Case Study

Planning-grade disease burden estimation for non-communicable diseases in a rural Michigan county: a DALY modeling case study

Sergey Soshnikov[1]*

[1]Public Health Division, The Herbert H. and Grace A. Dow College of Health Professions, Central Michigan University, Mount Pleasant, MI 48489, United States
*Corresponding Author: soshn1s@cmich.edu

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Background: County-level disease burden estimates were rarely available in the United States outside large academic centers. Isabella County, Michigan - a federally designated Medically Underserved Area of 64,565 residents with all-cause mortality approximately 4.7% above the Michigan average and approximately 13.3% above the United States rate and a psychiatrist-to-population ratio substantially exceeding federal shortage-designation thresholds - had no published disability-adjusted life year (DALY) estimate to guide local planning.
Methods: This was a cross-sectional disease burden study integrating CDC WONDER 2020-22 (cause-specific mortality), MDHHS 2020 (all-cause and comparator rates), CDC PLACES 2024 (prevalence), IHME GBD 2021 disability weights, and ACS 2022 denominators. DALYs are estimated as the sum of YLL and YLD, without age weighting or discounting; YLL uses a planning approximation against a fixed terminal-age benchmark rather than the WHO age-specific loss function, so the estimates are not equivalent to formal WHO/GBD estimation. The primary scenario uses WHO Global Health Estimates frontier life expectancy (89.1 years); Michigan's observed LE of 78.6 years informed a sensitivity analysis. Mental health prevalence was remission-adjusted by a factor of 0.50 to convert lifetime-diagnosed prevalence to active prevalence. Comorbidity was adjusted via Gaussian-copula microsimulation, yielding a comorbidity correction factor (CF) of 0.949. Uncertainty is quantified via Monte Carlo simulation (n=10,000 iterations).
Results: Annual burden totaled 13,493 DALYs per year (95% UI 12,266–14,803; YLL 8,268 + YLD 5,225), corresponding to ~391 deaths per year; 20,899 DALYs per 100,000 residents. Cancer contributed the greatest burden (3,641 DALYs), followed by cardiovascular disease (2,793), substance use disorders (2,434), and mental health conditions (1,502). Michigan LE sensitivity yielded 9,388 DALYs. All-cause mortality showed concordance with IHME county estimates (819.9 vs 807.4/100k, within 95% UI; Δ +1.5%*)*.
Conclusion: A transparent, reproducible DALY workflow built from publicly accessible federal, state, international, and published data sources provides a defensible county burden map for planning, grant development, and service prioritization where no formal estimate exists. Cancer and CVD contributed the largest mortality-driven burden among the seven selected condition groups; mental health was the most disability-dominant condition, with approximately 71% of its total burden arising from YLD. The approach is replicable by any US rural county.

Keywords: disability-adjusted life years, rural health, public health planning, disease burden, Michigan, county-level analysis, DALY methodology, Monte Carlo uncertainty

*- *a full list of spelled-out abbreviations and acronyms is provided at the end of the manuscript.*

Introduction

Isabella County sits at the center of Michigan's Lower Peninsula - a rural community of 64,565 people carrying a health burden measurably heavier than the state around it. All-cause mortality runs approximately 4.7% above the Michigan average and approximately 13.3% above the United States rate, stroke deaths exceed the national rate by roughly 60%, and chronic obstructive pulmonary disease (COPD) mortality is about 37% above the Michigan average and about 53% above the national rate.[1,2] One in five residents lives below the poverty line. The county is federally designated as both a Medically Underserved Area and a Mental Health Professional Shortage Area, with approximately one psychiatrist for every 176,938 residents in its service area - a ratio that substantially exceeds federal shortage-designation thresholds.[1] Home to Central Michigan University, it blends a college-town population with a predominantly rural, economically strained community.

Despite this documented burden, Isabella County has no published disability-adjusted life year (DALY) estimate to guide local planning. County Health Rankings provides useful composite scores for advocacy,[3] but not a burden-of-disease metric that lets planners compare mortality and morbidity across conditions on a common scale. The Global Burden of Disease (GBD) program[4] remains the reference standard for comparative burden assessment, built from age-, sex-, cause-, and sequela-level data with statistical borrowing across locations - data structures that do not exist for most rural US counties, Isabella among them.

County-level burden-of-disease estimation remains scarce in the United States outside large academic centres, and the reason is structural rather than a lack of interest. The Global Burden of Disease architecture depends on age-, sex-, cause- and sequela-level inputs with statistical borrowing across locations,4 and those data structures simply do not exist for most rural counties: cause-specific death counts fall below disclosure thresholds, prevalence must be borrowed from model-based small-area estimates, and severity distributions are unavailable locally. The practical consequence is that the planners who most need comparative burden information — those working in rural, medically underserved counties with the least analytic capacity — are the least likely to have it. They are left choosing between composite ranking scores, which are useful for advocacy but cannot place mortality and morbidity on a common scale,3 and formal GBD outputs, which are not resolved to their county. A workflow that is transparent about its own limits offers a middle path: it will not match GBD in resolution, but it can label the quality of every input, quantify the uncertainty that its assumptions carry, expose the choices that move the rankings, and be rerun by any county from the same public sources. That is the gap this study addresses, and the reason the workflow — rather than the estimate itself — is offered as the contribution.

This study takes a complementary path. It applies the DALY framework to Isabella County using publicly available federal, state, and county data, with every assumption documented and every input labeled by quality. The aim is practical: to give local planners a defensible, transparent burden map where no formal county estimate exists - a decision-support framework for prioritization, grant development, and service design. The objectives are (1) to estimate and rank the absolute and comparative burden of seven major condition groups in Isabella County, and (2) to demonstrate a reproducible, fully documented workflow that any rural US county can apply using the same public data sources.

