

Chronic drought, not acute heatwave, drives record summer live fuel moisture lows in temperate heathland

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Abstract

Wildfire risk is increasing in temperate heathlands. These ecosystems have previously been protected from severe summer wildfires because of their phenologically-high live fuel moistures (LFMC), but extreme weather events are increasingly overriding this resistance, leaving heathlands vulnerable to wildfire. Here we show the impact of experimental and observed meteorological drought on the LFMC and flammability of *Calluna vulgaris* from 2024–2025 and compare this to the impacts of the acute July 2022 heatwave in the UK. The prolonged drought in 2025 disrupted the phenological green-up of *Calluna*, leading to the lowest summer LFMC (44%) ever recorded in temperate heathlands and exceeding the previously recorded low during the 2022 heatwave by ~ 50%. Our findings suggest chronic extreme drying rather than acute temperature extremes pose the greatest risk for wildfires in temperate heathlands and highlight the emergence of a new era of wildfires characterised by non-linear LFMC dynamics under extreme weather conditions.

Introduction

Wildfires are becoming increasingly prevalent in traditionally non-fire-prone temperate regions such as the UK (Jones et al. 2022; Little et al. 2025). These regions have historically been protected from large, severe wildfires due to their humid, mild climate and regular rainfall. However, increased extreme events like heatwaves and drought, alongside anthropogenic warming, are increasing the risk of wildfires (Belcher et al. 2021; Arnell et al. 2021; Perry et al. 2022; Ivison, Little, Orpin, et al. 2025). Europe experienced its worst wildfire season on record in 2025, and within the UK wildfires burned ca. 47,179 ha (Fernando et al. 2026), including multiple major incidents on heathlands and moorlands that overwhelmed Fire & Rescue Services (Orlandi 2025). Within temperate regions like the UK, heathlands/moorlands are particularly important for wildfire risk. Wildfires in these ecosystems tend to dominate burned areas and experience 4–7-fold higher fire detection counts per unit area than forest or arable land covers (Ivison, Little, Orpin, et al. 2025). In the UK, heathlands/moorlands are dominated by the dwarf shrub *Calluna vulgaris* (hereon *Calluna*) and are of ecological importance as they are home to a number of endangered and rare invertebrate species (Warren 1991; Telfer and Eversham 1996).

In *Calluna*-dominated heathlands and moorlands, live fuel moisture content (LFMC; the water content of living vegetation) drives wildfire spread and behaviour (Davies et al. 2009). LFMC in temperate heathlands is strongly controlled by vegetation phenology. *Calluna*-LFMC is lowest in spring following winter senescence and increases through summer with vegetation green-up and new growth (Nikonovas et al. 2024; Belcher et al. 2025). Heathland flammability is thus also coupled to vegetation phenology due to its dependence on LFMC (Belcher et al. 2025). In contrast, the fuel moisture content (FMC) of dead vegetation is important for sustaining ignitions (Davies and Legg 2011), and the moisture content of the organic soil layer controls wildfire severity and the potential for smouldering combustion of soil carbon (Davies et al. 2013). While the latter two fuels respond strongly to the drying effects of fire weather, which is generally most extreme in summer (Little et al. 2024; Ivison, Little, Orpin, et al. 2025), it is rare for fire weather to impact the overall annual pattern observed in LFMC (Ivison et al. 2024; Ivison,

Little, Orpin, et al. 2025). This means that during summer when fire weather is at its most extreme, LFMC tends to be at its highest, which provides an ecosystem-wide resistance to summer heathland wildfires that would otherwise risk high severity wildfires smouldering into the dry organic soil layers. This is reflected in the UK's fire season, which is characterised by high numbers of heathland/moorland fires in spring, while summer fires tend to occur on croplands/grasslands and not heathlands (Nikonovas et al. 2024; Little et al. 2026).

However, exceptional weather conditions, bringing extreme temperatures and atmospheric dryness, can override this phenologically-driven resistance to summer fires in heathlands. This was observed during the July 2022 heatwave when dramatic reductions in LFMC and increases in live fuel flammability (in addition to the already low dead FMC and organic soil moistures) were observed, leading to synchronised extreme dryness and associated increased risk of severe wildfires (Iverson, Little, Orpin, et al. 2025). Droughts also affect wildfire behaviour, and drought–fire is the most common compound dry hazard event in the UK (Sutanto et al. 2020). By definition, droughts can bring about long-term reductions in fuel moistures, increasing wildfire risk and potential severity, but the effect of drought on wildfire risk within heathland ecosystems has not been well documented. Under experimental drought, moss and litter FMC were found to be affected to a larger degree than soil, whereas *Calluna* LFMC was unaffected in a single FMC sampling event (Grau-Andrés et al. 2018). However, the longer-term effects of prolonged drought on *Calluna* LFMC and flammability have not been investigated. In particular, the extent to which drought can impact the annual phenological pattern of *Calluna* LFMC is not known (Estiarte et al. 2016). We lack understanding of the complex dynamics of LFMC in these ecosystems, particularly under extreme weather conditions, which has translated to Fire & Rescue Services resource capacity being consistently overwhelmed during these events (London Fire Brigade 2023; John and Rein 2024). We urgently need to understand LFMC dynamics during extreme weather conditions to be able to develop predictive models that capture the increased wildfire risk to inform resource planning and decision-making.

