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Enhancing Resilience of Private Water Supplies to Meteorological Drought in Scotland

Policy Brief

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Overview

- The analysis highlighted that historically, meteorological drought has been temporally dynamic and spatially variable.
- Meteorological droughts had limited direct impact on PWS water quality, but iron levels exceeded permissible thresholds during extreme meteorological droughts.
- Landcover and source type were more influential on water quality with groundwater sources showing higher iron contamination risks.
- Surveys with Local Authority (LA) managers indicated widespread water security issues in PWS from 2017–2021, despite varying perceptions of drought risk.
- Projections for 2061–2078 indicated drier conditions with shorter but more frequent and intense droughts, creating challenges for water management in low-risk regions.

Introduction

Private Water Supplies (PWS) in Scotland, serving 3.4% of the population and numerous rural industries, face increasing risks due to climate change (Ash,2021). Meteorological droughts, characterised by prolonged periods of low precipitation, are becoming more frequent and intense, threatening both the availability and quality of water in these systems (Kirkpatrick *et al.,* 2021;). This research examines the impacts of drought on Scotland's PWS, identifies vulnerabilities, and provides evidence-based recommendations to strengthen water security under changing climatic conditions.

Research Undertaken

Using climate data, water quality records, and surveys of local authority managers, meteorological drought was assessed through the Standardised Precipitation-Evapotranspiration Index (SPEI) and its effects on water quality parameters were analysed. Statistical modelling helped identify key factors influencing water quality, while future climate scenarios highlighted potential risks under changing weather patterns. Local authority managers responsible for PWS oversight were surveyed to understand their perceptions of drought risks and management practices. Future meteorological drought was developed using climate projections, allowing exploration of potential long-term impacts on water quality.

Key Findings

1. **Historical Meteorological Drought Patterns and Impacts on PWS**
    - The **Standardised Precipitation Evapotranspiration Index (SPEI)** was used to identify meteorological drought periods across Scotland.
    - This study advanced previous work by employing a 1 km² resolution refined spatial scale, compared to broader analyses, providing a more accurate understanding of meteorological drought distribution across Scotland.
    - An examination of the historical period between 1981 and 2018 revealed that based on the 1 km² resolution SPEI, drought risk has been a persistent and significant concern in Scotland.
    - From 1990 onwards, the North, Central, West and island regions of Scotland showed an increase in meteorological drought frequency, intensity and severity, indicating a shifting risk landscape.
    - The lack of consistent spatial and temporal occurrences of meteorological droughts will complicate efforts to predict drought occurrences and their potential impacts.

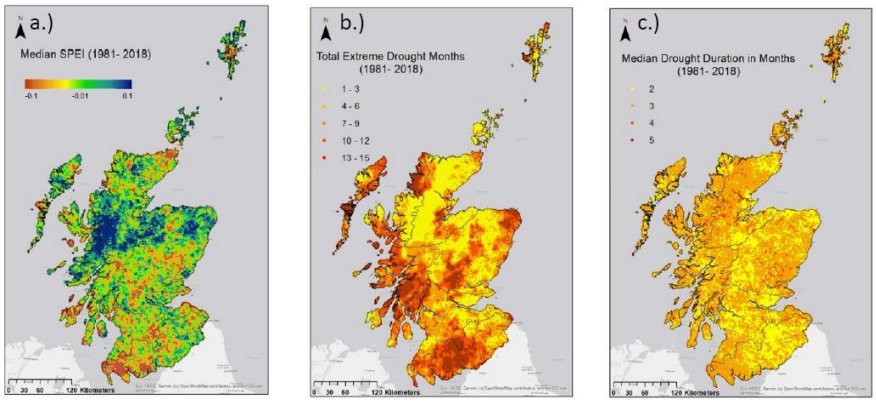

Figure 1: Spatial Meteorological Drought characteristics between 1981 and 2018, including a) median SPEI; b) total number of extreme drought months; c) median drought duration.