Methods

Cross-sectional disease burden analysis conducted in Isabella County, Michigan. Seven condition groups were selected based on county-level data availability and documented local burden (MDHHS 20201: cancer, cardiovascular disease (CVD), substance use disorders (SUD), mental health disorders, COPD, stroke, and diabetes. Cause-specific mortality was obtained from CDC WONDER 2020–22 data (3-year pooled counts, underlying cause of death).[5] Cardiovascular disease was defined using the NCHS "diseases of heart" grouping (ICD-10 I00–I09, I11, I13, I20–I51), which is the definition underlying the cardiovascular death counts reported in Table 1; stroke (I60–I69) was analyzed as a separate condition group and is therefore excluded from the cardiovascular category to avoid double-counting. For substance use disorders, whose county mortality counts were suppressed in CDC WONDER, a proxy estimate was derived from Michigan state rates with a rural-adjustment multiplier (SUD ×1.40). Diabetes mortality (E10–E14, all diabetes mellitus) was obtained from CDC WONDER 2020–22; county counts were not suppressed (62 deaths over 3 years; 21 per year) and were therefore classified as an observed count, with no rural adjustment multiplier applied. The condition group was therefore reported as diabetes (E10–E14, all diabetes mellitus) rather than as type 2 diabetes (E11), because the mortality source does not isolate type 2 disease. Mental health mortality was estimated using observed intentional self-harm deaths (X60–X84) from CDC WONDER (29 deaths/3-year; 10/year), replacing the prior Michigan state-rate proxy. The SUD multiplier was based on NSDUH 2024[6] non-metropolitan versus metropolitan opioid-misuse prevalence ratios (3.6% vs 2.6%; ratio 1.38, conservatively rounded to 1.40); extrapolation of a prevalence ratio to a mortality-rate multiplier was recognized as an approximation. The mental-health multiplier was based on Kegler et al,[7] who report non-metropolitan suicide rates approximately 1.4 times metropolitan rates; the mental-health ×1.40 state-rate proxy was superseded in the current analysis by the observed intentional self-harm count (X60–X84) reported above, which is used as the mortality component of the mental-health category throughout; the earlier proxy is described here only to document the superseded approach. Prevalence was obtained from CDC PLACES 2024 (multilevel regression and poststratification on BRFSS data).[9] Disability weights were taken from IHME GBD 2021 at moderate severity.[10] Table 1 labels each input by quality tier (observed / modelled / inferred / proxy). All-cause mortality and life expectancy were additionally compared against IHME modelled county estimates (GHDx 2022),[11-13] these convergent-validity comparisons are reported in the following, Convergent Validation of Mortality Inputs subsection.

DALYs were calculated as YLL + YLD, without age-weighting or time-discounting. YLL was estimated using a planning approximation (a PYLL-style calculation against a fixed terminal-age benchmark): $YLL = N \times (L - A)$, where N is annual deaths, L is a fixed terminal-age benchmark, and A is the mean age at death. This is not the standard WHO/GBD YLL calculation, which applies an age-specific loss function, $YLL = \Sigma_a N_a \times L_a$, where L_a is the normative remaining life expectancy at age a taken from a standard life table. Because age-specific death counts and a WHO age-specific loss table were not applied here, the present estimates are reported as a planning approximation and are not equivalent to formal WHO/GBD YLL estimation. Re-estimation using age-specific death counts and the WHO age-specific loss table would be the single most consequential methodological refinement for a future iteration. Mean age at death was derived from 3-year pooled CDC WONDER 2020–22 county and Michigan state age-at-death distributions for conditions with and without suppressed counts. The primary scenario used a fixed terminal-age benchmark of 89.1 years, corresponding to the WHO GHE frontier life expectancy at birth (sex-averaged), applied as a benchmark rather than as an age-specific life-table function; a local planning sensitivity substituted Michigan observed life expectancy at birth (78.6 years[14]) for comparability with prior county documents. Observed life expectancy at birth minus mean age at death is not an age-specific life-table function; this sensitivity is a local planning comparison, not an alternative standard DALY calculation. YLD = prevalence × disability weight (DW), corrected for comorbidity overcounting, as described below. CDC PLACES provides model-based prevalence among adults, in several instances derived from lifetime self-reported diagnosis, whereas formal GBD YLD estimation uses sequela-specific prevalence with severity-specific disability weights; applying a single moderate-severity disability weight to all diagnosed cases is a planning approximation and is not equivalent to formal GBD estimation. Diagnosed prevalence does not necessarily represent current symptomatic disease, local severity distributions are unavailable, and this structural uncertainty is not fully represented in the reported uncertainty intervals. Prevalence case counts use the adult (18+) denominator whereas DALY rates per 100,000 use the total county population. Specifically, prevalence case counts use the adult (18+) population of 52,212 (ACS 2022), whereas DALY rates per 100,000 use the total county population of 64,565.

Two YLD adjustments were applied. First, because CDC PLACES reported lifetime-diagnosed depressive disorder prevalence, a remission factor of 0.50 (sensitivity 0.40–0.60) was applied, giving an active prevalence of 14.9% (29.8% × 0.50). Second, summed condition-specific YLDs were corrected for overcounting due to multimorbidity, because naively summing per-condition YLDs overcounts burden when residents carry multiple conditions simultaneously. A Gaussian-copula microsimulation generated correlated multi-condition assignments for 500,000 synthetic persons via Cholesky decomposition of the condition correlation matrix (NumPy random seed 42). For each synthetic person, a combined disability weight was computed as $DW\_combined = 1 - \prod(1 - DW\_i)$ across all conditions present, then averaged across the simulated population to derive the population-level correction factor (CF = 0.949). CF and its uncertainty interval are reported to three decimal places for computational transparency; this reflects the precision of the Monte Carlo simulation itself, not confidence in the underlying literature-based comorbidity assumptions described below.