This urgency is compounded by the fact that both heatwave and drought events are predicted to increase in frequency, duration and severity across Europe (Sanderson and Ford 2016; Spinoni et al. 2018; Lhotka and Kysely 2022). Under even the lowest emission scenario, the occurrence of droughts, represented by the Soil Moisture Index, is predicted to increase by 22–123% (Grillakis 2019). The increase in drought frequency and severity is most significant in western Europe, including the UK, and southern Europe (Spinoni et al. 2018). In the UK, the 2022 unprecedented heatwave event saw records broken across the country, with temperatures exceeding 40 degrees Celsius for the first time (Yule et al. 2023). During this time, the UK experienced widespread wildfires, including the Wennington Fire that resulted in significant loss of structures and forced evacuations (John and Rein 2024).

The years 2024 and 2025 represented extremes in precipitation across the UK. In 2024, the UK experienced the 13th-wettest year since 1836 (Kendon et al. 2025), while 2025 experienced the driest spring in England since 1836 and became the warmest and sunniest year on record for the UK (Met Office 2026). The period from March to August 2025 saw less than 50% of average rainfall, with the

March–July period being the driest since 1921 in the UK (Environment Agency 2025; Met Office 2026). Here, we investigate the combined effect of extreme (high and low) precipitation across 2024 and 2025 and experimental drought (drought shelters) on the LFMC and flammability of *Calluna*. We compare these impacts of prolonged drought, both meteorological and experimental, to the impacts of an intense but short-lived heatwave on LFMC. By using data collected both during the drought experiment of 2025 and the 2022 July heatwave (Iverson, Little, Orpin, et al. 2025), we enable a direct comparison of acute (heatwave) versus chronic (drought) live vegetation FMC and flammability stressors, to inform wildfire risk prediction in temperate ecosystems under increasing climate extremes.

Methods

Experimental design

We established a drought manipulation experiment on a heathland site at Kinver Edge (52.435 °N, 2.257 °W) between March 2024 and October 2025. The site had an elevation of roughly 100 metres above sea level with freely-draining sandy soil (Farewell et al. 2011). The dominant vegetation was *Calluna*, interspersed with some bracken (*Pteridium aquilinum*), holly (*Ilex aquifolium*) and grasses.

The experiment comprised three treatments; a drought treatment, where approximately 50% of rainfall was diverted away from the plot using drought shelters; a control treatment, where no rainfall was diverted but a structure was built to account for the potential of this to affect the microclimate of the plot; and a 'ghost' control treatment, where a plot was marked but no structure was built, representing fully ambient conditions (Fig. 1). Each plot had an area of 1.5 x 1.5 metres, and there were seven replicates of each of the three treatment types, resulting in twenty-one plots in total.

Structures for the drought and control plots were built using a cuboid timber frame, 1.8 m tall at one side and 1.5 m at the opposite side (Fig. 1). For the drought treatment, plastic strips were cut from corrugated plastic sheeting and placed equidistantly to cover 50% of the plot. The structure gradient allowed rainwater to run down towards the shorter end of the structure, where guttering was attached to divert this into a container. Structures were angled towards the prevailing wind direction to reduce the possibility of rain being blown underneath the plastic strips. The rain covers were retained throughout the entire time period. For control treatments, plastic strips were replaced with bamboo poles to allow all precipitation to land inside the plot. Ghost plots were marked on the ground with twine.

To determine whether the treatment structures affected within-plot microclimates, a HOBO U23-001A PRO V2 logger (Onset Computer Corporation, Bourne, MA) was placed within the *Calluna* canopy of each plot and TMS-4 dataloggers (Wild et al. 2019) were placed near the centre of the plots to measure soil moisture and air temperature at three depths: 6 cm below the soil surface and above ground at 2 and 15 cm. Further TMS-4 dataloggers were placed at the edges of the plots for drought and control treatments to test for edge effects of the structures. As the treatment structures had a very limited impact, the analysis of these data and the results are presented in the Supplementary Material only (Table S11).

Data

Experimental drought data collection

Sampling of live *Calluna* (canopy and stem) and organic soil was carried out roughly every month from April to September in 2024 and 2025, on dry days where at least 24 hours had passed since the last rainfall (Table S1). Sampling was not possible in July 2024 due to frequent rainfall, and an extra sampling effort was carried out in July 2025 during a particularly hot period on the 12th of July to capture the effect of this on FMC.

Live *Calluna* was sampled by taking several clippings of the canopy and stem (< 2 mm diameter) from different plants within each plot. Canopy and stem were separated and for each layer, all clippings from a plot were merged and stored in a single aluminium tin. Organic soil (the top 5 cm of organic material beneath the surface litter and above the mineral soil) was sampled using a corer from at least two points within a plot which were merged into a single tin. Finally, a *Calluna* sample containing both canopy and stem was clipped from each plot for fuel flammability characteristics. All tins were sealed with masking tape. Temperature, relative humidity and wind speed were measured during sampling using a Kestrel weather meter (Kestrel Instruments, Boothwyn, PA).

FMC samples were weighed, dried in an oven at 80°Celsius for 48 hours and reweighed following the protocol of Little and Quiñones (2022) used in other *Calluna* fuel moisture studies for consistency (Little et al. 2023, 2024; Lewis et al. 2024; Iverson et al. 2024; Iverson, Little, Belcher, et al. 2025). FMC is calculated as:

$$FMC = (W - D) / (D - T),$$
 where W = wet weight, D = dry weight, T = tin weight.