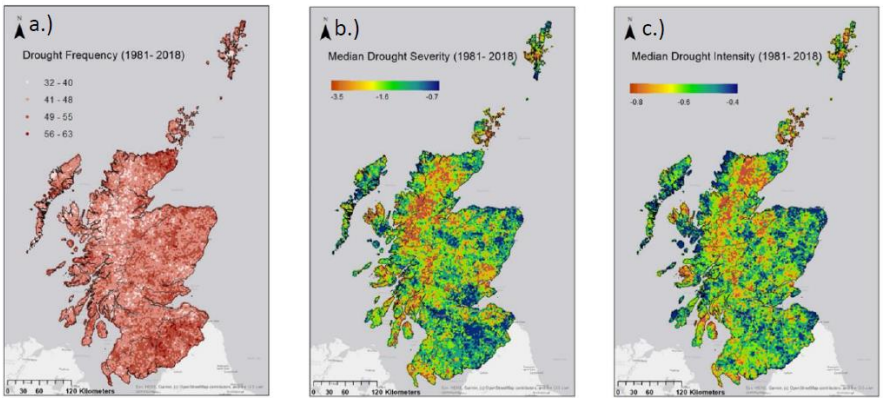

Figure 2: Spatial Meteorological Drought characteristics between 1981 and 2018 a) drought frequency; b) median drought severity; c.) median drought intensity using SPEI based on the HADUK-Grid dataset.

2. **Water Quality Risks During Meteorological Drought**
    - Based on the analysis of collated Water Quality Data, meteorological droughts were not found to contribute to deterioration in PWS water quality.
    - Concentrations of Iron seemed to be exceeding permissible levels in PWS during extreme drought conditions.
    - The analysis also revealed that PWS source type and landcover have greater influence on water quality parameters than meteorological drought conditions.
    - Manganese and nitrate concentrations in PWS reduced in regions with permeable geology, particularly Aberdeenshire and the Scottish Borders during meteorological droughts.
    - Groundwater supplies were more prone to Iron contamination during meteorological drought.
    - Pathogen contamination (***E. coli)***, was exacerbated during non-drought in certain areas, raising public health concerns.
    - Surface water sources showed more variability, reflecting immediate responses to rainfall deficits.

3. **Stakeholder Perspectives and Policy Gaps**
    - Surveys with Local Authority (LA) managers revealed that majority of the LAs in Scotland have experienced water security issues in PWS they manage between 2017 and 2021.
    - Island (Shetland, Orkneys and the Western Isles) authorities, perceived low drought risk despite SPEI data indicating severe dryness.
    - By integrating survey results with geographic and meteorological data, the research provided valuable insights into the relationship between LA experiences, concerns, and the spatial-temporal patterns of drought events.

4. **Future Meteorological Drought Risk in Scotland**
    - The future projections indicated a general trend towards drier conditions across Scotland, especially in the later decades (2061-2078), with significant regional variations.
    - A shift was observed compared to the historical period with drought duration decreasing in the future coupled with increasing frequency, intensity and severity.
    - Water management plans should incorporate more robust meteorological drought forecasting tools and early warning systems, particularly in the regions such as Argyll and Bute, Scottish Borders, Dumfries and Galloway, Highlands and Island regions previously considered low risk.

