

Earth Observation Data Integration to enhance Dengue forecasting performance: Evidence from Nepal

DHIS2 Climate & Health Academy
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UiO : **HISP Centre**
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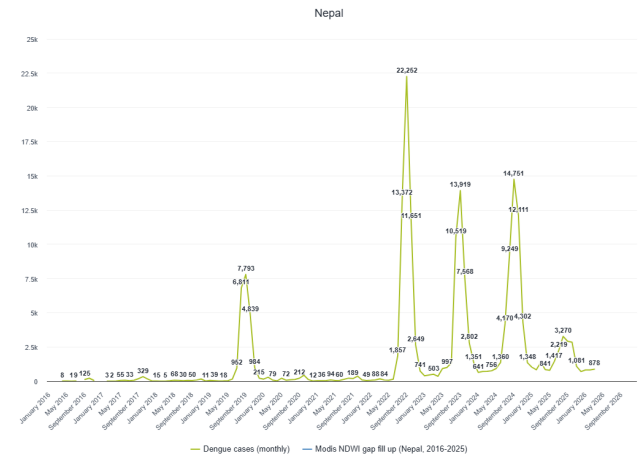


Outline

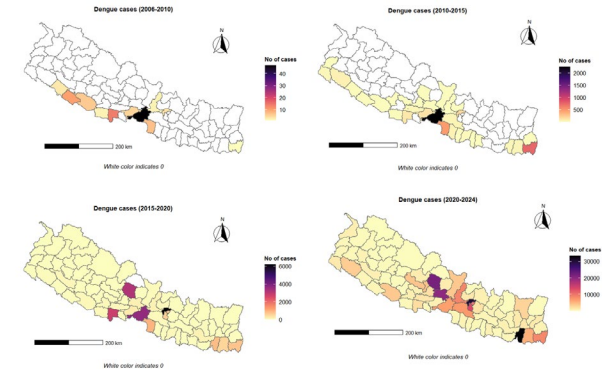
- Context
- Objectives
- Data and Methods
- Results
- Major findings
- Next Steps

Context

- ❑ Dengue is a rapidly expanding mosquito-borne illness transmitted by the *Aedes* mosquito in Nepal.
- ❑ Since 2022, Nepal has recorded thousand of cases annually, including several fatalities.
- ❑ Effective surveillance and early forecasting are critical to prepare for potential outbreaks and to allocate limited resources efficiently.
- ❑ Global climate datasets are widely used for dengue prediction and early warning models; however, their coarse spatial resolution may not adequately capture local environmental variability in heterogeneous countries such as Nepal.



Spatiotemporal dynamics of dengue in Nepal 2016-2026



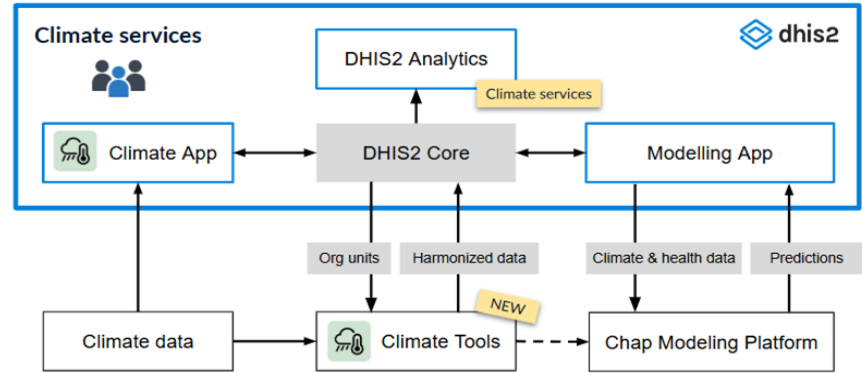
Context

- ❑ Earth Observation (EO) data provide high-resolution environmental variables (e.g., NDVI, NDWI, and LST) that can complement global climate data by capturing local-scale environmental conditions and potentially improving prediction performance.
- ❑ A major limitation of EO data is missing observations caused by cloud cover and other atmospheric conditions, and the impact of these data gaps on prediction performance remains insufficiently understood.
- ❑ Limited climate–health data infrastructure hinders the integration of climate and health data needed for evidence generation, disease forecasting, and informed health policy development.

