

Supplementary Material

Spatio-temporal Modeling of chikungunya in Brazil: Interplay of Climate, Mobility, and Socioeconomic Factors

1 Supplementary appendix

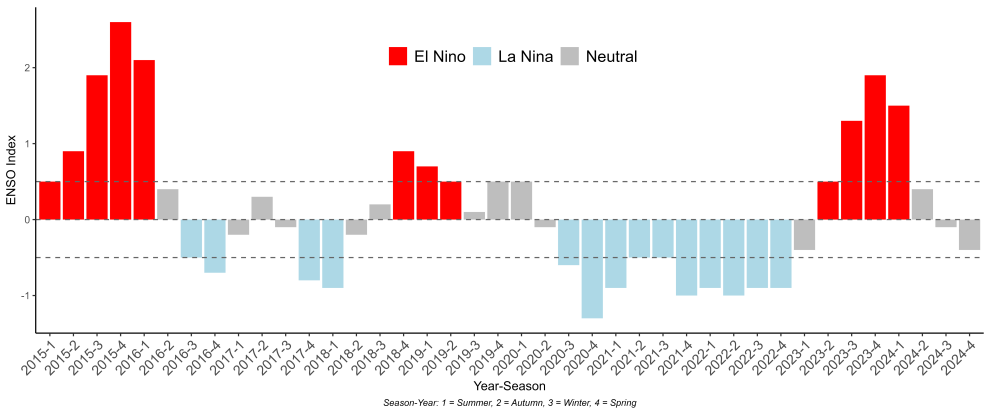


Fig. S1 Temporal pattern of ENSO (El Niño–Southern Oscillation) index values recorded by the NOAA's Oceanic Niño Index (ONI) by year and season from 2015 to 2024, Brazil.