Fuel flammability characteristics were measured by pyrolysis combustion flow calorimetry (PCFC), with an FAA Micro Calorimeter (Fire Testing Technology Ltd, East Grinstead, UK). This method has been previously used for assessing the flammability characteristics of *Calluna* and other heathland fuels in the UK (Iverson, Little, Belcher, et al. 2025). Subsamples of the stems (7–46 mg) and canopy excluding stems (3–27 mg) (hereafter referred to simply as ‘canopy’) were pyrolysed (heated in the absence of oxygen) at a constant heating rate of 3°C s⁻¹, to a maximum pyrolysis temperature of 750°C. The pyrolysate gases were then combusted at a temperature of 900°C. The N₂ flow rate was set to 80 cm³ min⁻¹ and the O₂ flow rate to 20 cm³ min⁻¹ (matching that of the natural atmosphere). Data derived from the resulting heat release profiles included the peak heat release rate (PHRR), the total heat release (THR), and the temperature at maximum rate of decomposition (Tmax). Due to equipment failure, flammability data were sporadic for 2024.

Meteorological Data

Weather data from the Winterbourne weather station in Birmingham (52°27'23"N, 001°55'39"W) were extracted to compare mean monthly total precipitation, number of precipitation days (> 0.2 mm) and mean monthly air temperature for April–September 2024 and 2025, relative to the long-term (1991–2020) monthly mean conditions. The Standardised Precipitation-Evapotranspiration Index for a three-month accumulation period (SPEI-3) from the European Drought Observatory (Vicente-Serrano et al. 2010) was extracted at a 10-daily temporal resolution and 0.25 x 0.25 degree spatial resolution for the experimental site from January 2024 to December 2025 (Vicente-Serrano et al. 2010). SPEI-3 is widely used as an indicator of short-term meteorological and agricultural drought as it accounts for both precipitation and potential evapotranspiration and is therefore sensitive to both temperature and precipitation fluctuations (Vicente-Serrano et al. 2012). The SPEI-3 measures the difference between precipitation and potential evapotranspiration (PET; calculated using the Hargreaves-Samani method (Hargreaves and Samani 1982, 1985)) with respect to the baseline period of 1991–2020 for a three-month accumulation period, also known as the climatic water balance deficit.

Data analysis

We assessed whether the control shelters had an observable effect on FMC and flammability characteristics using t-tests between ghost and control plot FMC, PHRR, THR and Tmax measurements per fuel for each sampling date (Tables S2:5). All tests were non-significant at $\alpha = 0.05$ except for one sample measurement per metric, namely FMC September 2025 measurements for *Calluna* canopy, PHRR August 2024 measurements for both canopy and stem, THR July 2025 for stem and Tmax June 2025 for canopy. We therefore group ghost and control measurements for all subsequent analysis. We then assessed the effect of the drought shelters using t-tests comparing the grouped ghost and control FMC, PHRR, THR and Tmax measurements with those from the drought shelters per fuel for each sampling date (Tables S6:9).

The experimental data from 2024 followed the same annual pattern in LFMC observed in Iverson et al.'s 2024 UK-wide assessment of heathland FMC from 2021–2023 and is thus representative of 'typical' annual LFMC patterns in the UK, which we compared to the chronic drought year of 2025. We also compared FMC between a 'typical' year, an extreme heatwave in 2022 (from Iverson, Little, Orpin, et al. (2025)), and the drought of 2025 to assess how extreme weather conditions affect FMC (Table S10). For these comparisons, all data from the drought experiment (ghost, control and drought plots) were combined due to the minimal effect of drought shelters on FMC. Because the heatwave event occurred in July, we use the July 2025 FMC data for the drought event. There were no July 2024 FMC samples collected due to rainfall, so we used the July 2021 FMC data from the UK-wide dataset to represent a 'typical' July as both years followed the same annual pattern in FMC. We subset the July 2021 and 2022 UK-wide FMC data to retain only sites with similar characteristics to our experimental site; sandy and freely draining soil, and elevation close to 100 m. Using t-tests, we compared this subset data to July data from the dry year of 2025, within which we merged data from all treatments (ghost, control and drought) as our analysis showed no effect of the drought shelters on FMC during this period.

Results

Here, we will describe two types of drought; (i) that which is caused by the drought shelters intercepting 50% of rainfall, which we will refer to as 'experimental drought' and (ii) the dry year of 2025, which we will refer to as 'chronic drought'.

Meteorological conditions during the experiment

In 2024, most months had greater total precipitation and a higher number of rainfall days than average, while mean air temperature was slightly lower than average in every month except July (Figure S1–3). In 2025, total precipitation was 55–67% lower than average from April to June and 67% lower than average again in August (Figure S1). The number of rainfall days was also lower than average in most months (22–45% lower than average April–June; Figure S2), and mean temperature was higher than average in all months except September (Figure S3).

The SPEI-3 indicated a period of prolonged meteorological drought through the spring and summer of 2025, including a period of climatic water balance deficit where conditions were 'extremely dry' lasting from May–August (Fig. 2). By contrast, 2024 was a largely wetter than average year, with 'moderately dry' conditions only experienced at the end of August.

Effect of experimental drought on live fuel characteristics

Experimental drought had no effect on *Calluna* canopy LFMC in either year. For *Calluna* stem, the only significant reduction in LFMC under experimental drought was in early-June 2025. The organic layer was most affected by experimental drought, with significant reductions in FMC under drought shelters observed during four sampling events: June 2024, and April, June and September 2025 (Table S2). Experimental drought had no effect on *Calluna* canopy or stem peak heat release rate (PHRR; indicative of potential maximum fire intensity) or temperature at maximum rate of decomposition (Tmax; indicative of ignition temperature) in either year, except for late-June 2025 canopy Tmax (Table S3,S5). There were some significant reductions in total heat release (THR; cumulative energy released per unit mass) under experimental drought, namely August 2024 stem, September 2024 canopy and early-June 2025 canopy and stem (Table S4). Because the effect of the drought shelters was minimal, data from all treatments (ghost, control and drought) were combined hereon.

