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Drought Exposure and Household Drinking-Water Disruption in Arid and Semi-Arid Western India

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Additional Declarations:

Ethics approval and consent to participate

This study used secondary, de-identified data from the National Family Health Survey-5 (NFHS-5). No primary data were collected for the present study, and no direct interaction with human participants was undertaken. Therefore, ethical approval and informed consent for the present analysis were not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The National Family Health Survey-5 (NFHS-5) household data used in this study are available through the Demographic and Health Surveys (DHS) Program, subject to the data-access requirements of the data provider. Interested individuals can access the data through the following portal by providing a brief description of the research objectives and methodology: https://dhsprogram.com/data/. The

Standardized Precipitation–Evapotranspiration Index (SPEI) data used to characterize drought exposure were accessed, processed, and downloaded free of cost through Google Earth Engine. The relevant SPEI dataset is available through the Google Earth Engine Data Catalogue.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AY conceptualized the study, conducted the data preparation and analysis, interpreted the findings, and drafted the manuscript. MJR provided supervision throughout the study, contributed to the interpretation of the findings, and critically reviewed and edited the manuscript. Both authors approved the final version of the manuscript.

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Abstract

Drought can compromise household water security by reducing water availability and placing additional pressure on water-supply systems, yet evidence linking objectively measured drought exposure with recent household-level disruption of drinking-water availability remains limited. This study examined the association between drought exposure and household drinking-water disruption in western India and assessed whether the association varied across residential, socioeconomic, and water-access contexts. Household-level data from the fifth round of the National Family Health Survey (NFHS-5), conducted during 2019–2021, were analysed for 56,555 households in Rajasthan and Gujarat. Drinking-water disruption was defined as the reported unavailability of water from the household's main drinking-water source for at least one day during the preceding two weeks. Drought exposure was derived from the Standardized Precipitation–Evapotranspiration Index (SPEI-01) and assigned at the survey-cluster level according to the month and year of interview. Survey-weighted logistic regression was used to estimate the association, complemented by analyses of predicted probabilities, effect modification, and selected subpopulations. Drought-exposed households had higher odds of reporting drinking-water disruption than households without drought exposure (adjusted OR 1.42, 95% CI 1.19–1.69), and the association persisted after adjustment for socio-demographic, socioeconomic, and water-system characteristics. Predicted probabilities showed a corresponding increase in the likelihood of disruption under drought exposure. The association was evident across several residential, social, wealth, and water-source subgroups, although formal interaction tests did not indicate statistically significant effect modification. These findings highlight household drinking-water continuity as an important dimension of climate-related water security and underscore the need to strengthen drought-responsive water-supply resilience in water-stressed regions.

Keywords: Climate variability; Household water insecurity; Water-supply reliability; Hydroclimatic extremes; Water resilience.

1 Background

Water security is increasingly recognized as a multidimensional component of climate vulnerability, encompassing not only the physical availability of freshwater but also its accessibility, reliability, safety, and continuity for household use (Jepson et al. 2017; Wutich et al. 2017). Climate variability and anthropogenic climate change are altering precipitation regimes, temperature, evapotranspiration, and the frequency and intensity of hydroclimatic extremes, thereby increasing pressure on water resources and water-supply systems (Singh and Kumar 2015; Madhusoodhanan et al. 2016). Drought is particularly consequential because sustained deficits in precipitation and available water can reduce surface-water storage, constrain groundwater recharge, and intensify competition for increasingly limited water resources (Nistor et al. 2020). These climatic pressures can extend beyond reductions in physical water availability to affect the reliability and continuity of domestic water supplies, particularly where households depend on climate-sensitive sources or water systems with limited capacity to withstand environmental stress. Evidence from drought-affected settings indicates that household experiences of water insecurity may manifest through intermittent or unreliable supplies and are shaped by the capacity and organization of local water systems. (Mullin 2020; Egge and Ajibade 2023). Evidence synthesized across diverse settings demonstrates that seasonal variation in precipitation, temperature, and freshwater availability is associated with changes in household experiences of water adequacy, reliability, affordability, and safety, while prolonged drought remains comparatively understudied as a driver of household water insecurity (Broyles et al. 2022). Water insecurity can, in turn, generate broader social and health consequences by increasing the time and physical effort required to obtain water, constraining hygiene-related practices, disrupting livelihood activities, and increasing exposure to health risks (Tucker et al. 2014; Jepson et al. 2021b; Adams et al. 2022). Consequently, understanding how drought conditions translate into disruptions in household drinking-water availability is important for assessing climate-related water security and for designing resilient water-supply systems.

Evidence from drought-prone and water-stressed settings across different regions indicates that climatic and hydrological variability can be reflected in household experiences of water insecurity (Charilaou and Hussein 2026). In the semi-arid interior of Ceará, Brazil, household research conducted during the 2011–2017 drought documented multidimensional water insecurity, including water distress, water sharing, and supply intermittency, with distinct experiences across rural and urban households (Jepson et al. 2021a). Evidence from arid and semi-arid areas of eastern Africa similarly demonstrates that household water insecurity is shaped not only by climatic stress and water scarcity but also by the reliability of water infrastructure, accessibility of water sources, and socioeconomic conditions (Balfour et al. 2020; Ford et al. 2023; Njoroge et al. 2024). In northern Kenya, research among pastoralist households has documented substantial water insecurity in arid environments, where spatial and temporal variability in water availability interacts with livelihood

conditions and existing water-governance arrangements (Balfour et al. 2020; Ford et al. 2023). Research from the Ethiopian lowlands further shows that the reliability of water-supply infrastructure is closely related to household water-security experiences, highlighting the importance of functioning and dependable water systems in climate-stressed environments (Libey et al. 2022). Longitudinal evidence from rural Bangladesh has also demonstrated substantial seasonal variation in household water insecurity, including changes in water adequacy and interruptions in supply, underscoring the importance of temporal variability in understanding household water experiences (Broyles et al. 2023). Collectively, these studies suggest that drought-related household water insecurity is not determined solely by reductions in physical water availability; rather, its expression depends on the interaction between climatic stress, water-source reliability, infrastructure, accessibility, and household socioeconomic conditions.

Within India, household water security has increasingly been examined through complementary spatial, infrastructural, and household-level perspectives. National evidence from NFHS-5 has demonstrated substantial geographic variation in household drinking-water disruption, showing that access to an improved water source does not necessarily translate into continuous water availability (Jain et al. 2026; Yadav et al. 2026). Recent spatial analysis has further identified significant geographic clustering and geographically varying correlates of household water disruption across India, indicating that the determinants of service continuity are not spatially uniform (Yadav et al. 2026). Evidence from the semi-arid Purulia district of eastern India similarly demonstrates that domestic water poverty extends beyond physical water scarcity and reflects differences in water access, infrastructure, socioeconomic capacity, and human development (Goswami and Ghosal 2022). More directly relevant to climatic stress, recent longitudinal research using nationally representative Indian household data has reported a positive association between drought and multidimensional household water poverty, while showing that institutional and household characteristics can modify the relationship (Nongbri et al. 2025a). Related evidence has also linked temperature shocks with increased household water poverty, further indicating that climatic variability can influence household-level water deprivation through pathways extending beyond conventional measures of physical water availability (Nongbri et al. 2025b). Taken together, these findings indicate that climate-related water insecurity in India needs to be considered not only in terms of water-resource availability but also in relation to the continuity of household water services and the social and infrastructural conditions that shape how climatic stress is experienced.

