

Five Years of COVID-19 in Tocantins, Brazil: Epidemiology, Vaccination Impact, and SARS-CoV-2 Genomic Dynamics (2020 - 2025)

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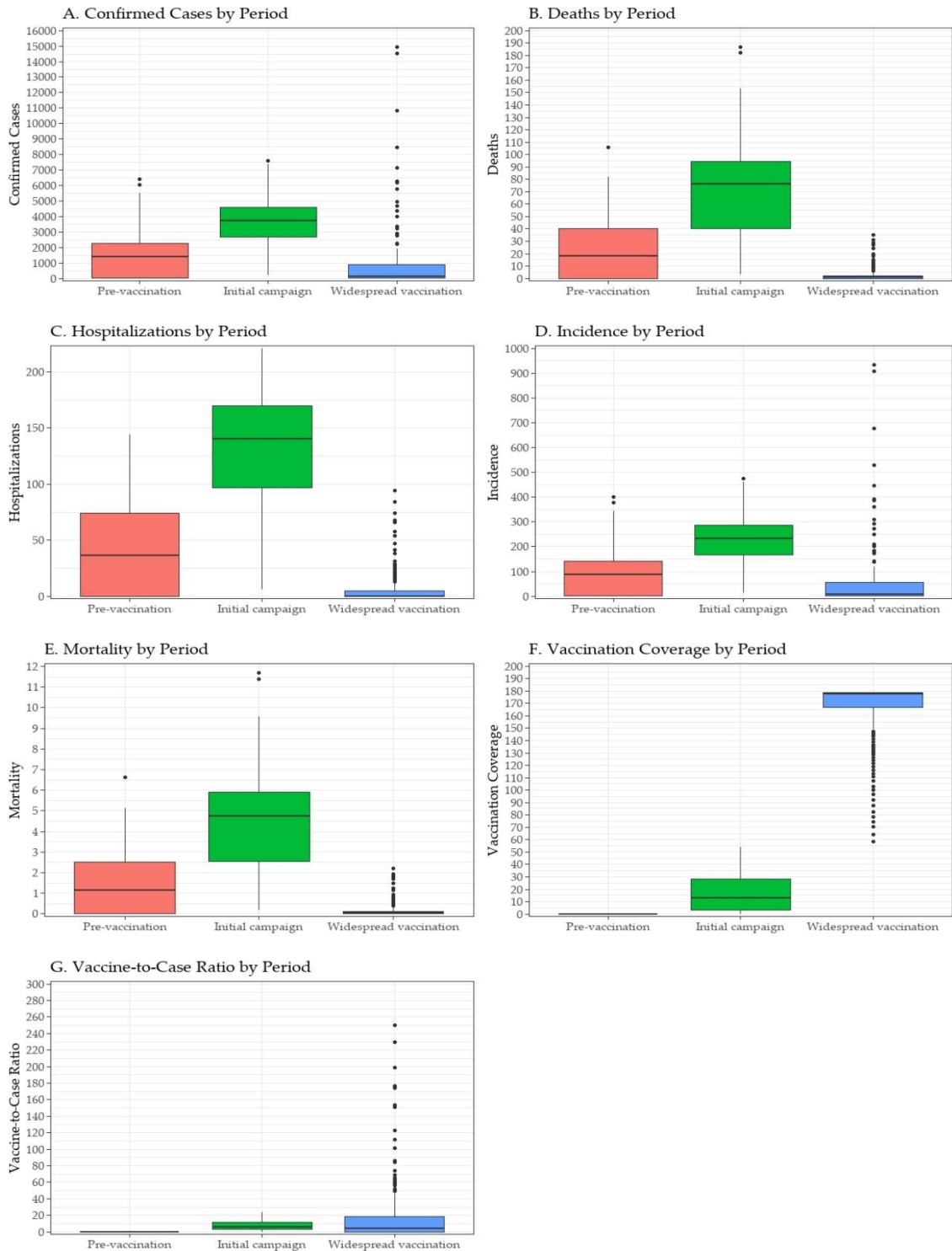


Figure S1. Distribution of key COVID-19 epidemiological indicators across vaccination phases in Tocantins, Brazil (2020–2025). Boxplots show weekly values for (A) confirmed cases, (B) deaths, (C) hospitalizations, (D) incidence (per 100,000 inhabitants), (E) mortality rate (per 100,000 inhabitants), (F) vaccination coverage (%), and (G) vaccine-to-case ratio, stratified into three epidemiological periods: pre-vaccination, initial rollout, and widespread vaccination. Boxes represent the interquartile range (IQR) with horizontal lines indicating medians; whiskers extend to $1.5 \times$ IQR, and dots denote outliers. ANOVA revealed significant differences across all periods for all variables ($p < 0.001$).