Bridging the Climate–Health Data Gap

- ❑ Climate, Earth Observation (EO), and health data systems are often fragmented and poorly integrated.
- ❑ Limited interoperability between climate and health information systems hinders climate-informed disease surveillance and forecasting.
- ❑ DHIS2's expanding geospatial ecosystem, powered by Climate Tools and CHAP, and more recently climate services enables the integration of climate, EO, and health data to support disease forecasting and early warning systems for dengue and other climate-sensitive diseases.

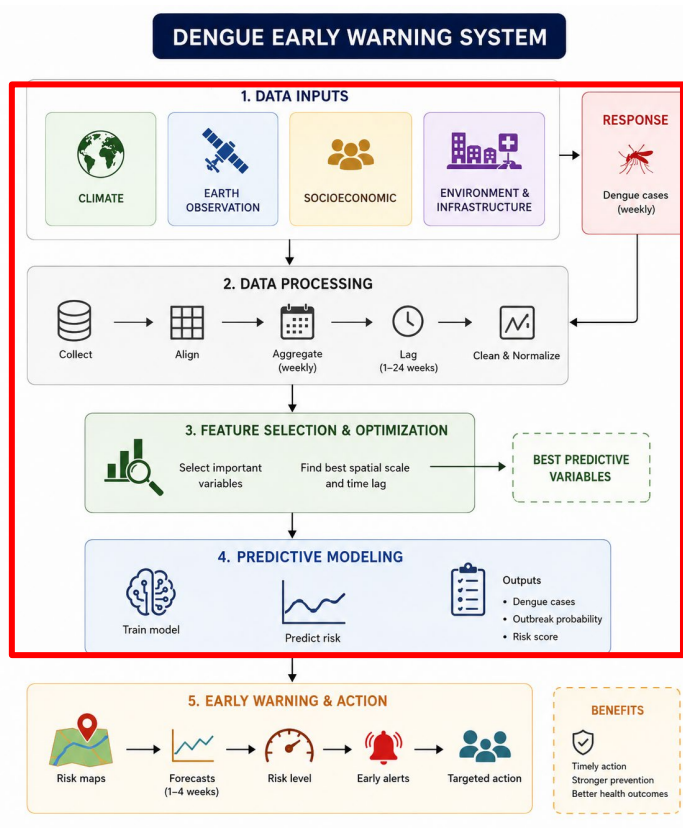
DHIS2 System and CHAP Modelling Platform



Objective of the study

- ❑ Assess the role of EO-derived variables in improving predictive model performance.
 - ❑ Evaluate the impact of EO data gaps on prediction accuracy.
 - ❑ Compare prediction performance using climate data, EO data, and integrated datasets.
 - ❑ Examine the effectiveness of EO data gap-filling approaches across spatial scales.
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Early Warning System Layout



$$\text{Dengue Cases} = f(\text{Climate}, \text{Population})$$

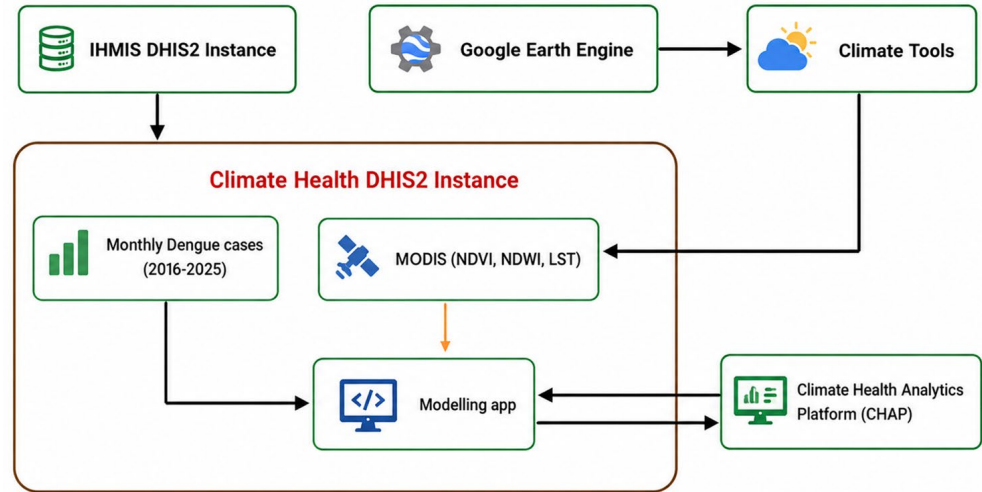
$$\text{Dengue Cases} = f(\text{Climate}, \text{EO Variables}, \text{Population})$$

