Disaggregation of life expectancies in Mexico from the state to the municipal level and their visualizations from 1990 to 2020

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Content

Introduction

Background

Material and Methods

Results

Conclusions

Basic references

Introduction

- One pivotal index for summarizing human mortality in a geographic point is the so-called life expectancy at birth, $e_{x.}$
- It serves as an indicator of well-being in societies, and it is used to estimate the human development index in countries and regions (Conceição, 2020).
- Regarding Mexico, the life expectancy is a significant to formulate public policies. For instance, states or municipalities with low life expectancy are susceptible to economic support through national programs.

Introduction

- During President Peña' 's administration (2012-2018), a social program aimed to reduce poverty and the number of starving people (“Cruzada contra el hambre"). However, when the resources were allocated, several municipalities were omitted.
- There are no official figures about life expectancy yet for municipalities in Mexico, and this situation could be similar in other developing countries.
- Objective: estimate life expectancies at the municipal level using sociodemographic variables taken from the national Population census and counts, or other official sources and valid linear models. The statistical coherence from states and municipalities is taken care of.

Background

- Mortality rates are the conventional tool to directly estimate life expectancies (see for details Sanders, 2019). It makes sense to use it when the number of units at the sub-national level (or deeper) is relatively low.
- Collecting data and its handle could be too tedious and laborious. For Mexico, there are more than 2,500 municipalities per every selected year.
- Statistics coherence is the second obstacle to overcome if all of the information is at hand. That is, the life expectancies at the municipal level should be coherent with the state and official estimates.

Background

- Statistical software R can easily estimate mortality tables, such as MortalityTables (Kainhofer, 2021) and LifeTables (Sharrow and Sevcikova, 2015).
- Despite a long processing time, because more than 2,500 municipalities are given for the Mexican case generating life tables and extracting life expectancies is possible.
- Assuming this is not an information drawback for Mexican municipalities in the selected years, statistical coherence between state and municipal levels became a considerable challenge.

Background

- Another possibility is the Swanson's model (1989) in that is required both the crude death rate and the percentage of the population aged 65 years and over.
- It has been employed at national and sub-state (or regional) levels, Swanson (1989), Swanson et al (2009), Paredes and Silva (2017) and Picazzo et al (2020). Information in Mexico is unavailable for many municipalities.
- Esparza and Baltazar (2018), Ali et al. (2022), Pisal et al. (2022). They dismiss statistical coherence.
- Using multiple linear regression models, Duque et al (2018) confirm relationships between life expectancy and social determinants in Brazil. Girum et al (2018), bivariate linear regression proves that life expectancy has an inverse and significant linear relationship with child mortality rate, and a positive relation with the Human Development Index (HDI) and adult literacy rate.

Material and Methods

- Several variables were taken from official sources: CONAPO (Consejo Nacional de Población, 2018) based on national census and counts from 1990, 1995, 2000, 2005, 2010, 2015, and 2020 elaborated by the Mexican Institute of Statistics (INEGI); CONEVAL (Consejo Nacional de la Evaluación de la Política Pública) for various social, health and economic indices; and the Health Secretary (Secretaria de Salud, SS), data related with the COVID-19 pandemic. All of them for getting figures at the state and municipal level for each year. The final variables considered, due they were significance in the mentioned models below, are listed in Table 1.

Table 1. Variables and their Sources

Variable	Description	Source
ANALF	% Illiteracy	CONAPO
SPRIM	% Population without primary school	
OVSDE	% Population without adequate toilet facilities	
OVSEE	% Population without electricity	
OVSAE	% Population without municipal water	
VHAC	% overcrowded homes	
OVPT	% households with dirt floor	
PL5000	% Population in a rural area	
PO2SM	% Population with low wages	
CONF/POB	Confirmed COVID-19 cases/Total population	SS/INEGI

Source: own elaboration

Material and Methods

- We take ex's from CONAPO (2018) and García and Beltran (2021) based on records from INEGI.
- First, to explain the life expectancies at the state level, $e_{x,t,s}$, for $t = 1990, 1995, \dots, 2020$, ignoring how they were estimated, we consider the following statistical model

$$e_{x,t,s} = \beta_{0,t} + \beta_{1,t}x_{1,t} + \beta_{2,t}x_{2,t} + \beta_{3,t}x_{3,t} + \dots + \beta_{k,t}x_{k,t} + u_t \qquad (1)$$

where $\beta_{0,t}, \beta_{1,t}, \beta_{2,t}, \beta_{3,t}, \dots, \beta_{k,t}$ are coefficients to estimate; $x_{1,t}, x_{2,t}, x_{3,t}, \dots, x_{k,t}$ are the set of available variables at the state level; and u_t represents a random error, all at time t. Then, stepwise algorithm for getting the best models was employed: one per year, so seven models were estimated (α=15%). The final models fulfilled the standard assumptions.

Material and Methods

- Second, the life expectancies at the municipal level, $\hat{e}_{x,t,m}$ were calculated as follows

$$\hat{e}_{x,t,m} = \hat{\beta}_{0,t} + \hat{\beta}_{1,t}x_{1,t,m} + \hat{\beta}_{2,t}x_{2,t,m} + \hat{\beta}_{3,t}x_{3,t,m} + \cdots + \hat{\beta}_{k,t}x_{k,t,m} \quad (2)$$

where $\hat{\beta}_{0,t}, \hat{\beta}_{1,t}, \hat{\beta}_{2,t}, \hat{\beta}_{3,t}, \dots, \hat{\beta}_{k,t}$ are the estimated coefficients coming from (1); $x_{1,t,m}$, $x_{2,t,m}, x_{3,t,m}, \dots, x_{k,t,m}$ are the same independent variables, but at the municipal level, and m the number of municipalities. Given that it is an estimated model, the random error is omitted. In other words, equation (1) helps estimate the municipal-level life expectancies.

Material and Methods

- Third, re-built the state-level life expectancies, $\bar{\bar{e}}_{x,t,s}$, per year through the expression for each state

$$\bar{\bar{e}}_{x,t,s}=\alpha_1\hat{e}_{x,t,1}+\alpha_2\hat{e}_{x,t,2}+\cdots+\alpha_m\hat{e}_{x,t,m}=\sum_{i=1}^{m}\alpha_i\hat{e}_{x,t,i} \quad (3)$$

where, without loss of generality, it is assumed that quantity of municipalities for each state is m and α_m is the ratio (weight) given by

$$\alpha_m=\frac{Total\ population\ in\ the\ mth\ municipality\ from\ the\ state\ s\ in\ the\ year\ t}{Total\ population\ in\ the\ state\ s\ in\ the\ year\ t}.$$

- Validate the statistical coherence: Spearman correlation between $e_{x,t,s}$ and the $\bar{\bar{e}}_{x,t,s}$was measured. Additionally, and as a summary using root mean square error (RMSE), given by $\sqrt{\frac{\sum\ (e_{x,t,s}-\bar{\bar{e}}_{x,t,s})^2}{32}}$ per year.

