Science Talks 8 (2023) 100271

Contents lists available at ScienceDirect

Science Talks

journal homepage: www.elsevier.es/sctalk

Water Shortage Risk Index (WSRI) at the neighbourhood scale. The case of Mexico City

Armando Cepeda Guedea [a,*], Carmelina Bevilacqua [b]

[a] Università degli Studi Mediterranea, 89100 Reggio Calabria, Italy
[b] Sapienza Università di Roma, 00196 Rome, RM, Italy

ARTICLE INFO

Keywords:
Water shortage
Neighbourhood scale
Mexico City
Distance method
Urban marginalization

ABSTRACT

Water security is one of the main challenges that cities around the world face especially in Megalopolis such as Mexico City that struggle to provide safe and accessible fresh water to their inhabitants. The research project presents a Water Shortage Risk Index at the neighbourhood scale for Mexico City. The index is built into four main factors which are social, infrastructure, environment and innovation each of them with their respective levels. Each neighbourhood is compared to a synthetic neighbourhood that holds the ideal values for water security in urban contexts. The bigger the distance to the ideal synthetic neighbourhood the bigger the risk of water shortage in the neighbourhood. Once obtained the Water Shortage Risk Index it is compared with the already existing Urban Marginalization Index to obtain the most vulnerable neighbourhoods in Mexico City providing the areas that require the most attention in future water security projects and policies. The research aims to contribute to further exploring water shortage management at the neighbourhood scale that will allow local governments to implement more efficient projects and policies to reduce water shortage risk in Mexico City.

Video to this article can be found online at https://doi.org/10.1016/j.sctalk.2023.100271.

* Corresponding author.
E-mail address: armando.cepeda@unirc.it (A. Cepeda Guedea).

http://dx.doi.org/10.1016/j.sctalk.2023.100271
Received 10 August 2023; Received in revised form 4 September 2023; Accepted 7 September 2023

Figures and tables

Table 1
The main drivers for water shortage identified for Mexico City and the typology they are associated.

Drivers	Typology of Water Shortage
1. Climate Change	Availability
2. Droughts	
3. Overexploitation of water sources	
1. Pollution of water sources	Quality
2. Poor quality of recycled water	
1. Overwhelmed infrastructure	Accessibility
2. Marginal areas without water infrastructure	

Table 2
Identified factors associated with water shortage in Mexico City with their respective levels.

Factor	Level	Literature support
Social	Population density	Maria José de Sousa Cordao et al. [3]
	Daily water consumption	Maria José de Sousa Cordao et al. (2020), Field work [4]
	Industrial units	Walker et al. [1], Field work (2022)
	Monthly income	Maria José de Sousa Cordao et al. (2020)
Infrastructure	Reported pipe leaks	Maria José de Sousa Cordao et al. (2020)
	% People without water service	INEGI [5], Fieldwork (2020), OECD [2]
	Bulk water delivery	INEGI (2020), Fieldwork (2020)
Enviroment	Reported potable water contamination	Walker et al. [1], OECD [2], L.S Pereira et al. [6]
	Drought risk	Walker et al. [1], OECD [2], L.S Pereira et al. (2009)
Innovation	Rainwater collection units	Walker et al. [1], UNESCO [7]

Table 3
Ideal values for water security in urban contexts for Mexico City.

Level	Ideal value
Population density	15,000 inhabitants per km2
Daily water consumption	150 Litres per day
Industrial units	0
Monthly income	5000–7000 USD
Reported pipe leaks	0
% People without water service	0
Bulk water delivery	0
Reported potable water contamination	0
Drought risk	5 (no concern)
Rainwater collection units	0.25 per inhabitant

Table 4
Water Shortage Risk Index for Mexico City ranges. Every observed value (O) was contrasted with an ideal value (I) within each level, giving Delta as a result: $\mathbf{\Delta} = |\mathbf{O} - \mathbf{I}|$. The ratio will be calculated between the Delta for each neighbourhood, and the summatory of all the deltas for a given level. Hence, the ratio $\mathbf{r_i}$ for each neighbourhood will be calculated by: $\mathbf{r_i} = \frac{\Delta_i}{\Delta_T}$. Once $\mathbf{r_i}$ is calculated within the levels, it is added and grouped by factors, which gives us the value of $r_{social}, r_{infrastructure}, r_{envirnonment}$ and $r_{innovation}$ for each neighbourhood. Then, these $\mathbf{r}$ values are added and summarized into: $R_i = r_{social} + r_{infrastructure} + r_{envirnonment} + r_{innovation}$. Then R_i is divided by 10 levels to transform it into $\overline{R}_i$ which is the index from which the neighbourhoods were ranked $\overline{R}_i = \frac{R_i}{10}$. For the ranking, the $\overline{R}_i$ for each neighbourhood is compared with a proposed normal distribution for which the values of μ and σ were calculated in an ideal scenario for the population. That is why $= \frac{1}{N}$, where N equals the number of the 1759 analyzed neighbourhoods. As it is a normal distribution, and none of our values can be less than zero, the Standard Score formula was used to identify the standard deviation that characterizes the proposed distribution: $Z = \frac{x - \mu}{\sigma}$. Where: $Z = -3.99$, $x = 0$, $\mu = \frac{1}{N} = 0.000568$ and $\sigma =$ Unknown. By solving the equation of the ideal normal population distribution curve, the values of μ and σ were obtained.