$$\text{Dengue Cases} = f(\text{Climate} + \text{EO} + \text{Urbanization} + \text{Socioeconomic Factors})$$

Optimized Operational Forecasting Model

Data and Methods

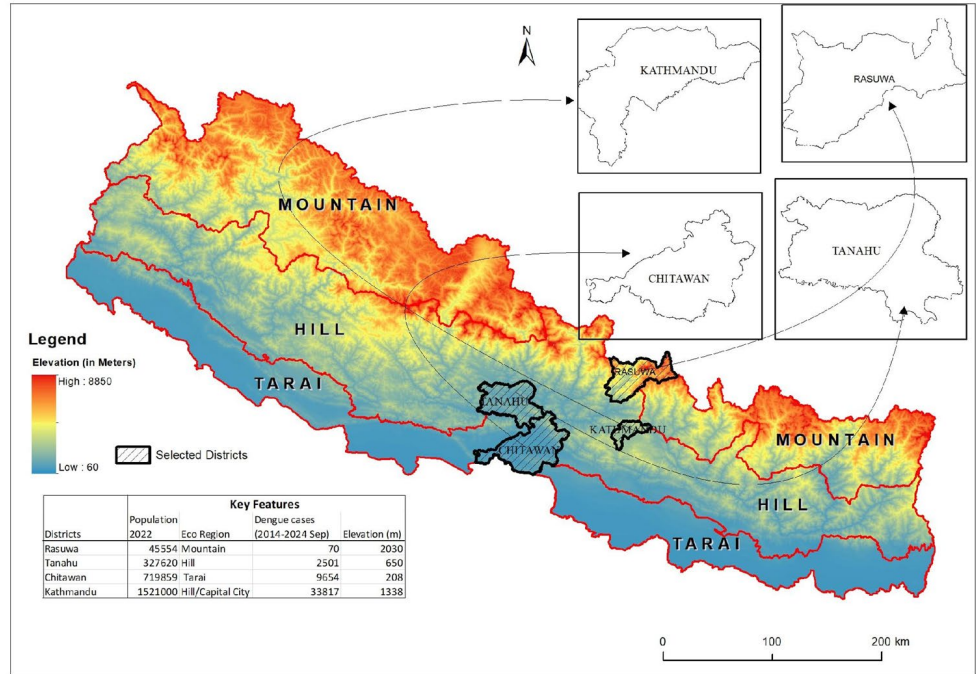
- Monthly confirmed dengue cases reported in HMIS
- MODIS based covariates (Normalized Difference Vegetation (NDVI), Normalized Difference Water Index (NDWI) Land Surface Temperature
- WHO EWARS Model in the CHAP platform