Results

- The estimated models to explain them for $t = 1990, 1995, \ldots, 2020$ are as follows,

$$\hat{e}_{x,1990,s} = 71.397 - 0.01760\, OVPT + 2.481\, I_{Qr} - 1.233\, I_{Oax} + 1.0988 I_{Mx} - 1.266\, I_{Ver}$$

$$\hat{e}_{x,1995,s} = 72.703 - 0.02880\, OVSAE + 1.237\, I_{Qr} + 0.833\, I_{Ags} - 0.906\, I_{Oax}$$

$$\hat{e}_{x,2000,s} = 76.704 - 0.0842\, OVSEE - 0.02882\, PO2SM$$

$$\hat{e}_{x,2005,s} = 76.519 - 0.0246\, SPRIM - 0.0822\, OVSEE - 0.00959\, PO2SM$$

$$\hat{e}_{x,2010,s} = 73.874 - 0.03\, SPRIM - 0.0343\, OVPT - 0.00967\, PO2SM$$

$$\hat{e}_{x,2015,s} = 76.645 - 0.0584\, SPRIM - 0.1171\, OVSEE - 0.0332\, VHAC$$

$$\hat{e}_{x,2020,s} = 73.569 + 0.1054\, OVPT - 0.0691\, VHAC - 18.8\, \frac{CONF}{POB} - 1.288\, I_{BC} - 1.458\, I_{Gro} + 1.077\, I_{Chis} + 0.774\, I_{Mor}$$

- Valid models. R^2: 62.99, 71.30, 82.01, 83.09, 80.44, 85.56, 65.10, respectively.

Results

State	C	E	C	E	C	E	C	E	C	E	C	E	GB	E
	1990		1995		2000		2005		2010		2015		2020	
Aguascalientes	72.26	71.27	73.53	73.53	76.00	75.37	76.06	75.69	75.32	74.95	75.43	75.27	72.53	72.49
Baja California	71.49	71.25	72.67	72.32	75.53	75.84	75.83	75.89	75.14	74.97	75.48	75.31	71.29	71.28
Baja California Sur	71.41	71.15	72.44	72.44	75.11	75.31	75.57	75.65	75.13	75.03	75.35	75.05	72.65	72.40
Campeche	70.75	70.97	71.70	72.08	74.02	74.14	74.80	74.92	74.50	74.54	74.21	74.19	72.01	71.57
Chiapas	71.90	71.25	72.35	72.55	74.00	75.58	74.65	75.78	74.49	74.98	73.73	75.36	73.41	73.16
Chihuahua	71.16	71.03	72.62	72.59	75.31	75.23	75.53	75.52	74.79	74.74	74.92	74.94	71.45	72.62
Ciudad de México	71.49	70.50	72.62	71.71	75.44	73.20	75.75	74.20	75.53	73.36	76.19	73.05	71.87	72.28
Coahuila	71.35	71.23	72.71	72.47	75.46	74.73	75.76	75.45	74.97	74.68	75.20	74.96	71.82	71.59
Colima	71.25	71.35	72.61	72.64	75.18	75.57	75.58	75.95	74.93	75.23	74.99	75.70	72.64	72.20
Durango	71.04	71.04	72.32	72.41	74.84	74.48	75.23	75.18	74.55	74.56	74.61	74.75	72.73	72.68
Guanajuato	71.25	71.10	72.62	72.39	75.08	74.93	75.40	75.22	74.84	74.58	74.73	74.70	72.64	72.12
Guerrero	70.56	70.52	71.43	71.69	73.57	73.48	74.28	74.47	73.63	73.56	72.71	73.41	71.31	71.31
Hidalgo	69.96	70.87	71.74	72.11	74.40	73.96	75.14	74.92	74.64	74.30	74.58	74.59	72.27	72.09
Jalisco	71.86	71.17	72.79	72.46	75.31	75.16	75.70	75.57	75.04	74.86	75.01	75.09	73.30	72.54
México	72.27	72.27	73.02	72.46	75.40	75.05	75.63	75.64	75.03	74.82	74.99	75.04	71.91	71.96
Michoacán	70.93	70.89	72.20	72.32	74.53	74.57	74.96	74.98	74.43	74.09	74.35	74.22	73.12	72.60
Morelos	70.73	71.01	72.42	72.43	74.83	74.99	75.28	75.57	74.76	74.64	74.74	74.90	73.34	73.36