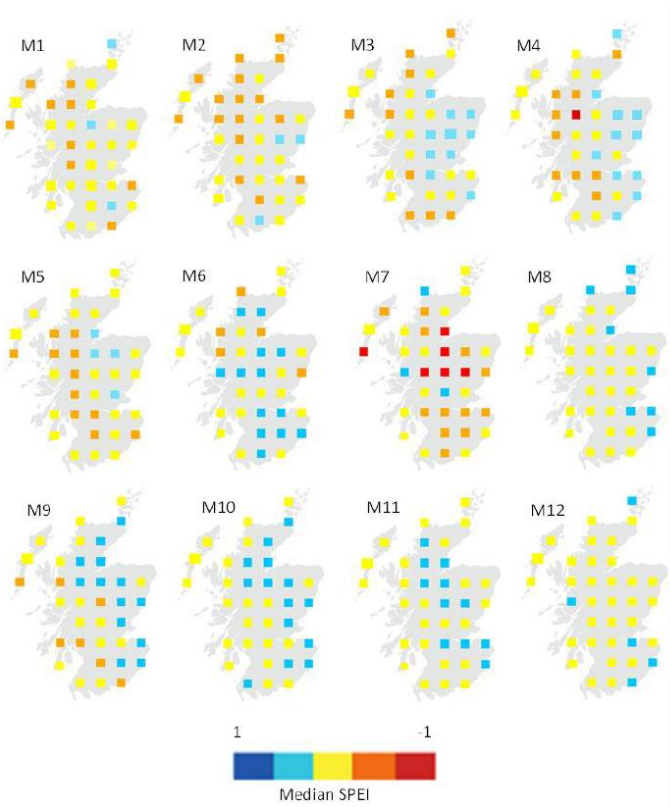

Figure 3: Median SPEI from 2041-2078 for 12 model members, where "M" stands for model member of UKCP-18 dataset. The small squares represent each of the 36 sites, and the colour of the square corresponds to the SPEI value rounded to zero decimal places. The median SPEI values were categorised as: Dark blue > 0.5; Light blue: SPEI<= 0.5 and > 0; Yellow =0; Orange SPEI < 0 to >=-0.5; Red SPEI < -0.5.

Conclusions

This research highlighted the complexity of drought risk and its implications for water security in Scottish PWS. Future droughts will pose an increasing challenge, especially in regions that were not previously considered vulnerable, requiring proactive management strategies and targeted research efforts. By incorporating multiple drought metrics, including duration, frequency, severity, and intensity at a refined spatial scale, the study offered a detailed understanding of how drought risk varies spatially and temporally across Scotland, particularly in the Northwest, West, South and Central parts of Scotland as drought patterns have been observed to shifting to these regions. This approach enabled the study to project localised drought impacts on water security, especially for PWS, and provide specific recommendations for mitigating future risks. Although PWS water quality did not show drought as a major driver of contamination, Scotland's broader drought risk management strategy will need urgent adaptation to address shifting geographical risk patterns, regional vulnerabilities, and the need for enhanced water quality monitoring. The findings highlight the need for enhanced water quality monitoring in liaison with LAs, particularly during and immediately after drought events, as this is when the greatest water quality impacts may be detected. Implementing robust monitoring protocols during these critical periods will improve our understanding of water quality dynamics and support timely interventions.

Policy Implications or Recommendations

1. **Develop Regionalised Drought Response Strategies**

   There is a need for enhanced localised monitoring systems to track meteorological drought onset, duration, intensity, severity and especially post-drought recovery phases, which may reveal water quality impacts in PWS.

2. **Enhance Monitoring and Data Integration**
   - Implement **standardised monitoring protocols** to ensure consistent water quality assessments across all regions.
   - Increase sampling frequency during and immediately after drought periods to detect emerging contaminants and assess long-term impacts.
3. **Strengthen Resilience of PWS**
   - Provide technical and financial support for upgrading infrastructure in vulnerable PWS, including enhanced treatment facilities and improved borehole construction.
   - In addition, the current classification system, which divides PWS into large regulated (Type A) and small non-regulated (Type B) categories based on usage does not fully address the specific vulnerabilities of different water sources. Instead, LAs in collaboration with the DWQR should prioritise creating distinct source-based profiles (e.g., groundwater, surface water, spring-fed) for each PWS.
4. **Bridge the Gap Between Authorities and Users**
   - Foster a shared conceptual understanding of drought risks among local authorities, users, and policymakers through targeted education and outreach campaigns.
   - Address user vulnerabilities by incorporating social and economic dimensions into drought management plans, ensuring that all stakeholders are informed and prepared.

Implementation Pathway

1. **Short-Term (0–2 years)**: Establishing standardised sampling protocols.
2. **Medium-Term (2–5 years)**
   - Establish source-specific action plan for PWS such as establishing protection zones for shallow springs and aquifers.
   - Conduct Water quality sampling at regular, short intervals, particularly during periods of drought or water stress at a selection of representative sites sourcing data from PWS users.
3. **Long-Term (5–10 years)**
   - Develop a Drought Vulnerability Index (DVI).
   - Establish a centralised water quality and drought monitoring database to support adaptive management.

References

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