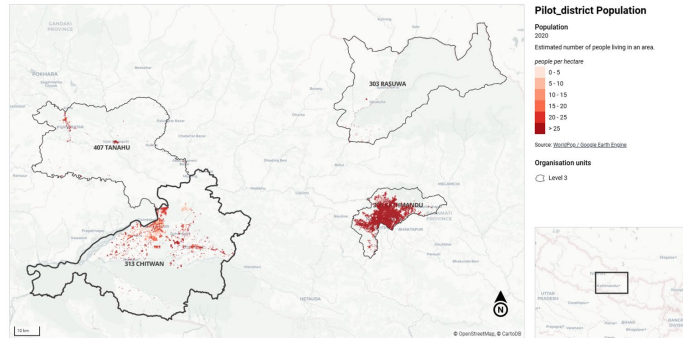
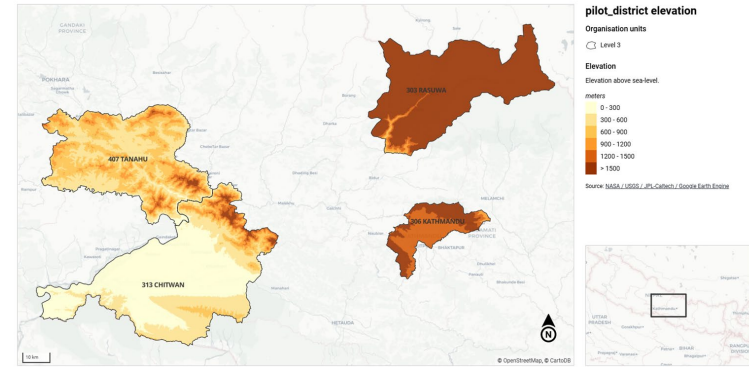
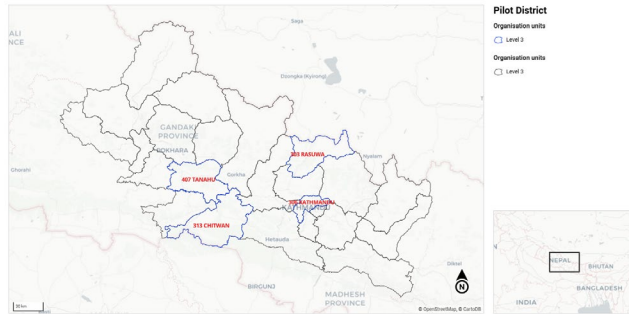
Intervention Districts for Piloting

Pilot districts representing diverse geographical terrains/ecological regions

Lowlands/plains-Chitwan,
Hills-Tanahu,
Valley- Kathmandu
Mountainous region-Rasuwa



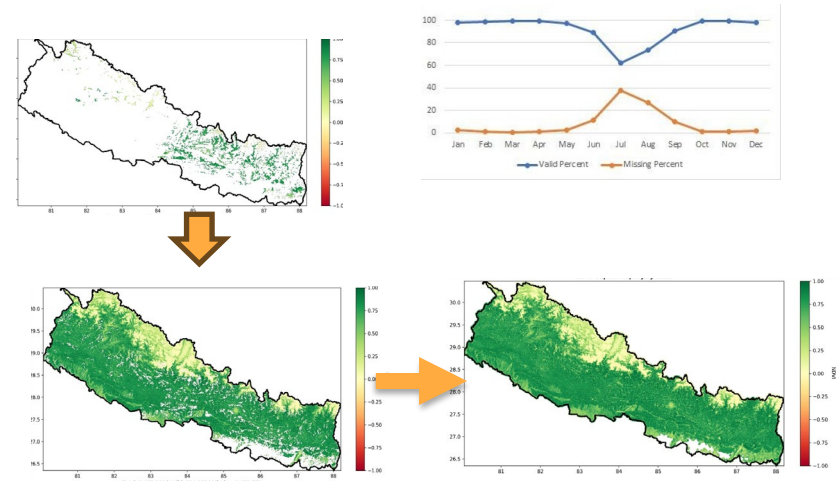
Intervention Districts for Piloting



- Altitudinal gradient from lowland to highland
- Micro climatic variation
- Variation in incidence of dengue cases
- Variation in population density

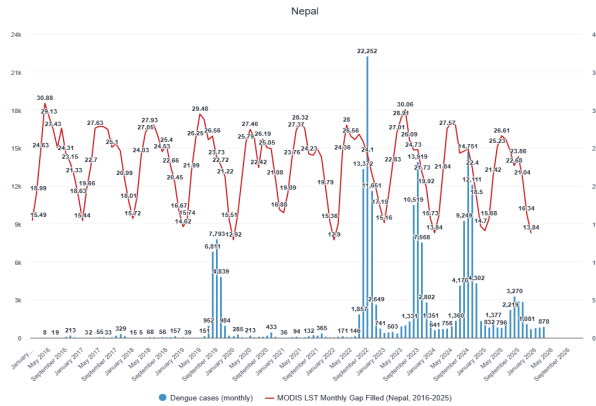
Data gap issues in EO Data (example of NDVI)

- ❑ EO data provide high spatial and temporal resolution, enabling continuous monitoring of heterogeneous landscapes and improving the accuracy of predictive models over the coarse global climate data
- ❑ Cloud cover remains a major challenge, often creating data gaps and limiting the availability of consistent observation
- ❑ Understanding seasonal cloud-cover patterns, data-gap dynamics, and appropriate gap-filling techniques is essential before utilizing EO data for analysis and modeling.

