

## Indications of recent warm and dry summers' impact on private wells for drinking-water supply in Germany: a review of press articles

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### ABSTRACT

Climatic changes lead to seasonal droughts with declining groundwater levels, and – especially in rural regions – private wells in the upper aquifer might fall dry. However, only limited information and no systematic administrative reporting of the extent are available for Germany yet. Therefore, a systematic analysis of newspaper articles as a promising source of information was conducted for the extraordinarily hot summers of 2018, 2019 and 2020. The results of the database searches were analysed with respect to frequency and local and regional hot-spots, relations to climatic data, extent of the reported dry-fallings and emergency water supply. The analysis indicates hotspots particularly for the federal states of Saxony, where a subsidy programme for connecting to the public water supply was reissued in 2019, for Bavaria and North Rhine-Westphalia. Emergency supply was realised through various approaches. It was partly required until the winter months and did not always have drinking-water quality. As private wells are particularly vulnerable to the effects of climate change, their operators should be involved as a stakeholder group in future discussions about allocating water resources to increasingly competing uses in periods of scarcity.

**Key words:** climate change, drought, dry summer, private wells, small-scale water supplies, water scarcity

### HIGHLIGHTS

- An analysis of newspaper articles showed the impacts of warm and dry summers on private wells and regional hot spots in Germany.
- Private wells are particularly vulnerable to the effects of climate change.
- Emergency water supply was partly required into the winter months.
- Increased willingness to connect to the central water supply exists among operators of private wells, and a subsidy programme was reissued.

### INTRODUCTION

The last summers in Germany were particularly dry and hot. While a survey among mostly larger public water suppliers reported on impacts on water supply in the dry year 2018 (DVGW 2018), no such overarching information is available for private wells, although private wells running dry may have significant effects on those connected to these systems.

Limited evidence suggests that private wells are particularly vulnerable to the effects of climate change (WHO EURO 2016). However, no comprehensive data are available on the impact of climate phenomena on private wells in Germany.

The German water sector is characterised by a high number of water supplies, including small public supplies (7,154 water supply zones supplying 10–1,000 m<sup>3</sup>/day (Bundesministerium für Gesundheit, Umweltbundesamt 2020)) and numerous private wells. The German Drinking-Water Ordinance (2020) stipulates requirements for drinking-water supplies, including private wells that supply fewer than 50 persons or provide less than 10 m<sup>3</sup>/day as an average for own consumption only, or as part of a commercial or public activity (these very small supplies will, in the following, be referred to as private wells). Information on the number of private wells and further details are available in Germany at the local level, and no regular national reporting is legally required. While, in the European Region, 7% of the population receives their drinking water from private

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wells (Rickert *et al.* 2016), according to the latest published data from 2016 approximately 509,000 inhabitants or 0.6% of the population of Germany were not connected to the public water supply, with the largest numbers of people not connected in the federal states of North Rhine-Westphalia, Bavaria and Baden-Wuerttemberg (Destatis 2021). These inhabitants are assumed to be supplied by private wells.

Typically, operators of private wells are not organised in associations, and operating their drinking-water supplies is not their main occupation. For these reasons, it was considered unlikely that data on the effects of climate on private wells in Germany had been published by operators, and no such data compilation was known to the authors.

The goal of this study is to depict to what extent information has been published in press articles on the effects of recent climate phenomena, particularly hot and dry summers, having affected private drinking-water wells in Germany and to document developments to address the related challenges. It also aims to collate information on other competing water withdrawals or water-use restrictions included in the press.

## MATERIALS AND METHODS

### Databases for scientific and non-scientific publications

The databases ScienceDirect, Scopus, Wiley and Springer were selected as the biggest and most relevant databases for peer-reviewed literature.

For press articles, the database portal *wiso* available at <https://www.wiso-net.de/dosearch> was used to search data from 231 press media in Germany, 180 of which were categorised as 'press Germany', with the others from Austria/Switzerland or categorised as international. The database contains national press media, media from 15 of the 16 federal states, and from rural areas as well as big cities with a population of >100,000 inhabitants. Furthermore, newsletters from the German trade press publisher EUWID (<https://www.euwid.de/fachmedien/wasser-und-abwasser/>) were searched for the years 2018–2020.