Effect of chronic drought on phenological LFMC patterns

Calluna canopy and stem data obtained both during the experiment in 2024 and during a UK-wide sampling regime in 2021 showed a phenological curve, where LFMC increased towards summer, as plants greened up, and decreased into autumn as they senesced (Fig. 3). During the chronic drought of 2025, this pattern was noticeably disrupted; instead of increasing in the summer, LFMC showed a large decrease from June, with *Calluna* canopy LFMC reaching an average low of 44% (averaged across all

plots) and *Calluna* stem LFMC reaching an average low of 51% in August. The phenological disruption was visible in the dramatic impact on the extent and timing of *Calluna* flowering (Fig. 4). LFMC of both fuel components increased in late September, which coincided with heavy precipitation during early September.

Effect of chronic drought on fuel flammability

Calluna canopy and stem flammability characteristics show that *Calluna* was consistently more flammable in 2025 compared to 2024 (Fig. 5). PHRR peaked in late summer 2025, though even in spring, 2025 PHRR exceeded the maximum PHRR recorded in all of 2024. *Calluna* canopy THR was notably high in 2025, peaking in late summer, consistent with the decrease in temperature of maximum decomposition. Stems had a large difference in Tmax between 2024 and the drought year of 2025. PHRR and THR (but not Tmax) followed similar annual patterns to that of LFMC (Fig. 3), with LFMC decreases explaining ~ 30% of PHRR and THR increases (Figure S4).

Chronic drought versus acute heatwave impacts on LFMC

For all fuels (*Calluna* canopy, *Calluna* stem and the organic layer), FMC during the heatwave of July 2022 was significantly lower than what would be expected during a baseline 'normal' July. For *Calluna* canopy and stem, LFMC during July 2025, following prolonged spring meteorological drought, was significantly lower than both baseline and heatwave LFMC. At the peak of the 2025 drought in August, average low live *Calluna* canopy and stem moisture contents were reduced by an additional 47.6% and 35.4%, respectively, compared to the average lows experienced during the peak of the 2022 heatwave. For the organic layer, FMC during the heatwave and drought were similar (Table S10; Fig. 6).

Discussion

Chronic drought breaks the phenological control on fuel flammability

The year 2025 was characterised by exceptionally low precipitation levels, with the SPEI-3 index indicating conditions reached 'extremely dry' levels between May and August. This corresponds to a disruption in the phenological cycle of *Calluna* LFMC, whereby the seasonal increase in LFMC with the summer green-up was replaced with a drastic drop in LFMC (Fig. 3) leading to the lowest summer LFMC of *Calluna* canopy and stem ever recorded in England and equivalent to the lowest LFMC ever recorded during winter senescence in the UK (Davies et al. 2010). This unprecedented observation was the result of a chronic drought beginning in March 2025, which was uninterrupted until September 2025. Similarly, in 2022, the acute July heatwave also disrupted the phenological cycle of *Calluna* in several regions of the UK, resulting in homogeneously low FMC across heathland ecosystems and increased wildfire risk (Iverson, Little, Orpin, et al. 2025). At the time, these observations were the lowest summer LFMC recorded in temperate heathlands/moorlands and raised concerns about the effect of acute extreme

heatwave events on heathland wildfire risk. However, during the drought of 2025, the reduction in *Calluna* LFMC greatly exceeded even that observed during the 2022 UK heatwave, with mean *Calluna* canopy and stem LFMC nearly 50% and 35% lower during the peak of the drought, respectively. This means that the risk of wildfire occurrence and severity experienced during chronic drought was greater than during acute heatwave conditions, with *Calluna* canopy and stem LFMC dropping significantly below their ignition thresholds of 65% and 60%, respectively, for much of summer 2025 (Taylor et al. 2021). Indeed, Fire & Rescue Services were called to suppress eight wildfires within the Kinver Edge National Trust during the spring and summer of 2025, which is unprecedented for the area (Alex Murison, National Trust Kinver Edge Ranger, personal communication).

Heathland resilience and recovery from drought conditions

Previously reported effects of experimental drought on physiological characteristics of *Calluna* are varied. New shoot growth is typically maintained under experimental drought (Albert et al. 2011; Haugum et al. 2021). Biomass has been found to either remain unaffected (Kongstad et al. 2012; Haugum et al. 2021) or become reduced (Peñuelas et al. 2004) under experimental drought, and this effect may depend on the age of the *Calluna* plants (Meyer-Grünefeldt et al. 2015). One experiment found that the biomass response of *Calluna* to drought only occurred with concurrent meteorological drought (Kongstad et al. 2012), which is consistent with our observed reduction in LFMC during the extremely dry year of 2025. We observed largely a lack of response of *Calluna* LFMC and flammability (both canopy and stem) to experimental drought alone. This is consistent with Grau-Andrés et al. (2018) who found no effect of experimental drought on *Calluna* LFMC. This may be because rain-out drought shelters reduce precipitation inputs but not necessarily the plant-available water as the root zone moisture content may be unaffected and create an edge effect that reduces the stress imposed by the drought shelters on LFMC (Robinson et al. 2016); this is supported by the lack of effect of drought shelters on measured soil moisture (Table S11). In contrast, organic layer FMC was reduced under experimental drought on some sampling dates. The FMC of moss and litter beneath *Calluna* has also been found to be affected by experimental drought (Grau-Andrés et al. 2018), highlighting that fuels that are not connected to the wider hydrological system respond more readily to precipitation deficits imposed under experimental drought. Previous studies have found that certain characteristics of *Calluna* (biomass, photosynthetic rates) were found to recover following rewetting, and that *Calluna* can also increase its water-use efficiency during experimental drought (Gordon et al. 1999). These experiments therefore demonstrate the resilience of *Calluna* to moderate meteorological surface drought (but not drought that depletes the root zone moisture content) and highlight the chronic conditions required to affect the physiology of *Calluna* to the extent observed in our experiment during 2025.