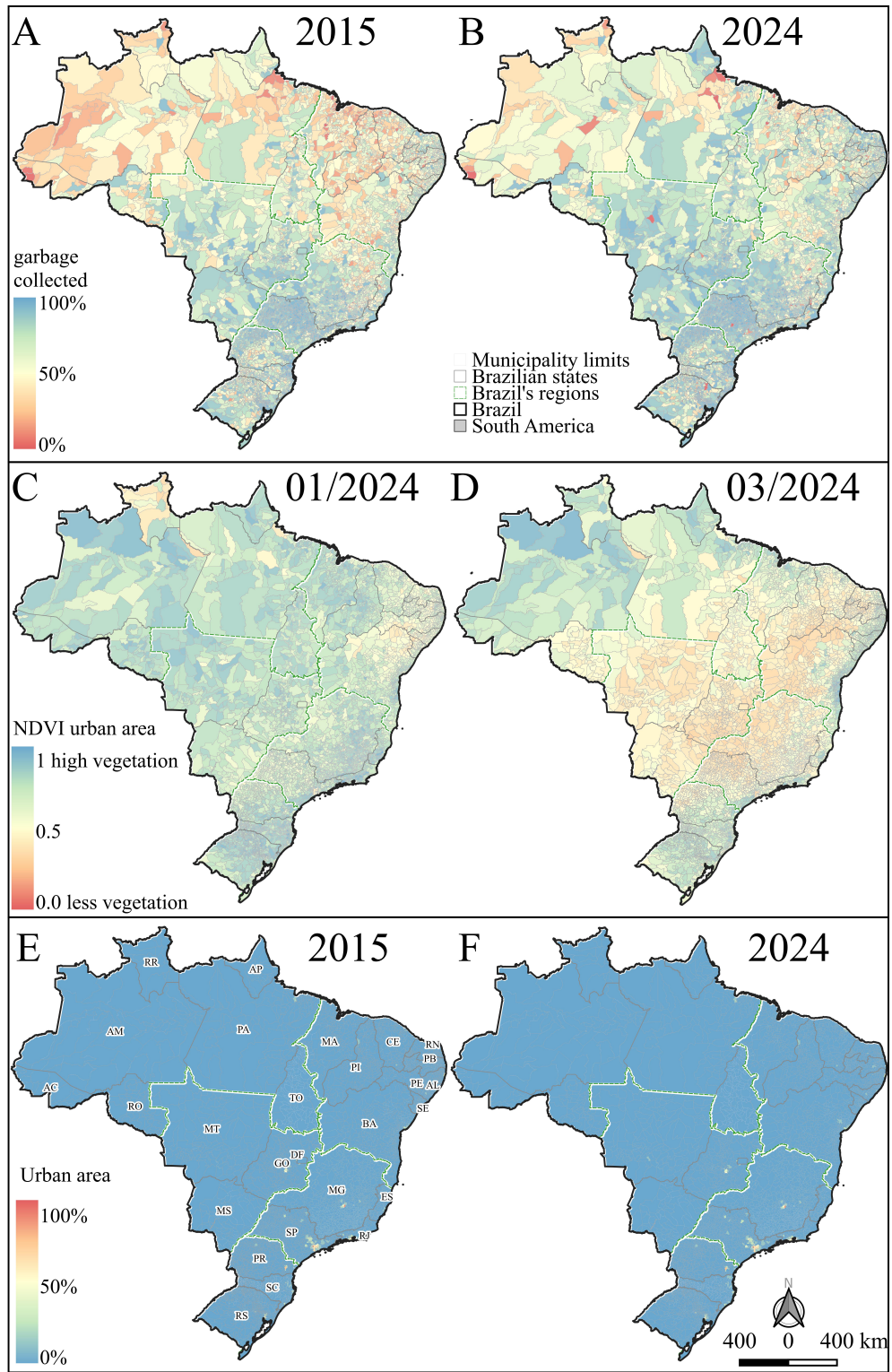


Fig. S2 Map of socioeconomic variables (% of households: a,b -garbage collected - projection to 2015 and 2024), environmental variables average (c,d - NDVI in urban area (summer-2024 and winter-2025), e,f - % of urban area (2015 and 2024) in Brazilian municipalities. Source: Supplementary Table. SSI.