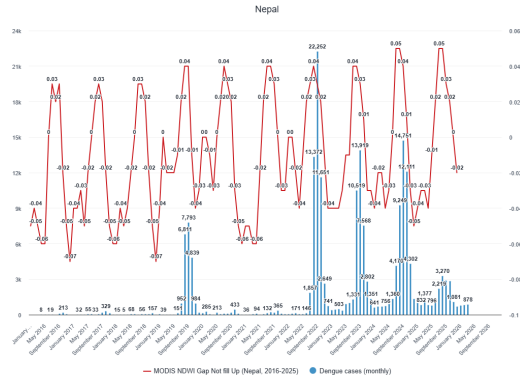


Results

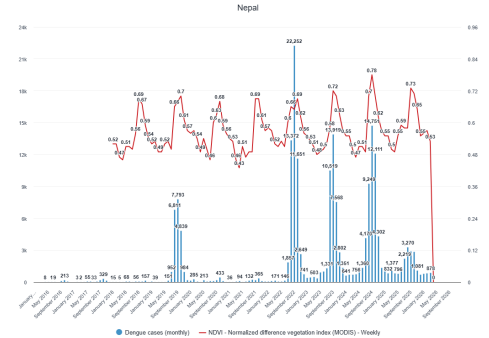
LST and Dengue



NDWI and Dengue



NDVI and Dengue



Results

Pearson Correlation Coefficient

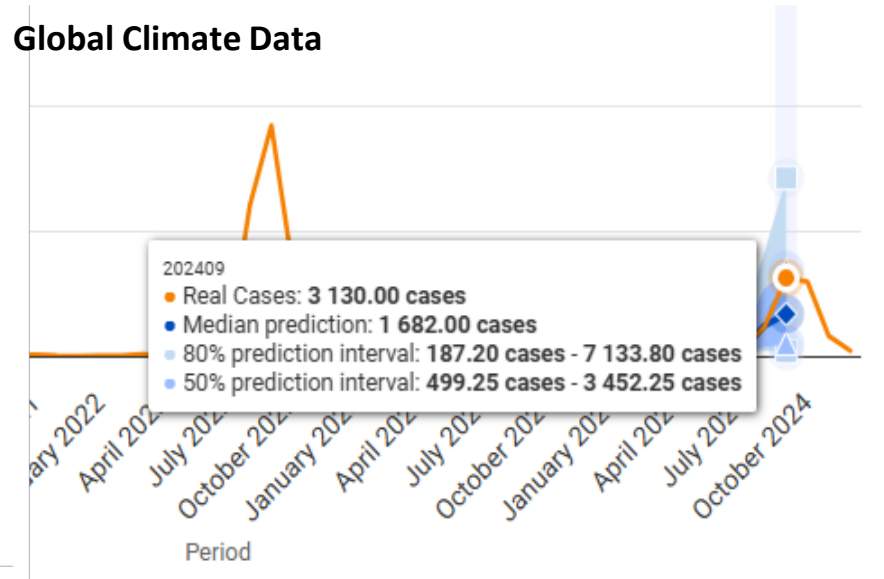
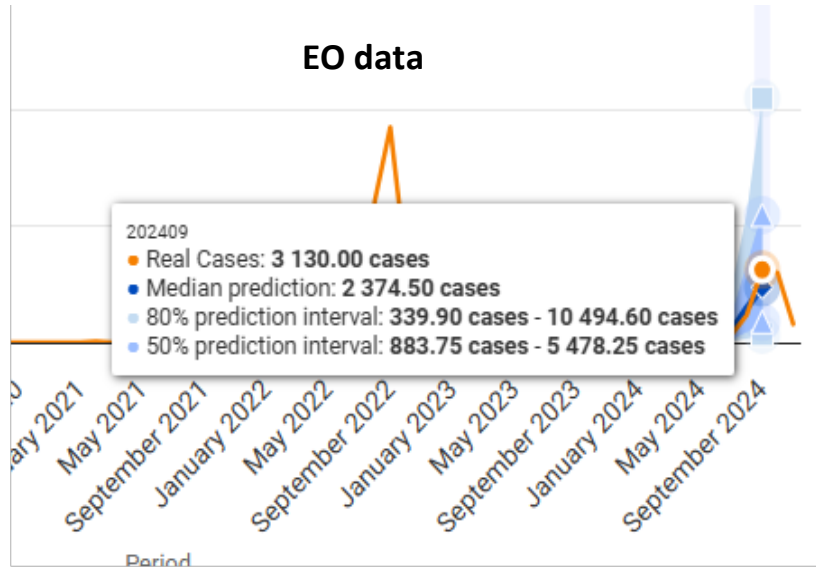
Variable	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
NDWI	0.048	0.095**	0.051	0.128***	0.006	0.082*	0.081*	0.253***	0.190***	0.171***
NDVI	0.054	0.085**	0.001	0.107**	0.038	0.078*	0.069*	0.177***	0.143***	0.116***
LST	0.027	0.111***	0.021	0.068*	0.045	0.101**	0.074*	0.108***	0.103**	0.187***