We observed a rapid increase in *Calluna* LFMC in September 2025 following several precipitation events and associated reduction in drought conditions. This suggests that despite the prolonged period of extreme drought and warm temperatures leading to record-low fuel moisture contents and increased wildfire risk, *Calluna* LFMC is capable of rebounding in the short term to chronic drought LFMC reductions. What is unclear, is whether the chronic drought will have a longer-term impact on the timing

and extent of green up in the years to come. Summer precipitation and wet day frequency is expected to decrease in the UK (Rajczak and Schär 2017), with Aalbers et al. (2018) noting a 10–30% decrease in mean daily summer precipitation for the period 2071–2100. Furthermore, even under the most mild climate change scenarios, the intensity and severity of soil droughts are expected to increase (Grillakis 2019). Further research is needed to determine the physiological drought conditions under which *Calluna* is unable to recover, marking a sharp long-term increase in wildfire risk when exceeded. Conversely, winter mean and extreme precipitation is expected to increase under climate change scenarios (Rajczak and Schär 2017; Aalbers et al. 2018). Further research is also needed to examine what levels of precipitation are required for *Calluna* to recover from spring and summer drought with consideration to potential adaptation strategies for sensitive heathland ecosystems under climate change.

A need for predictive models that capture non-linear LFMC responses

Temperate regions are entering a new era of wildfire regimes, characterised by an increasing frequency and intensity of atmospheric extremes, but existing LFMC models are not capable of capturing non-linear responses and tipping points in LFMC reductions that exist outside the envelope of historical observations (Iverson, Little, Orpin, et al. 2025). This leads to high-risk situations where fuels are much drier and more flammable than predicted under atmospheric extremes, which may leave Fire & Rescue Services misinformed of the potential wildfire behaviour. While a lack of LFMC and flammability measurements under extreme weather conditions has significantly limited our understanding of complex, non-linear LFMC dynamics to date, this study provides valuable observational data that capture non-linear reductions in LFMC and increases in flammability under atmospheric extremes that break the phenological control on summer fuel flammability. These insights highlight a key mechanism underpinning the emergence of novel wildfire regimes in temperate regions and provide an important empirical foundation to inform the next generation of predictive models needed to capture the increase in wildfire risk expected in our changing climate.

Declarations

Competing Interests

The authors declare no competing interests.

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Author Contribution

K.L. and K.I. contributed equally to the study. K.L., K.I., L.J.G., C.M.B., A.M. and N.K. developed the study design; K.L., K.I. and N.K. collected data; K.L., K.I. and A.C. analysed the data; K.L. and K.I. led the writing of the manuscript; all authors contributed to the review and editing of the manuscript prior to submission.

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Data Availability

The research data generated will be made publicly available upon acceptance of the manuscript via FigShare.

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Figures

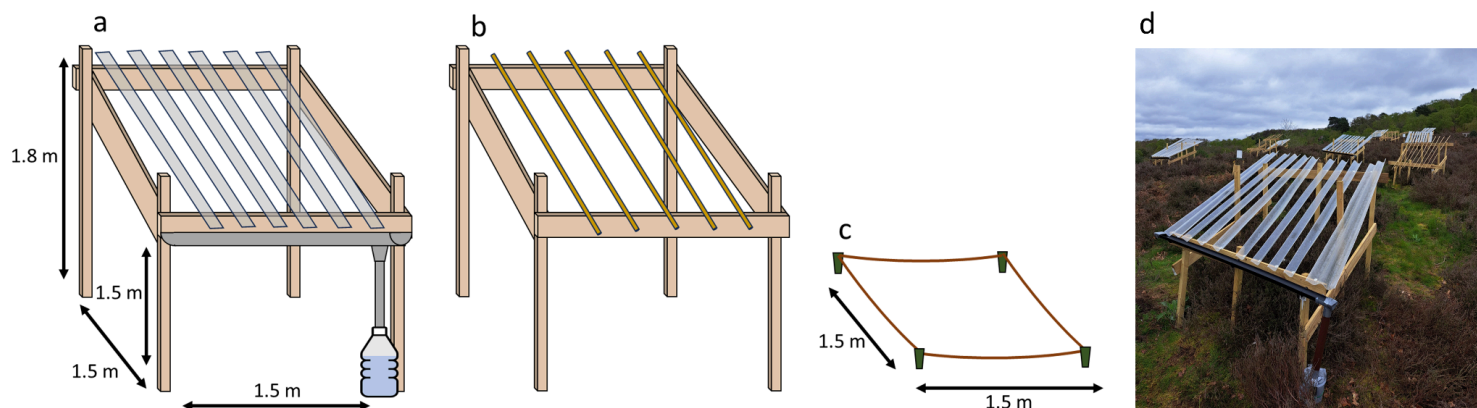


Figure 1

Experimental design of the three treatments: a) drought treatment comprising a wooden structure with plastic strips, cut from corrugated plastic sheeting, on top. Strips cover ~50% of plot area and divert rainfall to a gutter and container to prevent excess rainfall from falling directly outside the plot; b) a control with a wooden structure to account for the potential for structure to alter microclimate of plot. Plastic strips are replaced with bamboo poles to allow rain to fall into the plot; c) 'ghost' control without a structure where a 1.5 x 1.5 m plot was marked in the heathland using pegs and twine. Completed experiment is shown in (d).