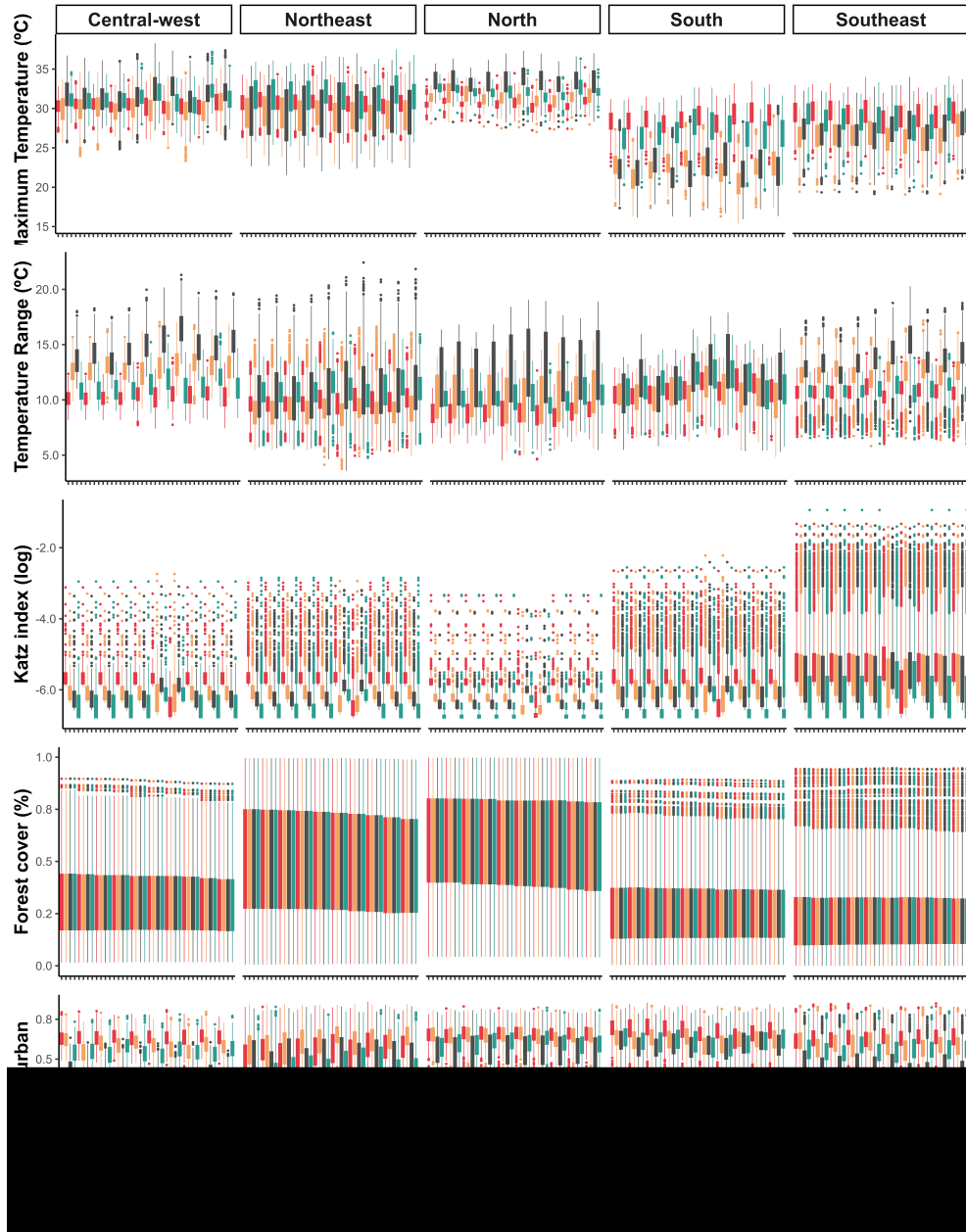


Fig. S3 Seasonal distribution of variables across Brazilian regions and year-season from 2015 to 2024 by Brazilian municipalities. Maximum temperature (°C), temperature range (°C), Katz index (log), Forest cover (%), and NDVI in urban area.

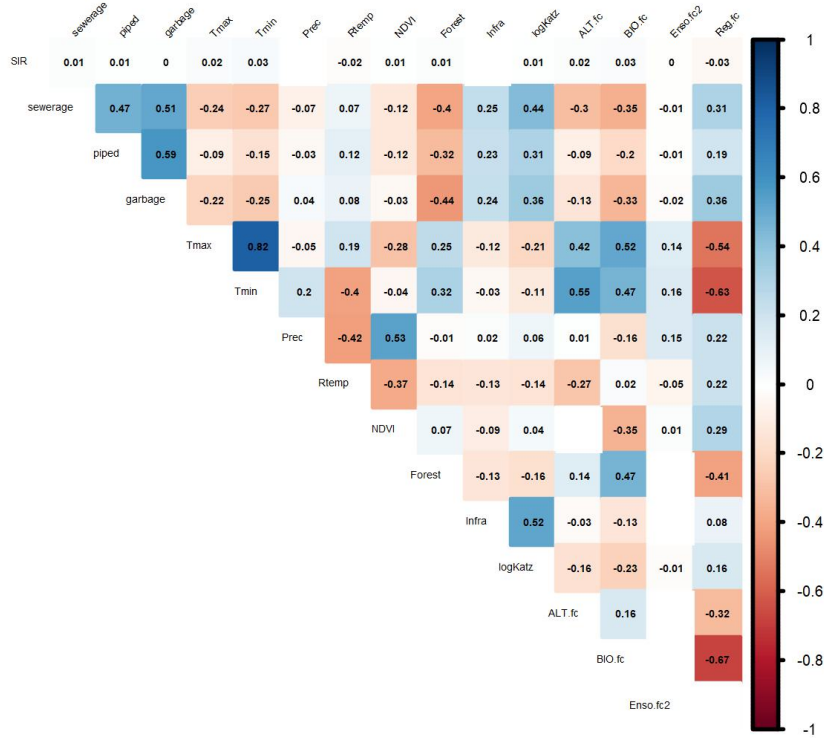


Fig. S4 Collinearity between the study variables.