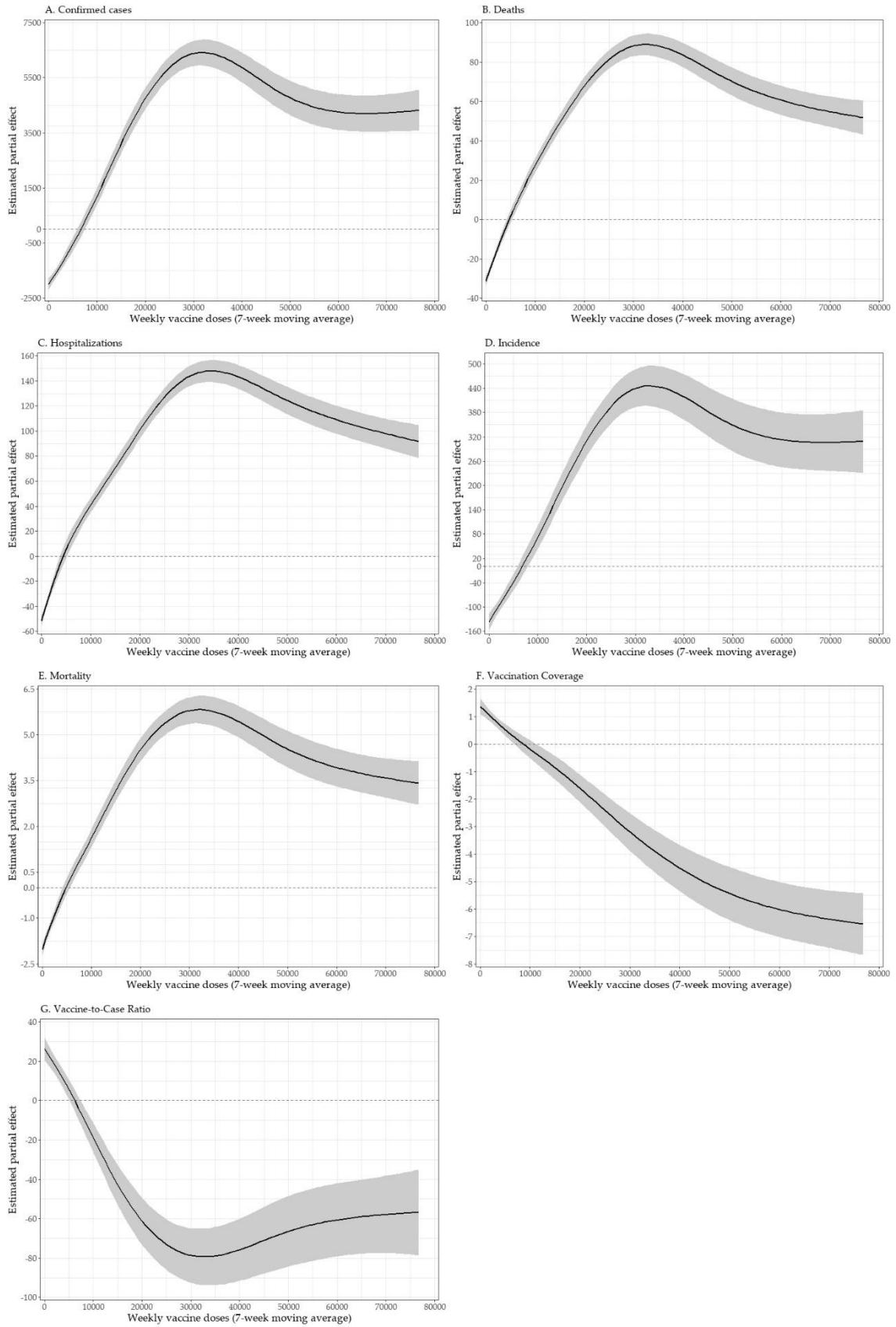


Figure S2. Partial effect plots showing the association between weekly COVID-19 vaccination and key epidemiological indicators in Tocantins, Brazil: (A) confirmed cases, (B) deaths, (C) hospitalizations, (D) incidence, (E) mortality, (F) vaccination coverage, and (G) vaccine-to-case ratio. Shaded areas represent 95% confidence intervals. All models were adjusted for temporal trends (weeks) and seasonal variation (ISO week).