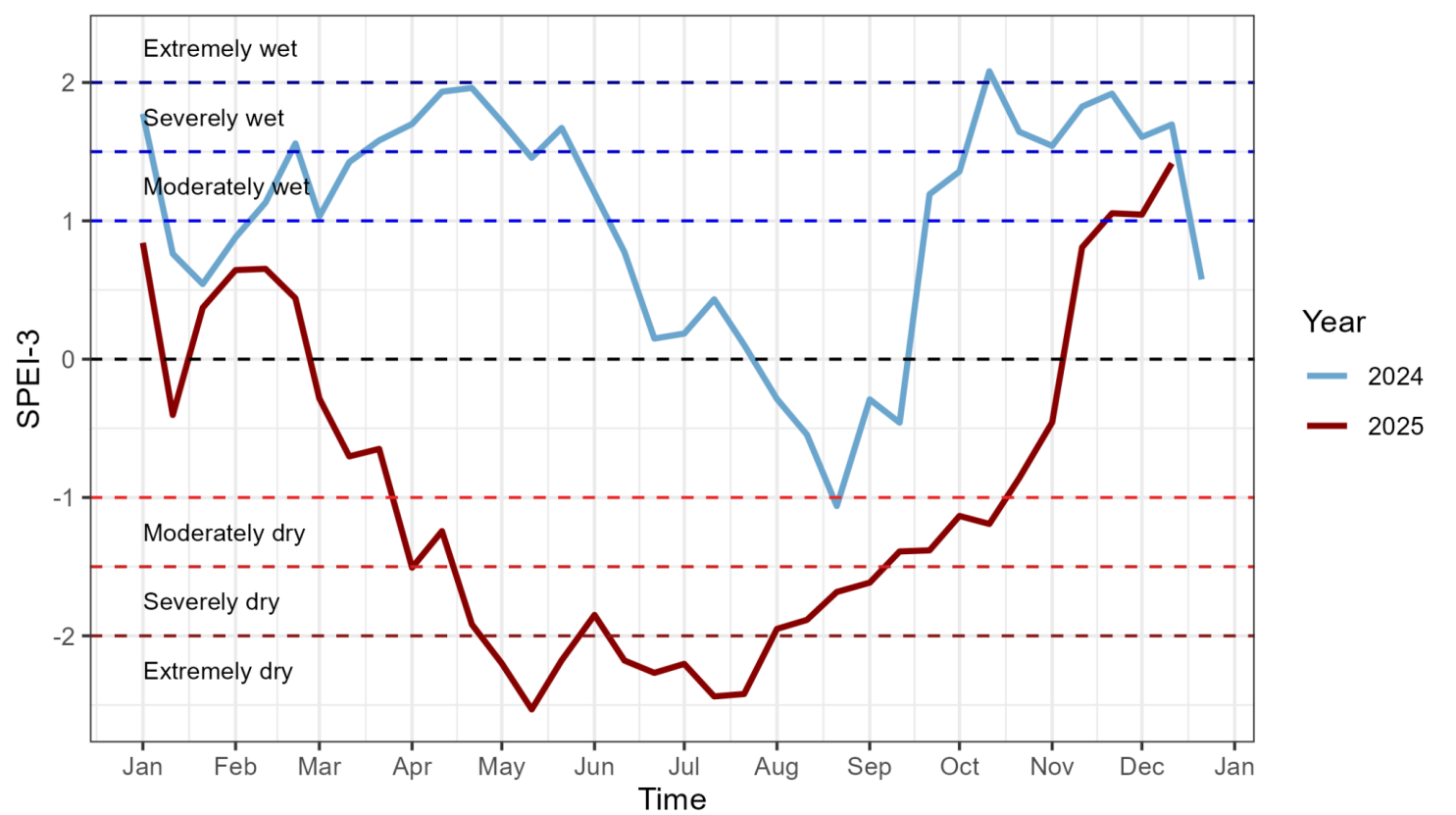


Figure 2

Ten-day Standardised Precipitation-Evapotranspiration Index accumulated over three months (SPEI-3) for 2024 (blue solid line) and 2025 (red solid line). Dashed lines indicate thresholds between increasingly severe drought (negative values) and wet (positive values) conditions (European Drought Observatory, <https://drought.emergency.copernicus.eu>, European Commission—JRC, 2012–2026).