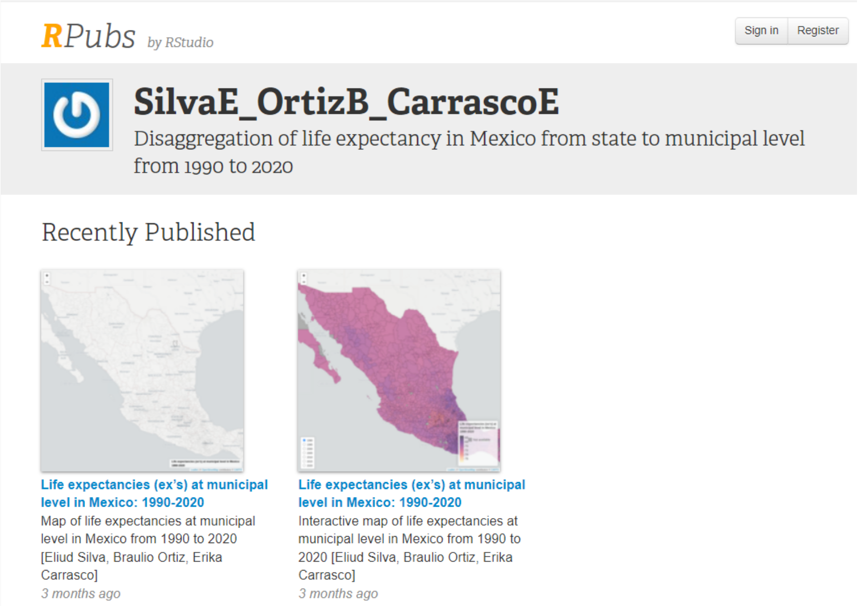
State	C	E	C	E	C	E	C	E	C	E	C	E	GB	E
	1990		1995		2000		2005		2010		2015		2020	
Nayarit	70.64	71.02	72.10	72.32	74.65	74.58	75.23	75.02	74.75	74.62	74.82	74.47	73.13	72.43
Nuevo León	71.43	71.29	72.75	72.55	75.53	75.65	75.88	75.93	75.23	75.09	75.45	75.47	72.87	72.46
Oaxaca	69.24	69.24	70.85	70.85	73.28	73.30	74.09	74.29	73.87	73.35	73.61	73.37	72.80	72.72
Puebla	70.57	70.87	72.12	72.09	74.44	74.14	75.02	75.02	74.58	74.09	74.32	74.17	72.16	72.17
Querétaro	71.90	71.10	72.88	72.40	75.23	74.66	75.58	75.40	75.14	74.90	75.14	75.07	73.02	72.15
Quintana Roo	73.47	73.47	73.63	73.63	75.85	74.86	75.92	75.49	75.18	74.88	74.94	74.61	71.45	71.98
San Luis Potosí	70.16	70.88	71.86	71.94	74.16	73.67	74.89	74.84	74.58	74.23	74.37	74.51	72.05	71.40
Sinaloa	70.76	70.98	72.10	72.36	74.69	74.82	75.19	75.35	74.62	74.57	74.62	74.68	71.54	72.47
Sonora	71.03	71.08	72.31	72.53	75.02	75.16	75.40	75.64	74.74	74.76	74.88	75.09	71.54	71.92
Tabasco	71.66	71.15	72.34	71.70	74.73	74.37	75.21	75.24	74.67	74.61	74.53	74.58	71.73	72.00
Tamaulipas	70.40	71.15	72.11	72.39	74.83	74.62	75.40	75.47	74.79	74.74	74.74	74.92	72.32	72.01
Tlaxcala	70.87	71.15	72.41	72.58	74.99	74.69	75.47	75.36	74.88	74.59	74.76	74.87	72.21	72.06
Veracruz	69.50	69.50	71.31	71.62	73.47	73.61	74.46	74.75	74.38	73.94	74.02	73.98	72.70	72.36
Yucatán	70.03	71.07	71.51	72.29	73.89	74.22	74.61	74.95	74.34	74.27	74.13	74.12	71.84	70.65
Zacatecas	70.61	71.10	71.98	72.21	74.57	74.51	75.08	75.08	74.61	74.39	74.53	74.70	72.18	72.37
Means	71.06	71.06	72.31	72.31	74.79	74.64	75.27	75.26	74.75	74.53	74.69	74.66	72.31	72.17
Variances	0.70	0.44	0.34	0.24	0.45	0.47	0.23	0.20	0.15	0.22	0.40	0.36	0.39	0.29
ρ_S		0.74		0.74		0.65		0.66		0.66		0.61		0.66
RMSE		0.49		0.34		0.60		0.39		0.46		0.67		0.51

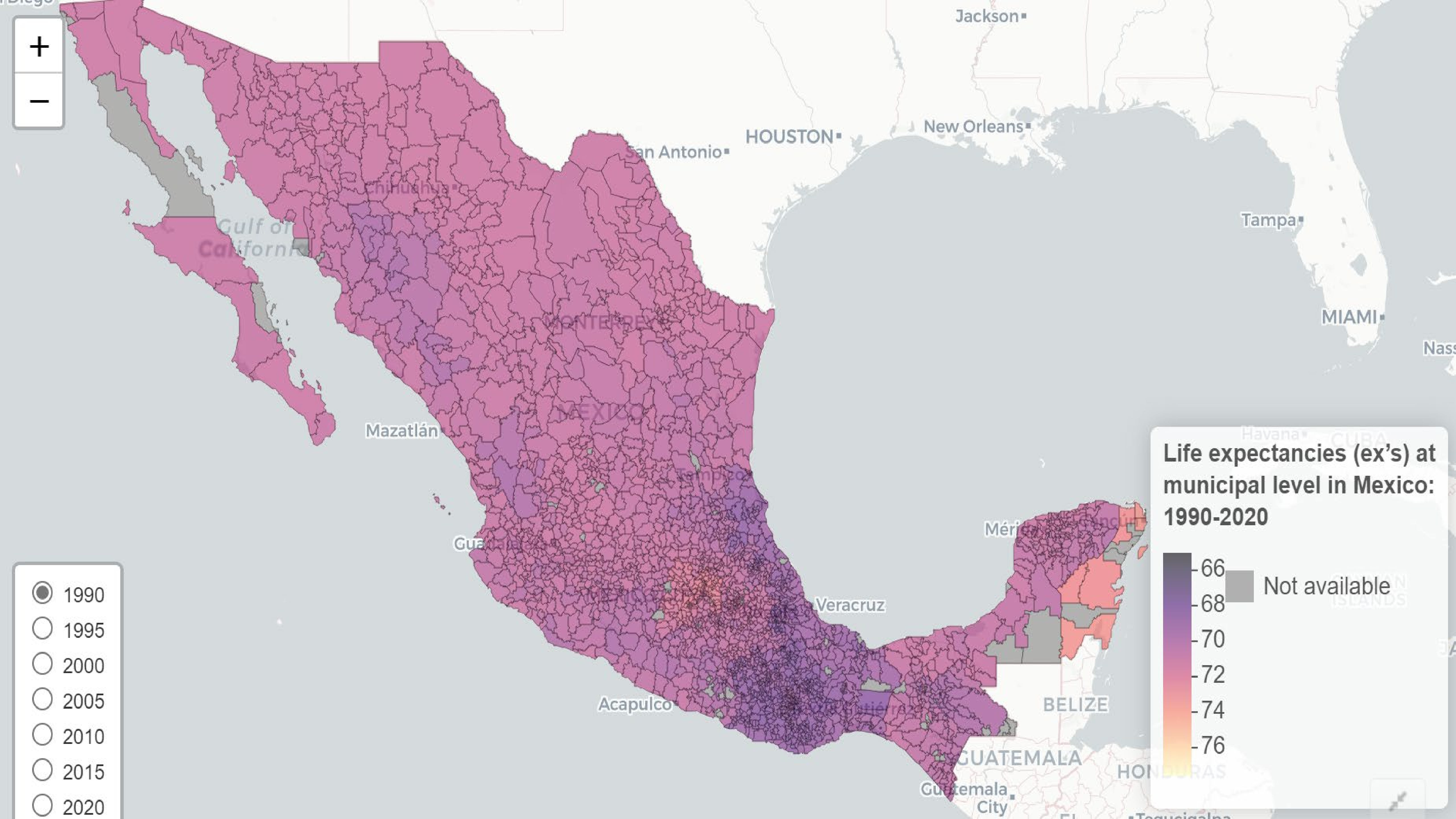
Note. C: CONAPO; E: Estimate; GB: estimates taken from García and Beltrán (2021).