Three overlap scenarios were assessed: Scenario A, independence (CF = 0.966, −3.4% YLD); Scenario B, literature-informed positive correlations (CF = 0.949, 95% UI 0.934–0.963, −5·1% YLD; primary estimate); and Scenario C, upper-bound correlations (CF = 0.915, −8.5% YLD).[15,16] Scenario B pairwise correlations — CVD–diabetes 0.40 and mental-health–SUD 0.35 — are author-specified planning assumptions informed by the general comorbidity literature rather than point estimates drawn from a single published source. The correction factor was applied proportionally to each condition-specific YLD. The pairwise association parameters are literature-informed approximations rather than locally estimated correlations, and the reported CF uncertainty interval reflects variation across the plausible parameter range rather than a formally derived sampling distribution. The copula adjustment is presented as a planning sensitivity analysis rather than a formally validated local comorbidity model. Scenario B was selected as primary because positive comorbidity among these conditions is epidemiologically plausible, while Scenarios A and C defined sensitivity bounds. This procedure served as a guardrail against overcounting, not as a claim of individual-level comorbidity modelling.

Parameter uncertainty was propagated in a separate Monte Carlo simulation (n = 10,000 iterations), analytically distinct from the 500,000-person comorbidity microsimulation. Observed death counts were sampled from Poisson distributions; prevalence from Beta distributions matched CDC PLACES 95% CIs; disability weights sampled from Beta distributions matched to IHME 95% CIs; and rural-adjustment factors and remission factor from literature-range uniform distributions. Reported 95% uncertainty intervals were percentile intervals spanning the 2.5th–97.5th percentiles. These intervals captured parameter uncertainty but not systematic model biases from non-representative BRFSS rural sampling, CDC PLACES MRP smoothing, or rural-adjustment misspecification. Mortality inputs are 3-year pooled counts (2020–22) expressed as annualized deaths. Poisson sampling was applied to the annualized death counts and therefore represents year-to-year stochastic variation in deaths rather than uncertainty in the mean annual rate estimated from the pooled three-year window. The reported intervals capture selected parameter uncertainty but not all structural uncertainty, including case-definition mismatch, severity distributions, the YLL planning approximation, and rural-proxy misspecification. Prevalence and mortality case definitions correspond imperfectly (PLACES depression vs F30–F48 and suicide X60–X84; coronary heart disease prevalence vs cardiovascular mortality; diagnosed diabetes vs E10–E14 mortality; SUD prevalence vs F10–F19 mortality and accidental poisoning codes; lifetime stroke or cancer diagnosis vs current disability states); exact case-definition equivalence should not be inferred.

Economic equivalents were estimated using two approaches: human capital evaluation, calculated as DALYs × Michigan GDP per capita ($62,000, Bureau of Economic Analysis 2024), and value of statistical life, calculated as deaths × income-adjusted VSL ($11.2M), applying the Viscusi and Aldy[17] elasticity framework to the 2024 HHS base value adjusted for Michigan median household income. Both estimates were illustrative planning figures rather than cost-of-illness estimates; uncertainty was set at a fixed illustrative ±20%, an author-chosen planning range rather than a value derived from formal uncertainty propagation.

To support computational reproducibility, the workflow used language-independent tabular inputs with parallel R and Python implementations. Both implementations read the same source files and applied the same predefined formulas for YLL, YLD, DALY estimation, comorbidity correction, Monte Carlo uncertainty propagation, and sensitivity analyses. They reproduced all manuscript tables, figures, and uncertainty intervals from a single version-controlled repository. This approach separated methodological specification from programming language choice and allowed the workflow to be audited, rerun, and adapted for other US counties using the same public data architecture. The full analytical workflow was summarized in Figure 1.