A large set of terms and various combinations thereof were used for the database queries for both the scientific databases (in English and German) and the press media database (in German translation): Germany; dry; aridity; dry season; dry year; dry summer; drought summer; drought; drought period; drought spell; drought year; summer; summer months; heat; drinking water; water; groundwater; shortages; water shortage; supply shortage; water-saving; private self-supply; private drinking-water supply; private water supply; domestic wells; private wells; climate change; change in climate; extreme weather; weather extremes; emergency supply; year 2018; year 2019; year 2020; and restriction garden irrigation. All press articles are listed in the Supplementary material.

### Climate data

Climate data were obtained from the German national meteorological service (Deutscher Wetterdienst 2021).

## RESULTS AND DISCUSSION

### Quantitative results of the literature search

No results from Germany were found in the queries in the databases searched for scientific literature. As these main databases did not yield any results, it was considered unlikely that the search of other smaller databases would lead to the identification of scientific literature on the topic. The lack of scientific reports may be due to various reasons, including the operators of private wells not being likely to publish peer-reviewed literature, and a lack of available information to publish.

No sources were contained in the press media database from the federal state of Bremen; however, as it is a so-called city-state, the significance of private wells for drinking-water supply is considered low. While the sources from Berlin, Hamburg and Saarland contained sources from big cities only, and the sources from Thuringia contained none from a big city, the sources from all other federal states contained both, indicating that rural areas where private wells prevail are covered in the press articles reviewed. The numbers of sources available that were relating to single federal states and not from big cities were (in decreasing order) 19 (Lower Saxony), 15 (Bavaria), 15 (Hessia), 10 (Baden-Wuerttemberg), 8 (Rhineland-Palatinate), 5 (North Rhine-Westphalia), 5 (Saxony), 4 (Thuringia), 3 (Mecklenburg-Western Pomerania), 2 (Brandenburg), 1 (Saxony-Anhalt) and 1 (Schleswig-Holstein).

The search of the press media database portal resulted in 40 (2018), 18 (2019) and 50 (2020) matches of typically rather short press articles for the search terms, and another 1 (2018) and 6 (2019) matches found in the EUWID newsletters

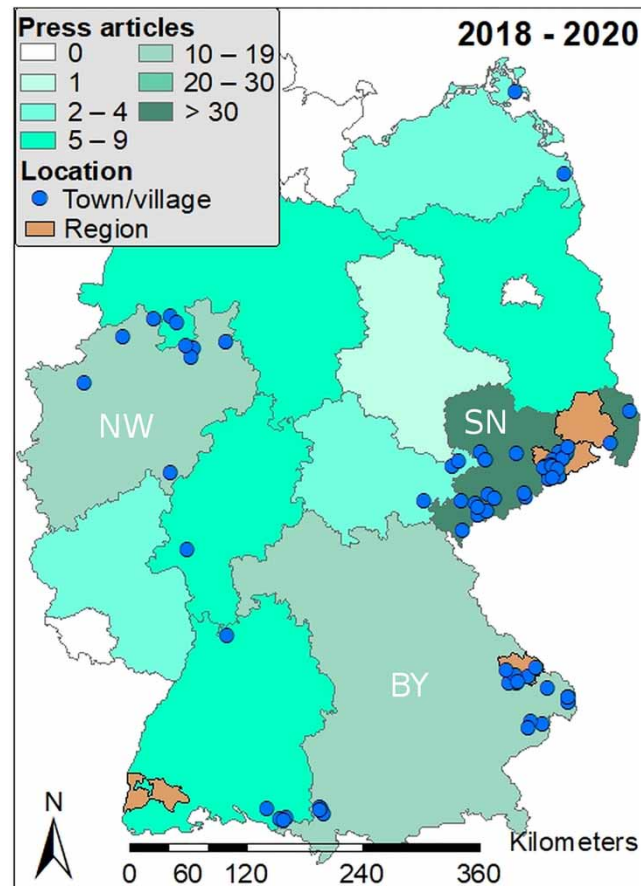
(see Figures 1 and 2). Where articles specifically addressed a local town, village or region within the respective federal state, these are shown in the figures.