Results

- All visualizations were created using the open-source JavaScript library "'leaflet' available in R.

https://rpubs.com/SilvaE_OrtizB_CarrascoE





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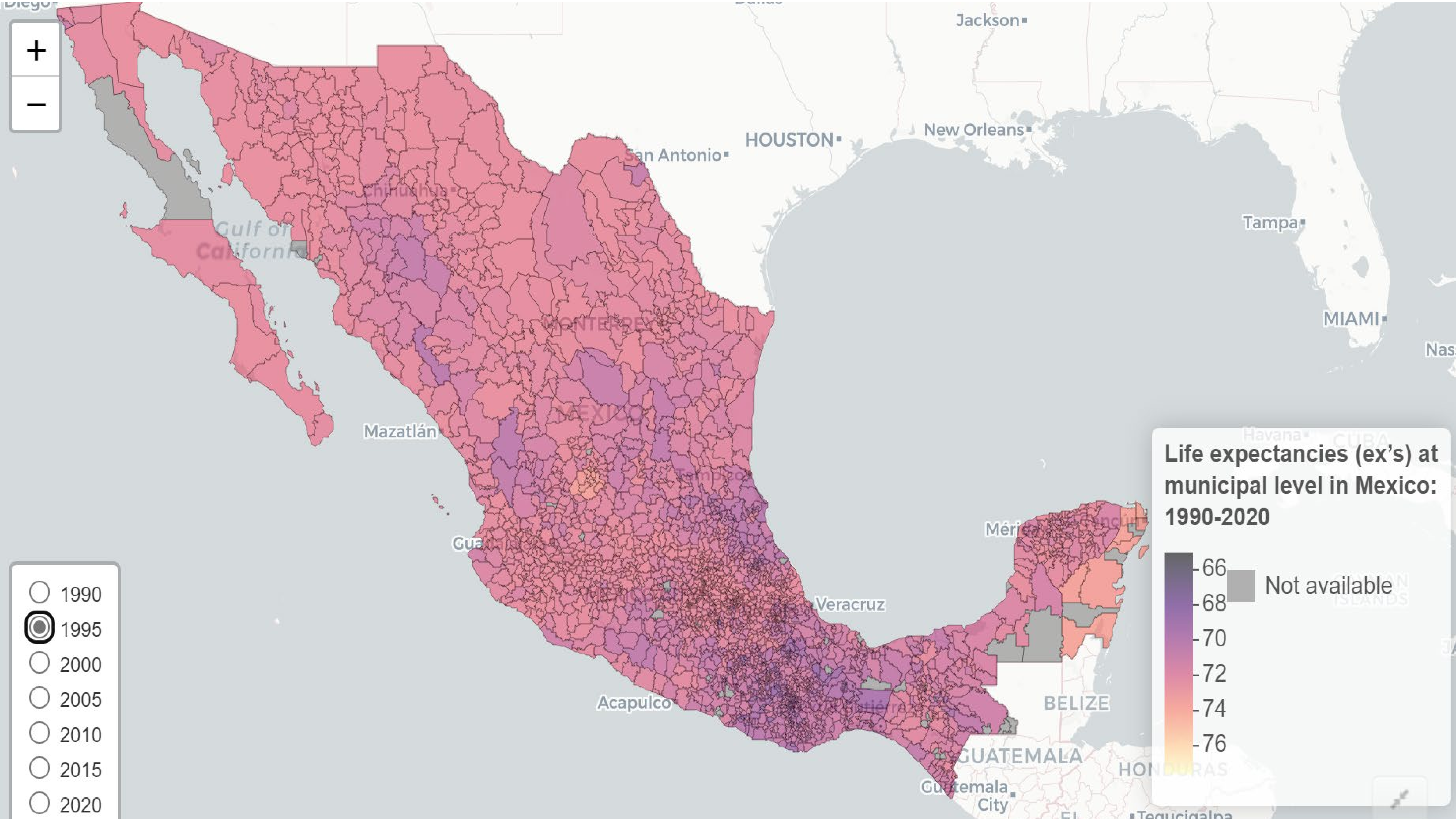