Risk level	from	to
Very low risk ($\mu < -2\sigma$)	0.000143	0.000285
Low risk ($-1\ \sigma > \mu > -2\sigma$)	0.000285	0.000427
Moderate risk ($\mu + -1\sigma$)	0.000427	0.000711
High Risk ($1\sigma < \mu < +2\sigma$)	0.000711	0.000853
Highest risk ($\mu < +2\sigma$)	0.000853	0.000995

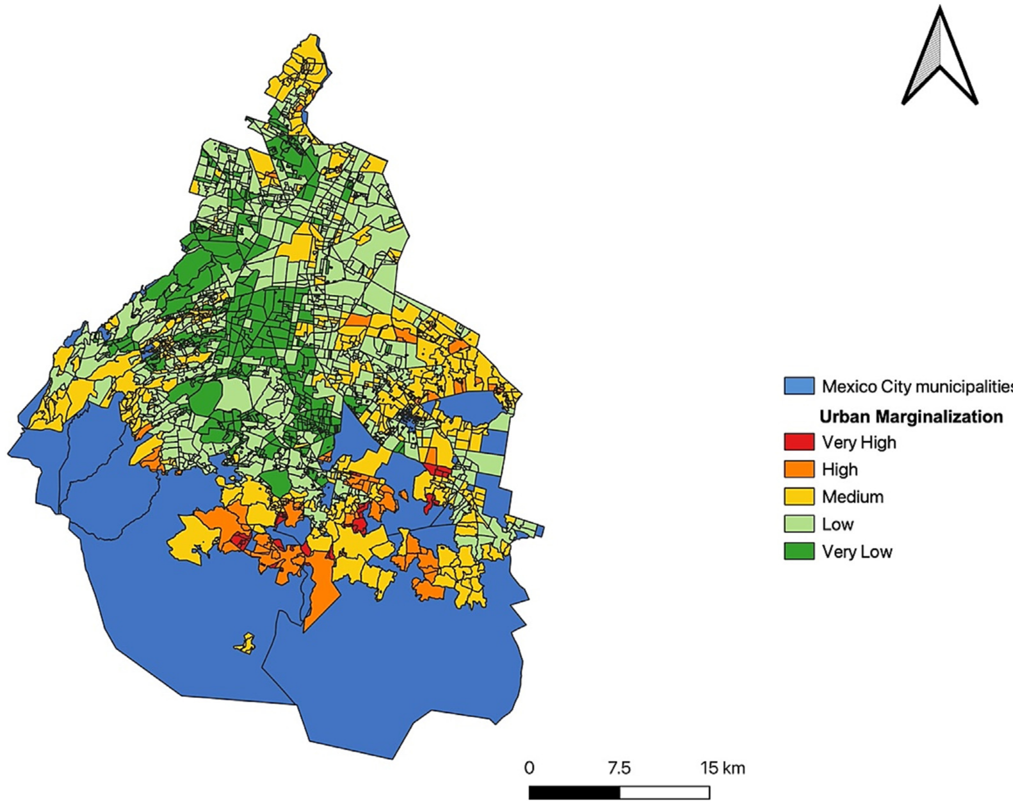

Fig. 1. Map of Urban marginalization at the neighbourhood level in Mexico City in 2020. This Index is obtained based on the distance method by Pena Trapero [8]. The evaluated factors are related with education, income and accessibility to services. The most vulnerable areas are located in the peripheries of the city.

