https://doi.org/10.5194/egusphere-2026-678
Preprint. Discussion started: 12 February 2026

Brief communication: Drought economic assessments must include human health impacts

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Abstract. The economic valuation of drought-related health interventions reveals that ensuring groundwater access during severe droughts could avert significant losses in Northeast Brazil. Estimated benefits from reduced diarrhea hospitalizations and mortality total 9.92% of local GDP. When scaled to state level, avoidable losses may reach USD 1.15 billion, which are comparable to the economic drought's impacts on productive sectors, such as agriculture, livestock, and industry, underscoring the macroeconomic relevance of investing in resilient water infrastructure in a health-promoting perspective.

1 Introduction

Numerous studies underline the economic impacts of droughts, highlighting losses experienced in productive sectors, such as agriculture, industry, energy production, and navigation (Naumann et al., 2021; Mishra et al., 2025). Surprisingly, economic consequences of droughts for human health have not been widely reported (Schmitt et al., 2016; Fleming-Muñoz et al., 2023; Sarmiento et al., 2023). Apart from costs of medical treatment, a blind spot seems especially present with regard to the economic benefits of implementing salutogenic (i.e., health-promoting) protective measures against human-health effects of drought, such as equipping poor communities with alternative drinking-water supply systems (Costa et al., 2025).

Recent analysis of secondary data and hydro-epidemiological modelling showed that groundwater access reduced diarrhea hospitalizations during severe drought (2012–2020) in part of the drought-affected drylands of Northeast Brazil (De Sousa et al., 2025). In this study, using this model, we estimated the number of diarrhea hospitalizations averted by groundwater access during the severe drought. Then, we estimated the associated economic benefits, adjusting values for 2025, using secondary health data and supporting literature. Finally, we translated our findings to a much larger drought-affected region. This allowed

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us to estimate the economic costs of not having non-interrupted access to clean water during the recent period of drought (2012–2020).

2 Materials and Methods

2.1 Study area and data availability

The study of was conducted in the state of Ceará (Figure 1), where 90% of the territory lies within Brazil's semi-arid region. The state of Ceará is home to over 9 million people, distributed across 184 municipalities, and is dependent on scarce water resources. Since 2012, the population of this region has been affected by the most severe drought to be recorded in Northeast Brazil. This drought has highlighted the need for large-scale water supply and public health measures to overcome the impact of drought-related waterborne diseases, such as diarrhea (Costa et al., 2025).

The Brazilian Ministry of Health publishes data on the number of diarrhea hospitalizations, days of hospitalization, hospitalization costs, and hospitalization mortality at municipality and monthly scales for the whole Brazil (Ministério da Saúde, DATASUS, 2025).

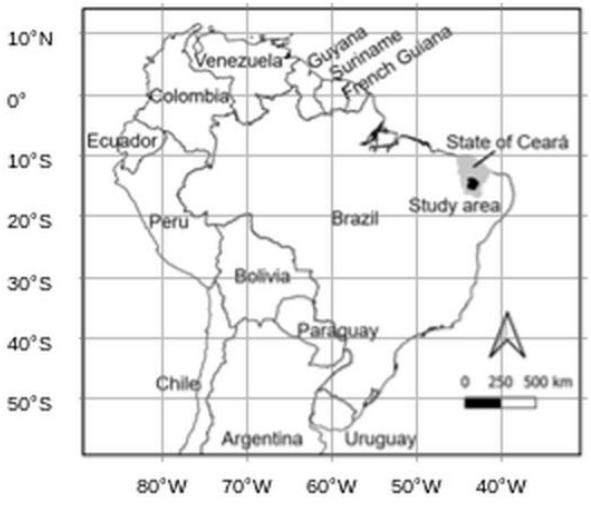

Figure 1: Location of the study area.