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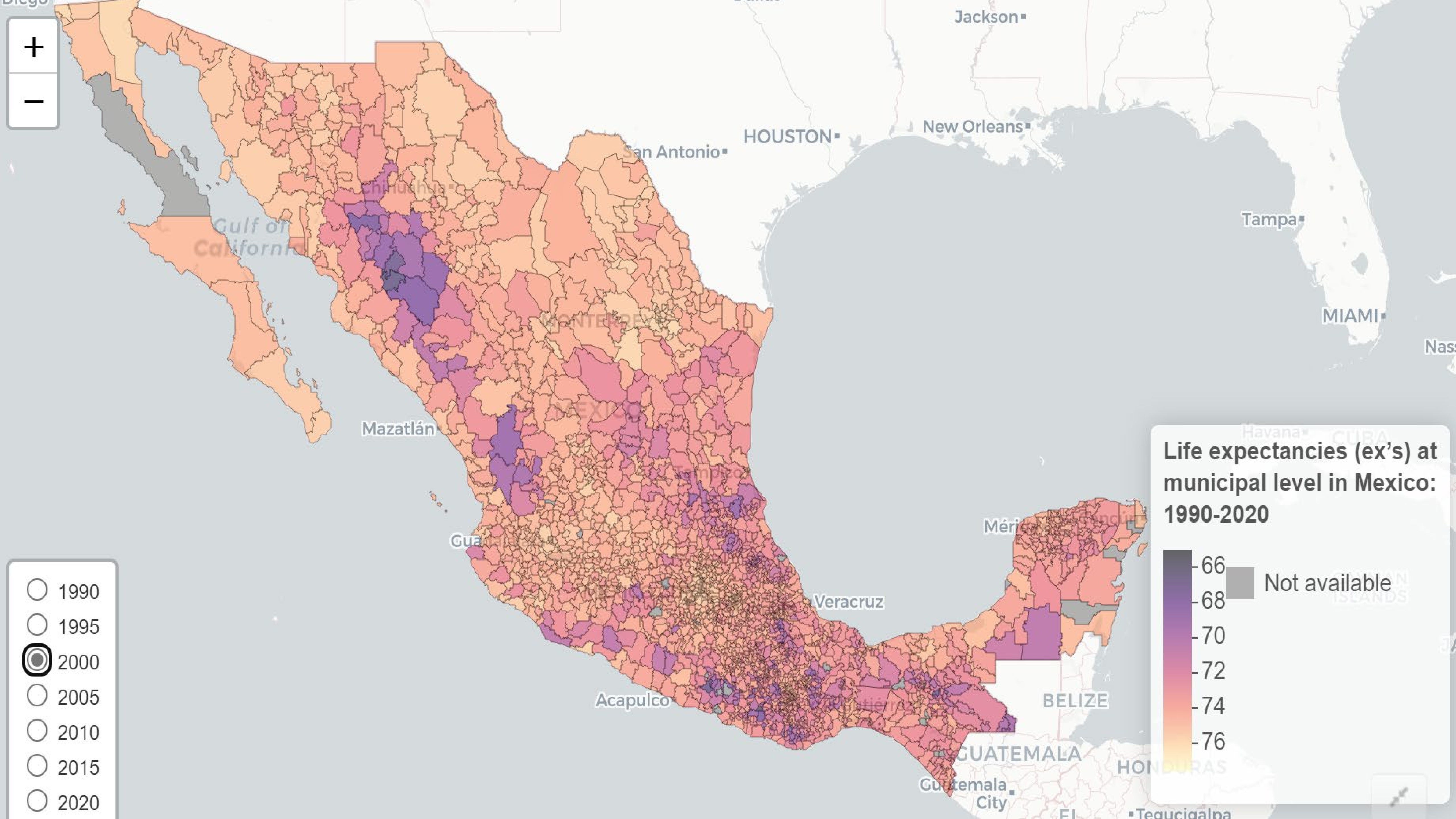
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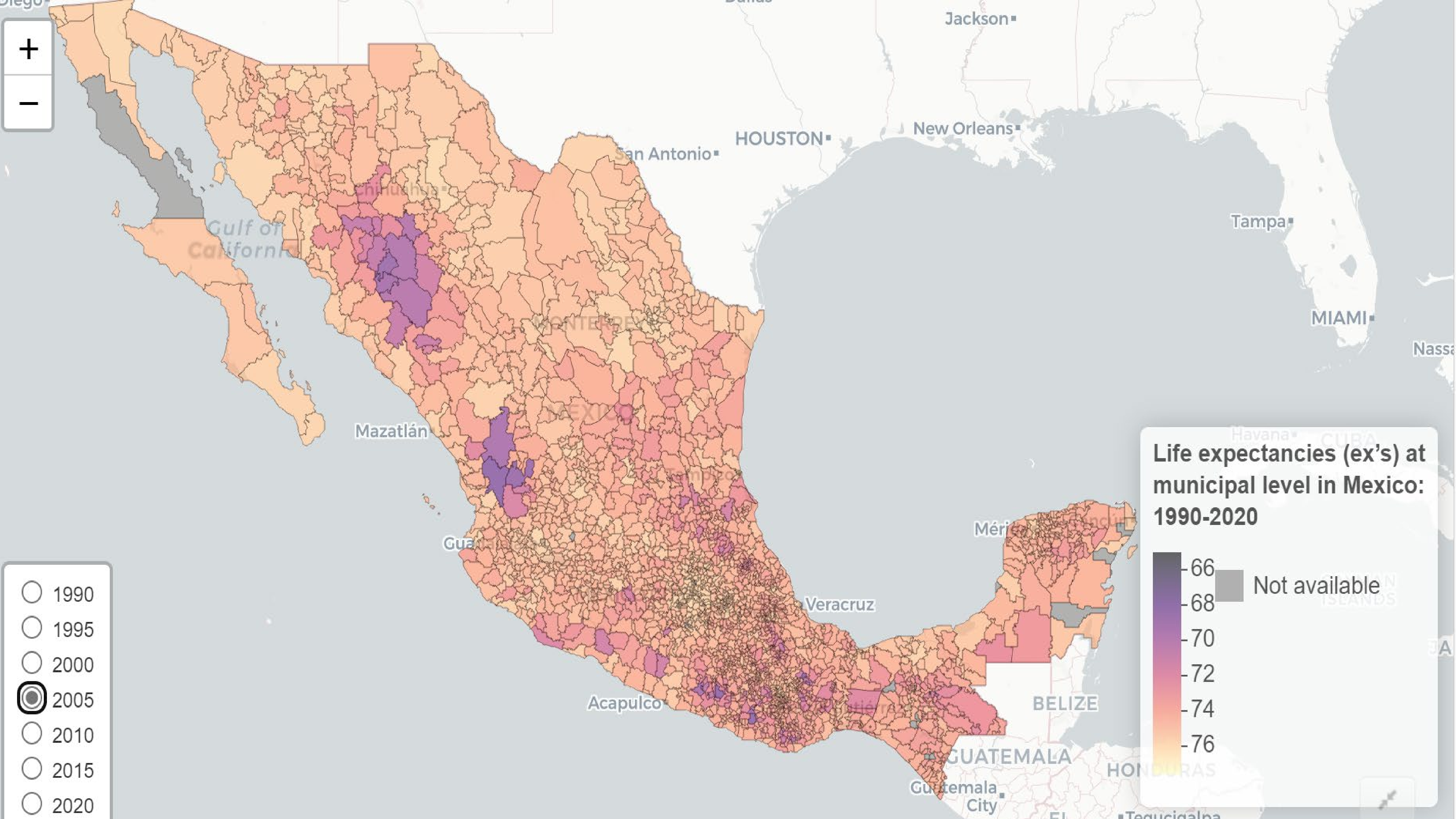