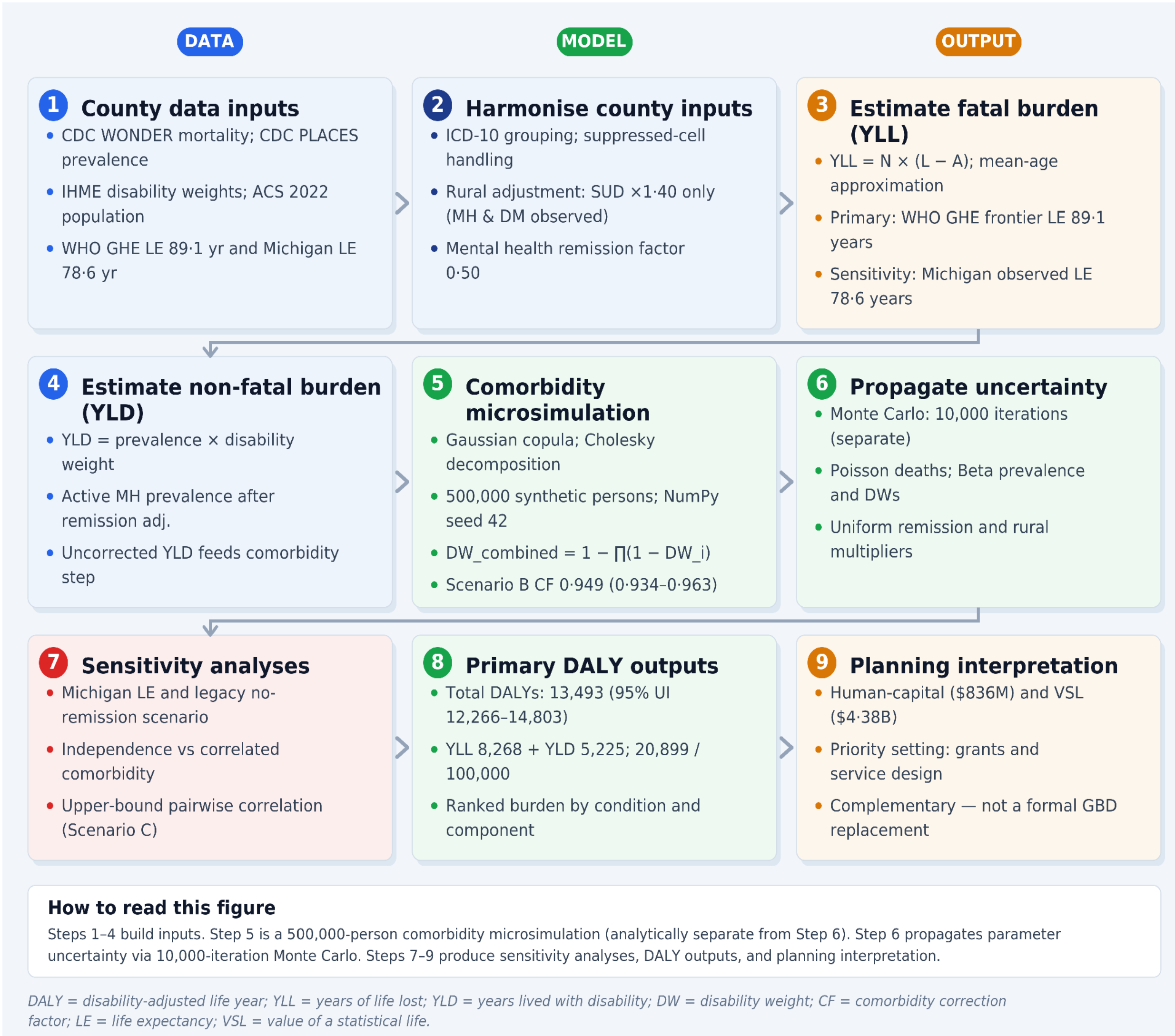

Figure 1. Analytical workflow for transparent county DALY estimation, Isabella County, Michigan. The workflow proceeds from public data inputs (CDC WONDER, MDHHS, CDC PLACES, IHME GBD, ACS) through data quality classification, YLL and YLD computation, Monte Carlo uncertainty propagation (n = 10,000), comorbidity correction (Gaussian-copula microsimulation), and convergent validation against IHME county estimates, to final DALY estimates, economic burden, and planning output. Each data input is labeled by quality tier (observed / modelled / inferred / proxy).

Results

Disease Burden

Under the WHO GHE frontier reference life expectancy (89.1 years) with remission-adjusted mental health prevalence, total estimated burden was 13,493 DALYs per year (Monte Carlo median 13,475; 95% UI 12,266–14,803; YLL 8,268 + YLD 5,225), representing ~391 deaths per year and a crude rate of 20,899 DALYs per 100,000 residents. YLL constituted 61% of total burden, reflecting the high mortality load from cancer and cardiovascular disease. Table 1 presents the primary burden estimates, and Figure 2 shows the YLL/YLD decomposition by condition.

Table 1. Estimated disease burden, Isabella County, Michigan, 2022 (WHO GHE frontier-reference LE 89.1 years; mental health remission-adjusted)

Condition (ICD-10)	Prevalence (cases)	Deaths/ yr	YLL (frontier LE)	YLD	DALYs (95% UI)	Rate (/100k)	Rank	Data source
Mental health (F30–F48)	7,780*	~10	431	1,071	1,502 (1,013–2,087)	2,326	#4	Deaths: CDC WONDER 2020–22 suicide (X60–X84), observed; prevalence: CDC PLACES 2024 (remission-adj)
Cancer (C00–C97)	4,020	~114	2,519	1,122	3,641 (3,042–4,272)	5,639	#1	CDC WONDER 2020–22 (observed)
Substance use (F10–F19)	3,749	~28	1,263	1,171	2,434 (1,763–3,179)	3,769	#3	State rate × rural adj. ×1·40
CVD — diseases of heart (I00–I09, I11, I13, I20–I51)	3,691	~149	2,548	245	2,793 (2,379–3,225)	4,326	#2	CDC WONDER 2020–22 (observed)
COPD (J44)	4,287	~36	576	806	1,382 (1,048–1,759)	2,140	#5	CDC WONDER 2020–22 (observed)
Stroke (I60–I69)	1,671	~33	528	501	1,029 (771–1,313)	1,594	#6	CDC WONDER 2020–22 (observed)
Diabetes (E10–E14)	6,062	~21	403	311	714 (504–948)	1,105	#7	CDC WONDER 2020–22 (observed)
Total	-	~391	8,268	5,225	13,493 (12,266–14,803)	20,899	-	-

*DALYs = disability-adjusted life years; YLL = years of life lost; YLD = years lived with disability. Frontier-reference LE = 89.1 yr (WHO GHE, sex-averaged). 95% UI: Monte Carlo (n = 10,000). Comorbidity CF = 0.949 (Scenario B, correlated). *MH (mental health) prevalence remission-adjusted: 29·8% × 0·50 = 14·9% active (7,780 cases). Raw no-remission MH YLD = 2,138. Totals may differ slightly from the sum of displayed rows because calculations used unrounded estimates.*