Nevertheless, an important empirical gap remains in understanding how short-term drought exposure translates into disruption in household drinking-water availability. Existing research has largely examined spatial patterns of water disruption, multidimensional water poverty, or broader dimensions of household water access(Goswami and Ghosal 2022; Nongbri et al. 2025a; Jain et al. 2026; Yadav et al. 2026), while comparatively limited evidence directly links an objectively derived drought indicator

to whether households recently experienced an interruption in drinking-water availability. This distinction is important because continuity of supply represents a dimension of water security that conventional indicators based primarily on water-source type or infrastructure coverage may not adequately capture (Goswami and Ghosal 2022; Jain et al. 2026). The gap is particularly relevant in the arid and semi-arid environments of western India, where recurrent hydroclimatic stress interacts with heterogeneous water sources and uneven household water infrastructure. Although recent Indian evidence has linked drought with household water poverty (Nongbri et al. 2025a), there remains limited evidence on whether contemporaneous drought conditions are associated specifically with reported disruption in household drinking-water availability. The present study addresses this gap by combining household-reported drinking-water disruption with contemporaneous climatic drought exposure and examining whether the observed association persists after accounting for demographic, socioeconomic, and water-system characteristics.

Against this backdrop, the present study examines whether contemporaneous drought exposure is associated with an increased likelihood of household drinking-water disruption and whether this relationship varies across residential, socioeconomic, and water-access contexts. Using NFHS-5 household data from Rajasthan and Gujarat linked with the Standardized Precipitation–Evapotranspiration Index (SPEI), we quantify the association between climatic drought exposure and recent household-reported disruption in drinking-water availability through survey-weighted regression models, complemented by analyses of predicted probabilities, effect modification, and selected subpopulations. By linking an objective measure of hydroclimatic stress with household-level evidence of water-service reliability, this study extends existing research on water security beyond conventional measures of water-source access and provides empirical insight into how drought-related climatic stress is translated into disruptions in household drinking-water availability in water-stressed regions.

2. Data and methods

2.1 Data source

This study used household-level data from the fifth round of the National Family Health Survey (NFHS-5), conducted during 2019–2021 across India. NFHS-5 is a nationally representative, large-scale household survey implemented by the International Institute for Population Sciences (IIPS), Mumbai, under the aegis of the Ministry of Health and Family Welfare (MoHFW), Government of India. The survey covered 28 states and 8 union territories and successfully interviewed 636,699 households, providing comprehensive information on household characteristics, socioeconomic conditions, and health-related indicators (IIPS/India and ICF 2022).

NFHS-5 employed a multistage stratified sampling design, with sampling procedures implemented separately for rural and urban areas. In rural areas, villages were selected as primary sampling units (PSUs) using probability proportional to size (PPS), followed by the systematic selection of households within selected PSUs. In urban areas, the sampling proceeded through the selection of wards, followed by Census Enumeration Blocks (CEBs), and subsequently households within selected CEBs. This design was intended to ensure appropriate representation of rural and urban populations while maintaining the probabilistic structure of household selection (IIPS/India and ICF 2022).

2.2 Study design

This study adopted a cross-sectional analytical design using secondary household-level data from NFHS-5. The analysis examined the association between household drought exposure and reported drinking-water disruption among households in arid and semi-arid region of western India, represented by Rajasthan and Gujarat.

2.3 Study population and sample selection

The initial NFHS-5 dataset comprised 636,699 households across India. For the present analysis, the study population was restricted to households from the state of Rajasthan and Gujarat, yielding 61,185 households. Of these, 4,630 households were excluded because information on household drinking-water disruption was missing or reported as “Don’t know.” The final analytical study population therefore comprised 56,555 households (Fig. 1).

For regression analysis, the drought-only model included all 56,555 households with valid information on the outcome. Subsequent multivariable models included 54,981 households because of missing information on one or more covariates.

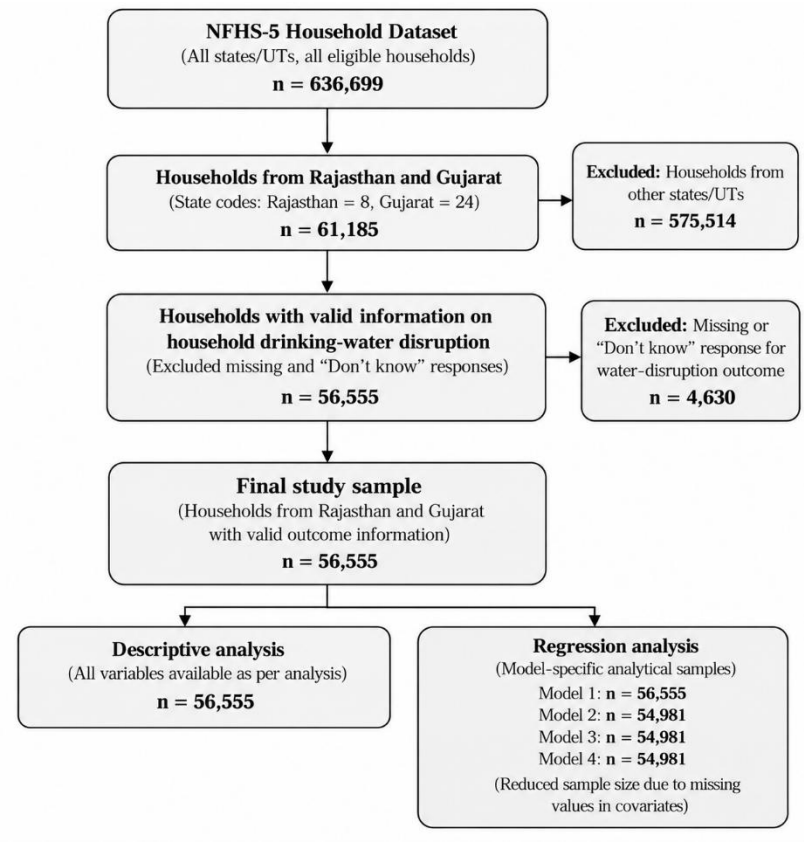


Fig. 1. Selection of households for the analysis of drought exposure and household drinking-water disruption.

Note: NFHS-5, National Family Health Survey–5.

2.4 Study variables

2.4.1 Outcome variable

The primary outcome was household drinking-water disruption, measured using the NFHS-5 household questionnaire item that asked whether water from the household's reported source was unavailable during the preceding two weeks. For the present analysis, a household was considered to have experienced drinking-water disruption if it reported that water from its source was unavailable for at least one day during this reference period. The outcome was subsequently recoded as a binary variable, with 0 indicating no reported disruption and 1 indicating disruption. Households with missing or "Don't know" responses were excluded during sample construction.