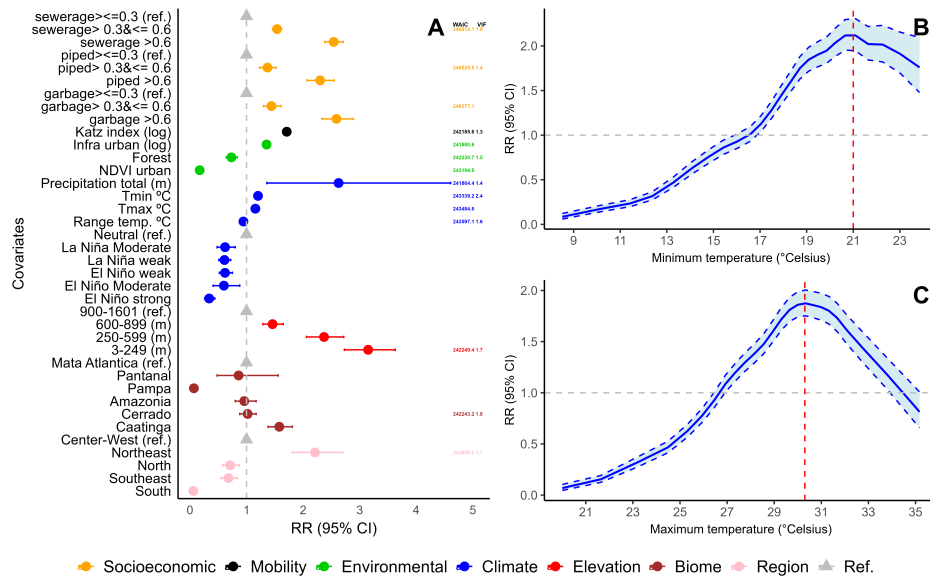


Fig. S5 Distribution of posterior mean values and 95% credible intervals for chikungunya relative risk in Brazil of the models with separate covariates (a), minimum temperature (b) and maximum temperature non-linear (c).