The three federal states with the most matches are Saxony (44) in the east of Germany, North Rhine-Westphalia (18) in the west and Bavaria (17) in the south. No matches were found for 5 of the 16 federal states, namely Berlin, Bremen, Hamburg, Saarland and Schleswig-Holstein. The one article found for Saxony-Anhalt was not connected to private wells for water supply.

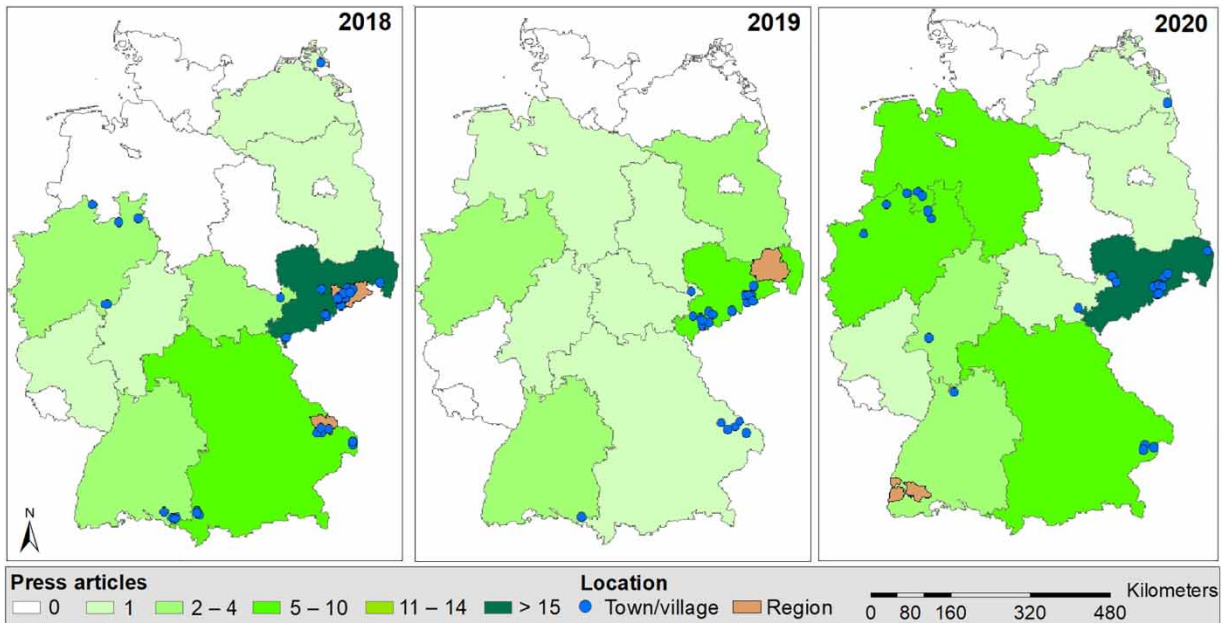
For some of the federal states, the number of publications matches the number of private wells and population not connected to the public water supply: in 2016, North Rhine-Westphalia had the largest population of all 16 German federal states not connected to the public water supply, followed by Bavaria; however, Saxony had the 6th largest population not connected to the public water supply (Destatis 2021). The numbers of private wells in the city states of Berlin, Bremen and Hamburg are very low. The number of publications found per federal state may also be influenced by the number of press sources available per federal state that are not related to big cities. The fact that both North Rhine-Westphalia and Saxony do not have a high number of press sources that are not related to big cities, but are among the federal states with the highest number of press articles, supports the relative importance of this topic, especially in these areas.

There was no clear increase or decrease in the number of federal states in which articles on the topic were published in the three considered years 2018, 2019 and 2020. Figure 3 shows the distribution of published articles in the respective calendar months.

While in 2018, articles on the issue were exclusively published in the second half of the year, the distribution was more widespread in 2019 and 2020, with a focus on the months of January, July and August in 2019 and July–October in 2020. This can partly be explained by the topic having become relevant during the summer months in 2018, and remaining relevant



**Figure 1** | Number of publications found in literature search per federal state for 2018–2020 with labels for Bavaria (BY), North Rhine-Westphalia (NW) and Saxony (SN).



