR, North Kalimantan had the highest ASR of YLD (1990–2023), while the lowest shifted from the Riau Islands (1990) to North Maluku (2023). This shift may be associated with the higher use of oral hormonal contraceptives in the Riau Islands (48.8% in 2007 and 7.3% in 2024) than in North Maluku (30.3% and 1.3%, respectively).[31] The previous study suggested that hormonal contraception is associated with an increased risk of CC, and that long-term oral use increases the risk by 2.21–2.27 times. [32–34]

B. Spatial Distribution and Spatial Autocorrelation of YLD

Most Java provinces, which have relatively well-developed health systems, were in the 50th–90th percentile for YLD in 1990, 2007, and 2023. VIA screening coverage from the Indonesia Health Profiles 2016 and 2024 showed that provinces with relatively high screening coverage were concentrated in Java. More equitable access to health facilities with adequate cancer management may prolong patient survival, which could partly explain the higher YLD estimates in Java. Furthermore, West Sumatra and North Kalimantan were in the 90th–99th percentile across all three observation years, indicating a high and persistent burden. The 2007 Basic Health Research of Indonesia (Riskesdas: 5.6%) and the 2023 Indonesia Health Survey (SKI: 2.0%) placed West Sumatra among the provinces with the highest cancer prevalence. West Sumatra's high YLD may be associated with low screening coverage (7% in 2016 and 11% in 2024) and a TFR that has remained above the national average since the 1970s.[35] A high TFR reflects high parity, which may increase CC risk through cervical trauma from repeated deliveries, hormonal changes during pregnancy, and chronic infections, all of which are risk factors for HPV infection.[36]

In contrast, North Maluku consistently had low YLD (1–10% percentile) relative to other provinces, despite external reports of very low VIA coverage (1.39% in 2016 and 4.36% in 2024), a TFR above the national average, and high premarital sex among adolescent girls (11.3%) and boys (30.6%); 8.07 and 5.19 times higher than the national average, respectively.[15,35,37,38] This suggests that the true burden in North Maluku may not be as low as the GBD estimate, although GBD already incorporates modeling approaches to address incomplete source data, and this study did not directly quantify underascertainment. Therefore, we do not assert that the true YLD in North Maluku is greater, as this would require a dedicated validation analysis.

Furthermore, global Moran's I did not indicate a statistically significant spatial pattern for YLD in any year, similar to an analysis of CC incidence in China, where Moran's I was not significant at the 95% confidence level.[39] However, Local Moran's I identified East Kalimantan as a consistent L-H outlier (low YLD surrounded by high-YLD provinces) across all three years. Meanwhile, Gorontalo shifted from an H-L outlier (1990) to a cold spot (2007 and 2023). This shift should be interpreted with caution, as Gorontalo became an autonomous province only in 2000. Therefore, GBD input data for earlier years were limited, potentially affecting estimate stability. Nevertheless, CC incidence is generally influenced by social vulnerability,

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socioeconomic factors, and access to health services.[40] Gorontalo's shift from a high YLD to a low YLD between 1990 and 2007 may possibly be explained by improvements in related epidemiological factors. The persistent cold spot at the end of the observation period suggests Gorontalo's improvement was consistent and that neighboring provinces did not deteriorate significantly.

C. Years of Life Lost (YLL) Trend, 1990 – 2023

The national AAPC for YLL during 1990–2023 was 0.62% (95% CI: 0.53–0.74%), indicating that the burden of premature death from CC in Indonesia increased by an average of 0.62% per year, with the highest APC in 2018–2021. In 2021, the national YLL and that of 18 provinces peaked (Appendix 2), which may be associated with the COVID-19 pandemic. A previous study said that CC mortality in Indonesia may have increased during the pandemic because healthcare services were suspended or reduced.[41] Travel restrictions and fear of COVID-19 transmission also reduced care-seeking. A similar situation was reported in Romania, where many new CC cases went undetected, and access to treatment was hindered.[42] Post-pandemic, as healthcare services resumed and restrictions were lifted, the national YLL rate declined. This pattern is consistent with, but not direct evidence of, an association between the resumption of healthcare services and reduced mortality, as this study did not analyze causal pathways. Provincially, South Kalimantan had the highest and lowest APC of YLL. The largest increase in 2018–2021 may reflect pandemic-related service disruptions and the reallocation of 40% of the health budget to the COVID-19 response.[43] The sharp decline in 2021–2023 may reflect improvements in the local healthcare system after the pandemic, although attributing this specifically to local government intervention would require further analysis.