2.4.2 Main exposure: drought

The primary exposure was drought, measured using the Standardized Precipitation Evapotranspiration Index (SPEI) (Beguer A et al. 2023). A one-month SPEI (SPEI-01) was used to capture short-term moisture conditions corresponding to the timing of the NFHS-5 household interview. Following the drought classification adopted in previous studies, a SPEI value of ≤ -1.0 was considered indicative

of drought conditions, whereas values > −1.0 were classified as non-drought conditions (Vicente-Serrano et al. 2010).

The drought measure was assigned at the NFHS-5 cluster level. For each household, the month and year of interview were used to identify the corresponding current-month SPEI-01 value for its cluster. Clusters with a SPEI-01 value of ≤ −1.0 in the interview month were classified as drought-affected, while those with values > −1.0 were classified as non-drought-affected. This cluster-level exposure was subsequently linked to individual household records and used as the primary explanatory variable in the regression analyses, with 0 indicating non-drought exposure and 1 indicating drought exposure.

2.4.3 Covariates

Covariates were selected a priori based on evidence from previous empirical studies and their potential relevance to household drinking-water access, socioeconomic vulnerability, and susceptibility to drought-related water disruption (Shah et al. 2023; Singh and Naik 2024; Biswas et al. 2025; Ashrit and Joshi 2025). The selected variables were grouped into demographic, socioeconomic, and water-related characteristics. Demographic characteristics included place of residence, age and sex of the household head, social group, and religion. Place of residence was categorized as urban or rural; age of the household head as below 30, 30–59, and ≥60 years; sex as male or female; social group as Scheduled Caste (SC), Scheduled Tribe (ST), Other Backward Class (OBC), and Other; and religion as Hindu, Muslim, Christian, and other religions. Socioeconomic characteristics comprised household wealth, educational attainment, disability status, and electricity access. Household wealth was measured using the NFHS-5 wealth index and categorized into five quintiles from poorest to richest, while educational attainment was classified as no education, primary, secondary, and higher education; disability was coded as whether at least one household member had a disability, and electricity access was treated as a binary household characteristic. Water-related characteristics included the primary household drinking-water source, time required to obtain drinking water, and availability of a water pump. The primary drinking-water source was categorized as piped water, groundwater, surface water, and other sources; water collection time was classified as water available on the premises, up to 30 minutes, and more than 30 minutes; and water-pump availability was represented as a binary variable.

2.5 Statistical analysis

In this study, all the analyses were carried out after accounting the complex survey design of NFHS-5, including sampling weights, primary sampling units, and strata. Descriptive statistics were estimated using survey-weighted procedures, and categorical characteristics were summarized as weighted proportions with corresponding 95% confidence intervals (CIs). Design-adjusted statistical tests were

used to examine differences in the prevalence of household drinking-water disruption across selected demographic, socioeconomic, and water-related characteristics.

The association between drought exposure and household drinking-water disruption was assessed using survey-weighted binary logistic regression, with results presented as odds ratios (ORs) and 95% confidence intervals (CIs). Four sequential models were specified to examine the robustness of the drought–water-disruption association with progressive adjustment for potential confounding and household water-system characteristics. Model 1 included drought exposure alone. Model 2 additionally adjusted for selected demographic and socioeconomic characteristics of the household. Model 3 further incorporated electricity access as an additional household socioeconomic characteristic. Model 4 additionally adjusted for water-related characteristics, including household drinking-water source, time required to obtain drinking water, and water-pump availability. This sequential specification allowed assessment of changes in the estimated drought association following adjustment for progressively broader sets of household characteristics and water-access conditions. Because water-related characteristics may potentially represent factors through which drought conditions influence household water availability. The general model specification was as follows:

$$logit[P(Y_i = 1)] = \beta_0 + \beta_1 D_i + \beta_2 X_i + \beta_3 E_i + \beta_4 W_i \qquad \ldots\ldots Equ\ 1$$

where Y_i denotes household drinking-water disruption, D_i represents drought exposure, X_i represents demographic and socioeconomic characteristics, E_i represents electricity access, and W_i represents water-related characteristics. The sequential models were obtained by progressively introducing these terms into the equation.

To complement the relative measures obtained from logistic regression, adjusted predicted probabilities of drinking-water disruption were estimated for households exposed and unexposed to drought using the fully adjusted model 4. The corresponding average marginal difference (AMD) in predicted probability was calculated and expressed in percentage points, providing an absolute measure of the association that facilitates interpretation beyond the odds ratio scale. Potential heterogeneity in the association was examined by testing interactions between drought exposure and place of residence, social group, and household wealth quintile. For each interaction, subgroup-specific adjusted predicted probabilities and AMDs were estimated, and design-adjusted Wald tests were used to evaluate the joint statistical significance of the interaction terms.

As robustness analyses, the extended water-system-adjusted model was re-estimated separately across Rajasthan and Gujarat, urban and rural households, and major drinking-water-source groups. These subgroup analyses were conducted to examine the consistency of the drought–water-disruption association across different geographical, residential, and water-access contexts rather than to generate independent causal estimates. All analyses were performed using Stata 17.0 with survey-

239 design procedures. Statistical tests were two-sided, and a p-value <0.05 was considered statistically
240 significant.

241 **Results**

242 **3.1 Characteristics of the study households**

243 The study population comprised 56,555 households, with substantial variation in household
244 demographic, socioeconomic, and water-access characteristics (Table 1). Overall, 24.56% of
245 households reported drinking-water disruption during the preceding two weeks, while 5.47% were
246 classified as exposed to drought based on the study-specific drought indicator. The majority of
247 households were rural (65.14%) and were headed by males (87.18%). Approximately two-thirds of
248 household heads were aged 30–59 years (66.57%), while 27.17% were aged 60 years or above. Other
249 Backward Classes constituted the largest social group (45.64%), followed by Other (20.97%),
250 Scheduled Caste (18.49%), and Scheduled Tribe (14.91%) households. Hindu households accounted
251 for 89.27% of the study population, followed by Muslim households (9.29%).

252 The socioeconomic and water-access profile showed that 25.13% of households belonged to the
253 richest wealth quintile, while 13.05% belonged to the poorest quintile. Secondary education was the
254 most common educational category among household heads (43.85%), whereas 27.83% had no
255 formal education. Most households had access to electricity (97.75%) and reported piped water as
256 their primary drinking-water source (71.37%), followed by groundwater (21.05%). Water was
257 available on the premises for 84.64% of households, while 13.95% required up to 30 minutes and
258 1.40% required more than 30 minutes to obtain drinking water. A water pump was available in
259 18.50% of households.