**Figure 2** | Number of publications found in literature search per federal state for 2018, 2019 and 2020.

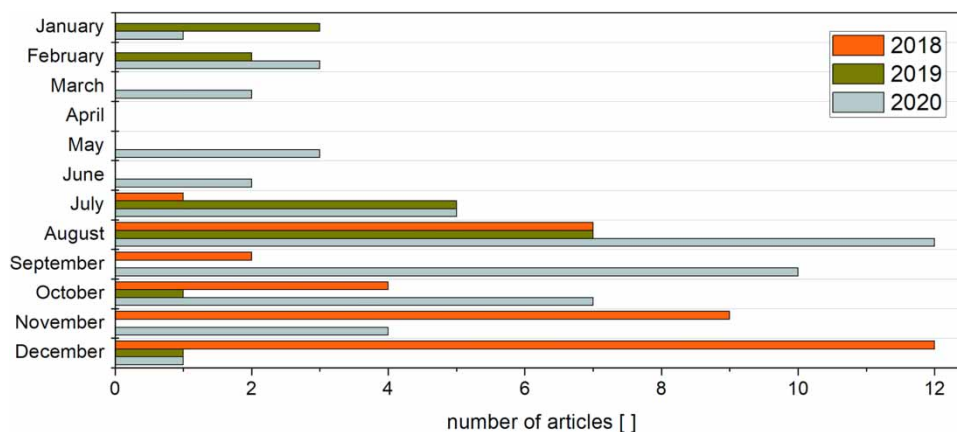
throughout the subsequent years. The fact that a significant number of articles from 2019 and 2020 referred to the conditions in 2018 and not to current conditions supports this hypothesis. Furthermore, a number of articles from 2019 and 2020 addressed not only current climatic conditions, but other topics such as current activities to provide a technical remedy, or reissued subsidy programmes, the timing of which may have influenced the time of publication.

### Thematic topics in the press articles

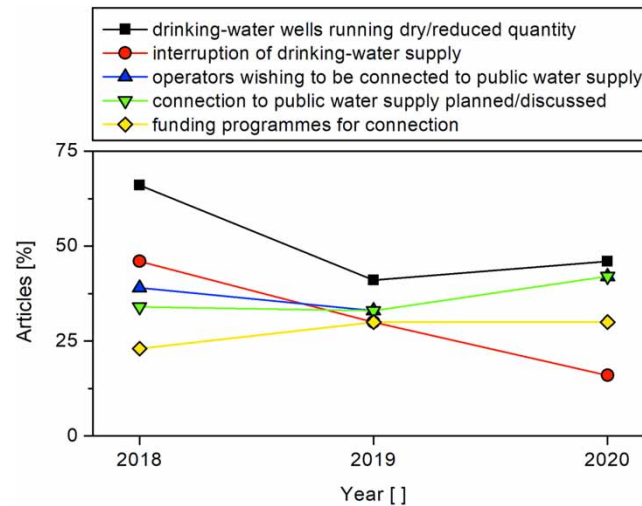
The majority (83%) of the articles addressed drinking water. A significant fraction (30%) focused on other topics, with some articles addressing drinking water as well as other topics.

61% of the articles mentioned private wells; however, 62% actually described issues related to private wells used for drinking-water supply, with some articles applying the term ‘private wells’ with a different meaning, mostly for wells used for watering gardens. Some articles addressed private wells but referred to them with a different terminology.

55% of the articles addressed drinking-water wells running dry or having reduced quantity available (66% in 2018, 41% in 2019 and 46% in 2020). 31% addressed an interruption of the drinking-water supply (46% in 2018, 30% in 2019 and 16% in 2020) (see Figure 4). The tendency that these issues appeared to be less prominently addressed over time also matches the fact



**Figure 3** | Total number of publications per calendar month found in the press article search for 2018–2020.



**Figure 4** | Distribution of thematic topics found in the press article search for 2018–2020.

that numerous articles from 2019 and 2020 referred to the conditions during the hot summer in 2018, rather than current respective problems with the drinking-water supply. While larger water suppliers have better chances to switch to other water sources in times of reduced quantity available, this is not possible for operators of private wells that rely on a single source. Drilling of new wells (13% of the articles) and deepening of the existing wells (10%) as options to react to climate effects were described in a rather low number of articles.