Maluku had the highest AAPC for YLL, indicating that premature mortality due to CC increased at the fastest rate among all provinces. Theoretically, YLL is calculated by multiplying the number of deaths by the number of years of life lost at the time of death, based on life expectancy. In Maluku, CC mortality rose from 12.76 (95% UI: 7.26-21.95) in 1990 to 59.51 (95% UI: 33.03-98.59) in 2023.[6] As deaths rise sharply, YLL also increases. A previous study reported that vaccination and two lifetime screenings, combined with good cancer management, could prevent 300,000 deaths by 2030.[44] However, screening coverage in Maluku was very low. Post-pandemic, VIA coverage in Ambon, the provincial capital, was below 5%, with about 2% positive results, of which 15% were strongly suspected to be CC and required follow-up at referral healthcare facilities.[45] The head of a Community Health Center (Puskesmas) in Central Maluku stated that women of reproductive age lack awareness of the VIA test, and these women attributed their reluctance to embarrassment and fear.[46] In addition, 70% of CC patients in Indonesia are diagnosed at a late stage, resulting in low survival rates.[47] Yogyakarta had the lowest AAPC for both YLL and YLD. Based on the trend graph alone, regardless of the rate of change (APC-AAPC), North Kalimantan consistently had the highest ASR YLL throughout the observation period, while the lowest ASR shifted from the Riau Islands to Yogyakarta, which may be attributable to more developed healthcare services and CC management in Yogyakarta.

D. Spatial Distribution and Spatial Autocorrelation of YLL

As noted in the previous study, Java has better healthcare infrastructure and higher screening coverage than other regions, yet most Javanese provinces remained in the 50–90% percentile for YLL. This may be associated with urban-rural disparities in healthcare access, which may have led to some women being diagnosed at advanced stages despite adequate regional capacity. A published study found that rural Puskesmas and sub-health centers (Puskesmas pembantu) had lower service-readiness and availability scores than urban ones.[48] Women in rural Java may therefore face barriers to early detection and adequate CC management, increasing the risk of premature mortality. Furthermore, North Kalimantan was consistently in the 90-

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99% percentile for YLL, whereas the Riau Islands remained in the low percentile class in all three observation years. Cancer prevalence in the Riau Islands declined from 3.8% (Riskesdas 2007) to 1.87% (Riskesdas 2018) and 0.8% (SKI 2023). However, other reports indicated inadequate health facilities and relatively higher risk factors in the province, including a high rate of female smoking, premarital sexual activity among adolescents above the national average, and high use of oral hormonal contraceptives.[37] These factors would be expected to increase CC cases and deaths, yet the Riau Islands showed the opposite result, so further research is needed to explain this inconsistency.

Global Moran's I showed no significant spatial patterns for YLL. Local Moran's I identified East Kalimantan as an L-H outlier in 1990, 2007, 2023, and Gorontalo as a cold spot in 2007, meaning that Gorontalo and its neighboring provinces simultaneously had low YLL. This Gorontalo's cold spot cannot be attributed to a CC control program, as the program had only been formalized that year and its impact was not yet visible.

E. Disability-Adjusted Life Years (DALY) Trend, 1990 – 2023

The DALY of CC has increased nationally, with an AAPC of 0.63% (95% CI: 0.54–0.76%), meaning DALY rose by an average of 0.63% per year from 1990 to 2023. This contrasts with declining trends in global and Southeast Asian regions. A previous study reported that the global ASR of DALY for CC fell from 1990 to 2021, with an EAPC of -1.27% (95% CI: -1.36 to -1.17%) globally and -0.78% (95% CI: -0.89 to -0.67%) in Southeast Asia.[18] Another study reported a global AAPC of -1.3% (95% CI: -1.4 to -1.2%).[21] In Indonesia, YLL accounted for 97.61% of total DALY, consistent with a Taiwanese study in which YLL accounted for 95.9% of cancer-related DALY in 2021.[20] Cancer generally has a high YLL because of its high mortality, aggressive progression, and frequent late diagnosis.