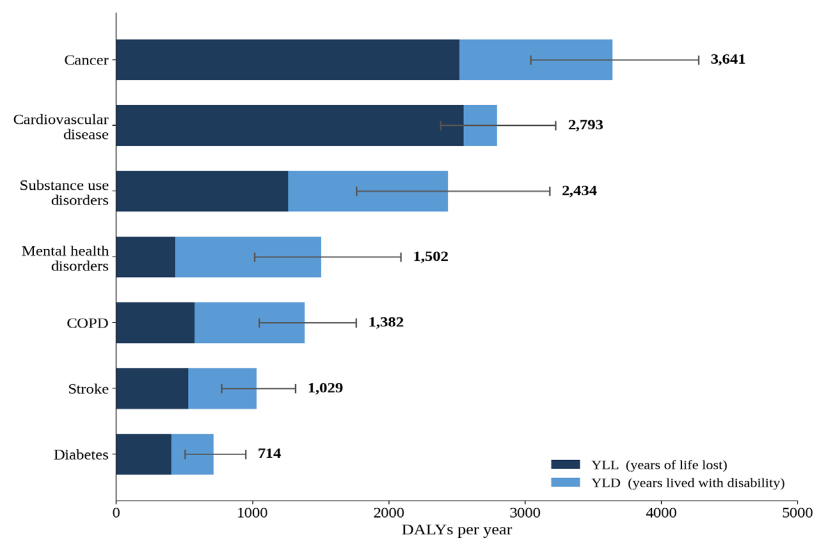

Figure 2. Estimated disease burden by condition group, Isabella County, Michigan, 2022. YLL = years of life lost (dark shading); YLD = years lived with disability (light shading). Total DALYs shown at right of each bar. Primary planning scenario: WHO GHE frontier-reference LE 89.1 years with remission-adjusted mental health prevalence (×0.50 correction factor). Bars sorted by total DALY burden. Uncertainty intervals for each condition are reported in Table 1.

Sensitivity Analyses

The Michigan observed LE sensitivity (78.6 years) while retaining remission-adjusted mental health prevalence and comorbidity correction was presented in Table 2. Under this sensitivity, total burden was 9,388 DALYs; cancer remained first (2,444 DALYs), followed by SUD (2,140), mental health (1,397), and CVD (1,228). Figure 3 summarized how YLD burden shifts across comorbidity scenarios (Scenarios A, B, C).

Table 2. Sensitivity analysis: YLL and DALY estimates under Michigan observed life expectancy (78.6 years) in 2022.

Condition	Mean age at death (yr)	YLL (MI LE 78.6 yr)	YLD (unchanged)	DALYs (Michigan LE)	Rank (Michigan LE)
Mental health	46	326	1,071	1,397	#3
Cancer	67	1,322	1,122	2,444	#1
SUD	44	969	1,171	2,140	#2
CVD	72	983	245	1,228	#4
COPD	73	198	806	1,004	#5
Stroke	73	182	501	683	#6
Diabetes	70	182	311	493	#7
Total	-	4,162	5,225	9,388	-

YLD values reflect remission-adjusted mental health prevalence (same as primary scenario). Totals may differ slightly from the sum of displayed rows because calculations used unrounded estimates.

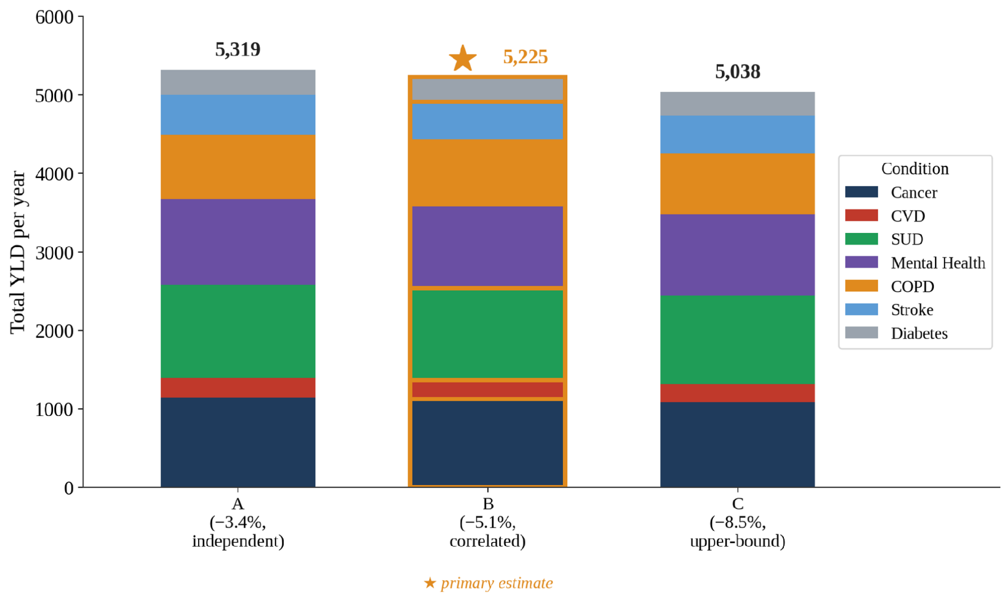

Figure 3. Sensitivity of 2022 YLD estimates to the comorbidity correction assumption. Stacked bars show per-condition disability burden under three comorbidity scenarios: Scenario A (independence, CF = 0.966, −3.4% YLD), Scenario B (literature-informed positive correlation via Gaussian copula, CF = 0.949, −5.1% YLD; ★ primary estimate), and Scenario C (upper-bound correlation, CF = 0.915, −8.5% YLD). The purpose is to show the direction and approximate magnitude of overcounting in aggregated condition groups, not to claim individual-level comorbidity modelling.

Convergent validation of mortality inputs

The mortality backbone - death counts and rates used to estimate YLL - was evaluated against two independent reference sources: (1) IHME's modeled county-level all-cause mortality rates and life expectancy,[11-13] and (2) CDC WONDER 2020–22 cause-specific mortality, the primary data source for this study. The comparison was limited to mortality and LE, because IHME did not publish county-level DALYs or YLD estimates; therefore, disability burden cannot be externally validated at county resolution.

Two systematic offsets were expected and were not treated as errors. First, IHME reports age-standardized rates using a GBD reference population, whereas this workflow reports crude rates. This difference affects absolute rate levels and means the two are not directly comparable, but it should not alter the direction of the comparison. Second, the IHME county file covered 2019, preceding the COVID-19 excess mortality peak in 2020–21 and the opioid surge in 2021–23. Accordingly, the Lakes Linked workflow (this study's open, reproducible DALY pipeline; www.lakeslinked.com) 2020–22 rates for CVD and SUD were expected to exceed IHME 2019 values, reflecting real temporal change.