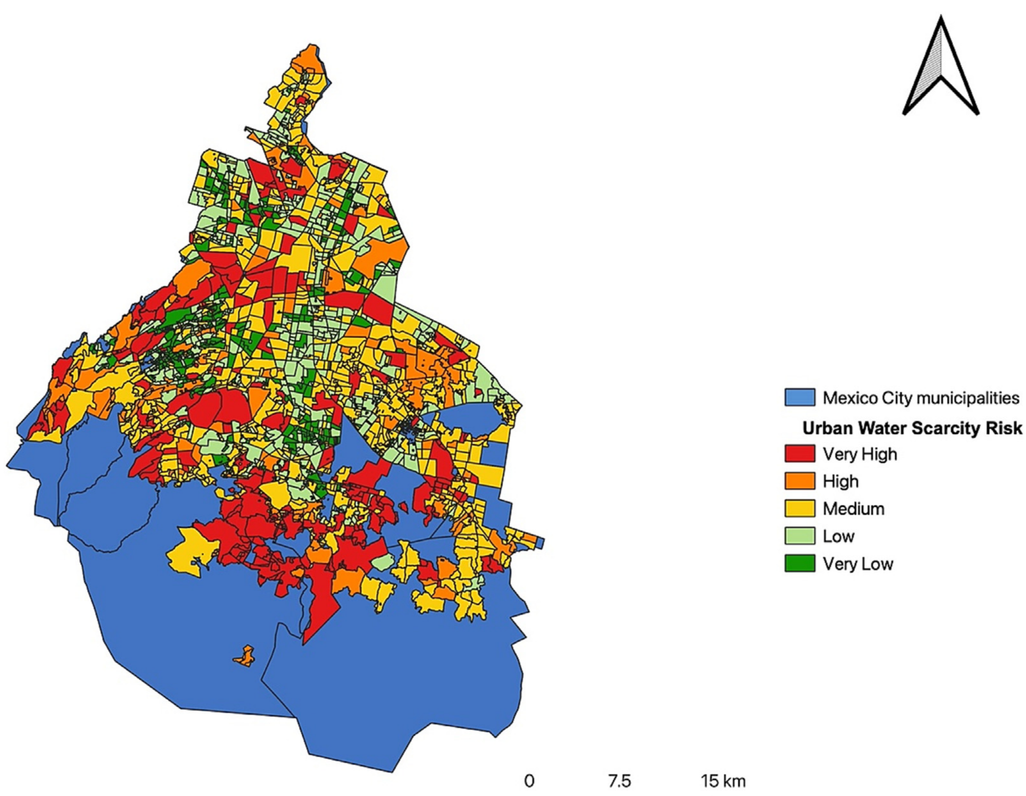

Fig. 2. Water Shortage Risk Index for Mexico City. This Index is obtained based on the distance method by Pena Trapero (1977). Each neighbourhood is compared with a synthetic ideal neighbourhood regarding water security. The distance of the neighbourhood to the ideal one determines the levels of risk.

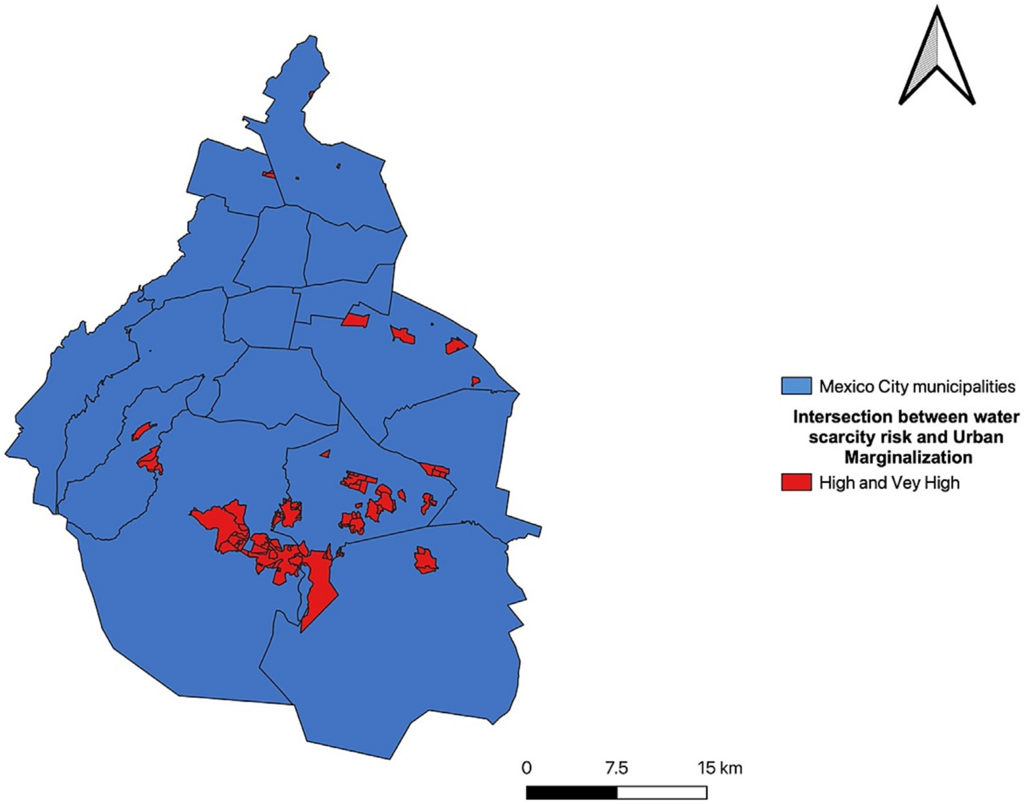

Fig. 3. Identified vulnerable neighbourhoods in Mexico City where water shortage intersects with urban marginalization.