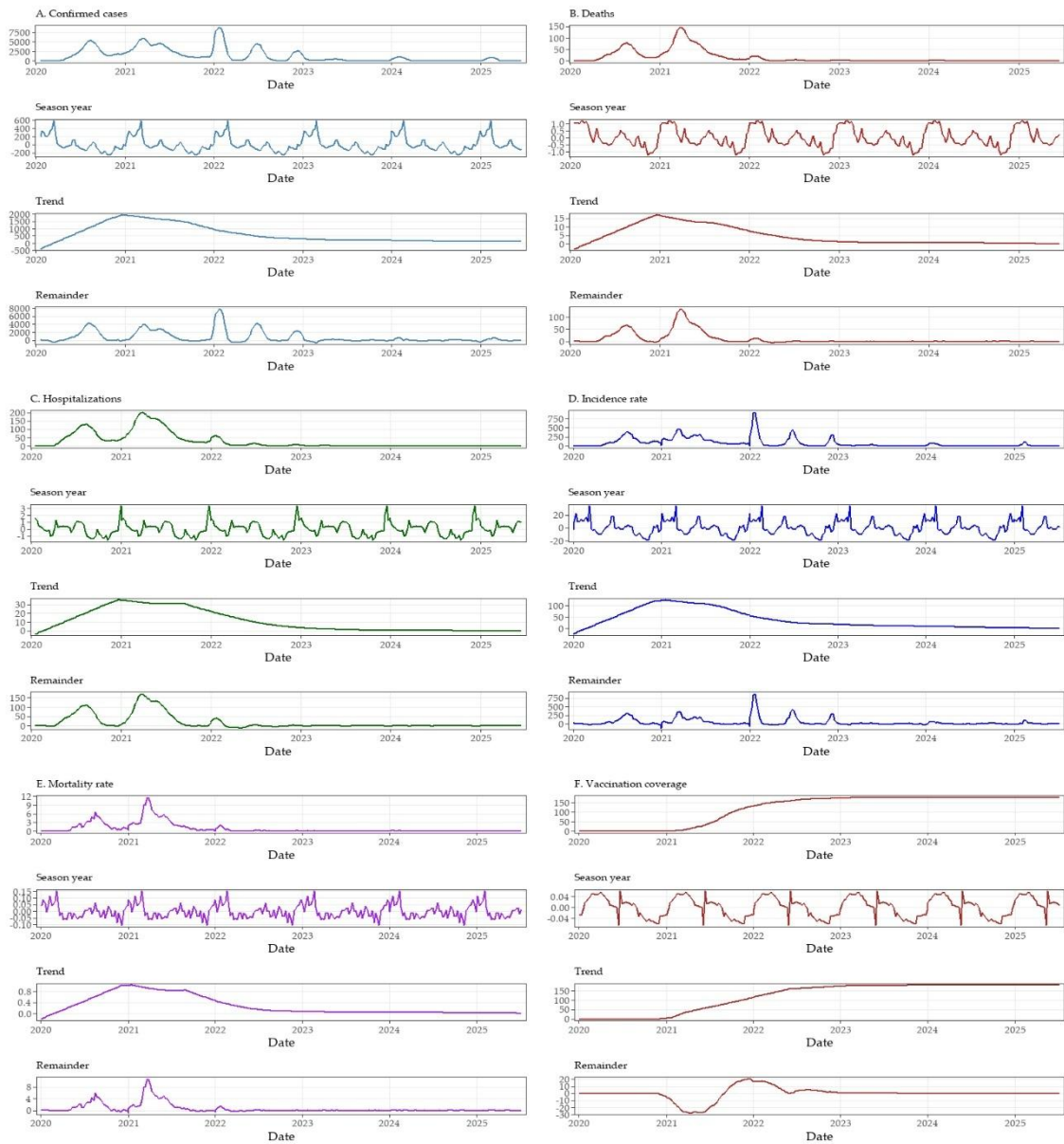


Figure S3. Seasonal–trend decomposition using Loess (STL) applied to weekly COVID-19 epidemiological time series in Tocantins, Brazil (January 2020–July 2025). Each panel (A–F) shows the decomposition of a specific indicator into four components: *Observed* (original series), *Seasonal* (recurring intra-annual patterns), *Trend* (long-term trajectory), and *Remainder* (irregular fluctuations). The indicators analyzed were (A) confirmed cases, (B) deaths, (C) hospitalizations, (D) incidence rate per 100,000 inhabitants, (E) mortality rate per 100,000 inhabitants, and (F) vaccination coverage. Pronounced mid-year seasonal peaks were evident for confirmed cases, incidence, and deaths, while trend components captured the epidemic’s progression and the impact of vaccination campaigns.

Spatial area under investigation

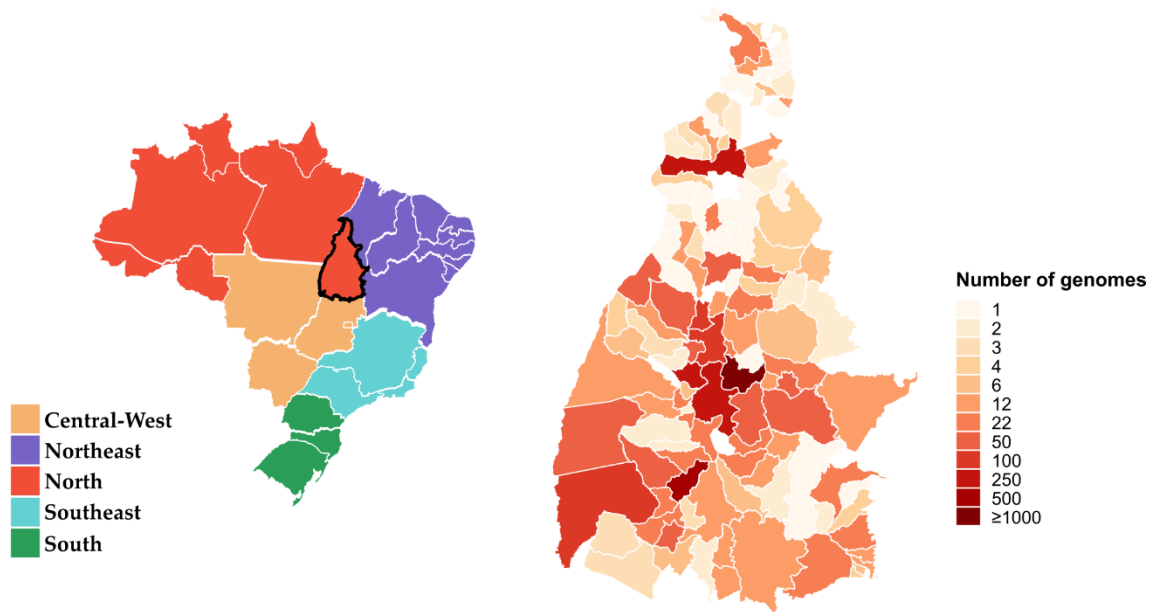


Figure S4. Spatial distribution of SARS-CoV-2 genome sequences obtained in Tocantins, Brazil, from September 2020 to May 2025. *Left:* Political map of Brazil highlighting major geographic regions, with the state of Tocantins outlined in black. *Right:* Choropleth map of Tocantins showing the number of sequenced genomes per municipality. Color intensity reflects sequencing volume, with the highest counts observed in Palmas and neighboring municipalities. Genomic data were retrieved from the GISAID EpiCoV database, and cartographic layers (municipal and state boundaries) were sourced from the IBGE digital cartographic database using the *geobr* package in R.