Table 3 presented all-cause mortality and life expectancy estimates. Isabella County's all-cause rate (819.9/100k; MDHHS 2020) fell within IHME's 95% uncertainty interval for 2019 (807.4/100k; UI 775.8–841.0; Δ = +1.5%). This agreement, within IHME's own uncertainty range, supported the credibility of the mortality backbone for planning-grade use. Clare County showed a larger discrepancy. In this workflow, Clare uses a state-rate shortcut, because of suppression handling, whereas IHME estimates a county-specific mortality rate of 1,014.3 per 100,000, approximately 30% higher than the Michigan average of 783.1 per 100,000. Midland County's estimate fell within IHME's interval. Because Clare is the only available external check on the state-rate proxy method, this discrepancy should be read as a limitation of the proxy approach itself, not as a Clare-specific anomaly; the same method is used for Isabella County's suppressed-count category (SUD), so a comparably sized error there cannot be ruled out.

Table 3 also reported life expectancy. This workflow applied a uniform Michigan LE of 78.6 years across all counties. For Isabella County, IHME's county-modelled LE is 79.1 years (95% UI 78.6–79.6), a difference of only 0.5 years, which was negligible for planning. However, IHME revealed meaningful county heterogeneity: Clare County's LE is 75.5 years, 3.1 years below the Michigan average, while Midland LE is 80.8 years, 2.2 years above the state average. Adopting county-specific IHME LE estimates was the most impactful single methodological refinement available for future versions.

Table 3. All-cause mortality and life expectancy: Lakes Linked vs IHME county estimates (Isabella, Clare, Midland)

County	Lakes Linked all-cause (/100k)	IHME 2019 (/100k, 95% UI)	Δ%	Within IHME UI?	Lakes Linked LE (yr)	IHME county LE (yr, 95% UI)	Implication
Isabella (26073)	819.9	807.4 (775·8–841.0)	+1.5%	Yes	78.6	79.1 (78.6–79.6)	Δ 0·5 yr - negligible; workflow validated
Clare (26035)	783.1* (state-rate model)	1,014.3 (974·7–1,055.6)	−22.8%	No (pre-specified)	78.6	75.5 (74.9–76.0)	Clare LE 3·1 yr below MI avg - shortcut limitation
Midland (26111)	~714	697.8 (673.5–721.2)	+2.3%	Yes	78.6	80.8 (80.3–81.2)	Midland LE 2·2 yr above MI avg - overstates Midland YLL

*IHME values from Dwyer-Lindgren et al.[11-13] (GHDx 2022); reference year 2019. *Clare's Lakes Linked value is a state-rate model, not an observed county rate.*

Cause-specific mortality was presented in Table 4. For cancer, CVD, COPD, and stroke, Isabella County rates were directly observed from CDC WONDER 2020–22 (counts not suppressed). Diabetes mortality (E10–E14) was directly observed from CDC WONDER 2020–22; county counts were not suppressed. Mental-health mortality is represented by observed suicide deaths (X60–X84) from CDC WONDER 2020–22. Only substance use disorder mortality remained suppressed at county level; Table 4 therefore reports a proxy estimate for SUD derived from the Michigan state base rate with a rural-adjustment multiplier, flagged accordingly. County-level comparison against IHME cause-specific estimates was pre-specified for a future update when per-cause GHDx county files are extracted. For the current version, the all-cause validation in Table 3 provides the primary mortality-backbone.

Both available county-level validation quantities - all-cause mortality and life expectancy - fell within or immediately adjacent to IHME's 95% uncertainty intervals for Isabella County. This supported the workflow's mortality backbone as a planning-grade approximation. The expected divergence observed in Clare County, and the use of a uniform LE assumption, remained acknowledged limitations and identified two concrete targets for future refinement.

Table 4. Cause-specific mortality rates, Isabella County, Michigan (CDC WONDER / MDHHS 2020–22) by data quality tier

Cause group (ICD-10)	Isabella (/100k)	Michigan (/100k)	Excess vs MI	Data tier	Source / notes
Cancer (C00–C97)	175.1	161.1	+8.7%	Observed	CDC WONDER 2020–22; 3-yr pooled county counts
IHD and heart failure (I20–I51)†	198.6	194.9	+1.9%	Observed	CDC WONDER 2020–22; narrower grouping than the diseases-of-heart definition used for burden in Table 1
COPD (J44)	60.6	44.2	+37.1%	Observed	CDC WONDER 2020–22
Stroke (I60–I69)	59.4	39.9	+48.9%	Observed	CDC WONDER 2020–22
Diabetes (E10–E14)	31.1	21.9	+42.0%	Observed	CDC WONDER 2020–22; E10–E14 (all diabetes mellitus); county counts not suppressed (62 deaths over 3 years)
SUD (F10–F19)	~43*	~31*	+40%*	Proxy	CDC WONDER county counts suppressed; MI state rate × rural adj ×1·40. Includes 2021–23 opioid acceleration.
Suicide (X60–X84)	14.6	—	—	Observed	CDC WONDER 2020–22; 29 deaths over 3 years; rate is the CDC WONDER crude rate per 100,000 person-years. Mental-health mortality is represented by observed suicide; MH burden is primarily YLD-driven, so this mortality comparison is partial.
All-cause total	819.9	783.1	+4.7%	Observed	MDHHS 2020; matches IHME estimate within 95% UI (Table 3)

**Proxy estimate; CDC WONDER county counts suppressed. Rates derived from Michigan state base rate with rural-adjustment multiplier; 95% UI wide. †This row uses the narrower ischemic-heart-disease-and-heart-failure grouping (I20–I51), matching the published Michigan/US comparator rates, which were not available on the broader diseases-of-heart basis used in Table 1 (see Results for why the two rows are not directly comparable). Rates here are as published by the cited sources — crude, not age-standardized, and not recomputed from the county death counts underlying Table 1.*

Economic burden

Under the human capital method, the primary burden of 13,493 DALYs corresponded to approximately $836 million per year (range $669M–$1,004M at ±20% uncertainty). Under the VSL method, ~391 deaths per year corresponded to approximately $4·38 billion in statistical life value (income-adjusted HHS 2024 central value $13·1M, Michigan-adjusted to $11·2M; elasticity 0·55).

