Brief communication: Drought economic assessments must include human health impacts

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Abstract. Drought economic assessments tend to focus on productive sectors, such as agriculture, livestock and industry, while providing limited attention to human-health effects of drought. 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, 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 us to estimate the economic costs of having 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). However, its database, called DATASUS, can compromise uncertainties due to dependence on filling out of forms in the executing hospitals, which generates the possibility of bias in the reporting of information, with a probability of including multiple or wrong diagnoses in the database, in addition to the risk of underreporting (Viana et al., 2023). Despite these uncertainties, DATASUS remains a valuable, large-scale source for observational studies when the research results are treated with caution in a conservative manner.

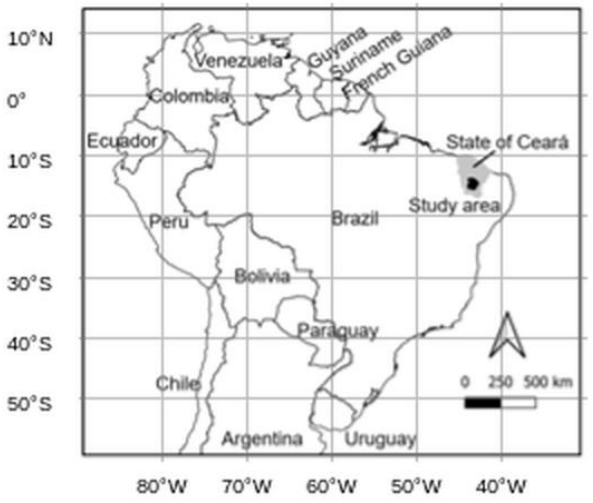

Figure 1: Location of the study area.

2.2 Hydro-epidemiological modelling

With the aim to analyze the impact of severe drought and groundwater access on water security and the prevalence of diarrhea-related hospitalizations in a large tropical semi-arid region of Brazil, De Souza et al. (2025) adjusted a hydro-epidemiological modelling for ten municipalities in Ceará (the black-coloured region in Fig. 1), which have similar socio-economic and sanitation infrastructure comparing to other municipalities of the same large dryland region. The studied municipalities belong to the same health administrative superintendency region and have a rather variable amount of groundwater use for human consumption, ranging from 0.03% to 99.63% of total water for this end (De Souza et al., 2025).

In this hydro-epidemiological modelling, 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 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. The time horizon of the targeted and explanatory variables was the whole meteorological drought (2012-2017) and drought recovery (2018-2020) period prior to the covid-19 pandemic outbreak in Ceará state. Therefore, the values of the variables were accumulated over 2012-2020.

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

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 having 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; $p < 0.05$), 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; $p < 0.05$) cumulative over 2012-2020, 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).

These 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). Therefore, investments in reliable water supply are not only important for public health, but also highly relevant from a macroeconomic perspective, and that the true costs of drought are underestimated when health effects are excluded.

Moreover, these findings are likely be relevant to other drylands, where about 2 billion people live (UNNCD, 2017), because exposure to mild or severe drought is significantly associated with an increased diarrhea risk among children under five in 51 low- and middle-income countries, being stronger in dry zones (Wang et al., 2022).

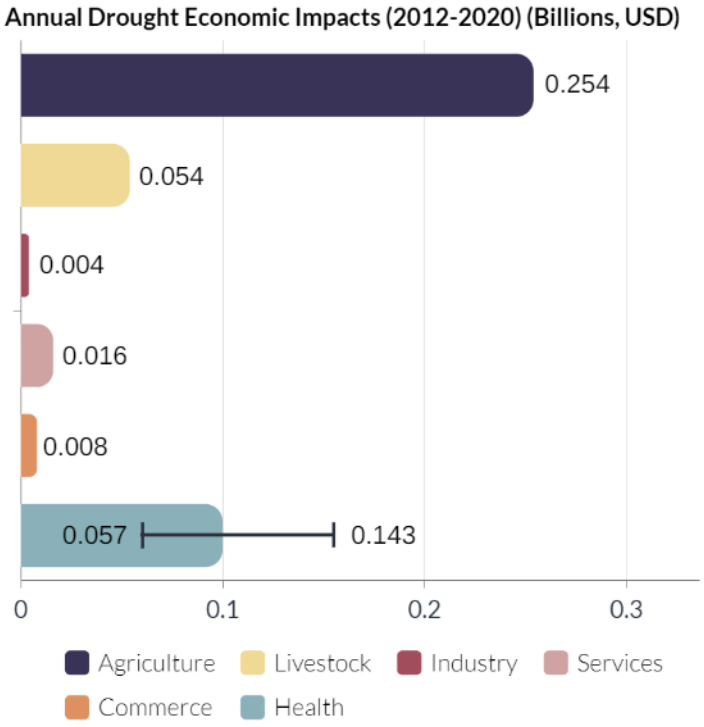

Figure 2: Annual drought economic impacts on productive sectors (agriculture, livestock, industry, services, and commerce) and on the health sector related to diarrhea hospitalizations in the state of Ceara, 2012–2020.

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, these broader societal disruptions might substantially contribute to a greater

economic impact of drought than the values reported here. On the other hand, in drought-affected and resource-constrained areas, some cases may not reach formal health facilities, which could lead to measurement error and potential underestimation of impacts. Furthermore, the translation of impacts from ten municipalities to the entire state under severe drought impacts (116 municipalities), while informative, assumes a uniformity of effect that may not fully reflect local socioeconomic and infrastructural heterogeneities, which may not be completely captured by sample size and selection. For instance, it is expected that municipalities serving with a much better sanitation coverage are more resilient against human-health effects of drought.

4 Final considerations

The 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. Moreover, there are many other drought-induced or drought-modified human health impacts, such as vector-borne, respiratory, and cardiovascular diseases (e.g. Moreira et al. 2020; 2024), which may also have relevant economic impacts and demand measures and policies far beyond the water management alone.

Data availability

The data used in this study are not publicly available because they were obtained by governmental institutions. Data may be made available upon reasonable 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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