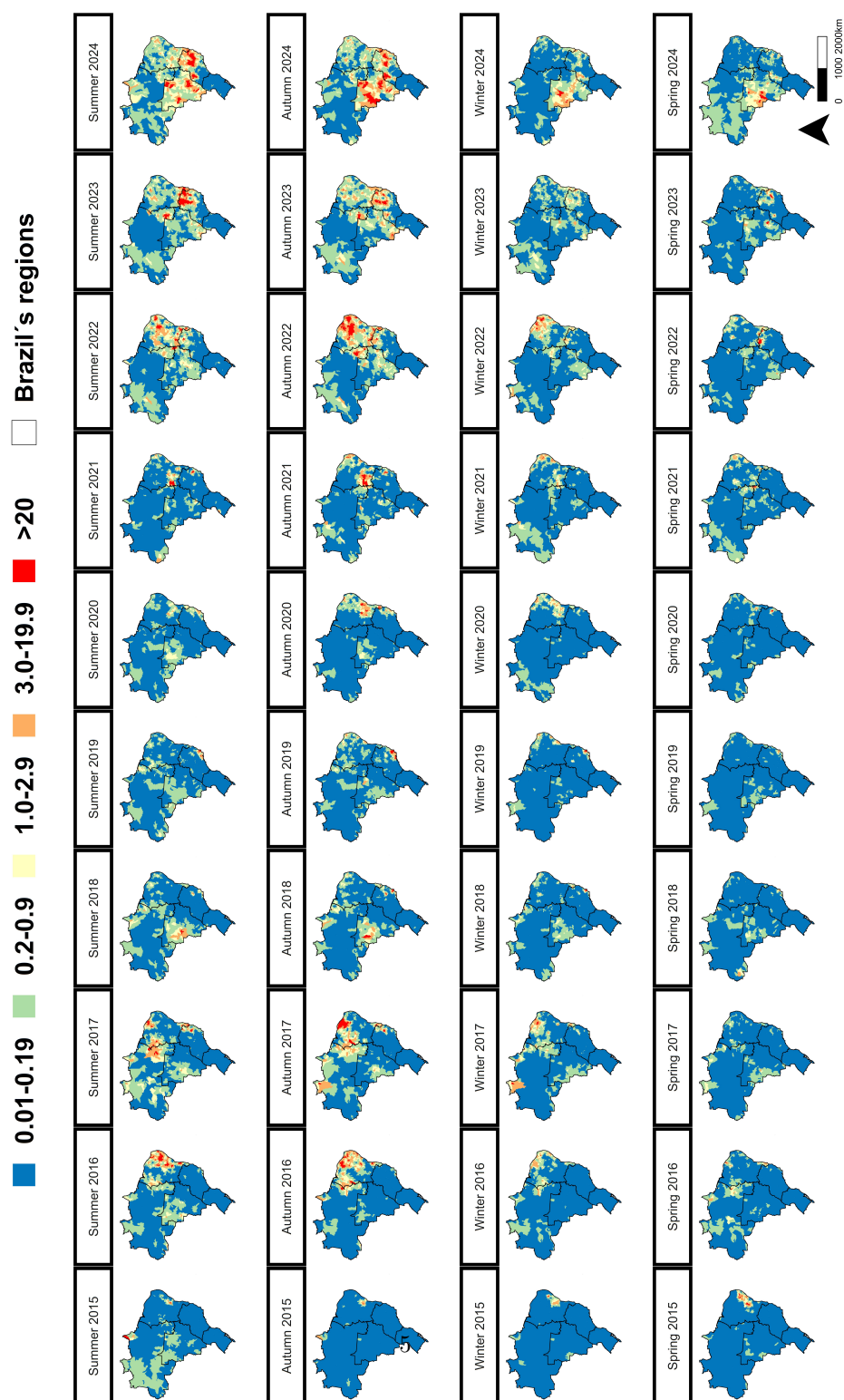


Fig. S6 Spatial distribution of the posterior mean of CHIKV incidence rate (per 10.000) across Brazilian municipalities for season and years 2015-2024.