2.2 Hydro-epidemiological modelling

De Souza et al. (2025) adjusted a hydro-epidemiological modelling for ten municipalities in Ceará (the black-coloured region in Fig. 1), in which the diarrhea hospitalizations' rate (CP) was a function of both groundwater access and drought severity. This modelling was based on a multiple linear regression model (Eq. 1; $R^2_{adj.} = 0.75$; $p < 0.01$). They considered the number

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of groundwater-use licenses for drinking water (GWL) as a measure of groundwater access whereas drought severity was estimated by drought duration (DD) and magnitude (DM), using a drought index.

$$CP = -0.423 \cdot GWL + 0.590 \cdot DD - 1.075 \cdot DM \quad (1)$$

GWL (95% CI: −0.841, −0.001; $t = -2.48$; $p < 0.05$), DD (95% CI: 0.085, 1.095; $t = 2.861$; $p < 0.05$) and DM (95% CI: −1.581, −0.569; $t = -5.197$; $p < 0.01$) were significant predictors in the model (Eq. 1), showing values of variance inflation factor smaller than 2.5, suggesting that there was weak collinearity among covariates. During a recent long-lasting period of drought (2012-2020), the hydro-epidemiological modelling revealed that access to groundwater was associated with fewer hospitalizations, while prolonged but less severe droughts were linked to increased hospitalizations. The magnitude of the drought had an approximately twofold greater impact, in absolute terms, than drought duration or groundwater access. Nevertheless, access to groundwater remained a critical factor in counteracting the health impacts of drought, particularly in reducing diarrhea-related hospitalizations in the studied municipalities.

2.3 Economic valuation of avoided morbidity and mortality

In this study, using the hydro-epidemiological modelling, we estimated the number of diarrhea hospitalizations averted by groundwater access for the ten studied municipalities, during the severe drought. Given the reported mortality rate of diarrhea hospitalizations (Ministério da Saúde, DATASUS, 2025), we could also estimate the average number of deaths averted. Then, with the number of diarrhea hospitalizations averted, the economic valuation of avoided morbidity was carried out taking into account (a) the average diarrhea hospitalization cost (Ministério da Saúde, DATASUS, 2025), and (b) the absence in workplace due to adult hospitalizations, but also to assist children and elderly in the hospitals, based on days of hospitalization and an average income equal to minimum wage in Brazil. Finally, with the number of the deaths averted, the economic valuation of avoided mortality was based on the average Brazilian value of statistical life (Stivali, 2024). We also translated the economic estimates for these specific municipalities to a much larger drought-affected region, covering the whole state of Ceará, assuming similar economic and drought conditions, which allows a broader estimation of the economic costs of not having non-interrupted access to clean water during the recent period of drought (2012–2020).

3 Results and discussion

3.1 Health and economic impacts of groundwater access during drought

During the severe drought, we estimated that the average number of diarrhea hospitalizations averted would be 3,822 (95% CI: 2,180–5,482; $p < 0.05$) by groundwater access. Since the reported mortality rate of diarrhea hospitalizations is equal to 1.64%, the average number of deaths averted is 63 (95% CI: 36–90; $p < 0.05$). The economic benefits from averted hospitalizations are USD 0.31 million (95% CI: USD 0.18–0.45 million; $p < 0.05$), considering a diarrhea hospitalization cost of USD 80.64. The economic benefits from averted deaths are USD 68.67 million (95% CI: USD 39.24–98.10 million; p <

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0.05), considering the average Brazilian value of statistical life of USD 1.09 million. Moreover, we could estimate an economic benefit of USD 0.12 million (95% CI: USD 0.07–0.18 million; $p < 0.05$) due to the absence in workplace.

3.2 Upscaling regional health impacts to the state level

Therefore, the total economic benefit of the reduction of diarrhea hospitalizations by groundwater access during the studied severe drought is USD 69.10 million (95% CI: USD 39.49–98.73 million; $p < 0.05$), which is equivalent to 9.92% of GDP of the ten studied municipalities (Instituto Brasileiro de Geografia e Estatística, 2021). Since 63% of the municipalities have experienced drinking water shortage during the worst period of the drought (Costa et al., 2025), we assumed there was a potential economic loss for 116 municipalities in the state of Ceara alone (63% of 184 municipalities in total), because of avoidable diarrhea hospitalizations by implementing non-interrupted access to clean water, such as groundwater access. Considering a loss like the impact found previously for the sample of ten municipalities, the estimated economic loss for the whole state of Ceara would be USD 801.60 million (95% CI: USD 458.07–1,145.28 million; $p < 0.05$), which is equivalent to 2.15% of state's GDP (Instituto Brasileiro de Geografia e Estatística, 2021).