Because YLL dominates DALYs, changes in DALY rates tend to move in tandem with YLL. Consequently, the joinpoints, APC segments, and provinces with the highest and lowest AAPCs were nearly identical to those of YLL. Yogyakarta had the lowest AAPC for YLD, YLL, and DALY, which may reflect a low prevalence of CC risk factors. Yogyakarta recorded the highest national high school completion rate (89.69%), and a School Participation Rate (APS) of 54.72% for ages 19-24.[49,50] Higher educational levels may foster public awareness of early detection and healthy lifestyles. Its low TFR (1.89) indicates low parity, which reduces the risk of cervical trauma from vaginal childbirth, hormonal changes during pregnancy, and chronic HPV infections.[35,36] Yogyakarta also had a relatively high median age at first marriage (23.5 years) compared to other provinces, and its unmet need percentage (4.31%) was below the national level (5.32%), reflecting good service coverage and quality that may have contributed to the highest female life expectancy in the country (77.40 years).[31,51]

However, these data do not fully align with Riskesdas 2007–2008 and SKI 2023, which consistently reported the highest national cancer prevalence in Yogyakarta. The National Health Profile further notes that screening coverage in Yogyakarta has declined [8% (2016), 4.2% (2020), 1.06% (2024)]. Despite this decline, the proportion of positive VIA results increased. This illustrates a complex epidemiological pattern in which risk factors, case detection, health services, cancer prevalence, and disease burden are not entirely linear. Therefore, further study is needed to understand this pattern.

Based on ASR values alone, North Kalimantan had the highest ASR of YLD, YLL, and DALY throughout the 34-year observation period. This may reflect limited access and healthcare infrastructure in border regions, which are associated with low capacity for early detection and cancer management. A previous analysis of hospital infrastructure development policies in border areas found limited healthcare human resources (due to regulations on contract workers and dependence on specialist doctors deployed by the national government), fiscal management issues, inadequate medical facilities and technology, and poor

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transportation access.[52] These findings should also be interpreted with caution because North Kalimantan became an autonomous province only in 2012, limiting the availability of input data for earlier periods. Furthermore, all GBD estimates are derived from statistical modeling, although IHME applies adjustments to account for data limitations.

F. Spatial Distribution and Spatial Autocorrelation of DALY

The percentile maps for YLD, YLL, and DALY show that North Kalimantan was consistently in the 90th-99th percentile, and its AAPCs for the three indicators also show an increasing trend. This is concerning because the province with the highest burden continues to worsen, which may exceed the capacity of its still-limited healthcare facilities. According to FokusBorneo (August 7, 2024), the director of RSUD dr. H. Jusuf SK, the province's largest hospital, stated that North Kalimantan lacks specialist oncology consultants and that the secondment of medical personnel to hospitals outside Kalimantan has hindered cancer care. BPJS Kesehatan requires doctors to work full-time, but given the personnel shortage, secondment is likely; therefore, BPJS cannot cover chemotherapy costs at that hospital. In addition, the 2025 Health Profile of North Kalimantan reported that few Puskesmas conducted CC screening and that cryotherapy data for VIA-positive cases were unavailable, indicating suboptimal follow-up of preventive services at primary healthcare facilities. NTT was in the 90th-99th percentile for all indicators in two of the three years and never reduced its CC burden, as its APC consistently increased without a significant decline. Beyond health services, this may be linked to the population's risk profile: risk factors for precancerous lesions among women in NTT include age at first marriage (<20 years), more than three pregnancies, and a history of abnormal vaginal discharge.[53] Low awareness of screening and the archipelagic geography also create barriers to access.

