Topic 13 Measuring and modeling fuel change in relation to drought

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Climate change could lead to increased frequency and intensity of drought events affecting fuel flammability, through its moisture content and dead-fuel loads, which are two major components controlling fire behaviour. We measured fuel moisture content in a wide-range of plant species across the Mediterranean basin. Seasonal plant moistures were compared to drought indices. Vulnerability to necromass production was assessed by measuring cavitation, and long-term fuel amount adjustments were explored across a precipitation gradient. We found that the Drought Code (DC) index is a good index to capture the fire season, but should be complemented with species functional traits. Prolonged droughts may enhance fire risk but plant and ecosystem-level adjustments may act as strong mitigators.

Implications for policy and management

- *Plant species differ in their seasonal variability in live fuel moisture content and their vulnerability to cavitation, so managers must know the species characteristics to understand their system sensitivity to climate extremes.*
- *Seasonal course of sensitivity can be modeled by the DC, but local adjustments must be considered based on local vegetation.*
- *Necromass needs surveying because it will potentially become a key variable for fire ignition propagation.*
- *Managers should be alerted to species changes favouring reduced moisture and increased necromass production.*
- *Fire hazard may increase during several decades before decreasing in some regions due to fuel limitation.*

The problem: The projected increased temperature and drought (Giorgi and Lionello, 2008) should affect fuels through fire behaviour factors: seasonal water status, fuel load, and live/dead ratio. We hypothesize non-linearity and specific responses, critical for accurately predicting fire frequency, intensity and burned areas. We used rainfall interception and gradient analysis to capture extreme events, and considered mixed species ecosystems with contrasted water use strategies to answer these questions: 1) to what extent generic weather-derived drought indices can be reliable tools for fuel moisture projections, 2) how species can promote differentially branch mortality and dieback, 3) how leaf area and plant density adjustments might mitigate these processes.

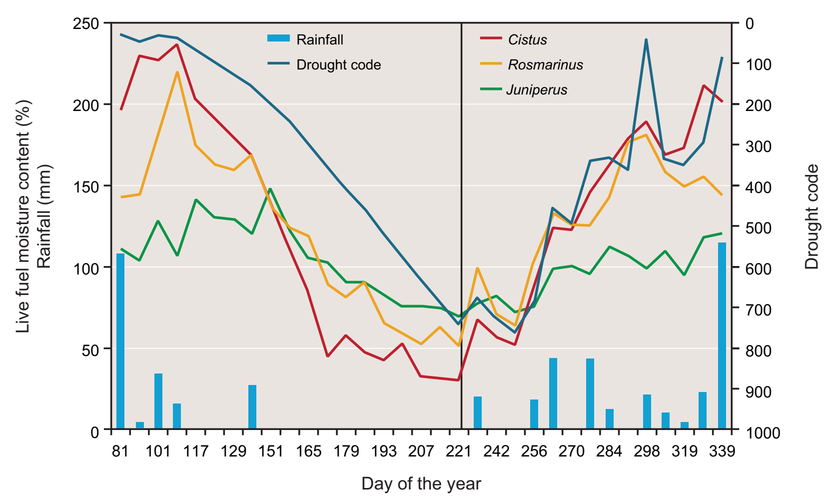


Fig. 13.1: Variation of the drought code (DC) for different types of Mediterranean plant species with contrasted water holding strategies. This figure shows that in the falling phase of moisture content (winter to spring) DC was not close to the live fuel moisture content and rainfall. It correlated much better during the moisture raising phase (mid-summer to autumn), thus suggesting that DC is more appropriate to identify the end of fire danger season rather than the date of starting. In some species less sensitive to drought (e.g., Juniperus) live moisture content is weakly correlated with DC.

The approach: Fuel moisture and soil/plant water fluxes were investigated during several fire seasons at 3 study sites (Sardinia, France, Tunisia) and in several plant species. Measurements were taken in the natural environment or in a rainfall interception experiment simulating a 7 months dry spell. Measurements were tested against empirical and process-based models to simulate actual fuel moisture content. To capture the seasonal pattern of drought intensity and fire season length, we calculated the DC of the Fire Weather Index (FWI) and plant water content in the main shrub species using a water budget model. Changes in fine fuel amount were investigated through leaf litterfall and shoot elongation as a response to drought, and we made laboratory experiments for the vulnerability to cavitation susceptible to produce necromass. Regional scale information on tree dieback and adjusted tree density across drought gradients were used as indicators for long-term processes which are hard to capture experimentally.

Achievements: We found species-specific responses to seasonal changes in soil moisture. High-desiccating species severely adjust their moisture content across the season, while others keep hydrated throughout the year. Isohydric species could block their water flux early in the season while anisohydric species followed the soil water content, and in turn were more able to rehydrate after small rainfall events. All species reached minimum seasonal water content, but with values that were not extremely low; yet, they exhibited a prolonged live-fuel dryness period each year.

A fair correlation between DC and live fuel moisture was established, but with the differences among species mentioned above (Fig. 13.1). DC was appropriate to identify the end of the fire danger season, with substantial correlation with fire occurrence. More complex process-based models can predict species responses according to functional strategies with mitigation feedbacks through leaf area adjustment limiting water loss.

We found that potential critical thresholds after extreme drought are possible. However, despite no major extremes in live fuel moisture during prolonged drought, critical thresholds could be reached when live fuel is converted into dead fuel able to desiccate down to extremely low values. Species experienced differential vulnerability to cavitation in relation to their hydraulic strategies (Fig. 13.2). Direct mechanisms for actual necromass production are still unclear for accurate predictions, but tree die-back was observed after extreme years in Southern France, leading to increased fire hazard. On the contrary, at the most southern bound of Mediterranean climate, significant tree density adjustments are observed as a long-term adjustment, leading to crown discontinuity preventing severe crown fires. Figure 13.3 summarizes short to long-term trends in fire risk associated to climate change in Mediterranean environments.