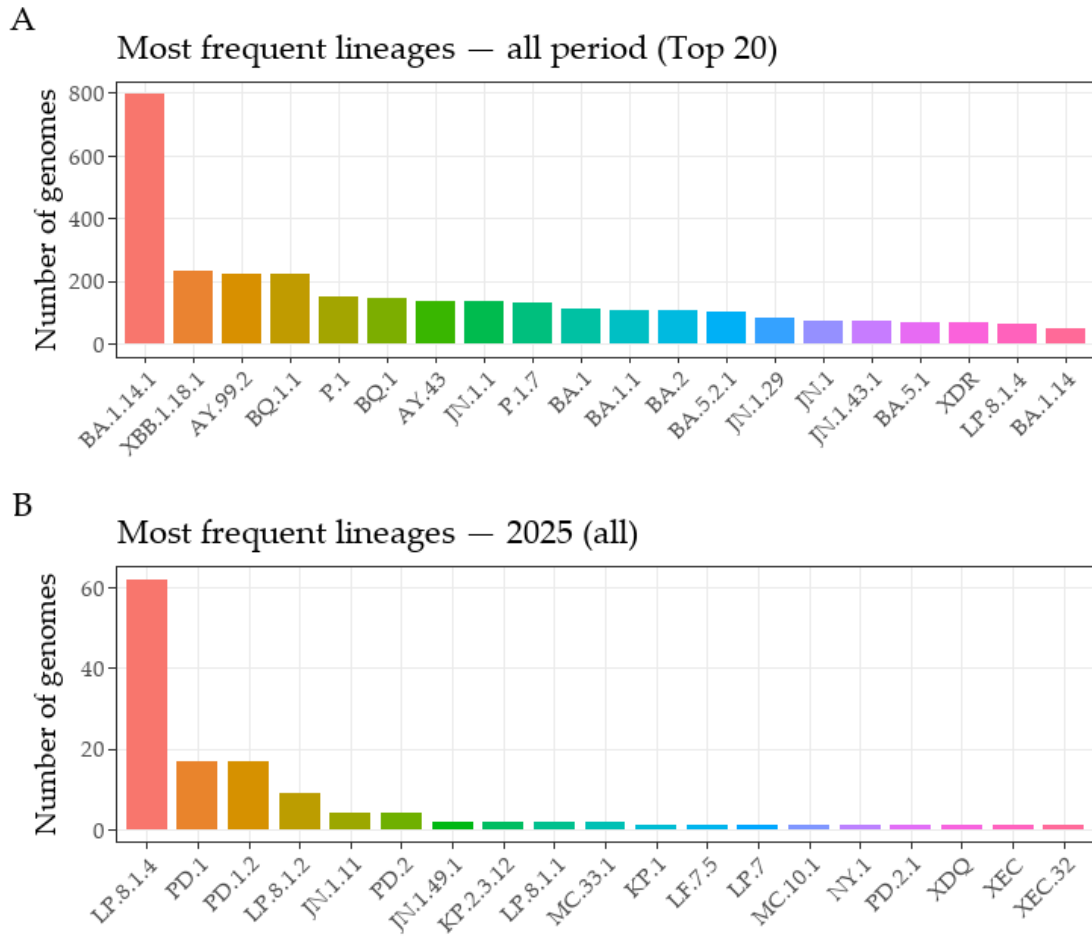


Figure S5. SARS-CoV-2 lineages detected in Tocantins, Brazil, from September 2020 to May 2025. **(A)** The 20 most frequently identified lineages across the full study period, illustrating the dominance of BA.1.14.1, XBB.1.18.1, AY.99.2, BQ.1.1, and P.1. **(B)** Distribution of lineages identified between January and May 2025, showing the predominance of LP.8.1.4 and the emergence of PD sublineages (PD.1, PD.1.2, PD.2), along with sporadic detections of other variants. Counts are based on genome sequences retrieved from GISAID, with monthly relative frequencies normalized across lineages.

