Applying Climate Attribution Methods to Transform Dengue Surveillance in Indonesia

Swapnil, Anupriya, Prateek

Recent advances in climate–disease modeling have demonstrated that anthropogenic climate change can be directly linked to shifts in dengue transmission intensity and geography. While these methods have been piloted in Latin America, they offer a powerful, underutilized opportunity for Indonesia—a country bearing the highest dengue burden in Southeast Asia, with transmission reported in 488 of its 514 districts across a vast and climatically diverse archipelago.

Indonesia's current dengue surveillance and response strategies are largely informed by province-level analyses, which mask critical heterogeneity in transmission dynamics. In contrast, the country already collects and maintains **district-level (kabupaten/kota) case data**, offering a uniquely granular foundation for precision public health. By adapting cutting-edge climate attribution frameworks—originally developed to quantify how human-induced warming altered dengue risk in other tropical settings—we can now move beyond descriptive correlations to **causal, district-specific estimates of climate-driven dengue risk**.

Why This Is Novel and Impactful

1. **From Correlation to Causal Attribution at Unprecedented Resolution**
   Existing Indonesian studies identify associations between climate variables (e.g., rainfall, El Niño) and dengue incidence but cannot isolate the contribution of anthropogenic climate change. By integrating counterfactual climate simulations (with and without human influence) with district-level case data, we can quantify the *fraction of dengue cases attributable to climate change* in each district—something never before attempted in Southeast Asia.

2. **District-Level Thermal Optima Mapping**
   Dengue transmission peaks within a narrow thermal window (~26°C). In Indonesia's heterogeneous climate—from equatorial Sumatra to highland Papua—some districts may be approaching, at, or exceeding this optimum. Applying **non-linear climate–dengue response functions** at the district level allows us to:

   - Identify areas where warming is *expanding* transmission into previously low-risk zones (e.g., highland districts in Java or Sulawesi).
   - Flag districts where excessive heat may *suppress* transmission, altering seasonal expectations. This enables dynamic, climate-informed vector control scheduling tailored to local thermal conditions.

3. **El Niño–Climate Change Interaction Forecasting**
   Indonesia's multi-annual outbreaks (2016, 2019, 2024) align with El Niño phases. However, El Niño events today unfold atop a background of anthropogenic warming. By combining observed El Niño indices with counterfactual climate scenarios, we can disentangle natural variability from human-driven amplification—improving early warning for future high-risk years.

4. **Precision Resource Allocation**
   Urban population density—not just urbanization proportion—is strongly linked to dengue incidence after adjusting for surveillance bias. Overlaying district-level urban density maps with climate-attributable risk can prioritize:

   - High-density, climate-vulnerable districts for intensified vector control and vaccine rollout.
   - Low-surveillance, climate-sensitive districts for diagnostic capacity strengthening.

5. **Operational Integration with Existing Systems**
   Indonesia already operates digital surveillance platforms similar to Brazil's Infodengue. Embedding climate attribution modules into these systems would generate real-time, district-level risk scores—enabling preemptive action weeks before expected case surges.

Strategic Advantages of District-Level Data

While province-level analyses obscure local variation (e.g., coastal vs. mountainous regencies within a single province), district-level modeling captures microclimates, urban heat islands, and localized water storage behaviors that drive transmission. This granularity is essential in an archipelago where a 3–4 month west-to-east shift in dengue seasonality reflects monsoon progression—not disease spread.

Moreover, district-level attribution supports decentralized public health decision-making. Local health offices could receive tailored alerts based on their specific climate–dengue relationship, rather than relying on national averages that poorly reflect local risk.

Conclusion

Leveraging Indonesia's district-level surveillance infrastructure with state-of-the-art climate attribution methods represents a paradigm shift—from reactive outbreak response to proactive, climate-resilient dengue control. This approach is novel because it moves beyond correlation to quantify the *human fingerprint* on dengue risk in one of the world's most vulnerable countries. The impact is potentially transformative: preventing thousands of cases through smarter timing, targeting, and scaling of interventions in a warming world.

Data Type	Source / Dataset	Temporal Coverage	Spatial Resolution	Availability
Dengue incidence	Ministry of Health of the Republic of Indonesia (Arbovirus Working Team)	2016–2024	District-Level	Available upon reasonable request from the Ministry of Health; not publicly posted
Population estimates	Badan Pusat Statistik (BPS) – Indonesia Census Data	2010, 2020 (interpolated for 2016–2024)	District-Level	Publicly available via bps.go.id
Climate variables aggregated: mean and pop weighted	ERA5-Land (ECMWF)	2015–2024*	~9 km raster, aggregated to province - but we can do this for districts too.	Publicly available via Copernicus Climate Data Store (doi:10.24381/cds.e2161bac)
Oceanic Niño Index (ONI)	NOAA Climate Prediction Center	2015–2024	Global index	Publicly available at psl.noaa.gov/enso/
Urbanisation already aggregated: urbanisation population percentage, urbanisation area percentage	Global Human Settlement Layer (GHSL) – GHS-SMOD	2020 (static)	1 km raster, aggregated to province - we are in process of getting it by district but won't have it for every year	Publicly available via ghsl.jrc.ec.europa.eu
Surveillance capability district level	Lim et al. (2025), *Nature Communications*	Static estimate	Province-level (urban-adjusted)	Derived from published global estimates; original data in cited source
Population raster (for aggregation)	LandScan Global Population Database	Annual (2016–2024 interpolated)	1 km	Available via Oak Ridge National Laboratory (requires license)

no need: everything already aggregated