In cases where wells had run dry, increased willingness to connect to the central water supply system were reported, although not always in combination with a willingness to give up their private wells: 41% of articles (39% in 2018, 33% in 2019 and 42% in 2020) described that the operators wished to be connected to the public water supply, and 39% of articles (34% in 2018, 33% in 2019 and 42% in 2020) described that such connections were actually planned or discussed as a measure to compensate for the climatic effects on private wells (see Figure 4).

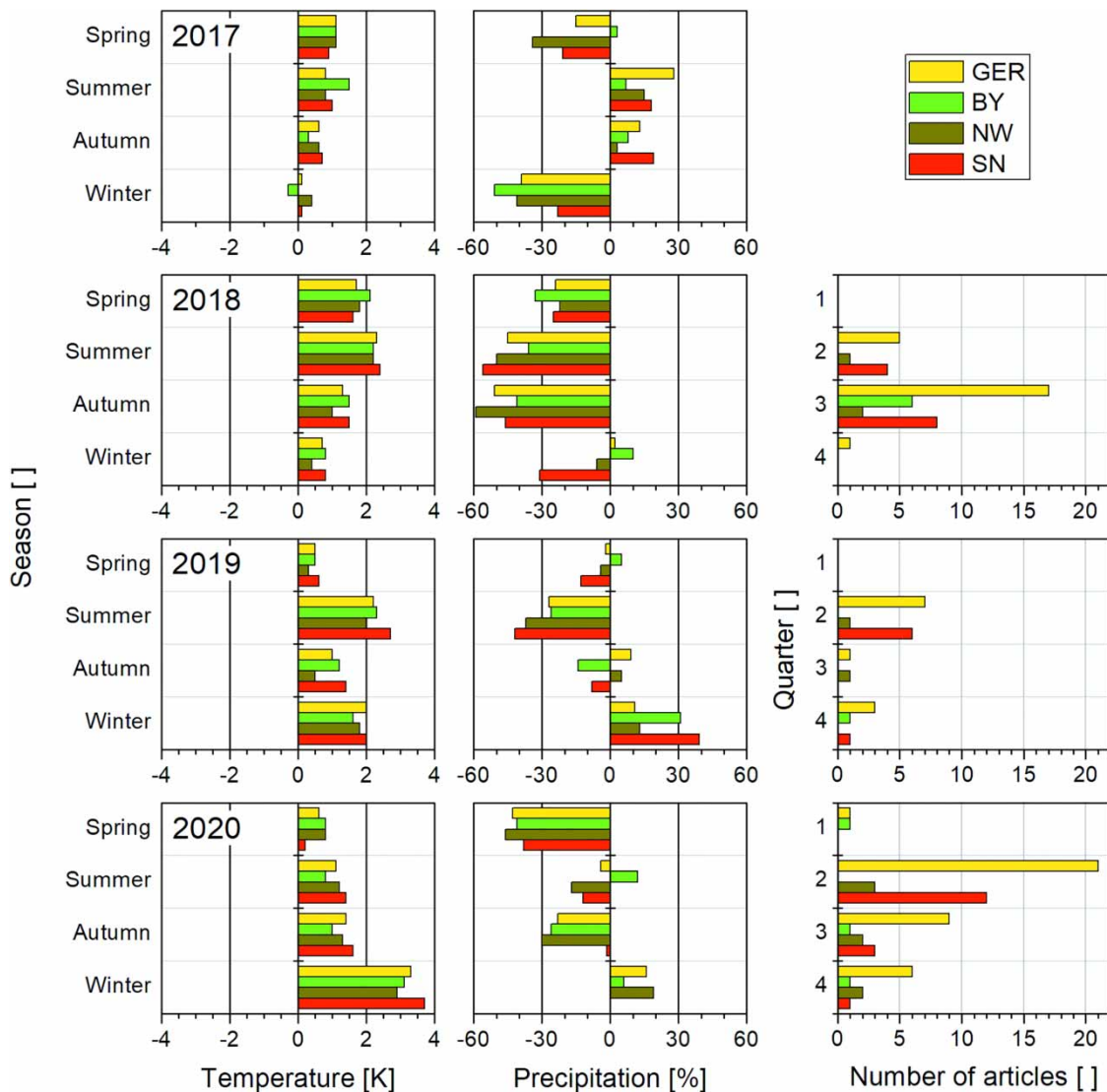
Major issues for connecting to the central water supply are costs for such a connection: as the premises are often in remote locations, connecting costs can be above average, and in some federal states subsidy programmes that had been in place some years or decades ago are not in place anymore. 29% of the articles mentioned current or former funding programmes for connecting properties served by private wells to the public water supply (23% in 2018, 30% in 2019 and 30% in 2020) (see Figure 4). 79% of the articles referring to such programmes were from the federal state of Saxony, where a temporary funding programme was reissued in April 2019. Municipalities and public water suppliers could apply for these subsidies. The goal of the programme was to make the necessary adaptations to change climate conditions and to strengthen rural areas, and the subsidy amount of up to 65% of the costs for connection doubled for cases of hardship to up to €40,000 per property in 2020 (Saxon State Ministry for Energy, Climate Protection, the Environment and Agriculture 2021). In September 2019, 14 water suppliers were supported with approximately €10.5 million to connect 3,600 inhabitants or 1,300 premises to the public water supply (Saxon State Chancellery 2020). In all other federal states, articles referred to former programmes that are not in place anymore. Articles also addressed questions of fairness of cost allocation if all consumers of a water supply had to bear the relatively high costs for connecting few individual premises through the unified water price paid by all.