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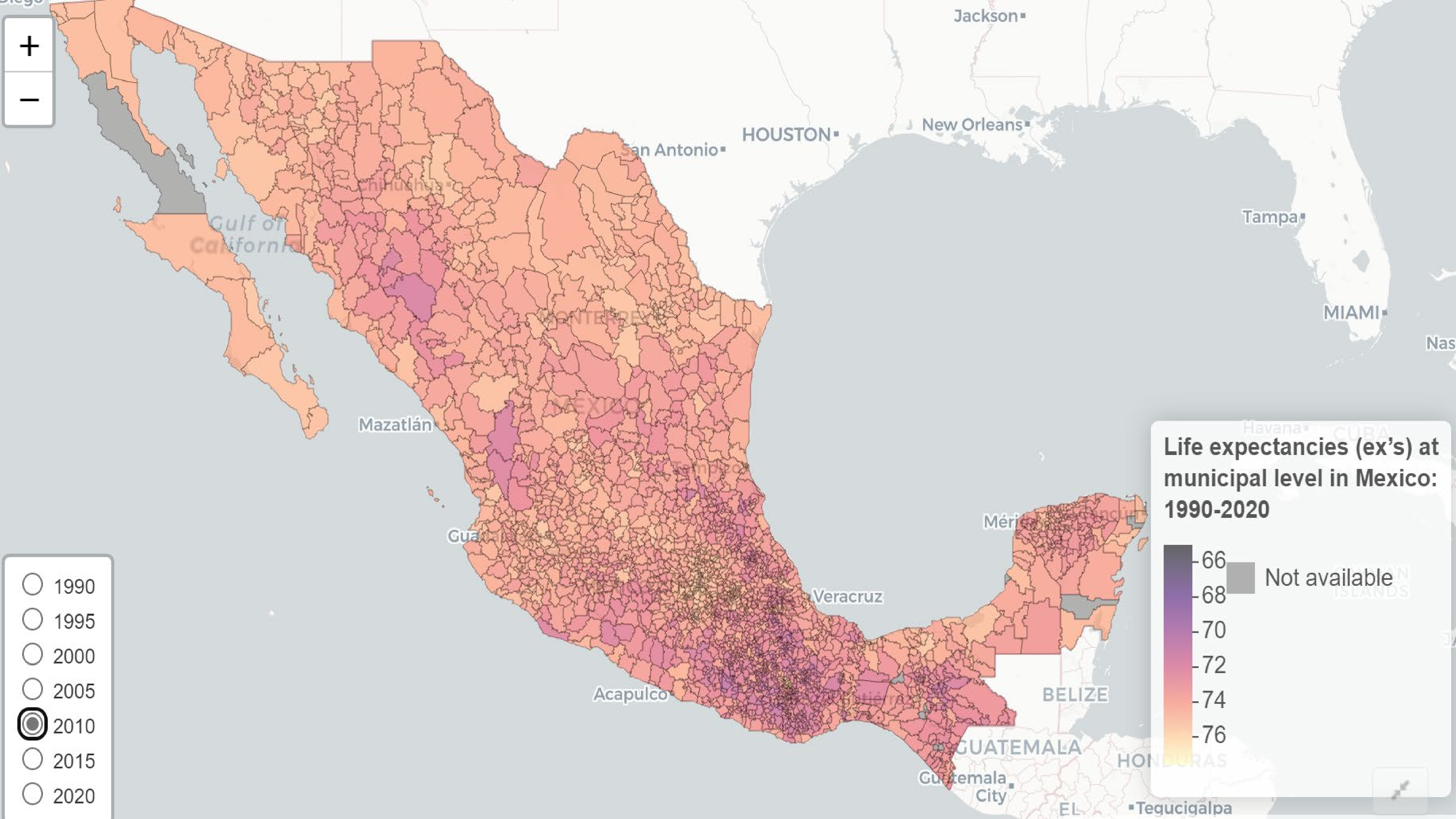
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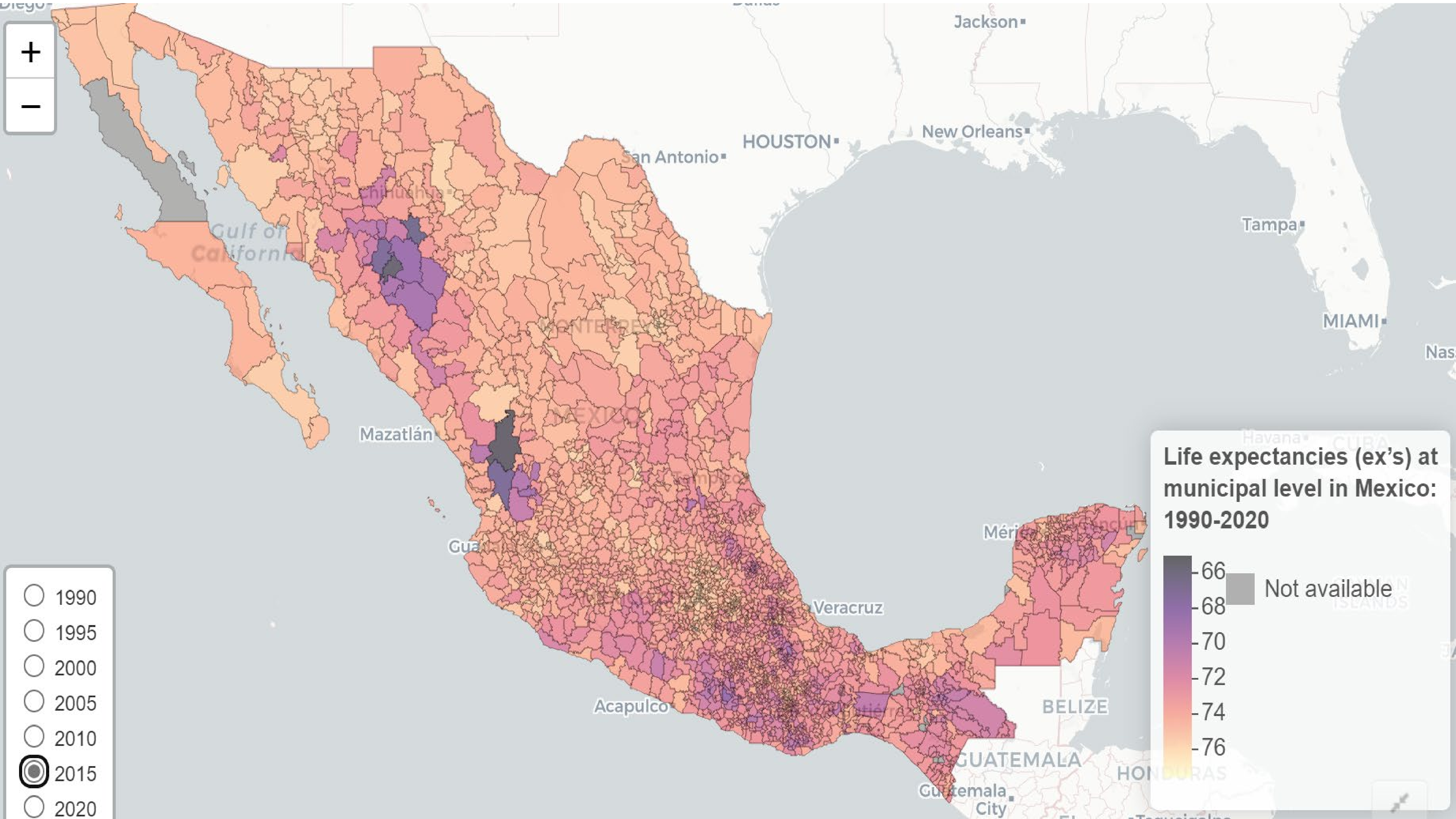