Year-wise Pearson correlation coefficients (r) between dengue cases and environmental variables (NDWI, NDVI, LST) in Nepal, 2016–2025. Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; blank = not significant.

Evaluation Plot

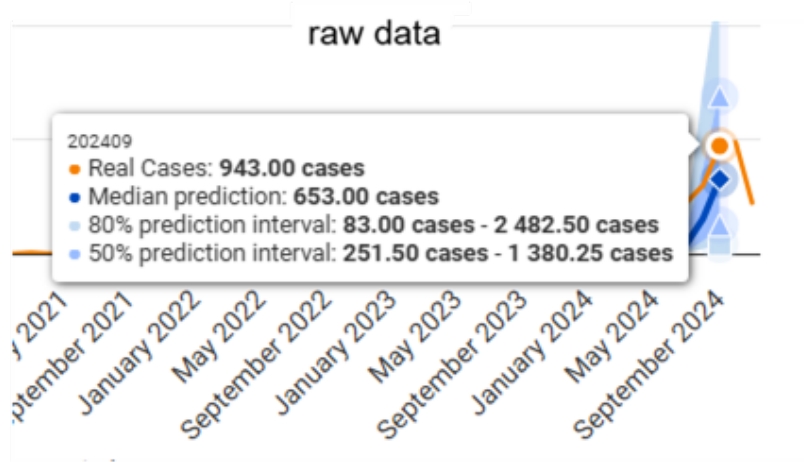
Earth Observation (EO) data vs Global Climate Data