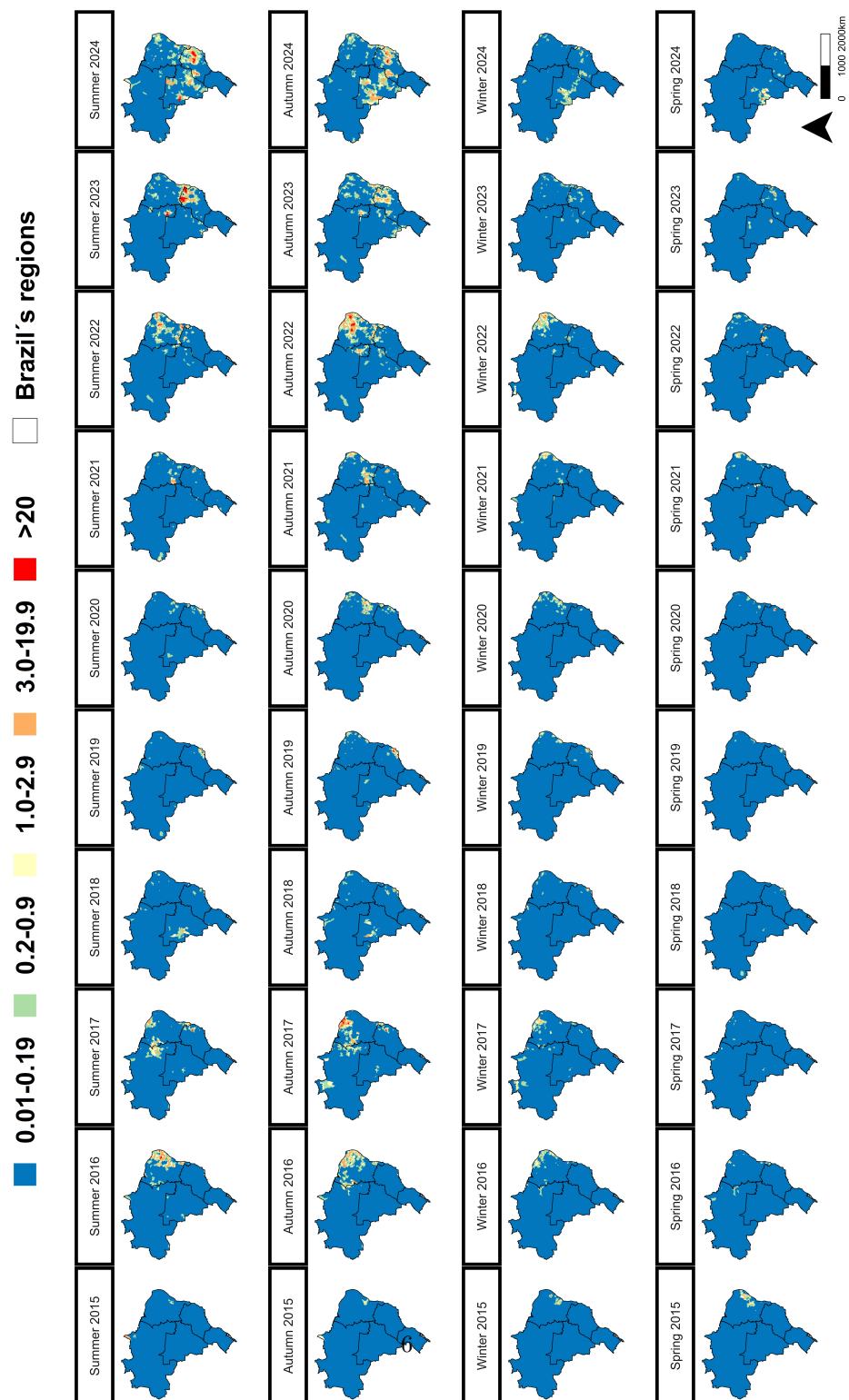


Fig. S7 Spatial distribution of the posterior lower of CHIKV Incidence rate (per 10.000) across Brazil municipalities for season and years 2015-2024.