Global Moran's I showed no significant global spatial autocorrelation in YLD, YLL, or DALY in any year, consistent with studies of CC incidence and mortality in China and age-standardized incidence rate (ASIR) in Iran.[54,55] This may reflect provincial heterogeneity in service quality, early detection coverage, and sociodemographic conditions, although this study did not examine these variables and the interpretation remains hypothetical. LISA identified East Kalimantan as an L-H outlier in all years for all three indicators. East Kalimantan had a low unmet health care need (3.86%) and the highest VIA coverage (38.19%) compared with its neighbors (4.12-10.05%). This may reflect provincial heterogeneity in service quality, early detection coverage, and sociodemographic conditions, although this study did not examine these variables and the interpretation remains hypothetical. LISA identified East Kalimantan as an L-H outlier in all years for all three indicators. East Kalimantan had a low unmet health care need (3.86%) and the highest VIA coverage (38.19%) compared with its neighbors (4.12-10.05%). [15,56]

This condition suggests better early detection capacity and access to care, which may help explain its lower CC burden despite being surrounded by high-burden provinces.

National CC screening coverage remained low between 2007 and 2018, with only 3.6 million (9.8%) of 34.7 million targeted individuals screened by 2018.[57] According to the 2018 Indonesia Health Profile, Papua had the lowest coverage (0.91%), while the latest data showed South Papua (0.02%) as the lowest.[15] Cancer prevalence was 1.58% (Riskesdas 2018) and 0.5% (SKI 2023) in Papua and 0.7% (SKI 2023) in West Papua. Nevertheless, Papua and West Papua did not have the highest increases in CC burden; AAPCs for DALY were 0.95% and 0.51%, respectively (Appendix 3), and the ASRs for the three variables were not in the high-percentile group.

Specialist doctor ratios in Papua and West Papua were 0.07 and 0.11 per 1,000 population, respectively, below the national target of 0.2 per 1,000 population.[58] These findings suggest a possible data quality concern, as persistently low screening coverage and limited specialist workforce may be associated with underascertainment of CC cases. However, GBD estimates already

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incorporate modeling to address incomplete source data, and this study did not directly quantify underascertainment. Accordingly, we do not claim that the true burden of CC in Papua exceeds the GBD estimate.

G. Forecasting

In 2028, the DALY burden of CC in Indonesia is projected to reach 273.226 per 100,000 population (95% PI: 228.693–317.759). Projected increases in YLD (9.31%), YLL (1.63%), and DALY (1.80%) may increase demand for healthcare services, treatment management, and the financial burden on Indonesia's National Health Insurance. According to 2018 BPJS claims data, direct treatment costs for CC amounted to Rp393 million, while total costs in 2035 are projected at Rp2-4 trillion (early stage) and Rp9-10 trillion (advanced stage).[14,59] Rising YLL may also cause productivity loss. In 2018, productivity loss from CC in Indonesia reached Rp23.174 trillion, and in 2022, it reached €456 million in Europe (Present Value of Future Lost Productivity, PVFLP.[12,60] Meanwhile, studies at the global level (1990–2021), Southeast Asia (1980–2021), the United Kingdom (1990–2019), and Taiwan (2000–2021) found that the DALY of CC has actually been declining.[18,20,61,62]

The rising DALY in Indonesia warns the government to promptly improve all aspects that reduce CC burden. In Taiwan, declining DALYs reflect improved cancer control. Primary HPV DNA screening every five years with 70% coverage is the most effective and cost-effective method, reducing the age-standardized mortality rate (ASMR) by 63-67%, whereas VIA and Pap smear screening every three years are less effective and less cost-effective.[63] HPV vaccination, the primary prevention for CC, became a national program in 2023, targeting 11-year-old girls, with a national coverage rate of 80% by 2024.[64]

H. Study Limitation

This study relied entirely on secondary data from the GBD Study 2023, developed by the Institute for Health Metrics and Evaluation (IHME), so the results depend on IHME's methodology, assumptions, and estimation process. The GBD uncertainty intervals were not propagated into the joinpoint regression and forecasting analyses, which may have underestimated the true variability in the APC, AAPC, and forecasted values. Input data quality and availability also vary across provinces, which may lead to underestimation or overestimation. Administrative boundary changes in several provinces during 1990-2023 may have introduced inconsistencies in population denominators and affected trend comparability. Furthermore, the analysis included only the 34 provinces available in the GBD Study 2023 at the time of the study. We did not assess the sensitivity of the spatial analysis to alternative weight matrices. We calculated Global and Local Moran's I for selected time points rather than the full study period, which may not fully capture temporal shifts in clustering. The forecast relied solely on historical data and did not incorporate external variables. Therefore, the DES model's accuracy depends on the assumption that past patterns will continue without new interventions. We also evaluated model performance using in-sample validation rather than out-of-sample testing, which tends to overestimate predictive accuracy.