In Germany, the municipalities and federal states are responsible for providing emergency water supply in case of failure of the central water supply. Emergency water supply was addressed in 37% of the articles, mentioning that such supply was conducted with trucks (12%), from storage reservoirs (10%), users of private wells accessing drinking water at the premises of family members, friends, or in public buildings (7%), emergency supply by the fire brigade (4%) and temporary supply pipes (4%). Emergency supply was not just an issue in the summer months, but in some cases was described to be still necessary in November 2018 (Arbinger 2018; Brückner 2018; Brunner 2018; Ehrhartsmann 2018a; Frisch 2018a, 2018b; Jahnke 2018; Jajes 2018; Müller 2018; Schulte 2018; Spranger 2018) and December 2018 (Ehrhartsmann 2018b, 21; Trinkwasser-Engpässe bei Selbstversorgern in Sachsen nach langer Trockenheit 2018). It appears that a variety of approaches for emergency water supply have been applied when private wells ran dry, not all of which appear to present the provision of drinking

water to those connected to private wells. For example, accessing drinking water at premises of family members or friends appears to be rather a self-sought solution. Safety of the emergency water supply was not always guaranteed (Arbinger 2018; Ehrhartmann 2019; Keiner bleibt auf dem Trockenen sitzen 2020). Arbinger (2018) and Frisch (2018a, 2018b) described that fire brigade trucks pumped water into the wells that had fallen dry, and Arbinger (2018) and Schwere Zeiten für private Brunnenbesitzer (2019) described that emergency water supply was partly provided by milk trucks.

On the other hand, some central water supplies were reported to have introduced calls for reducing water consumption, with actual bans to use drinking water for watering gardens mentioned in only 3% of the articles. Paradoxically, this appears to be a motivational factor for individuals to drill their own wells for e.g. garden watering in case of water-use restrictions, thus further contributing to competing water uses. 7% of articles (2% in 2018, none in 2019 and 14% in 2020) addressed the drilling of new wells for watering gardens or filling private swimming pools, highlighting the conflict that times of water scarcity are often also times of increased water demand. In a German survey, 47% of public water suppliers also considered water rights related to raw water sources of importance to water suppliers during long dry periods (Niehus & Merkel 2020).

On the national political level, areas with current water usage competition are anticipated to be more severely affected in periods of drought (Deutscher Bundestag 2019). Competition for water already occurs in the areas of eastern Lueneburg



**Figure 5** | Deviations of seasonal averages of temperature and precipitation in relation to averages over 30 years (1981–2010) (Deutscher Wetterdienst 2021) and number of newspaper articles for the corresponding quarters with one row per year for Germany (GER) and the three federal states Bavaria (BY), North Rhine-Westphalia (NW) and Saxony (SN); the seasons relate to meteorological seasons, while the quarters are calendrical.

Heath (Lower Saxony), and central areas of eastern Germany, as well as the southern German moraine region (Bavaria), the southern Black Forest (Baden-Wuerttemberg), the Rhenish Slate Mountains (North Rhine-Westphalia, Rhineland-Palatinate, Hesse and Saarland) and the eastern-Bavarian bedrock area (Deutscher Bundestag 2019). While discussions on competition for water typically include the public water supplies as one of the main stakeholders to be considered, representatives of private well operators are often not involved. This represents a risk that those systems which appear to be particularly vulnerable to the effects of climate change are overlooked.