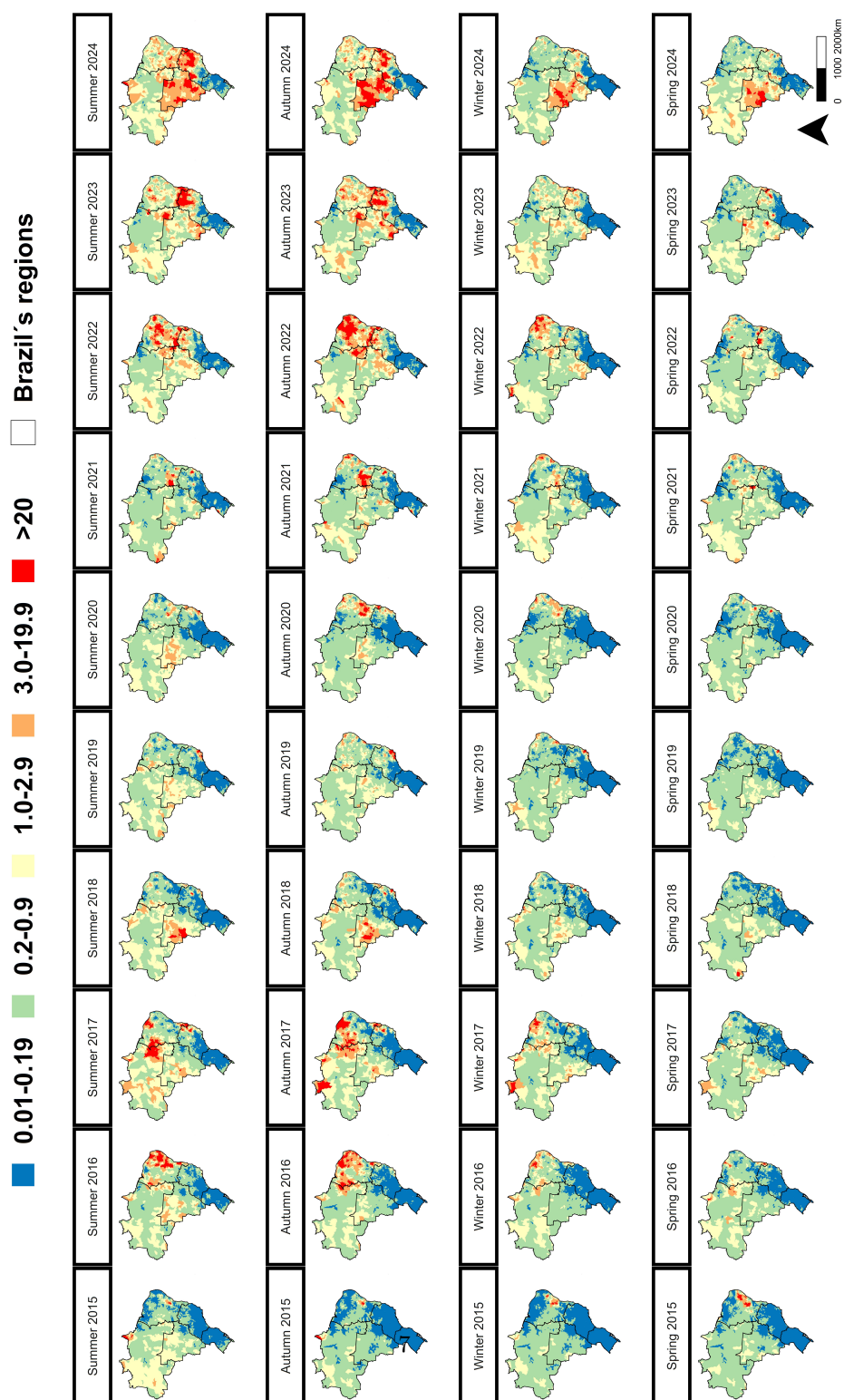


Fig. S8 Spatial distribution of the posterior upper of chikungunya Incidence Relative Risk in Brazil for season and years 2015-2024.

	Variable	Description	Source
Socio-economic	sewerage	The percentage of permanent private households (Base line ≤ 30 , > 30 to ≤ 60 , > 60 per municipality according to: Type of sewage system (sewage, rainwater system, and septic tank);	Censo IBGE 2010, 2022 [1, 2]. Arithmetic projections used for non-census years.
	pipeds garbage	Piped water supply; Destination of garbage collected by cleaning services.	
Climate	Prec	Total precipitation (mm) for season (every three months); (every three months with of three month lag).	Worldclim Version 2.1. Data from Jan. 2015 (or Oct. 2014 for lags) to Dec 2024[3, 4].
	Tmax	Average maximum temperature ($^{\circ}\text{C}$) for season ; (every three months with of three month lag).	
	Tmin	Average minimum temperature ($^{\circ}\text{C}$) for season; (every three months with of three month lag).	
	Range temp.	Thermal amplitude ($^{\circ}\text{C}$) (considering the subtraction of the maximum and minimum temperature) for season average; (considering the subtraction of the maximum and minimum temperature with of three month lag) for season average.	
	ENSO	El Niño-Southern Oscillation threshold of $\pm 0.5^{\circ}\text{C}$ for the Oceanic Niño Index (ONI) [3 month running mean]. Base line: $1 - (-0.5 < \text{ONI} < 0.5) = \text{Neutral}$, $2 - (-1.5 < \text{ONI} \leq -1.0) = \text{La Niña Moderate}$, $3 - (-1.0 < \text{ONI} \leq -0.5) = \text{La Niña Weak}$, $4 - (0.5 \leq \text{ONI} < 1.2) = \text{El Niño Weak}$, $5 - (1.2 \leq \text{ONI} < 1.9) = \text{El Niño Moderate}$, $6 - (\text{ONI} \geq 1.9) = \text{El Niño Strong}$.	
Environmental	Elevation	Altimetry (municipal average altitude). Base line 1 - (900-1601 meters), 2 - (600 – 899), 3 - (250 – 599), 4 - (3 – 249).	Center for Metropolitan Studies, CEM-USP[6], MapBiomás (collection 10). Data from 2015 to 2024[7].
	Urban area	Log of the percentage of urban areas per municipality.	
	Forest	The percentage of Forest areas per municipality.	
	Biome	Biome principal. Base line 1 - Mata Atlantica, 2-Pantanal, 3-Pampa, 4-Amazonia, 5-Cerrado, 6-Caatinga.	
	NDVI Urban	Normalized difference vegetation index (NDVI) in urban area.	
Mobility	Region	Brazilian region id (1 - Central-west, 2 - Northeast, 3 - North, 4 - Southeast, 5 - South)	GEE. Data from Jan. 2015 to Dec. 2024[8]. IBGE, 2022[9].
	katz index	Log of Katz rate calculations from information on mobility. Data from summer 2019 to spring 2021. 1 degree connectivity.	