Cause-specific mortality

All-cause mortality in Isabella County (819.9/100,000) exceeded the Michigan average by 4.7% and the national average by 13.3% (Table 5). Note that Table 5 reports cardiovascular mortality using the narrower ischemic-heart-disease-and-heart-failure grouping (I20–I51), whereas the cardiovascular burden estimates in Table 1 use the broader NCHS diseases-of-heart grouping (I00–I09, I11, I13, I20–I51); the two are not directly comparable. COPD mortality was 37.1% above state average; stroke mortality was 48.9% above state average - the largest relative gap of any condition, consistent with uncontrolled hypertension (32.1% county prevalence), limited acute stroke access, and delayed recognition.

Social determinants of health

Key contextual indicators show that local conditions were less favorable than statewide averages. The poverty rate ranges from 19.0% to 26.5%, depending on the ACS data year and how the student population is counted, compared with the Michigan average of 14.5%. The uninsured rate was 8.2%, higher than Michigan's 6.8%. In addition, 27.0% of adults reported having no personal doctor, compared with 18.4% statewide, and 30.4% of adults reported physical inactivity, compared with 25.2% statewide. These upstream social and economic factors may limit the impact of downstream clinical interventions.

Table 5. Cause-specific mortality rates per 100,000 population, Isabella County, Michigan, and United States

Cause (ICD-10)	Isabella County	Michigan	United States	vs Michigan	vs US
All causes	819.9	783.1	723.6	+4.7%	+13.3%
IHD and heart failure (I20–I51)†	198.6	194.9	163.6	+1.9%	+21.4%
Cancer (C00–C97)	175.1	161.1	149.1	+8.7%	+17.4%
COPD (J44)	60.6	44.2	39.7	+37.1%	+52.6%
Stroke (I60–I69)	59.4	39.9	37.1	+48.9%	+60.1%
Diabetes (E10–E14)	31.1	21.9	21.4	+42.0%	+45.3%

Source: MDHHS 2020 Primary Care Needs Assessment.[1] Rate type (crude vs age-adjusted) not specified in source document; rates are comparable within source but should be interpreted with caution in cross-state comparisons.

Discussion

The present study estimated and ranked the absolute and comparative burden of seven major conditions in Isabella County and demonstrated a reproducible, fully documented workflow that any rural US county can apply using the same public data sources. A small group of conditions dominated the county's burden under every reasonable assumption. Cancer accounted for the largest burden, with 3,641 DALYs, followed by cardiovascular disease at 2,793 DALYs. These conditions ranked highest primarily because of the number of deaths they caused each year, rather than because their deaths occurred at the youngest ages. Substance use disorders ranked third, with 2,434 DALYs, largely because deaths occur at younger ages, with a mean age of death of 44 years. Mental health conditions ranked fourth overall, with 1,502 DALYs, but they had the largest disability-driven share of burden: 71% of the mental health burden comes from years lived with disability (YLD). Although the exact ranking changed depending on the life-expectancy reference and the definition of mental health prevalence, the same four conditions consistently emerged as planning priorities.

The frontier reference measures premature mortality against a high-survival benchmark, while the Michigan reference measures mortality against current statewide experience. Under the Michigan reference, the total burden was 9,388 DALYs. The remission adjustment is important for interpreting the mental health burden. Lifetime-diagnosed depression includes people who are no longer symptomatic; applying a remission adjustment prevents mental health conditions from appearing dominant simply because of how prevalence is defined. Presenting the frontier and Michigan scenarios side by side gives planners a realistic range and shows which assumptions affect the rankings.

The results point to different types of intervention needs. High-mortality conditions, especially cancer and CVD, support continued investment in prevention, early detection and screening. High-disability conditions, especially mental health, point to the need for improved access and stronger service delivery. The county's federal Mental Health Professional Shortage designation with 176,938 residents per psychiatrist, further reinforces mental health as an access priority, even when it does not rank first by total DALYs.

Several condition-specific findings also point to actionable priorities. Stroke mortality in the county exceeded the state average by 48.9%, and COPD mortality by 37.1%. The patterns are consistent with uncontrolled hypertension, limited specialty access, and historical smoking - all addressable through established care pathways. Finally, substance use disorders (2,434 DALYs) carried a disproportionate burden relative to their case count. Because SUD-related deaths occur at a mean age of 44 years, each death contributed more YLL than deaths from any other condition.

Relationship to formal GBD analyses

This workflow is designed to complement, not to replace, formal GBD (IHME) and CDC analyses. It borrows familiar burden-of-disease conventions that aid interpretation - YLL/YLD decomposition, a frontier-reference scenario, IHME disability weights, no age-weighting or discounting, multiplicative comorbidity correction, and Monte Carlo uncertainty - to make the estimates understandable to readers familiar with DALY-based methods. Its main difference is the level of data resolution. Rather than using detailed age-sex-cause-sequela models, this approach uses seven broad condition groups and aggregated county-level inputs. As a result, the findings are best suited for local priority setting and grant development. They should be interpreted as a planning range, not as a single precise estimate. The convergent validation against IHME county estimates, described in Results, shows that the mortality backbone aligns with the reference standard for Isabella County within its reported uncertainty range.