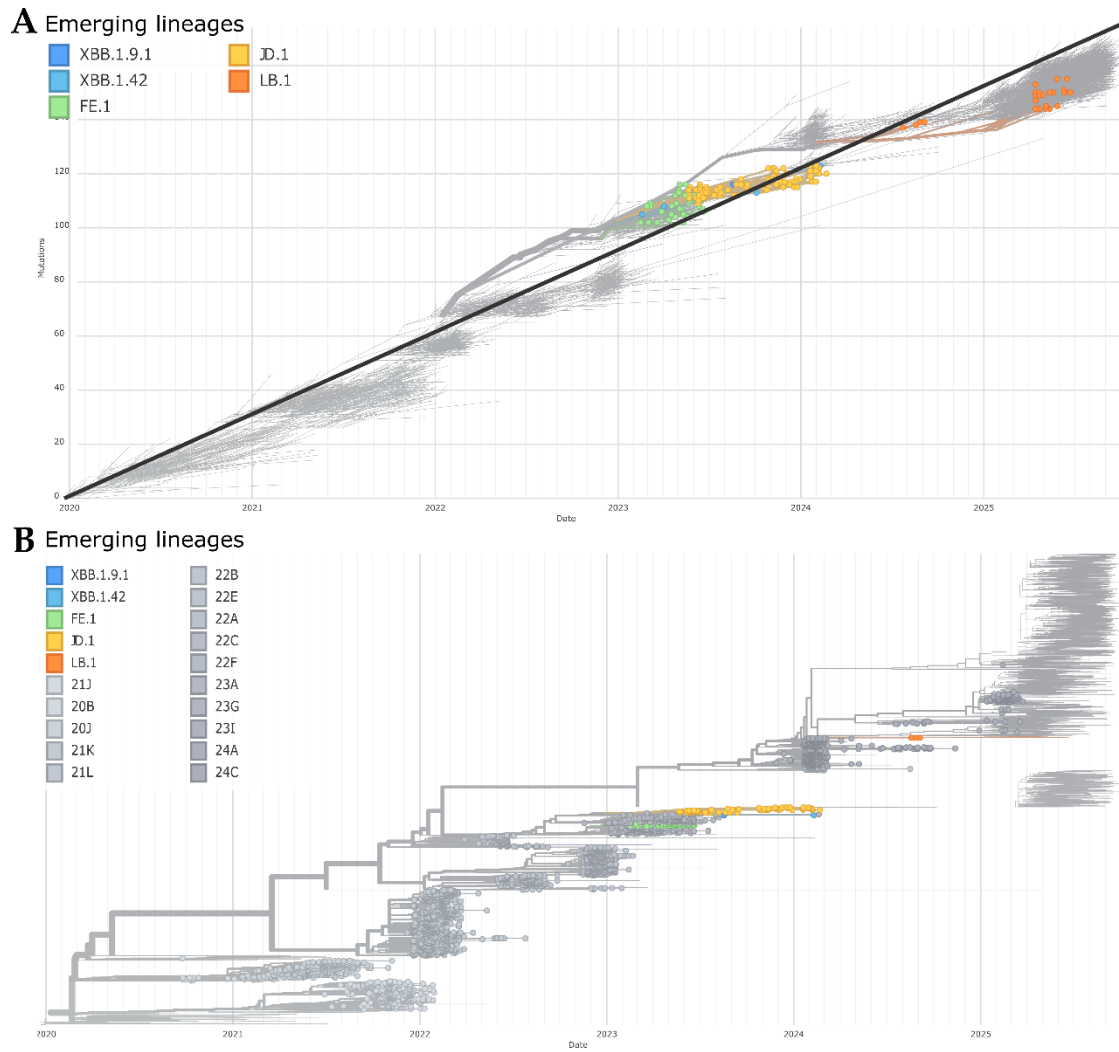


Figure S6. Emerging SARS-CoV-2 lineages in Tocantins visualized with Nextstrain/Auspice. **(A)** Root-to-tip regression plot highlighting emerging lineages—XBB.1.9.1, XBB.1.42, FE.1, JD.1, and LB.1 (colored points)—against the global background (gray). **(B)** Time-scaled phylogeny showing the same lineages embedded within the global tree, with all other tips shown in gray. Highlights indicate the recent expansion and phylogenetic placement of these lineages within international clades.

Table S1. SARS-CoV-2 genomic surveillance in Tocantins by municipality (study period). For each location, the table reports the number of distinct Pango lineages (“Number of lineages”) and lists the corresponding lineages detected. Lineage designations follow the Pango nomenclature current as of the time of analysis.

Location	Number of genomes	Number of lineages	Pango lineages
Palmas	1895	132	AY.101, AY.116, AY.34, AY.34.1.1, AY.42, AY.43, AY.43.2, AY.44, AY.46.3, AY.99.1, AY.99.2, B.1.1, B.1.1.28, B.1.617.2, BA.1, BA.1.1, BA.1.1.1, BA.1.1.14, BA.1.1.18, BA.1.14, BA.1.14.1, BA.1.14.2, BA.1.15, BA.1.17, BA.1.17.2, BA.1.18, BA.1.9, BA.2, BA.2.12.1, BA.2.56, BA.2.81, BA.2.9, BA.4, BA.4.1, BA.4.6, BA.5, BA.5.1, BA.5.1.15, BA.5.1.22, BA.5.2.1, BE.10, BE.9, BQ.1, BQ.1.1, BQ.1.1.18, BQ.1.1.36, BQ.1.1.5, BQ.1.1.60, BQ.1.18, BQ.1.5, CK.1.4, CV.1, DL.1, EF.1.1.1, EG.1, EG.5.1.1, EY.1, FE.1, FE.1.1.1, FE.1.2, GK.1, GK.1.1, JD.1, JD.1.1, JD.1.1.1, JD.1.2, JD.2, JN.1, JN.1.1, JN.1.1.3, JN.1.1.5, JN.1.11, JN.1.14, JN.1.16, JN.1.16.1, JN.1.16.3, JN.1.18, JN.1.20, JN.1.23, JN.1.29, JN.1.29.1, JN.1.3, JN.1.30, JN.1.4, JN.1.4.5, JN.1.43, JN.1.43.1, JN.1.49.1, JN.1.51, JN.1.55.2, JN.1.61, JN.1.7, JN.1.8.1, JN.2, JN.2.5, KP.2.18, KP.2.3.12, KR.5, LB.1, LB.1.4, LB.1.7, LF.7.5, LP.8.1.1, LP.8.1.2, LP.8.1.4, MC.10.1, MC.13, MC.33.1, MJ.1, MJ.2, NG.1, NY.1, P.1, P.1.7, P.2, PD.1, PD.1.2, PD.2, PD.2.1, XBB, XBB.1, XBB.1.16, XBB.1.18, XBB.1.18.1, XBB.1.5, XBB.1.5.19, XBB.1.5.59, XBB.1.5.7, XBB.1.5.70, XBB.1.5.86, XDR, XEC
Gurupi	262	57	AY.43, AY.99.2, B.1.1.28, BA.1, BA.1.1, BA.1.1.1, BA.1.14, BA.1.14.1, BA.2, BA.2.12.1, BA.2.3, BA.2.81, BA.2.9, BA.4, BA.4.6, BA.5.1, BA.5.2.1, BA.5.3.1, BE.9, BQ.1, BQ.1.1, BQ.1.13, DL.1, EG.1, FE.1.1, FE.1.2, JD.1, JD.1.1, JD.1.1.1, JN.1, JN.1.1, JN.1.23, JN.1.29, JN.1.29.1, JN.1.43, JN.1.43.1, KP.2.3, KP.3.1.1, KR.5, LP.7, LP.8.1.4, MC.11.3, MC.27, MJ.1, MJ.1.1, P.1, P.1.14, P.1.7, P.2, PD.1, XBB, XBB.1.18, XBB.1.18.1, XBB.1.5, XBB.1.5.70, XDR, XDR.1.1
Porto Nacional	210	39	AY.124.1, AY.34, AY.43, AY.46.3, AY.99.2, B.1.617.2, BA.1, BA.1.1, BA.1.14, BA.1.14.1, BA.2, BA.2.48, BA.2.81, BA.4, BA.5.1, BE.10, BE.9, BQ.1, BQ.1.1, CK.1.4, DL.1, FE.1, JD.1.1.1, JN.1, JN.1.1, JN.1.29, JN.1.43.1, JN.1.61, KR.5, LP.8.1.2, LP.8.1.4, MJ.2, P.1, P.1.7, PD.1, PD.1.2, XBB.1.18.1, XBB.1.5, XDR