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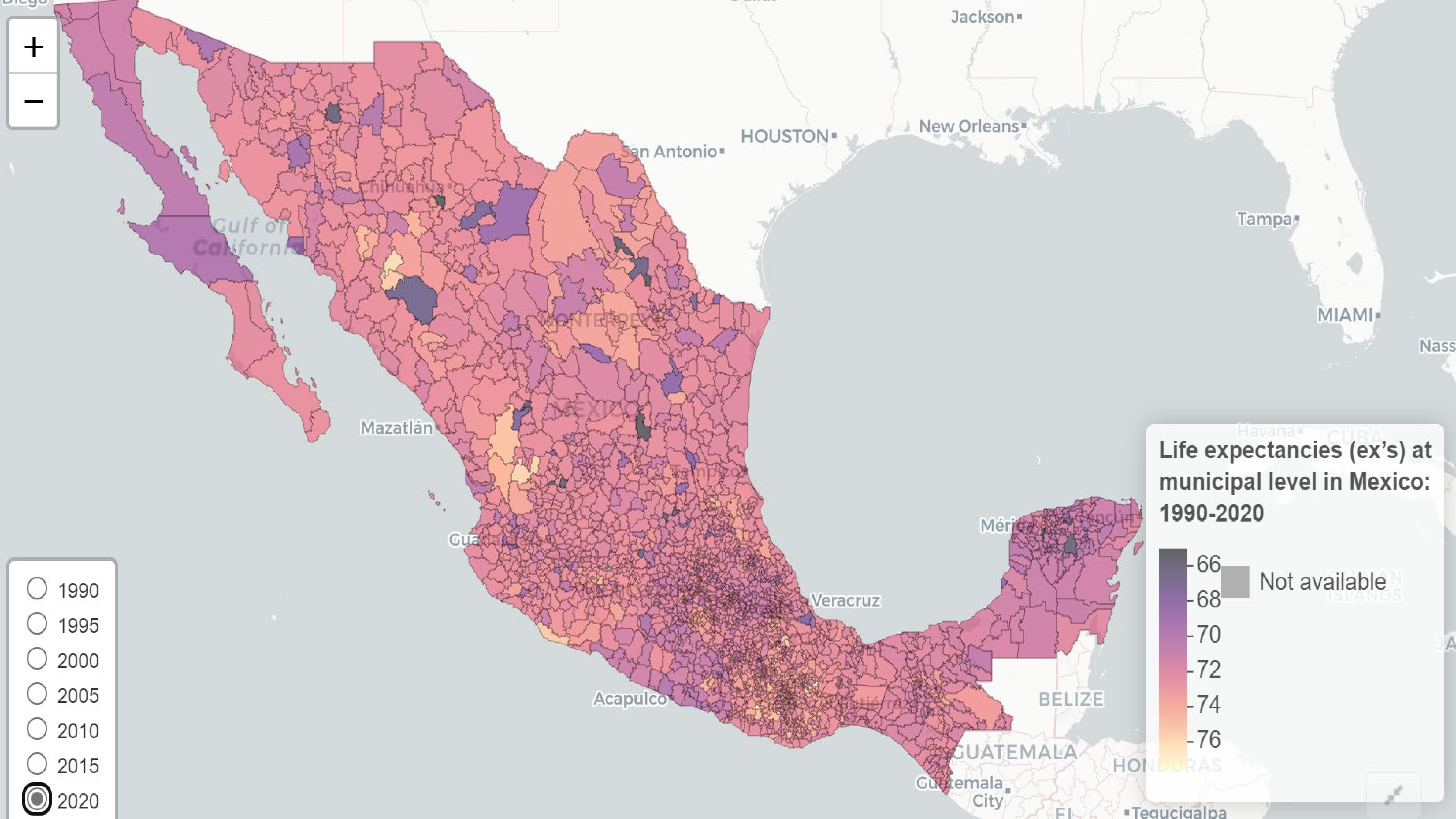