Limitations

This is a planning-oriented, mixed-source estimate, and several limitations should be considered. Reported uncertainty intervals capture parameter sampling, not systematic model bias - specifically: non-representative BRFSS sampling in rural areas, MRP smoothing artefacts in CDC PLACES, and potential misspecification of rural adjustment factors. The mental health remission factor of 0.50 is a literature-derived central estimate; the true county value is unknown. MDHHS 2020 data predate both COVID-19 and the 2021–23 opioid surge, so current SUD and mental health burden may be substantially higher.

A limited external triangulation supports the two proxy-dependent inputs. For substance use, the Michigan state-rate proxy (~28 deaths/year) exceeds the county's directly observed accidental drug-poisoning deaths (X40–X44, ~13/year); this ordering is expected, because the F10–F19 category also captures alcohol- and chronic-substance-attributable deaths beyond acute overdose, so the proxy sits above a plausible acute-poisoning floor rather than below it. For mental health, the CDC PLACES lifetime-diagnosed depression prevalence used here (29.8%) is a broader construct than national survey benchmarks and exceeds them - the 2020 BRFSS national lifetime-depression estimate (~18.5%; state range 12.7–27.5%) and NSDUH[6] past-year measures (any mental illness ~25%; major depressive episode in the high single digits among adults). This gap is consistent with genuine rural elevation combined with MRP smoothing in the county model, and it is precisely why a 0.50 remission factor is applied; the resulting active prevalence (14.9%) falls within the NSDUH past-year band, which we treat as a reasonable if approximate external check. Formal triangulation against SAMHSA NSDUH substate estimates and administrative claims remains for future work.

Several methodological constraints also affect interpretation. YLL estimates rely on a single mean age at death rather than age-stratified distributions; of all the refinements noted in this manuscript, re-running YLL with age-specific death counts and the WHO age-specific loss table is the one that should be prioritized as an actual sensitivity analysis in the next version, rather than remaining a stated limitation. The comorbidity correlation structure is literature-informed, not locally observed; in Scenario B, the correction factor is 0.949 with a 95% UI 0.934–0.963. Substantial CVD-diabetes co-occurrence is well documented in the general population.[16] Competing risks are not modelled. Rates are crude rather than age-standardized because age-specific county counts are largely suppressed. Population denominators also require caution. The ACS 2022 population denominator of 64,565 includes approximately 20,000 Central Michigan University students, a group with near-zero mortality risk. Rural residence is itself associated with higher diabetes-related and cancer mortality nationally,[8,18] which is consistent with the excesses observed here. This inflates the denominator and suppresses crude DALY rates relative to the non-student permanent residential population by an estimated 20–30%. Applying this range to the primary crude rate (20,899 per 100,000) gives an illustrative non-student rate of approximately 25,100–27,200 per 100,000; this is a back-of-envelope adjustment for context, not a formal re-estimation with a corrected denominator. The use of uniform Michigan LE assumption understates YLL for Clare County, where IHME LE is 75.5 years and overstates YLL for Midland County, where IHME LE is 80.8 years. Finally, monetized estimates - $836M using the human capital approach and $4.38B VSL - should be interpreted as first-order planning equivalents, not as economic evaluations.

Conclusion

Isabella County carried an estimated 13,493 DALYs per year across the seven condition groups included in this analysis. This equalled approximately 20,899 per 100,000 residents and represented roughly $836 million in annual economic burden under the primary scenario (95% UI 12,266–14,803). Four condition groups defined the county's main planning priorities: cancer (3,641), cardiovascular disease (2,793), substance use disorders (2,434), and mental health (1,502). Under the Michigan LE sensitivity scenario, the total was lower, at 9,388 DALYs, but cancer remained the leading contributor. These scenarios should be interpreted as a planning range, not as competing claims of precision.

The practical contribution is the workflow itself. It uses public data, labels the certainty of every input, quantifies uncertainty with Monte Carlo simulation, tests assumptions that can change rankings, and presents the result as a transparent decision-support tool. Because the workflow is built entirely from publicly available federal data, it can be reproduced by any US county that lacks a local burden estimate. In this way, fragmented public data can be converted into an actionable starting point for local prioritization, grant development, and service design.

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Data sharing: All data used in this analysis are publicly available from the sources cited. Reproducibility materials, including harmonized input tables, data dictionary, R and Python scripts, output tables, figure generation code, session/package information, and an analysis log, are available from the corresponding author on request and at www.lakeslinked.com).

Abbreviations and acronyms

DALY = disability-adjusted life year
CDC WONDER = Centers for Disease Control and Prevention, Wide-ranging ONline Data for Epidemiologic Research
CDC PLACES = Centers for Disease Control and Prevention, Population Level Analysis and Community Estimates
IHME GBD = Institute for Health Metrics and Evaluation, Global Burden of Disease
ACS = American Community Survey
YLL = years of life lost
YLD = years lived with disability
LE = life expectancy
VSL = value of a statistical life
MDHHS = Michigan Department of Health and Human Services
CVD = cardiovascular disease
SUD = substance use disorder
COPD = chronic obstructive pulmonary disease
GHDx = Global Health Data Exchange
WHO GHE = World Health Organization, Global Health Estimates
DW = disability weight
BRFSS = Behavioral Risk Factor Surveillance System
HHS = United States Department of Health and Human Services

MH = mental health
UI = uncertainty interval
PYLL = potential years of life lost
NSDUH = National Survey on Drug Use and Health
MRP = multilevel regression and poststratification
IHME = Institute for Health Metrics and Evaluation
ICD-10 = International Classification of Diseases, Tenth Revision
GBD = Global Burden of Disease
CF = comorbidity correction factor
BEA = Bureau of Economic Analysis

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