Araguaína	163	38	AY.43, AY.99.2, B.1.1, B.1.1.28, BA.1, BA.1.1, BA.1.14, BA.1.14.1, BA.1.17.2, BA.2, BA.5.1, BA.5.2.1, BE.10, BF.41.1, BQ.1, BQ.1.1, DL.1, GK.1, HV.1, JD.1.1, JN.1, JN.1.1, JN.1.11, JN.1.29, JN.1.43.1, KP.2.3.12, KR.5, LP.8.1.4, P.1, P.1.7, P.2, PD.1.2, PD.2, XBB.1.18, XBB.1.5, XBB.1.5.70, XDQ, XDR
Paraíso do Tocantins	113	33	AY.99.2, BA.1, BA.1.1, BA.1.1.14, BA.1.14, BA.1.14.1, BA.1.20, BA.5.1, BA.5.2.1, BQ.1.1, FE.1.1.4, FE.1.2, JD.1, JD.1.1.1, JD.2, JN.1, JN.1.1, JN.1.29.1, JN.1.4, JN.1.43.1, JN.1.7, KP.1, LP.8.1.4, P.1, P.1.7, P.2, PD.1, XBB.1.18.1, XBB.1.5, XBB.1.5.59, XBB.1.5.70, XBB.1.5.86, XDR
Formoso do Araguaia	73	26	AY.99.2, B.1.1.28, BA.1, BA.1.1, BA.1.14.1, BA.1.17, BA.1.17.2, BA.2, BA.2.12.1, BA.2.81, BA.4, BA.5.1, BA.5.2.1, BQ.1, BQ.1.1, BQ.1.10, DL.1, JD.1.1, JD.1.1.1, JN.1, JN.1.1, JN.1.43.1, P.1, P.1.7, XBB.1.18.1, XDR
Miracema do Tocantins	65	31	AY.43, BA.1, BA.1.1, BA.1.14.1, BA.1.17.2, BA.5.1, BA.5.3.1, BE.9, BQ.1, BQ.1.1, BQ.1.1.60, FE.1, GK.1, JD.1.1, JN.1, JN.1.1, JN.1.1.5, JN.1.29, JN.1.43.1, KR.5, LP.8.1.2, P.1, P.1.2, P.1.7, PD.1, XBB.1.18, XBB.1.18.1, XBB.1.5, XBB.1.5.70, XBB.2.3, XDR
Miranorte	53	14	AY.116, AY.43, AY.99.2, BA.1, BA.1.1, BA.1.14, BA.1.14.1, BA.1.15, BA.1.17.2, BQ.1, JD.1.1, P.1, P.1.7, XBB.1.5.86
Alvorada	42	17	AY.34.1.1, BA.1, BA.1.1, BA.1.14.1, BA.2, BE.9, BQ.1, BQ.1.1, JN.1, JN.1.1, JN.1.16, JN.1.4, JN.1.43.1, P.1, P.1.7, XBB.1.18.1, XDR
Dueré	39	15	BA.1.14.1, BA.1.17.2, BA.2, BA.2.81, BA.4.1, BA.5.1.35, BA.5.2.1, BQ.1, BQ.1.1, DL.1, JN.1.1, JN.1.29, PD.1.2, XBB, XBB.1.18.1
Araguacema	35	18	BA.1.14, BA.1.14.1, BA.2, BA.2.9, BA.4, BA.5.1, BA.5.2.1, BQ.1.1, BQ.1.1.36, JN.1, JN.1.1, LP.8.1.1, LP.8.1.4, P.1, P.1.7, PD.1, PD.1.2, XBB.1.18.1
Lagoa da Confusão	34	14	AY.42, AY.43, AY.99.2, BA.1, BA.4, BA.5, BA.5.1, BA.5.1.22, BA.5.2.1, BQ.1.1, LP.8.1.4, P.1, PD.1.2, XEC.32
Ponte Alta do Tocantins	31	11	BA.1, BA.1.14.1, BQ.1, BQ.1.1, DL.1, FE.1.2, JN.1.1, JN.1.29, JN.1.43.1, KR.5, XBB.1.18.1
Lagoa do Tocantins	29	8	BA.1, BA.1.1, BA.1.14, BA.1.14.1, BA.2, BA.5.1, BA.5.2.1, CK.1.4
Barrolândia	25	13	AY.99.2, BA.2, BA.5.1, BA.5.2.1, BE.10, BQ.1, BQ.1.1, JN.1, JN.1.1, LP.8.1.4, XBB.1.18, XBB.1.18.1, XBB.1.5.70
Guaraí	24	14	AY.99.2, B.1.1.28, BA.1.1, BA.1.14.1, BA.1.17.2, BQ.1.1, JD.1.1, JN.1, JN.1.1, JN.1.55.2, JN.1.61, LP.8.1.4, P.1, P.1.7