260 Table 1. Characteristics of the study households in the selected drought-prone regions of India.

Variable	Category	Unweighted n	Weighted % [95% CI]
Household water disruption	No disruption	41,960	75.44 [75.09–75.79]
	Disruption	14,595	24.56 [24.21–24.91]
Drought exposure	No drought exposure	53,226	94.53 [94.34–94.72]
	Drought exposure	3,329	5.47 [5.28–5.68]
Place of residence	Urban	15,508	34.86 [34.47–35.25]
	Rural	41,047	65.14 [64.75–64.75]
Age of household head	Below 30 years	3,558	6.26 [6.07–6.46]
	30–59 years	37,650	66.57 [66.18–66.95]
	60 years and above	15,347	27.17 [26.81–27.53]
Sex of household head	Male	49,362	87.18 [86.90–87.45]
	Female	7,193	12.82 [12.55–13.10]
Social group	Scheduled Caste	9,891	18.49 [18.17–18.81]
	Scheduled Tribe	10,538	14.91 [14.61–15.20]
	Other Backward Class	24,472	45.64 [45.22–46.05]
	Other	10,110	20.97 [20.63–21.31]
Religion of household head	Hindu	50,860	89.27 [89.02–89.52]
	Muslim	4,841	9.29 [9.05–9.53]
	Christian	240	0.32 [0.28–0.37]
	Other religion	614	1.12 [1.04–1.21]

Household wealth index	Poorest	9,080	13.05 [12.77–13.32]
	Poorer	11,669	18.43 [18.11–18.74]
	Middle	12,063	20.51 [20.19–20.84]
	Richer	12,365	22.88 [22.54–23.23]
	Richest	11,378	25.13 [24.78–25.49]
Educational attainment of household head	No education	16,831	27.83 [27.47–28.20]
	Primary	10,354	17.51 [17.21–17.83]
	Secondary	23,995	43.85 [43.44–44.25]
	Higher	5,343	10.81 [10.56–11.07]
Household disability status	No disability	54,575	96.49 [96.33–96.63]
	Yes	1,980	3.51 [3.37–3.67]
Household has electricity	No	1,435	2.25 [2.13–2.37]
	Yes	55,120	97.75 [97.63–97.87]
Source of drinking water	Piped water	38,428	71.37 [71.00–71.74]
	Groundwater	13,799	21.05 [20.72–21.39]
	Surface water	341	0.61 [0.55–0.68]
	Other sources	3,987	6.96 [6.76–7.17]
Household has water pump	No	45,947	81.50 [81.19–81.82]
	Yes	10,608	18.50 [18.18–18.81]
Time to drinking-water source	On premises	46,082	84.64 [84.35–84.93]
	Up to 30 minutes	9,637	13.95 [13.67–14.24]
	More than 30 minutes	836	1.40 [1.31–1.50]
Total		56,555	

Note: Unweighted *n* represents the number of sampled households. Weighted percentages and 95% confidence intervals are based on household sampling weights. The denominator varies slightly for some variables due to missing observations.

3.2 Prevalence of household drinking-water disruption

The prevalence of household drinking-water disruption was 33.95% (95% CI: 30.49–37.59) among households exposed to drought, compared with 24.01% (95% CI: 23.13–24.91) among those without drought exposure, representing a statistically significant difference (Wald F = 32.91, $p < 0.001$) (Table 2). Across demographic characteristics, disruption prevalence did not differ significantly by place of residence or sex of the household head, whereas a modest but significant variation was observed across age groups. Disruption was lowest among households headed by persons below 30 years (22.22%) and higher among those headed by persons aged 30–59 years (24.65%) and 60 years or above (24.88%; Wald F = 3.55, $p < 0.05$). Marked differences were observed across social groups, with the highest prevalence among Scheduled Caste households (27.70%) and the lowest among Scheduled Tribe households (16.43%; Wald F = 38.29, $p < 0.001$). Significant variation was also observed by religion, with prevalence ranging from 10.68% among Christian households to 27.57% among Muslim households (Wald F = 7.35, $p < 0.001$).

Household drinking-water disruption also varied significantly across socioeconomic and water-access characteristics. Prevalence differed across wealth quintiles (Wald F = 14.96, $p < 0.001$), ranging from 21.11% among the poorest households to 26.75% among the richer households, before declining to 22.20% among the richest. Educational attainment showed a significant gradient, with disruption declining from 25.80% among households headed by persons with no education to 20.92% among those with higher education (Wald F = 10.03, $p < 0.001$). Households with at least one member with a disability also reported a higher prevalence than households without disability (27.80% vs. 24.44%;

Wald F = 8.69, p < 0.01). In contrast, electricity access was not significantly associated with disruption prevalence. The strongest differences were observed across water-related characteristics. Disruption prevalence varied substantially by drinking-water source (Wald F = 84.16, p < 0.001), with the highest prevalence among households using surface water (31.69%) and the lowest among those relying on groundwater (15.52%). Households without a water pump had a higher prevalence than those with a pump (25.35% vs. 21.07%; Wald F = 31.26, p < 0.001). A particularly pronounced difference was observed according to the time required to obtain drinking water (Wald F = 55.19, p < 0.001), with disruption prevalence reaching 43.43% among households requiring more than 30 minutes, compared with 25.11% among households with water available on the premises and 19.28% among those requiring up to 30 minutes.

Table 2. Prevalence of household drinking-water disruption by socioeconomic, demographic, and water-infrastructure characteristics

Characteristic	Category	Prevalence (%)	95% CI	Design-adjusted Wald F
Drought exposure	No drought exposure	24.01	23.13–24.91	32.91***
	Drought exposure	33.95	30.49–37.59	
Place of residence	Urban	23.89	22.29–25.58	1.07
	Rural	24.91	23.95–25.89	
Age of household head	Below 30 years	22.22	20.33–24.23	3.55*
	30–59 years	24.65	23.74–25.57	
	60 years and above	24.88	23.80–25.99	
Sex of household head	Male	24.51	23.64–25.40	0.29
	Female	24.89	23.46–26.37	
Social group	Scheduled Caste	27.70	26.05–29.41	38.29***
	Scheduled Tribe	16.43	15.05–17.90	
	Other Backward Class	25.73	24.57–26.92	
	Other	24.59	23.06–26.18	
Religion of household head	Hindu	24.37	23.49–25.27	7.35***
	Muslim	27.57	24.90–30.41	
	Christian	10.68	6.65–16.72	
	Other religion	18.33	14.71–22.61	
Household wealth index	Poorest	21.11	19.72–22.58	14.96***
	Poorer	25.35	23.99–26.75	
	Middle	26.48	25.24–27.75	
	Richer	26.75	25.43–28.11	
	Richest	22.20	20.67–23.80	
Educational attainment of household head	No education	25.80	24.64–26.99	10.03***
	Primary	25.69	24.47–26.96	
	Secondary	24.21	23.20–25.24	
	Higher	20.92	19.06–22.91	
Household disability status	No disability	24.44	23.59–25.31	8.69**
	Yes	27.80	25.49–30.24	
Household has electricity	No	26.13	23.02–29.51	1.02
	Yes	24.52	23.67–25.39	
Source of drinking water	Piped water	27.36	26.32–28.43	84.16***

	Groundwater	15.52	14.33–16.78	
	Surface water	31.69	25.16–39.03	
	Other sources	22.48	20.32–24.79	
Household has water pump	No	25.35	24.44–26.28	31.26***
	Yes	21.07	19.72–22.48	
Time to drinking-water source	On premises	25.11	24.19–26.06	55.19***
	Up to 30 minutes	19.28	17.84–20.80	
	More than 30 minutes	43.43	38.45–48.54	
Total		**24.57**	**23.71-25.42**	

Note: Prevalence estimates are survey-weighted and account for the complex multistage survey design. Values are percentages of households reporting drinking-water disruption; Confidence intervals (CIs). The design-adjusted Wald F statistic tests the overall association between household drinking-water disruption and each categorical characteristic. $p < 0.05$, $p < 0.01$, $p < 0.001$. Estimates are based on the survey estimation sample; sample size varies slightly across characteristics because of missing observations.