We obtained historical data for YLD, YLL, and DALY independently from GBD Result Tools and applied separate DES models with independently optimized smoothing parameters to forecast each variable. Consequently, the identity DALY = YLD + YLL, which holds by definition, is not guaranteed in the forecasted values, and discrepancies may increase with the forecasting horizon. Therefore, the forecasted values should be interpreted as separate model outputs rather than strictly additive components. The explanations offered in the Discussion are based on ecological, aggregate-level data and were formulated post hoc; they are exploratory and should not be interpreted as evidence of individual-level causal mechanisms, given the risk of ecological fallacy.

Future research should examine the burden of CC across 38 provinces using age stratification, apply more diverse spatial approaches, explore the determinants of CC burden in each province in greater depth, and

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incorporate additional variables and a longer forecasting horizon, supported by out-of-sample validation.

I. Implication

The findings have implications for implementing the National Action Plan for Cervical Cancer Elimination in Indonesia, 2023–2030. Immunization, screening, health management, adequate financing, and health workforce strengthening must be accelerated in provinces with the highest AAPC of YLD (Riau Islands), the highest AAPC of YLL and DALY (Maluku), and provinces that consistently fall in the high percentile class for all variables, such as West Sumatra and North Kalimantan. In line with WHO recommendations, HPV DNA screening should be expanded beyond pilot areas, including through mobile early detection services in areas with limited transportation access. The government should also extend the national HPV immunization program to include both men and women across a wider age range.

Public awareness programs, education, monitoring, evaluation, and research activities should account for each province's sociodemographic characteristics, culture, and health literacy, as well as the specific characteristics of each target group. East Kalimantan's consistent L-H outlier pattern indicates a gap in health service capacity relative to its neighbors. Therefore, cross-sectoral collaboration, particularly interprovincial cooperation in Kalimantan, should be strengthened without neglecting other provinces.

Rising CC burden in Indonesia, along with its projected increase, highlights the need to accelerate referrals, reduce treatment wait times, and improve quality of care, including rehabilitative and palliative care, with adequate financing. The absence of significant global spatial autocorrelation suggests that province-specific policies matter more than region- or island-based approaches. Cultural barriers, stigma, social norms, and public perceptions regarding reproductive health remain challenges for CC prevention and early detection. Therefore, the National Action Plan should prioritize community-based approaches and public acceptance of the CC elimination program.

Conclusions

The burden of disease (YLD, YLL, DALY) due to CC in Indonesia increased from 1990 to 2023, with no statistically significant global spatial autocorrelation. Nationally, the highest APC was in 2007-2011 for YLD and in 2018-2021 for YLL and DALY. The Riau Islands had the highest AAPC of YLD, while Maluku had the highest AAPC of YLL and DALY; Yogyakarta had the lowest AAPC for all three. Based on age-standardized rate value alone, without accounting for the rate of change (APC or AAPC), North Kalimantan consistently had the highest burden throughout the observation period. On the percentile maps, North Kalimantan consistently fell in the high percentile class for all three indicators, while West Sumatra fell in the high percentile class only for YLD. Local spatial autocorrelation was detected only in Gorontalo and East Kalimantan. The burden of CC in Indonesia is projected to increase by 9.31% (YLD), 1.63% (YLL), and 1.8% (DALY) over the next five years (2024–2028). This study extends previous research by integrating temporal trend, spatial, and forecasting analyses using the latest GBD 2023 estimates across 34 provinces. The findings provide evidence to inform priority setting and support implementation of the national action plan for CC elimination.

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