Kathmandu District

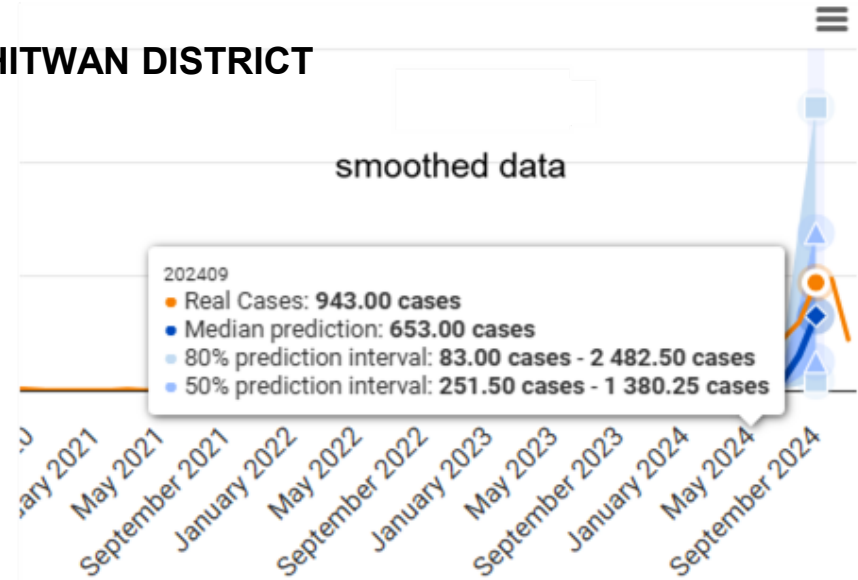


Evaluation Plot

Model Raw vs gap smoothed data

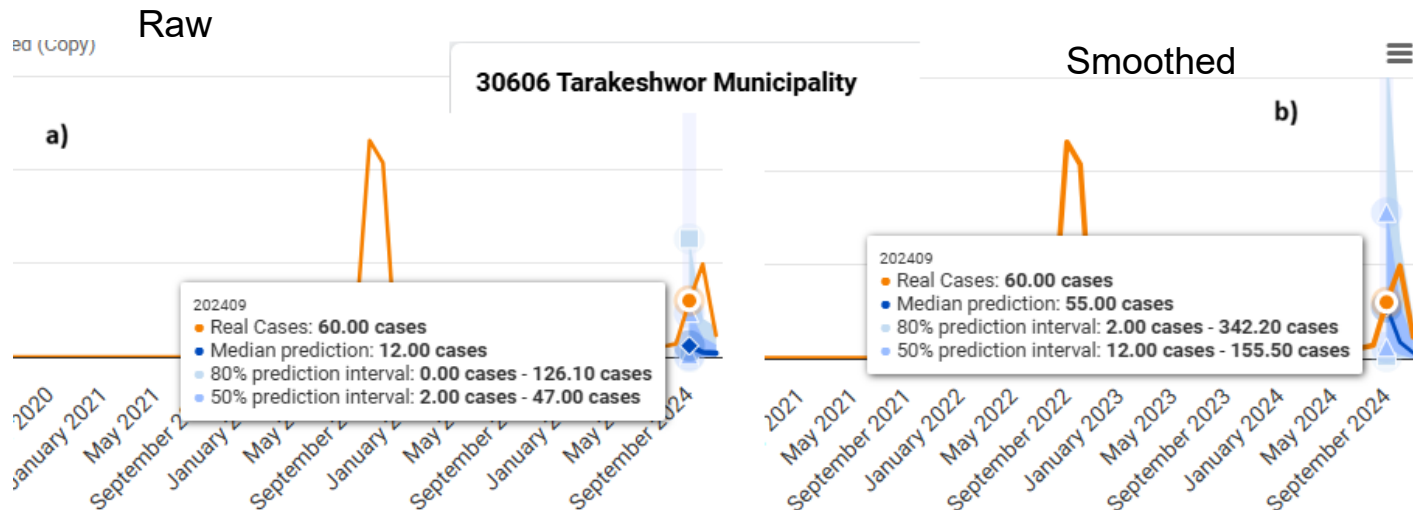


313 CHITWAN DISTRICT



Evaluation Plot

Model Raw vs gap smoothed data at municipal Scale



Main findings

- ❑ Models incorporating Earth Observation (EO) data generally demonstrated better predictive performance than models based solely on global climate data.
- ❑ Integrating EO variables with global climate datasets further improved forecasting accuracy.
- ❑ At the district level, data gaps had no significant impact on model performance, with predictions from gap-filled datasets being comparable to those from complete datasets.
- ❑ At the municipal level, however, spatial smoothing was counterproductive. Models using raw EO data, even with missing values, outperformed those based on spatially smoothed datasets.

Next plan

- ❑ Integrate socioeconomic and demographic factors, including urbanization, population density, human mobility, and social vulnerability indicators, into dengue forecasting models.
- ❑ Develop and optimize a tailored Spatiotemporal Random Forest (STRF) model that incorporates seasonality, spatial neighborhood effects, climatic factors, and other relevant control variables.
- ❑ Evaluate and compare alternative modelling approaches to identify the most accurate, robust, and operationally feasible forecasting model for routine implementation.
- ❑ Develop an operational dengue Early Warning System (EWS) that provides timely risk forecasts and supports evidence-based public health decision-making and response

Thank you so much