CRediT authorship contribution statement

Armando Cepeda Guedea: Conceptualization, Methodology, Writing – review & editing. **Carmelina Bevilacqua:** Supervision.

Data availability

The authors are unable or have chosen not to specify which data has been used.

Acknowledgements

This research work is the result of the synergetic activity of the TREnD (Transition with Resilience for Evolutionary Development) Project which has received funding from the European Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreements No. 823952 (TREND) and the SOUND (Smart Open Urban-rural iNnovation Data) Project that has received funding from the Italian Minister of University and Research (MIUR) under the PRIN—Progetti di Ricerca di Rilevante Interesse Nazionale Bando 2017 grant no. 2017JMHK4F.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] T. Walker, et al., Water Risk and Its Impact on the Financial Markets and Society, Palgrave Studies in Sustainable Business In Association with Future Earth, 2021, https://doi.org/10.1007/978-3-030-77650-3_1.
[2] OECD, Water Security for Better Lives, OECD Studies on Water, OECD Publishing, 2013, https://doi.org/10.1787/9789264202405-en.
[3] Maria José de Sousa Cordão, Iana Alexandra Alves Rufino, Priscila Barros Ramalho Alves & Mauro Normando Macêdo Barros Filho, Water shortage risk mapping: a GIS-MCDA approach for a medium-sized city in the Brazilian semi-arid region, Urban Water Journal, 17:7, 642-655, https://doi.org/10.1080/1573062X.2020.1804596
[4] Armando Cepeda Guedea, Field Work in Mexico City, Conducted by Armando Cepeda Guedea, 2022
[5] Mexican National Institute of Statistics and Geography, Índice de marginación urbana 2020 Nota técnico-metodológica, INEGI (2020).
[6] Luis Santos Pereira, Ian Cordery, Iacovos Iacovides, Coping with Water Scarcity, Springer, Dordrecht, 2009, https://doi.org/10.1007/978-1-4020-9579-5.
[7] UNESCO World Water Assessment Programme, The United Nations world water development report 2020: water and climate change, UNESCO, 2020.
[8] Jesus Pena Trapero, Problemas de la medición del bienestar y conceptos afines. Una aplicación al Caso Español, Spanish National Statistics Institute, 1977.

Further reading

[1] Manfred Kühn, Peripheralization: theoretical concepts explaining socio-spatial inequalities, Eur. Plan. Stud. 23 (2) (2015) 367–378, https://doi.org/10.1080/09654313.2013.862518.
[2] Hlavinek, T. Kukharchyk, I. Mahrikova, C. Popovska, Risk Management of Water Supply and Sanitation Systems, Springer, Netherlands, 2009.
[3] M. Majumder, Impact of Urbanization on Water Shortage in Face of Climatic Aberrations, SpringerBriefs in Water Science and Technology, https://doi.org/10.1007/978-981-4560-73-3_1.

[4] B. Fields, J.L. Renne, Adaptation urbanism and resilient communities: Transforming streets to address climate change, Adaptation Urbanism and Resilient Communities: Transforming Streets to Address Climate Change, Taylor and Francis Inc., 2021, https://doi.org/10.4324/9780429026805.
[5] Secretaria de Gobernacion, Índice de Marginación Urbana 2020 Nota Técnico-Metodológica, Secretaria De Gobernacion, Mexican Government, 2020.

Armando Cepeda Guedea is a PhD candidate at the Mediterranean University of Reggio Calabria with research periods at KU Leuven (Belgium), Northeastern University (USA), and Louisiana Tech (USA). His fields of study are water management and security, green infrastructures and urban transitions in peripheral contexts. His research has been presented in Mexico, the United States and Italy.

Carmelina Bevilacqua Is an Associate Professor at the Sapienza University of Rome and Horizon 2020 EU TREND research project coordinator. She has been the coordinator of multiple research projects for the European Union. Her research intertest are Urban Regeneration, European Cohesion Policy, Sustainable Urban Development and Community and City Planning.