3.3 Association between drought exposure and household drinking-water disruption

Drought exposure was consistently associated with higher odds of household drinking-water disruption across all four sequential models (Table 3). In the unadjusted model, households exposed to drought had 1.63 times higher odds of reporting drinking-water disruption than households without drought exposure (OR 1.63, 95% CI: 1.38–1.92; $p < 0.001$). The association remained evident after adjustment for demographic and socioeconomic characteristics (OR 1.52, 95% CI: 1.28–1.81; $p < 0.001$) and was essentially unchanged following further adjustment for electricity access (OR 1.52, 95% CI: 1.27–1.81; $p < 0.001$). After additionally accounting for water-related characteristics, the association was attenuated but remained statistically significant (OR 1.42, 95% CI: 1.19–1.69; $p < 0.001$). On the absolute scale, the adjusted predicted probability of drinking-water disruption was 24.10% (95% CI: 23.20–24.99) among households without drought exposure compared with 30.83% (95% CI: 27.33–34.32) among drought-exposed households (Table 4). This corresponded to an average marginal difference of 6.73 percentage points (95% CI: 3.08–10.37; $p < 0.001$), indicating a substantial absolute difference in the probability of household drinking-water disruption associated with drought exposure.

Beyond the primary exposure, several demographic and socioeconomic characteristics were associated with household drinking-water disruption in the extended model. Rural households had modestly higher odds of disruption than urban households (OR 1.16, 95% CI: 1.02–1.31), whereas age and sex of the household head were not statistically associated with the outcome. Compared with Scheduled Caste households, Scheduled Tribe households had lower odds of disruption (OR 0.63, 95% CI: 0.55–0.72), while the association for Other Backward Class and Other households was not statistically significant. Christian and other-religion households also had lower odds of disruption than Hindu households. Household wealth showed a non-linear pattern, with higher odds among poorer, middle, and richer households relative to the poorest group, while the richest group did not differ significantly. Higher educational attainment was associated with lower odds of disruption; households

headed by persons with secondary and higher education had lower odds than those with no education. Households with at least one member with a disability had modestly higher odds of disruption (OR 1.13, 95% CI: 1.00–1.27). Electricity access was associated with lower odds of drinking-water disruption (OR 0.75, 95% CI: 0.63–0.90).

Water-system characteristics showed some of the strongest associations with household drinking-water disruption. Compared with households using piped water, those relying on groundwater had substantially lower odds of disruption (OR 0.50, 95% CI: 0.45–0.55), while the association for surface water was not statistically significant and other water sources were also associated with lower odds (OR 0.76, 95% CI: 0.66–0.87). Compared with households with water available on the premises, those requiring up to 30 minutes to obtain water had modestly higher odds of disruption (OR 1.19, 95% CI: 1.09–1.27), while households requiring more than 30 minutes had markedly higher odds (OR 2.76, 95% CI: 2.21–3.44). Households with a water pump had lower odds of disruption than those without one (OR 0.87, 95% CI: 0.80–0.96). Overall, the sequential models demonstrated that the positive association between drought exposure and drinking-water disruption persisted after accounting for demographic, socioeconomic, and water-system characteristics, although its magnitude was reduced following adjustment for water-related factors.

345 Table 3. Association between drought exposure and household drinking-water disruption: sequential survey-weighted logistic regression models.

Characteristic	Category	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)
Drought exposure	No drought exposure	Ref.	Ref.	Ref.	Ref.
	Drought exposure	1.63*** (1.38–1.92)	1.52*** (1.28–1.81)	1.52*** (1.27–1.81)	1.42*** (1.19–1.69)
Place of residence	Urban	Ref.	Ref.	Ref.	Ref.
	Rural	—	1.04 (0.92–1.17)	1.04 (0.92–1.17)	1.16* (1.02–1.31)
Age of household head	Below 30 years	Ref.	Ref.	Ref.	Ref.
	30–59 years	—	1.10 (0.99–1.22)	1.10 (0.99–1.23)	1.09 (0.98–1.22)
	60 years and above	—	1.08 (0.95–1.22)	1.08 (0.95–1.22)	1.07 (0.94–1.21)
Sex of household head	Male	Ref.	Ref.	Ref.	Ref.
	Female	—	0.97 (0.90–1.05)	0.97 (0.90–1.05)	0.95 (0.87–1.03)
Social group	Scheduled Caste	Ref.	Ref.	Ref.	Ref.
	Scheduled Tribe	—	0.53*** (0.47–0.61)	0.53*** (0.47–0.61)	0.63*** (0.55–0.72)
	Other Backward Class	—	0.90* (0.82–0.99)	0.90* (0.82–0.99)	0.94 (0.85–1.03)
	Other	—	0.92 (0.82–1.03)	0.92 (0.82–1.03)	0.94 (0.84–1.05)
Religion	Hindu	Ref.	Ref.	Ref.	Ref.
	Muslim	—	1.15 (0.98–1.33)	1.15 (0.98–1.34)	1.13 (0.97–1.31)
	Christian	—	0.36** (0.20–0.65)	0.36** (0.20–0.65)	0.36** (0.20–0.65)
	Other religion	—	0.66** (0.50–0.87)	0.66** (0.50–0.87)	0.64** (0.48–0.84)
Wealth quintile	Poorest	Ref.	Ref.	Ref.	Ref.
	Poorer	—	1.16** (1.06–1.27)	1.21*** (1.10–1.32)	1.13* (1.03–1.24)
	Middle	—	1.18** (1.07–1.30)	1.23*** (1.11–1.36)	1.13* (1.01–1.25)
	Richer	—	1.20** (1.07–1.33)	1.25*** (1.12–1.40)	1.14* (1.01–1.28)
	Richest	—	1.00 (0.88–1.15)	1.05 (0.91–1.20)	0.96 (0.83–1.12)
Education of household head	No education	Ref.	Ref.	Ref.	Ref.
	Primary	—	0.96 (0.89–1.03)	0.96 (0.89–1.03)	0.96 (0.90–1.04)
	Secondary	—	0.88*** (0.82–0.94)	0.88*** (0.82–0.95)	0.89** (0.83–0.96)
	Higher	—	0.77*** (0.68–0.87)	0.77*** (0.68–0.88)	0.79*** (0.70–0.90)
Disability in household	None	Ref.	Ref.	Ref.	Ref.
	At least one member with disability	—	1.15* (1.02–1.29)	1.15* (1.02–1.29)	1.13* (1.00–1.27)
Electricity	No	Ref.	—	Ref.	Ref.
	Yes	—	—	0.77** (0.65–0.91)	0.75** (0.63–0.90)
Primary water source	Piped water	Ref.	—	—	Ref.
	Groundwater	—	—	—	0.50*** (0.45–0.55)
	Surface water	—	—	—	0.99 (0.69–1.43)
	Other sources	—	—	—	0.76*** (0.66–0.87)
Time to water source	On premises	Ref.	—	—	Ref.