Times of increased temperatures and reduced precipitation may not only have effects on the quantity of water available in sources for drinking water, but also on the quality (Sinisi & Aertgeerts 2011). The effects on the quality of drinking water were reported in 20% of the articles (14% in 2018, 19% in 2019, and 24% in 2020); however, no details were given in most articles, and there was often no clear connection to the climate effects. One article mentioned increased iron and manganese concentrations in the case of considering deeper groundwater layers as an alternative (Auf dem Land versiegen die Brunnen 2020).

### Relation of press article quantity with climate data

Despite the high complexity of water cycles and responses of water availability to meteorological conditions, information on publications was related to climate data in Figure 5 to identify potential parallel trends, with a particular focus on rainfall before the respective years and summer temperatures. The correlation of numbers of press articles with volumes of water abstracted by private wells could not be conducted, as no such quantitative information is available at the national level.

The temperatures in Germany during the summers in 2018–2020 were particularly high, with temperature anomalies of +2.3 K (2018), +2.2 K (2019) and +1.1 K (2020) significantly different from the reference period 1981–2010 (Deutscher Wetterdienst). Furthermore, the precipitation anomalies of –45% (in 2018), –27% (2019) and –13% (2020) compared to the reference period 1981–2010 (Deutscher Wetterdienst) indicate outstanding conditions.

For the whole of Germany and the three federal states with the most matches (Saxony, Bavaria and North Rhine-Westphalia), the number of articles in newspapers is compared to data on anomalies in temperature and precipitation (Deutscher Wetterdienst) in Figure 4 in order to unravel potential causalities. Meteorological data of 2017 are included since rainfalls in winter contribute significantly to the water availability in the following seasons.

The winter 2017 that showed a strong deviation in rainfall which continued during the subsequent seasons until winter 2018, as well as the temperatures in spring and summer 2018 that were higher than the long-term average, likely contributed to the peak in newspaper articles in summer 2018. The positive temperature anomaly in Saxony is above the German anomaly in summer, autumn and winter for all three calendar years. However, this is not clearly evident for Bavaria and North Rhine-Westphalia. As a large number of the articles from 2019 and 2020 referred to the situation in 2018, it is unlikely that climate conditions in 2019 and 2020 significantly influenced the number of articles published during these years.

## CONCLUSIONS

Private wells are particularly vulnerable to the effects of climate change, such as dry periods and periods of reduced rainfall leading to reduced groundwater formation, which was confirmed by the review of press articles. Making sure that they continually provide safe drinking water in rural areas is an important contribution to achieving the Sustainable Development Goal (SDG) 6.1 that aims to ensure safe drinking water to all (UN 2021).

No information on local water shortages could be found in the scientific literature, and no statutory reporting mechanisms on dry drinking-water wells exist at the German national level. Reports in local newspapers proved to be an important and accessible source of information about dry wells due to falling groundwater levels.

The regional distribution of reports partly corresponds with the distribution of private wells and climate data; however, it cannot be explained by this alone. The reissuing of a subsidy programme to support the connection of premises supplied by private wells to the central water supply appears to be a significant factor for the prominence of the topic in the federal state of Saxony.

The information reviewed also provided areas for which future action to support private wells particularly to increase resilience for future climate impacts should be discussed. Connecting to the central water supply system is one solution to address the challenges related to climate change impacts for private wells. However, solutions for financing such connections need to be discussed, and connection may not be feasible, including for hygienic reasons due to water stagnation, for all affected premises. Solutions for emergency water supply in cases where private wells run dry appear to be fragmented, and focus should be put on ensuring safe water not only in case of failure of public water supply, but also of private wells.

The competition of water uses is more prominent in times of dry and hot summers and is likely to become an even more relevant topic in the future. In finding solutions, it will be important to pay attention to the water supply of private wells in addition to public water supply and other uses, and ensure that consumers dependent on private wells are not left behind as a stakeholder group.

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## CONFLICT OF INTEREST

No conflict of interest was identified related to this work.

## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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