Monte do Carmo	23	5	AY.43, BA.1.14.1, BQ.1, DL.1, FE.1.2
Dois Irmãos do Tocantins	21	11	BA.1.14.1, BA.4.6, BQ.1, BQ.1.1, DL.1, JD.1.1.1, JN.1, JN.1.1, JN.1.29, JN.1.43.1, XDR
Pedro Afonso	21	11	AY.99.2, BQ.1.1, JN.1, JN.1.1, JN.1.11, JN.1.43.1, JN.2, P.1, P.1.7, PD.1, XDR
Aliança do Tocantins	21	11	BA.1, BA.1.14.1, BA.4.6, BA.5.1, BA.5.2.1, BQ.1, BQ.1.1.4, JD.1.1, JN.1.29, JN.1.29.1, KR.5
Arraias	20	11	BA.1, BA.1.1, BA.1.14, BA.1.14.1, BA.5.1, BA.5.2.1, BE.9, BQ.1.1, CK.1.4, P.1, P.1.7
Silvanópolis	20	10	AY.43, AY.99.2, BA.1, BA.1.1, BA.1.14.1, JN.1.1, JN.1.18, JN.1.20, JN.1.29, KR.5
Novo Acordo	19	13	AY.99.2, BA.1.1, BA.1.14.1, BA.2, BA.2.48, BA.5.1, BA.5.3.1, BQ.1, BQ.1.1, JD.1.1, JN.1.29, P.1, XBB.1.18.1
Taguatinga	18	9	AY.42, BA.1.1, BA.1.14.1, BA.1.15, BQ.1, BQ.1.1, JD.1, XBB, XBB.1.18.1
Cariri Do Tocantins	18	11	AY.43, BA.1.1, BA.1.14.1, BA.1.17.2, BA.5.1.22, BE.10, BQ.1.1, JN.1, JN.1.1, JN.1.29, XDR
Figueirópolis	17	7	AY.43, B.1.1.33, BA.1.1, BA.1.14, BA.1.14.1, P.1, P.1.7
Araguatins	16	6	AY.122, AY.43, B.1.1.28, BA.1.14.1, BQ.1.1, XBB.1.18.1
Brejinho de Nazaré	16	7	AY.43, AY.99.2, BA.1.1, BA.1.14, BA.1.14.1, P.1, XBB.1.18.1
Dianópolis	15	10	AY.99.2, BA.2, BE.9, BQ.1, BQ.1.1, BQ.1.1.56, BQ.1.18, CK.1.4, JN.1.29, XBB.1.18.1
Nova Rosalândia	15	2	BA.1, BA.1.14.1
Colinas do Tocantins	14	8	AY.124.1, AY.34.1.1, AY.43.2, AY.99.2, BA.1.14.1, JN.1.1, P.1, XDR
Lajeado	13	6	BA.1.14.1, BA.5.1.22, LP.8.1.4, PD.1, XBB.1.18.1, XBB.1.5.59
Santa Maria do Tocantins	13	5	AY.99.2, BA.1.14.1, BA.5.1, P.1.7, XBB.1.18.1
Santa Rosa do Tocantins	13	7	AY.99.2, BA.1.1, BA.1.14, BA.1.14.1, BA.2, BQ.1, BQ.1.1.4
Fátima	13	7	AY.99.2, BA.1, BA.1.1, BA.1.14.1, BA.5.1, BA.5.2.1, P.1.7
Araguaiana	12	4	B.1.1, B.1.1.28, P.1, P.2
Cristalândia	12	8	BA.1, BA.1.14, BA.1.14.1, BQ.1.1, GK.1, JD.1, JN.1.1, JN.1.43.1
Santa Tereza do Tocantins	11	5	AY.99.2, BA.1, BA.1.14, BA.1.14.1, P.1
Peixe	11	8	BA.1.1, BA.1.14.1, BA.2.81, FE.1.2, JD.1.1, JN.1.43, XBB.1.18.1, XBB.1.5.70
Mateiros	10	5	AY.6, B.1.1.33, BA.1.14.1, BA.4, P.1
Paraná	10	5	AY.99.2, BA.1.14.1, BA.5.2.1, P.1, P.1.7
Rio dos Bois	10	5	AY.99.2, BA.1.1, BA.1.14.1, P.1.7, XBB.1.18.1