	Up to 30 minutes	—	—	—	1.19* (1.09–1.27)
	More than 30 minutes	—	—	—	2.76*** (2.21–3.44)
Water pump	No	Ref.	—	—	Ref.
	Yes	—	—	—	0.87** (0.80–0.96)
Observations		56,555	54,981	54,981	54,981
Design df		2,601	2,600	2,600	2,600
Model F statistic		32.36***	12.10***	11.72***	20.83***

Note: OR = odds ratio; CI = confidence interval; Ref. = reference category; — = variable not included in the model. Estimates are from survey-weighted logistic regression accounting for the complex multistage survey design. Model 1 is unadjusted; Model 2 adjusts for socio-demographic characteristics; Model 3 additionally adjusts for household electricity; Model 4 additionally adjusts for primary water source, time to water source, and water pump. *p < 0.05, **p < 0.01, ***p < 0.001.

Table 4. Adjusted odds and predicted probability of household drinking-water disruption by drought exposure.

Measure	Estimate	95% CI
Adjusted odds ratio (OR)	1.42***	[1.19–1.69]
Predicted probability of water disruption among drought-unexposed households (%)	24.10***	[23.20–24.99]
Predicted probability of water disruption among drought-exposed households (%)	30.83***	[27.33–34.32]
Average marginal difference in predicted probability (percentage points)	6.73***	[3.08–10.37]

Note: Estimates are from survey-weighted Model 4. Predicted probabilities are adjusted predictive margins, and the marginal difference represents the average discrete change associated with drought exposure. CI = confidence interval; *p < 0.05, **p < 0.01, ***p < 0.001.

3.4 Adjusted differences in predicted probability by water-access characteristics

The absolute difference in the predicted probability of household drinking-water disruption associated with drought exposure remained evident across all water-access categories (Table 5). Among households using piped water, the adjusted predicted probability of disruption increased from 26.81% in the absence of drought to 34.05% under drought exposure, corresponding to an AMD of 7.24 percentage points (95% CI: 3.35–11.13; $p < 0.001$). The corresponding AMDs were 5.07 percentage points among groundwater users (95% CI: 2.22–7.93; $p = 0.001$), 7.22 percentage points among surface-water users (95% CI: 3.22–11.22; $p < 0.001$), and 6.42 percentage points among households using other sources (95% CI: 2.88–9.95; $p < 0.001$). A similar pattern was observed by time required to obtain drinking water. The predicted probability of disruption increased from 24.06% to 30.81% among households with water available on the premises, yielding an AMD of 6.75 percentage points (95% CI: 3.10–10.40; $p < 0.001$). The corresponding AMD was 6.41 percentage points among households requiring up to 30 minutes (95% CI: 2.87–9.94; $p < 0.001$) and 8.41 percentage points among those requiring more than 30 minutes (95% CI: 4.13–12.68; $p < 0.001$). Thus, drought exposure was associated with a consistently higher absolute probability of drinking-water disruption across different household water-access conditions, with the largest estimated difference observed among households requiring more than 30 minutes to obtain drinking water. These findings indicate that the association between drought exposure and household water disruption persisted across diverse water-access contexts, while the magnitude of the absolute difference varied between categories.

Table 5. Adjusted predicted probabilities and average marginal differences in household drinking-water disruption by water-access characteristics.

Water-access characteristic	Category	No drought, predicted probability (%)	Drought, predicted probability (%)	AMD (percentage points)	95% CI
Primary water source	Piped water	26.81	34.05	7.24***	[3.35–11.13]
	Groundwater	15.54	20.61	5.07***	[2.22–7.93]
	Surface water	26.65	33.87	7.22***	[3.22–11.22]
	Other sources	21.79	28.21	6.42***	[2.88–9.95]
Time to water source	On premises	24.06	30.81	6.75***	[3.10–10.40]
	Up to 30 minutes	22.03	28.44	6.41***	[2.87–9.94]

	More than 30 minutes	45.93	54.33	8.41***	[4.13–12.68]

Note: Predicted probabilities were estimated from the survey-weighted Model 4 specification, adjusted for demographic, socioeconomic, and water-system characteristics. Average marginal differences (AMDs) represent the adjusted difference in predicted probability of drinking-water disruption between drought-exposed and non-exposed households within each category and are expressed in percentage points. CI, confidence interval; AMD, average marginal difference.

3.5 Effect modification by place of residence, social group, and wealth

The association between drought exposure and household drinking-water disruption was examined across place of residence, social group, and wealth quintile using interaction models and subgroup-specific adjusted predictive margins (Table S1). The adjusted probability of water disruption increased under drought conditions across both urban and rural households, with average marginal differences of 11.91 percentage points (pp; 95% CI: 4.33–19.49) and 4.87 pp (95% CI: 0.81–8.94), respectively. Similarly, drought was associated with higher predicted probabilities of disruption across all social groups, with marginal differences ranging from 2.43 pp (95% CI: −3.40–8.25) among households classified as Other to 12.51 pp (95% CI: 1.02–23.99) among Scheduled Tribe households. Across wealth quintiles, the corresponding differences ranged from 1.25 pp (95% CI: −3.89–6.40) among poorer households to 11.16 pp (95% CI: 5.12–17.20) among richer households. Although the magnitude of the drought-associated difference varied across categories, the interaction tests did not indicate statistically significant effect modification by residence ($F(1, 2600) = 2.67$, $p = 0.103$), social group ($F(3, 2598) = 1.42$, $p = 0.236$), or wealth quintile ($F(4, 2597) = 1.83$, $p = 0.120$). Thus, the observed subgroup differences should be interpreted as variation in the magnitude of the association rather than evidence of statistically significant effect modification.

3.6 Subpopulation and robustness analyses

The association between drought exposure and household drinking-water disruption remained evident across most prespecified subpopulations (Fig. 2; Table S2). The association was significant in both Rajasthan (OR = 2.64, 95% CI: 1.44–4.85) and Gujarat (OR = 1.20, 95% CI: 1.08–1.31), and remained significant among urban (OR = 1.86, 95% CI: 1.33–2.62) and rural households (OR = 1.27, 95% CI: 1.04–1.57). By water source, the association was significant among households using piped water (OR = 1.38, 95% CI: 1.14–1.67) and other water sources (OR = 1.85, 95% CI: 1.14–3.00), whereas the estimate among groundwater-dependent households was not statistically significant (OR = 1.37, 95% CI: 0.84–2.23). Overall, the direction of association was consistent across the examined subpopulations, supporting the robustness of the main finding across geographic, residential, and water-source groups.