Table S1: Socioeconomic, climate, Environmental, and mobility variables and data sources.

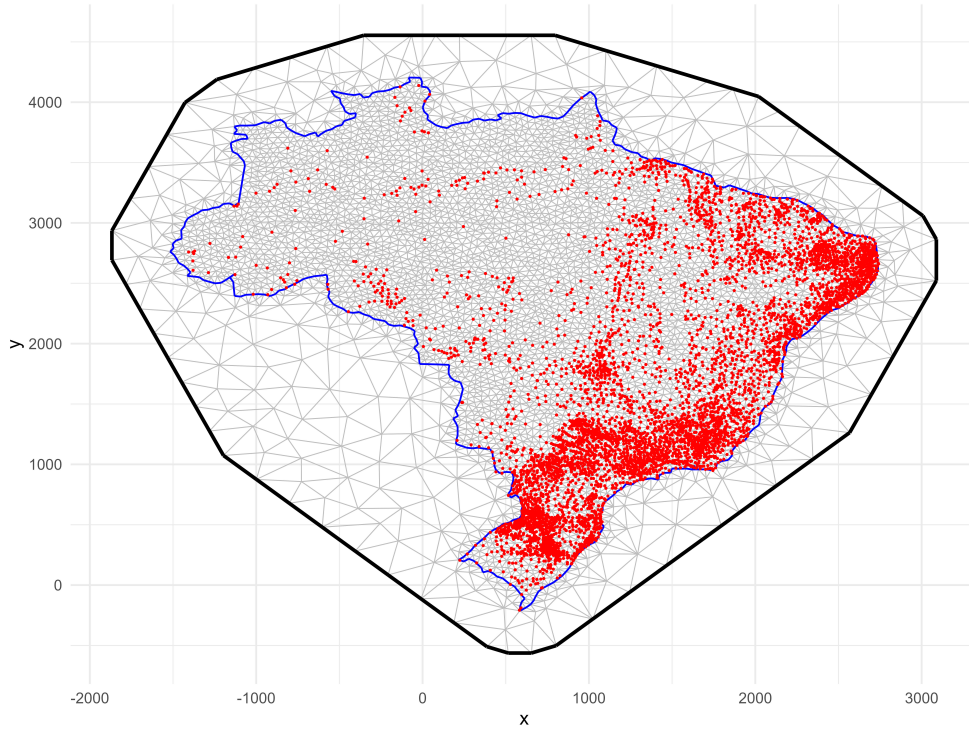


Fig. S9 Mesh for Brazil used in the final spatiotemporal model. Red points indicate the centroids of urban areas for each municipality analyzed.

References

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