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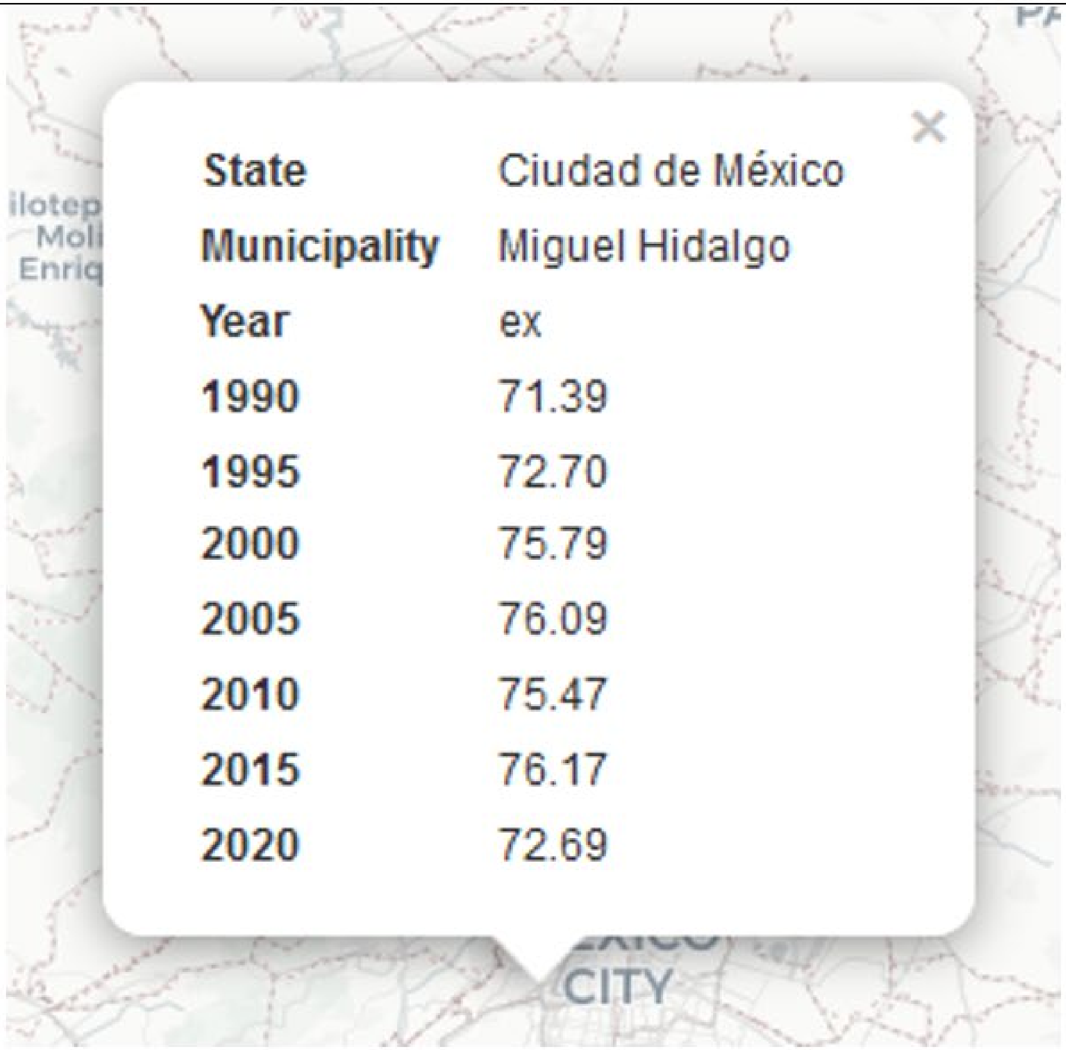
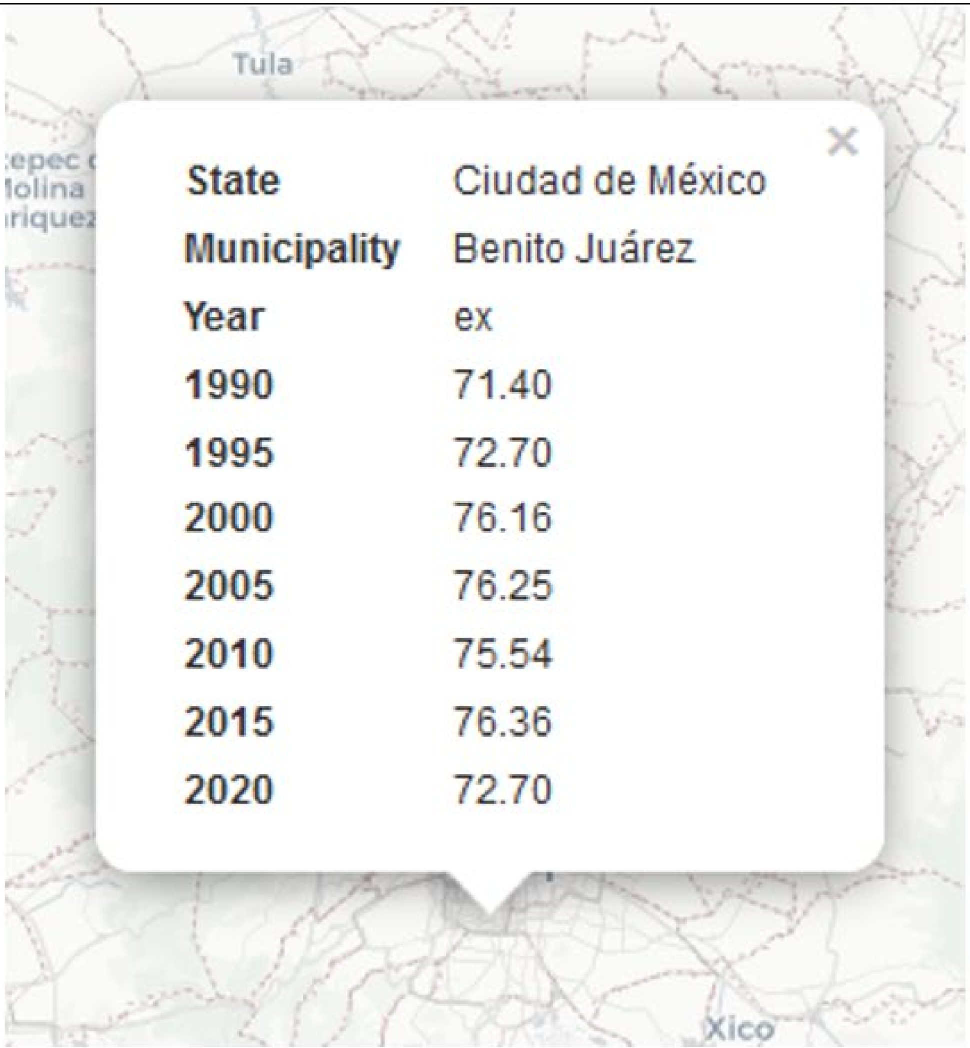
Results



State	Ciudad de México
Municipality	Miguel Hidalgo
Year	ex
1990	71.39
1995	72.70
2000	75.79
2005	76.09
2010	75.47
2015	76.17
2020	72.69



State	Ciudad de México
Municipality	Benito Juárez
Year	ex
1990	71.40
1995	72.70
2000	76.16
2005	76.25
2010	75.54
2015	76.36
2020	72.70

Conclusions

- Life expectancy is a crucial index that summarizes mortality across space and time.
- It is valuable because it can be helpful to decision-makers, allowing them to formulate public policies that can mitigate inequalities and poverty, among other adverse circumstances.
- Furthermore, its availability at the municipal level (or deeper) is significant, objective information can support the need to implement any emergent program in a specific space.
- The exposited strategy to estimate life expectancy at the municipal level is an asset in itself. It suggests how to disaggregate life expectancy at a deeper level from other researchers or statistics offices from Latin America or developing countries.
- Finally, an interpolation may represent an alternative for obtaining annual figures for states and municipalities.

Basic references

- CONAPO (2018). Proyecciones de la Población de México y de las Entidades Federativas 2016-2050. https://datos.gob.mx/busca/dataset/proyecciones-de-la-poblacion-de-mexico-y-de-las-entidades-federativas-2016-2050. And http://portales.segob.gob.mx/work/models/Derechos_Humanos/excel/Esperanza_de_vida_al_nacer.xlsx

- Conceição, P. (2020). Human Development Report 2020-The Next Frontier: Human Development and the Anthropocene. United Nations Development Programme.

- García-Guerrero, V. M., and Beltrán-Sánchez, H. (2021). Heterogeneity in excess mortality and its impact on loss of life expectancy due to COVID-19: evidence from Mexico. Canadian Studies in Population, 48(2-3), 165-200.

- Paredes, I., and Silva, E. (2017). Estimación de la esperanza de vida a nivel municipal y por marginación sociodemográfica: una aplicación del método de Swanson para el caso de México, 2010. Estudios Demográficos y Urbanos, 32(1), 97-129.

- Swanson, D. A. (1989). A state-based regression model for estimating substate life expectancy. Demography, 26(1), 161-170.