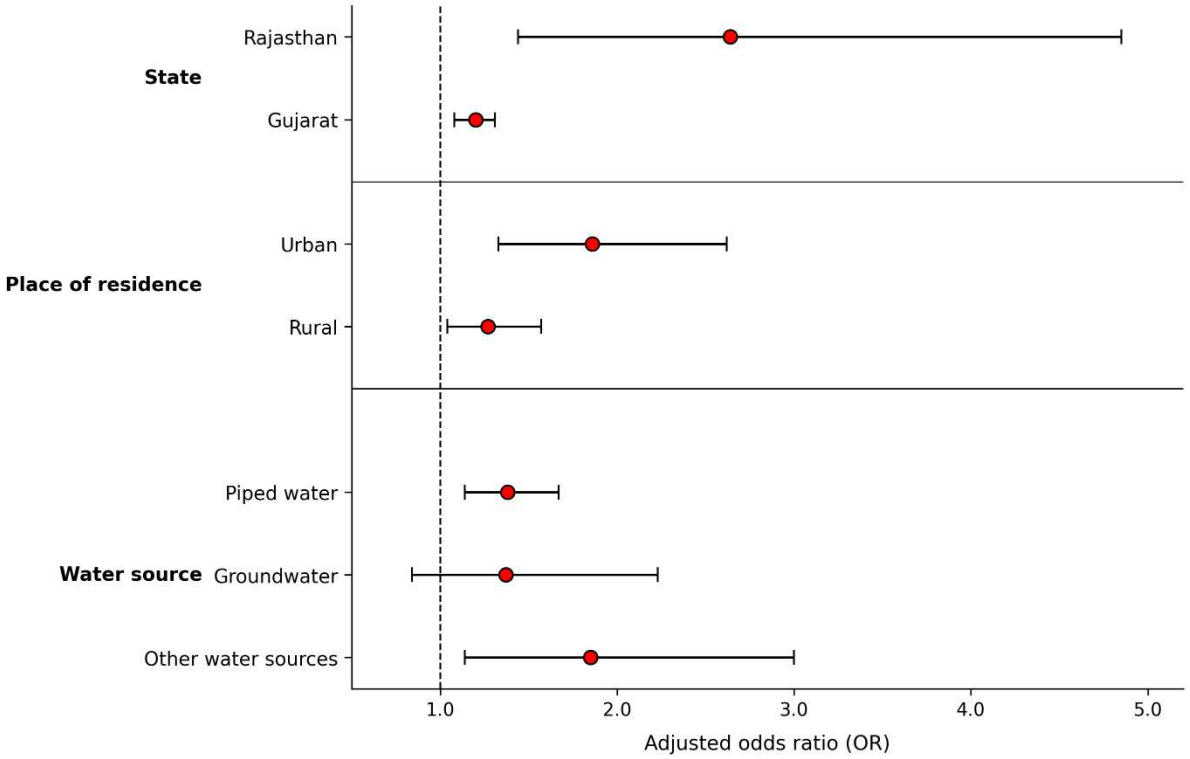


Fig. 2. Association between drought exposure and household drinking-water disruption across selected subpopulations.

Note: Estimates are from survey-weighted logistic regression models adjusted for relevant household characteristics and water-access factors. Forest plot presents adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for drought exposure across states, place of residence, and water-source groups. Red circles indicate OR estimates, horizontal lines represent 95% CIs, and the dashed vertical line indicates the null value (OR = 1.0).

4. Discussion

This study demonstrates that drought exposure is an important climatic correlate of household drinking-water disruption in the arid and semi-arid region of western India. By linking a standardized drought indicator with household-level information on the temporary unavailability of drinking water, the study extends drought research beyond its conventional emphasis on agricultural production, hydrological deficits, and ecosystem impacts to examine a direct dimension of household water security. This distinction is important because the consequences of drought are ultimately experienced through the reliability with which households can obtain sufficient water for everyday needs. Previous research in India has documented associations between drought and household water poverty and has shown that drought can increase the difficulty and burden of obtaining water for domestic use (Nongbri et al. 2025a). The present study contributes to this literature by examining drinking-water disruption as a specific household-level outcome within a large, nationally standardized survey framework and by considering climatic exposure together with household socioeconomic characteristics and water-access conditions. The findings therefore provide an empirical bridge between climate variability and household water insecurity, with relevance for both climate–water scholarship and the planning of resilient drinking-water systems in drought-prone regions.

The association between drought exposure and drinking-water disruption is consistent with growing evidence that climatic water stress can translate into deterioration in household water security. Previous research from India has shown that drought is associated with greater household water poverty, while studies from drought-prone communities have documented increased difficulty in securing domestic water and greater burdens associated with water collection during periods of water stress (Jepson et al. 2021a; Nongbri et al. 2025a). The persistence of the association after accounting for demographic, socioeconomic, and water-access characteristics in the present study suggests that drought remains relevant even after differences in household circumstances and water systems are considered. The consistency observed in the sensitivity and subpopulation analyses further indicates that the relationship is not confined to a particular geographic area, residential setting, or water-source category. These findings strengthen the evidence that drought-related water disruption represents a broader household-level manifestation of climatic water stress. Nevertheless, because the analysis is based on cross-sectional survey data, the observed relationship should be interpreted as an association rather than as evidence of a causal effect.

The relationship between drought and household drinking-water disruption can be understood within the interaction between climatic water availability and the capacity of water systems to maintain reliable supply (Nongbri et al. 2025b). Drought can reduce the availability and reliability of surface and groundwater resources while increasing pressure on sources that are already subject to competing domestic, agricultural, and other demands (Rahman et al. 2025; Bhardwaj and Mishra 2026). Evidence from drought-prone Indian communities shows that domestic water access becomes more difficult during periods of drought, with households facing greater burdens in obtaining water (Goswami and Ghosal 2022). Research examining household water insecurity has similarly demonstrated that climatic variability interacts with physical access, source characteristics, and local conditions to shape the ability of households to secure adequate water (Nongbri et al. 2025a). Importantly, drought does not necessarily translate into disruption simply because a water source becomes completely unavailable. Declining source yields, intermittent supply, increased competition for available water, reduced groundwater availability, or difficulties in operating distribution systems can all reduce the reliability of household water access (Zhu et al. 2024; Ayyash et al. 2025). Thus, a household may retain nominal access to a water source while experiencing periods in which that source cannot provide water when required. This distinction between the *presence* of a water source and the *reliability* of the service it provides is central to understanding how a climatic hazard can manifest as a household-level disruption.