São Salvador do Tocantins	9	4	BA.1.14.1, BA.4, BA.5.1, JD.1.1
Aguiarnópolis	9	7	AY.43, BE.10, BQ.1, BQ.1.1, JN.1.1, JN.1.29, XBB.1.18.1
Pindorama do Tocantins	9	4	AY.99.2, BA.1, BA.1.14.1, P.1
Tocantínia	9	6	AY.99.2, BA.1, BA.1.14.1, JN.1.55.2, P.1.7, XBB.1.18.1
São Bento do Tocantins	8	5	AY.43, BA.1.14.1, BA.1.17, BQ.1, DL.1
Lavandeira	8	3	BA.2, BA.5.1, P.1.7
Pequizeiro	8	3	BA.1.1, BA.1.14.1, BA.5.1
Abreulândia	8	7	AY.43, AY.99.2, BA.1, BA.1.14.1, BA.5.1, BQ.1.1, P.1
Aurora do Tocantins	8	4	BA.1.14.1, BN.1.3.1, JD.1.1, P.1.7
Colmeia	7	3	AY.99.2, BA.1, BA.1.14.1
Babaçulândia	7	3	AY.43, AY.99.2, BA.1.14.1
Aragominas	7	4	AY.43, BA.1.14.1, JN.1.1, JN.1.43.1
Pium	7	4	AY.99.2, BA.1.14.1, BA.5.2.1, P.1
Chapada da Natividade	7	7	AY.43, BA.1.1, BA.1.1.1, BA.1.14.1, BA.2, BA.5.2.1, JD.1.1
Palmeirópolis	7	3	BA.1.14.1, P.1, P.1.7
Pugmil	6	4	BQ.1, DL.1, JN.1.1.5, XDR
Miracema	6	3	AY.43, AY.99.2, P.1.7
Combinado	6	2	MC.33.1, P.1.7
Rio Sono	6	5	AY.99.2, BA.1.14.1, BQ.1.1, JD.1.1, P.1
Talismã	5	1	BA.1.14.1
São Valério da Natividade	5	1	BA.1.14.1
Nazaré	5	3	AY.43, BA.1.14.1, BA.5
Recursolândia	5	3	BA.1, BA.1.14.1, XDR
Marianópolis do Tocantins	5	4	BA.1.14.1, BQ.1, PD.1.2, XBB.1.18.1
Ponte Alta do Bom Jesus	4	2	BA.1.14.1, BA.1.17.2
Novo Alegre	4	3	BA.1.14.1, BA.5.1, P.1
Pau D'Arco	4	3	AY.34.1.1, BA.1.14.1, BA.1.17.2

Augustinópolis	4	2	AY.43, P.1
Caseara	4	2	BA.1.14.1, BQ.1
Carmolândia	4	4	BA.2, JN.1.43.1, XBB.1.18.1, XBB.1.5
Bom Jesus do Tocantins	4	4	BA.1.1, BA.1.14.1, BA.2, P.1
Goiatins	4	3	JN.1.1, KP.2.3.12, XBB.1.18.1
Itacajá	4	3	BA.1, JN.1.1, XDR
Sandolândia	3	3	B.1.1.28, P.1.7, XBB.1.18.1
Itaporã do Tocantins	3	2	BA.1.14, BA.1.14.1
Dois Irmãos do Tocantins	3	2	P.1, P.1.7
Divinópolis Do Tocantins	3	2	BA.1.14.1, XBB.1.18.1
Sucupira	3	3	BA.1.14.1, BA.5.2.1, JD.1.1
Araguacu	3	2	BA.1.14, BA.1.14.1
Muricilândia	3	2	AY.43, BA.1.14.1
Xambioá	3	2	AY.43, AY.99.2
Angico	2	2	AY.43, JN.1.43.1
São Miguel Do Tocantins	2	1	AY.43
Bernardo Sayão	2	2	BA.1.14.1, JN.1.29
Taipas do Tocantins	2	2	BA.2.81, XBB.1.18.1
Piraquê	2	1	AY.99.2
Santa Rita do Tocantins	2	2	BA.1.14.1, BQ.1
Santa Fé do Araguaia	2	1	BA.1.14.1
Tocantinópolis	2	2	BA.5.2.1, BQ.1
Filadélfia	2	2	BA.5.1, P.1
Lizarda	2	2	BA.1.14.1, JN.1.43.1
Fortaleza do Tabocão	2	2	BA.1.14.1, P.1.7
Crixás do Tocantins	2	2	BA.1.14.1, BA.2
Centenário	2	2	JN.1.1, JN.1.10

Monte Santo do Tocantins	2	2	BA.1, P.1.7
Oliveira ee Fátima	2	2	AY.34, XBB.1.18.1
Natividade	2	2	BQ.1.1, P.1
Jaú do Tocantins	2	2	BQ.1.1, P.1
Juarina	1	1	BA.1.1
Conceicao do Tocantins	1	1	P.1.7
Couto Magalhães	1	1	AY.3
Aparecida do Rio Negro	1	1	AY.99.2
Araguanã	1	1	BA.1.14.1
Ananás	1	1	BA.1.14.1
Itaguatins	1	1	AY.43
Goianorte	1	1	JN.1.61
Almas	1	1	BA.5.1
Tupirama	1	1	JN.1
Tupiratins	1	1	AY.43
Itapiratins	1	1	P.1.7
Luzinópolis	1	1	JN.1
Arapoema	1	1	AY.99.2
Esperantina	1	1	BA.1.14.1
Maurilândia do Tocantins	1	1	BA.1.14.1
Cachoeirinha	1	1	AY.43
Presidente Kennedy	1	1	B.1.1.28
Novo Jardim	1	1	BA.2
Porto Alegre Do Tocantins	1	1	BA.1.14.1
Axixá do Tocantins	1	1	XBB.1.18.1
Brasilândia do Tocantins	1	1	JN.1.18
Palmeirante	1	1	XDR

Palmeiras do Tocantins	1	1	JN.2.5
Bandeirantes do Tocantins	1	1	BQ.1
Barcarena	1	1	BA.5.2.1
Barra do Ouro	1	1	XBB.1.18.1
Palmeirópolis	1	1	P.1

Table S2. Data availability. GISAID Identifier: **EPI_SET_251017vr**. DOI: <https://doi.org/10.55876/gis8.251017vr>. All genome sequences and associated metadata included in this dataset are available in GISAID's EpiCoV database. To view the contributors of each individual sequence—including accession number, virus name, collection date, originating laboratory, submitting laboratory, and author list—visit **EPI_SET_251017vr** on GISAID. **Data snapshot:** The dataset comprises 3,961 individual genome sequences collected between 24 September 2020 and 2 September 2025 across one country (Brazil).

The complete table is available at <https://doi.org/10.55876/gis8.251017vr>.