Lessons learned and implications: The DC is a useful generic indicator of live fuel moisture and thus of fire danger. However, adjustments considering plant functional types and leaf area adjustments would improve its value. Increasing dry spells lead to longer fire season. Under climate change, critical thresholds could be reached due to increased drought length, leading to enhanced necromass load, which could exponentially increase fire hazard. In the long-term, as climate changes, sparser vegetation would likely develop as a result of recurrent droughts and heat waves. Such vegetation would better cope with drought, and would, likely, become less hazardous for fire occurrence.

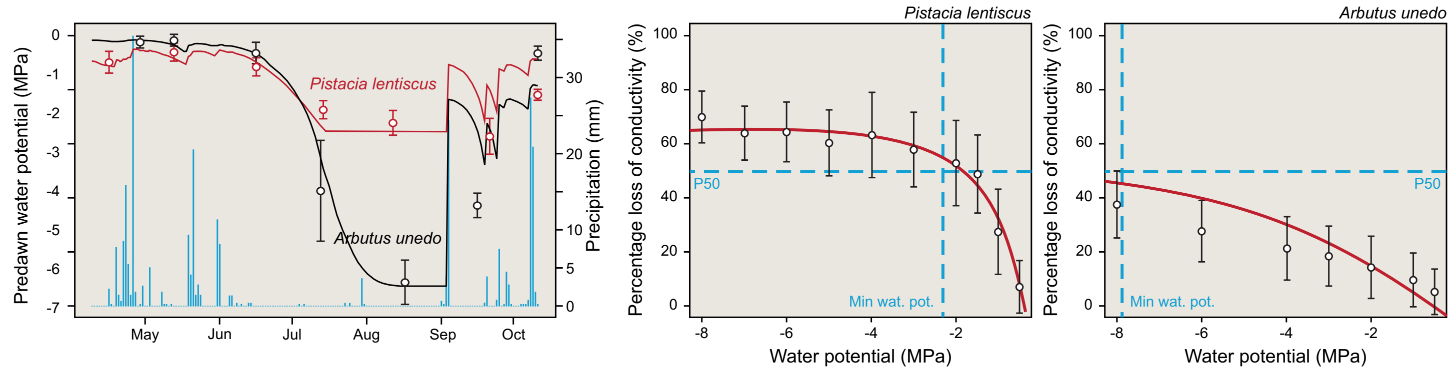
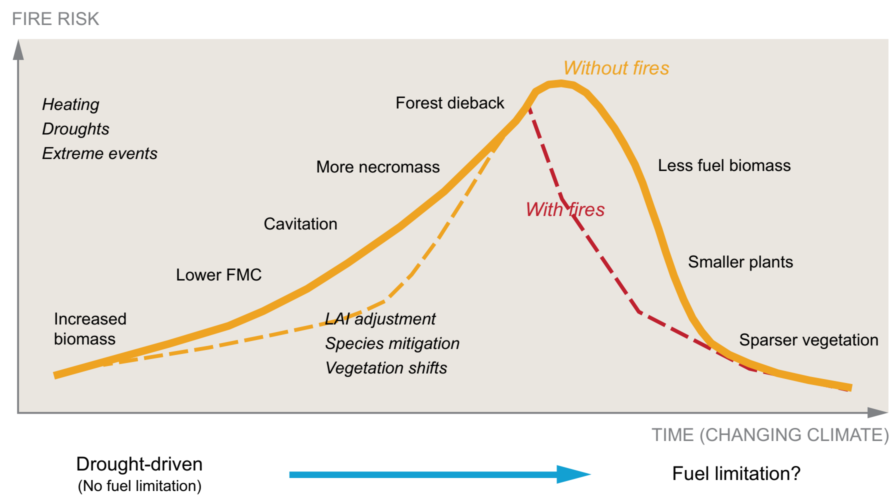


Fig. 13.2: Seasonal course of predawn water potential in relation to rainfall for Arbutus unedo and Pistacia lentiscus, two shrubby species with contrasted water strategies (left). Percentage loss of conductivity in relation to water potential for P. lentiscus and A. unedo (right). Differential vulnerability to cavitation is measured by the percentage of conductivity lost according to water potential. 50% loss of conductivity (P50) corresponds to field measurements of minimum water potential observed during the season.

Management implications of drought in a climate change context

- *The DC index should be adapted to soil water holding capacities and plant functioning for more precise assessments of regional fire risk and trend.*
- *Consider species differential functioning to identify key indicators for fuel combustibility.*
- *Warnings on necromass as a major variable for reaching critical thresholds in fire risk along time under climate change scenario.*
- *Consider tree density adjustment as a double benefit for tree water saving and durability and to reduce risk of severe fire spread.*
- *Manage fuels and landscapes: favour fire-smart management of forest landscapes and fuels, firewise and regional strategies.*

Fig. 13.3: A possible model for future fire risk in Mediterranean fertile environments (such as France, Spain, or Italy) indicates that fire could shift from drought-driven as today (i.e., fires depend mostly on fire weather since fuel biomass is sufficient) to increased fire occurrence or intensity during several decades due to climate change (mitigated by different adaptive strategies of vegetation), then to fuel-limitation in the long-term because vegetation will decrease in biomass and become sparser. The leaf area index (LAI) characterizes the extent of a species canopy.



Forest fires
under climate, social and economic changes in Europe, the Mediterranean and other fire-affected areas of the world

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Lessons learned and outlook

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