The study outcome related to water-source and water-access characteristics provide further evidence that household water security depends on more than the nominal type of drinking-water source. The persistence of the drought association across different water-source categories indicates that no single source type completely insulates households from climatic water stress. This observation is consistent

with recent evidence from India showing that drinking-water access is multidimensional, incorporating source quality, availability on premises, time required to obtain water, and other dimensions of service adequacy (Singh and Naik 2024). Research on rural drinking-water programmes has likewise shown that household wealth, education, caste and other household characteristics influence not only whether households have connections but also the conditions under which water is accessed and collected (Dutta et al. 2015; Gurung et al. 2023). The particularly strong relationship between disruption and longer water-collection time in the present study is therefore important because collection time captures an aspect of water accessibility that is not adequately represented by source classification alone. Taken together, these findings reinforce the need to distinguish between infrastructure coverage and reliable water service. Expansion of piped connections or improved-source coverage is an important component of water security, but climatic resilience also depends on the sustainability of water sources, continuity of supply, system maintenance, and the ability of households to access alternative sources when primary supplies become unreliable.

The sociodemographic correlates identified in the study further demonstrate that household drinking-water disruption is embedded within broader social and material conditions. The lower likelihood of disruption observed among households with greater educational attainment is consistent with evidence from India showing that education is associated with better access to drinking-water services and other dimensions of household water security (Ranjan 2025; Tirkey et al. 2026). Education may be related to greater access to information, livelihood opportunities, institutional resources, and the ability to navigate or adopt alternative water-access arrangements, although the present cross-sectional design does not allow these pathways to be established. The association of household wealth with water disruption also needs to be interpreted within the broader relationship between economic resources and access to water infrastructure. NFHS-based research has consistently shown socioeconomic gradients in household drinking-water access, while recent evidence from rural India indicates that wealthier households are more likely to have household-level water connections and face lower burdens associated with water collection (Malakar et al. 2018; Singh and Naik 2024). The observed differences across social groups likewise highlight that water security is not socially neutral. Caste and social-group inequalities in India have historically been reflected in access to basic services and household resources, and recent research continues to identify social-group differences in drinking-water and WASH conditions (Dutta et al. 2015, 2018; Kumar and Kharb 2024). The associations observed for electricity access and disability are also relevant in this context, as they may capture broader differences in household infrastructure, material resources, and the practical capacity to obtain water when conventional supply becomes unreliable. Importantly, these characteristics should not be interpreted as isolated individual-level determinants; rather, they represent dimensions

of the socioeconomic environment within which households experience and respond to climatic water stress.

The subgroup analyses provide an additional perspective on the distribution of drought-related drinking-water disruption. Although the magnitude of the association varied across residence, social group, and wealth categories, the formal interaction analyses did not demonstrate statistically significant effect modification by these characteristics. This distinction is important because variation in subgroup-specific estimates does not, by itself, demonstrate that drought has a statistically different effect across population groups. Instead, the findings indicate that drought-related disruption occurs across diverse social and residential contexts, while the surrounding socioeconomic and infrastructural environment may shape the level of household water security within those contexts. The robustness analyses similarly showed that the positive association remained evident across the major geographic, residential, and water-source subpopulations examined. The differences observed between Rajasthan and Gujarat may reflect variation in local hydrological conditions, source dependence, settlement patterns, and water-supply arrangements, but these contextual explanations require further investigation rather than being inferred directly from the present cross-sectional analysis. Overall, the consistency of the association across multiple analytical specifications supports the interpretation of household drinking-water disruption as an important pathway through which drought can affect everyday wellbeing. It also suggests that assessments of climate-related water vulnerability should consider not only the intensity of climatic exposure but also the social and infrastructural conditions that determine whether households can maintain reliable access to drinking water during periods of scarcity.

5. Policy Implications

The study findings support several actionable measures for strengthening drinking-water security in drought-prone western India. First, district water authorities should integrate seasonal drought indicators with drinking-water monitoring and establish predefined thresholds for action. When drought conditions intensify, identified high-risk settlements should trigger contingency measures such as activating alternative sources, increasing local water storage, and arranging temporary supplementary supplies before household disruption becomes severe.

Second, village and district water plans should monitor service continuity, not only household connections. Routine monitoring should record the frequency and duration of supply interruptions, seasonal source reliability, and household water-collection time. Settlements reporting prolonged interruptions or extended collection times should receive priority for source augmentation, distribution-system repair, or additional local supply points.

Third, drought-prone settlements should maintain more than one viable drinking-water source. Local water plans should identify and maintain backup sources, while groundwater recharge, rainwater harvesting, and rehabilitation of local water-storage structures should be prioritized where technically appropriate. Existing sources and distribution infrastructure should also be assessed before the dry season to identify systems likely to fail under drought conditions.

Finally, drought contingency planning should explicitly identify households and settlements with limited capacity to cope with supply interruptions. Areas with long water-collection times and greater socioeconomic vulnerability should be prioritized for emergency supplies, accessible water points, and household-level storage support. Together, these measures would shift drought response from reactive water provision towards early, locally targeted, and reliability-focused drinking-water management.

6. Strengths and Limitations

A major strength of this study is the use of a large, standardized household dataset that enabled the examination of drinking-water disruption across diverse household and water-access contexts in drought-prone western India. Linking household-level NFHS-5 information with a standardized drought indicator allowed the study to connect climatic exposure with a specific and policy-relevant dimension of household water security. The analysis also accounted for the complex survey design and progressively adjusted for demographic, socioeconomic, and water-access characteristics. The use of adjusted predictive probabilities, interaction analyses, and subpopulation analyses further strengthened the assessment by examining both the absolute magnitude and consistency of the observed association across different household contexts.

Several limitations should be considered when interpreting the findings. First, the cross-sectional nature of NFHS-5 limits the ability to establish temporal or causal relationships between drought exposure and water disruption. Second, drinking-water disruption was based on household-reported information and may therefore be subject to recall or reporting error. Third, drought exposure was assigned at cluster level using the spatial and temporal correspondence between the drought indicator and the NFHS-5 interview, which may not fully capture within-cluster variation in household exposure or the cumulative effects of drought preceding the survey period. Fourth, although the analyses incorporated several important household characteristics, residual confounding from unmeasured factors such as local water governance, groundwater conditions, infrastructure functionality, and household water-storage capacity cannot be excluded. Finally, the analysis was restricted to Rajasthan and Gujarat and therefore should not be interpreted as representative of all drought-prone regions of India. These limitations notwithstanding, the findings provide useful evidence on the relationship between climatic drought and household drinking-water reliability in two highly water-stressed states.

7. Conclusion

The present study found that drought exposure was associated with household drinking-water disruption in the arid and semi-arid region of western India, with the association remaining evident after accounting for key household and water-access characteristics. The findings indicate that household drinking-water reliability should be considered alongside conventional measures of drought and water availability when assessing climate-related water vulnerability. Strengthening drought preparedness through improved monitoring of water-service continuity, sustainable and diversified water sources, and targeted support for households facing greater water-access constraints may help reduce the risk of disruption during periods of climatic stress. Such approaches could contribute to progress towards SDG 6 (Clean Water and Sanitation) by supporting more reliable water services, SDG 13 (Climate Action) by incorporating drought risk into water-system planning, and SDG 10 (Reduced Inequalities) by recognizing differences in household capacity to cope with water stress, with potential relevance to SDG 3 (Good Health and Well-being) through improved household water security. Further longitudinal research is needed to clarify the temporal and causal pathways linking drought conditions with household drinking-water disruption.

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