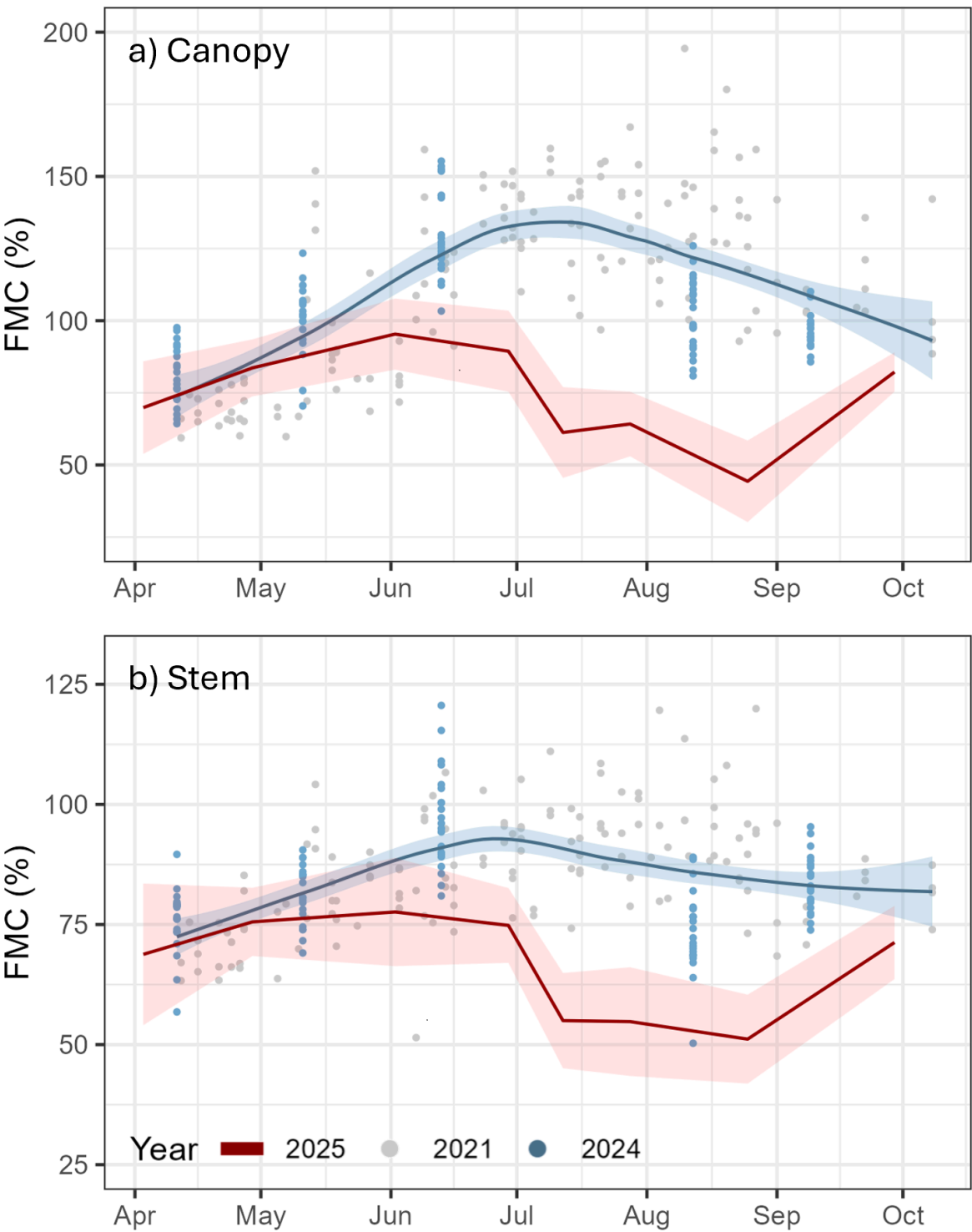


Figure 3

(a) Canopy and (b) stem live fuel moisture content (LFMC) measurements collected nation-wide in 2021 (grey dots) and at the experimental drought site in 2024 (blue dots for all plots) and 2025 (mean for all plots = dark red line; standard deviation = light red envelope). Data from all experimental treatment types (ghost, control and drought) are plotted. A loess smoothing line and confidence interval (dark blue line with light blue envelope) was fitted for the 2021 and 2024 data to visualise the phenological curve of *Calluna* fuel moisture content in a typical year.



Figure 4

Images taken at the experimental drought site in August 2024 (left) and August 2025 (right). The typical purple colour of the heathland in flower in August was significantly subdued, with *Calluna* looking much browner at the same time in 2025.