3.3 Conservative nature and limitations of the estimates

It is important to acknowledge that our economic estimations represent a conservative assessment, as they are necessarily bounded by data availability and methodological scope. The calculated benefits focus on direct, quantifiable costs associated with averted hospitalizations, lost productivity from caregivers, and the statistical value of lost lives. However, they do not capture other significant indirect and intangible additional economic impacts. These unaccounted effects include productivity losses from individuals missing work or education due to non-hospitalized illness, the long-term economic burden of psychological distress and its impact on workforce participation, and the costs associated with permanent or temporary migration away from affected areas. Consequently, the total economic impact of drought, considering these broader societal disruptions, is likely substantially greater than the values reported here. Furthermore, the translation of impacts from ten municipalities to the entire state, while informative, assumes a uniformity of effect that may not fully reflect local socioeconomic and infrastructural heterogeneities.

4 Final considerations

The findings present huge economic impacts from the implementation of water-supply-based protective measures related to diarrhea hospitalizations during severe droughts, which is comparable to economic drought's impacts on productive sectors in the same large dryland region (Ministério do Desenvolvimento Regional, 2024; Fig. 2). Furthermore, these findings suggest that this topic should be investigated broadly and deeply to improve our understanding of the economic effects of drought in relation to the health sector, which could support investment decision making in water and sanitation policies in underdeveloped drought-affected drylands.

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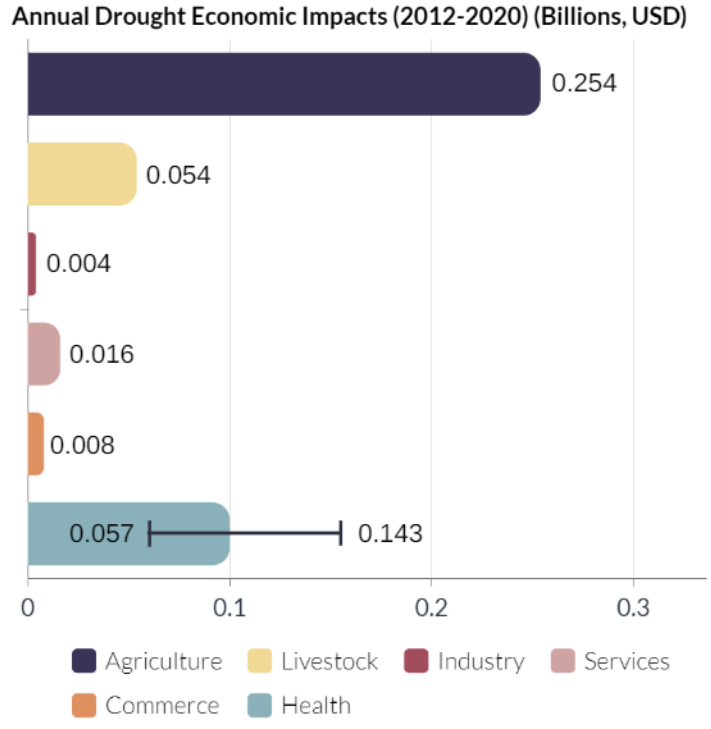

Figure 2: Annual drought economic impacts on productive sectors (agriculture, livestock, industry, services, and commerce) and on the health sector related to diarrhea hospitalizations in the state of Ceara, 2012–2020.

Data availability

Data can be made available upon request.

Author contributions

Writing: ACC, FGFS, PRO. Conceptualization, methodology, data collection and analysis: ACC, FGFS, RPM, PRO. All authors were involved in the reviewing and editing process.

Competing interests

The contact author has declared that none of the authors has any competing interests.

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Acknowledgements

This research was funded by the Dutch Research Council (NWO) and the National Council for Scientific and Technological Development from Brazil (CNPq).

Financial support

This study was supported by grants CNPq (reference numbers 402514/2021–1; 406348/2025–1; 302409/2022–0; 306380/2023–4), and from NWO (reference number W 07.30323.007).

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