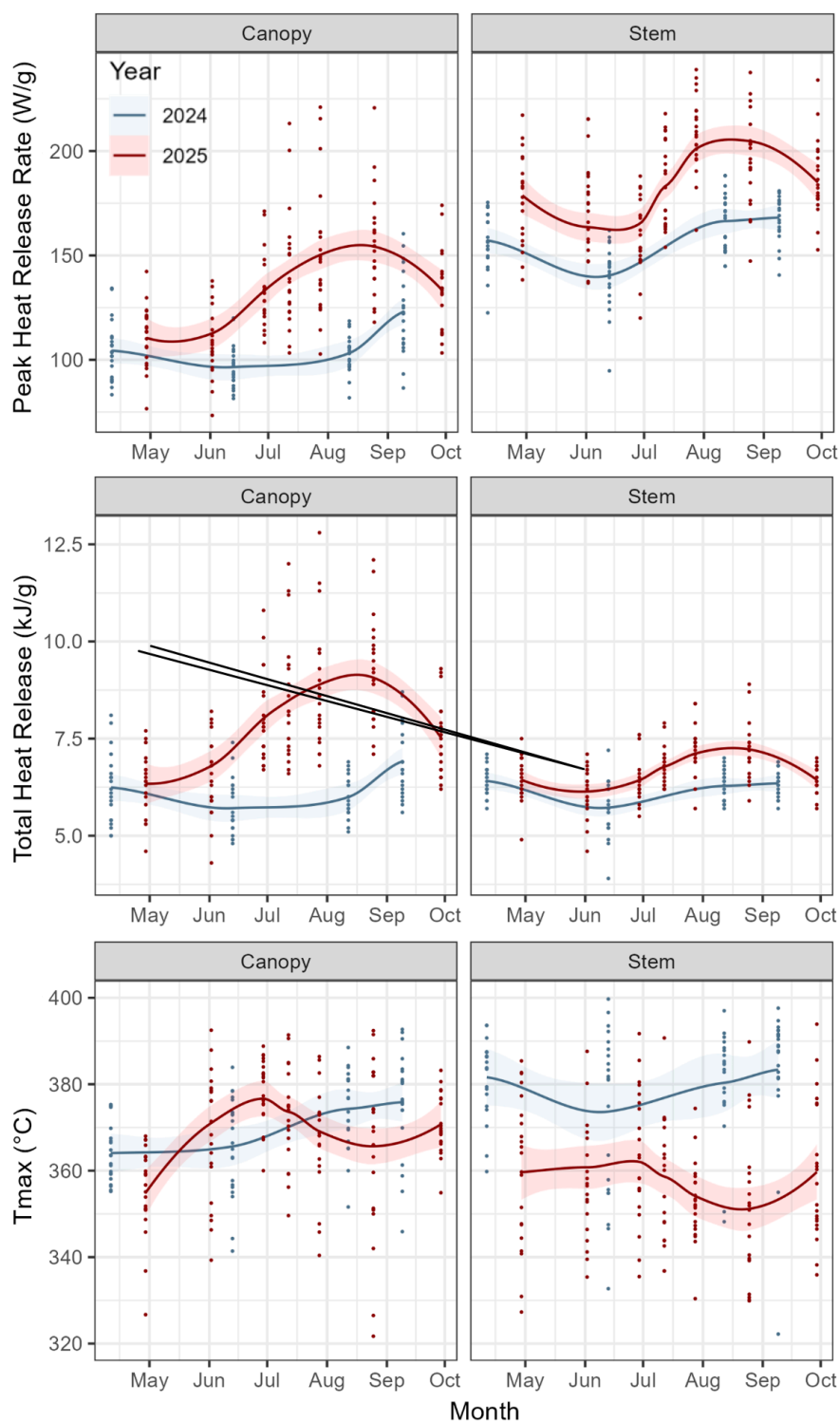


Figure 5

Peak Heat Release Rate (PHRR, W/g), Total Heat Release (THR kJ/g) and temperature of maximum decomposition (T_{max} , degrees Celsius) measured for canopy (left) and stem (right) in 2024 (blue) and 2025 (red). Loess smoothing lines and confidence intervals were fitted to the 2024 (dark blue line with light blue envelope) and 2025 (dark red line and light red envelope) data.

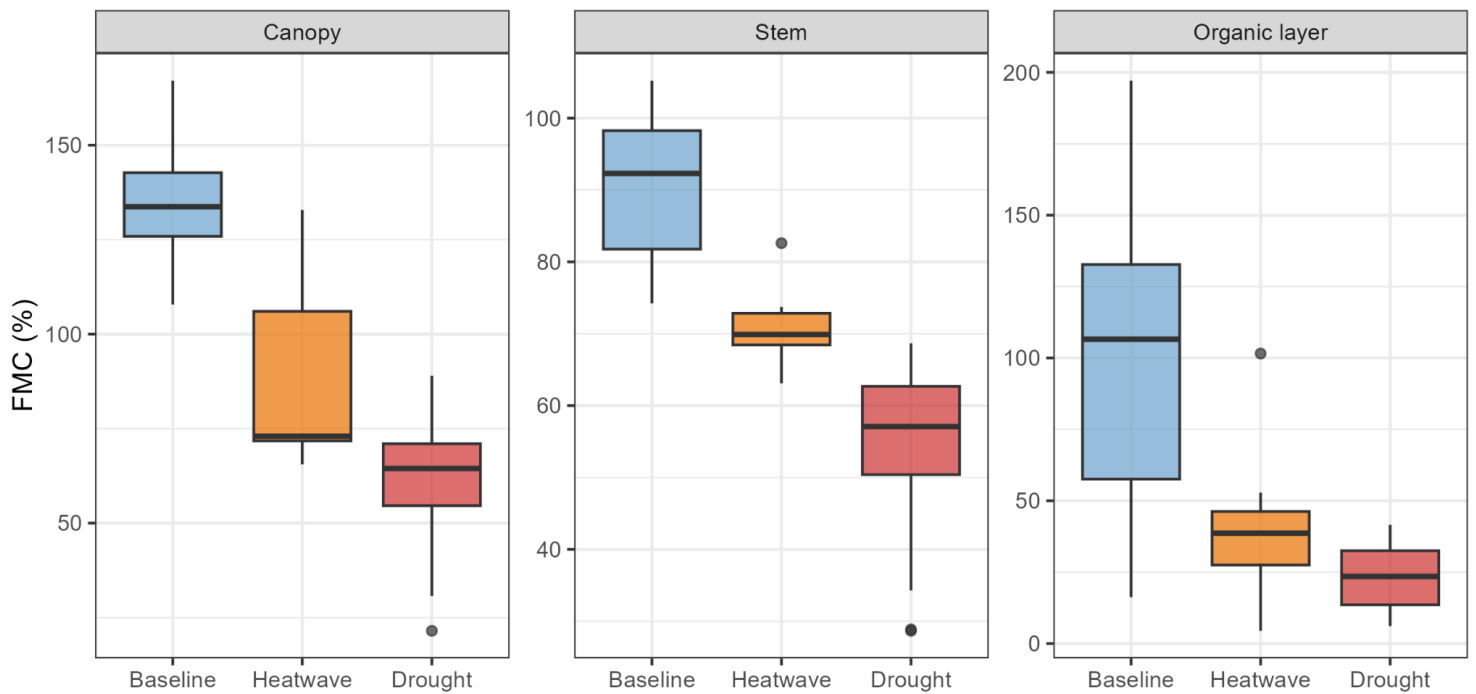


Figure 6

Comparison of canopy, stem and organic layer fuel moisture content (FMC) measured in July under baseline conditions (2021), during the heatwave of 2022 and the chronic drought of 2025.

Supplementary Files

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