Soil memories

Researchers from TEAGASC, the University of Innsbruck and the University of Manchester are investigating how drought and drought legacies affect plant–soil interactions in grasslands.

Grasslands are relatively simple above ground, but hidden below ground is an extraordinarily complex and interconnected system, on which healthy grasslands depend. Plants and soil microbes are continuously interacting. Plants deliver carbon via their root exudates, soluble sugars that are released from their roots, and litter – parts of the plants that have died. This carbon provides fuel for soil microbes, and microbes in turn support plant growth by supplying the essential nutrients that plants need to grow. Microbes also play a critical role in helping plants cope with stress, such as drought. Therefore, considering the intimate interactions between plants and soil microbes is essential for informing management to sustain healthy grasslands in a changing climate.

Plant–soil microbe interactions and drought

In Ireland, as in many parts of the world, rainfall is predicted to become more erratic, with more of the yearly rainfall in the winter, and hotter, drier summers. These changes in weather patterns will require adjustments in grassland management to maintain their productivity, quality, and the essential ecosystem services they provide. Droughts in recent years have highlighted the vulnerability of Irish grasslands to dry spells and the resulting impacts on fodder supplies. Droughts can have long-lasting effects on grassland functioning by disrupting the interactions between plants and soil microbes. Previous research has shown that drought decreases below-ground carbon transfer from plants to the microbial community (Fuchslueger *et al.*, 2018), alters the make-up of root exudates (Williams and de Vries, 2020), and causes long-lasting shifts in plant and microbial community composition (de Vires *et al.*, 2018). These changes affect the functioning of the microbial community, with cascading effects for nutrient cycling, plant growth, and the capacity of plants to resist and recover from subsequent droughts. Drought intensity (how low the soil moisture is) plays a key role in how drought affects grassland ecosystems. More intense droughts could shift microbial communities to a point where they can no longer recover, leaving legacies that have implications for ecosystem functioning (Bardgett and Caruso, 2020).

Assessing drought legacies

When and how drought legacies occur, and their implications for grassland plants and microbes, is the focus of an ongoing study. In summer 2020, grassland communities were exposed to eight different intensities of drought, from mild to intense, and their responses during and after the drought were studied. Drought reduced grassland productivity and carbon uptake. Soil microbial community functioning was compromised and carbon transfer from plants to microbes was reduced, signalling that drought disrupts the connection between plants and microbes. A week after the rains had returned, the soil microbial communities that had experienced a severe drought took up more carbon from plant root exudates than those that had experienced no drought or a mild drought (**Figure 1A**). Microbes drive nutrient cycling, and a fast microbial community recovery could affect plant nutrient uptake. Indeed, plant communities that had experienced a severe drought took up more nitrogen (N) than those that had experienced no drought or a mild drought (**Figure 1B**). Two months after the drought ended, plant communities that had previously experienced a severe drought produced more biomass than those that had not (**Figure 1C**). This could be because the plant community took advantage of an increase in N availability, as well as a shift in plant community composition: grass species became more dominant than herbs.

Future research

Much of how climate change, and associated increases in drought severity and frequency, will affect grasslands is unknown. A key outstanding question is: what are the longer-term effects of drought on grassland resilience to a subsequent drought? Do these effects change with increasing drought intensity? Future research will be focused on understanding if the legacies of drought on the soil affect grassland plant and microbial response to a subsequent drought. As droughts become more frequent and severe, these legacies will play a more prominent role in grassland ecosystem functioning, as they could hamper a grassland's ability to cope with subsequent droughts.

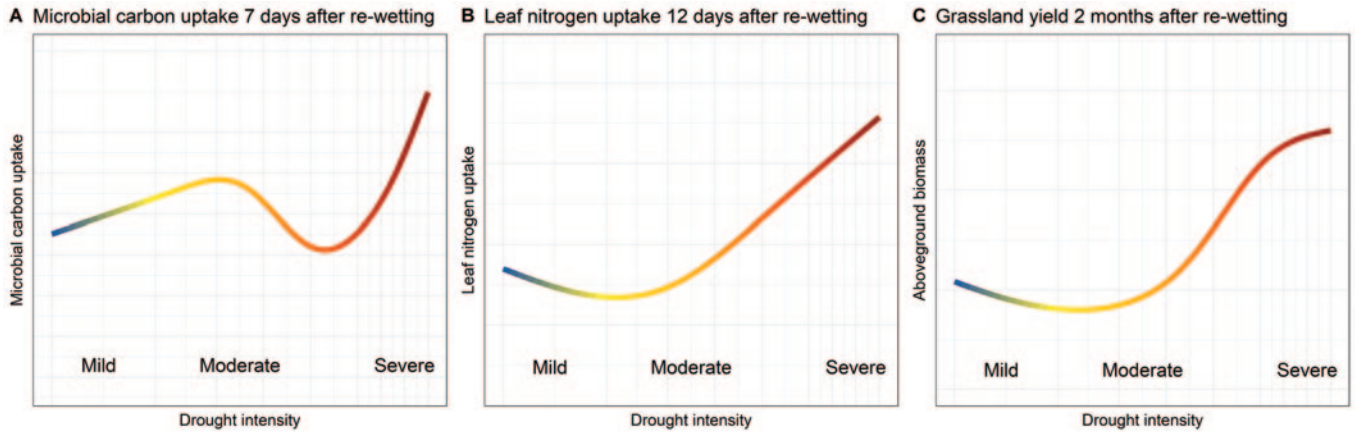
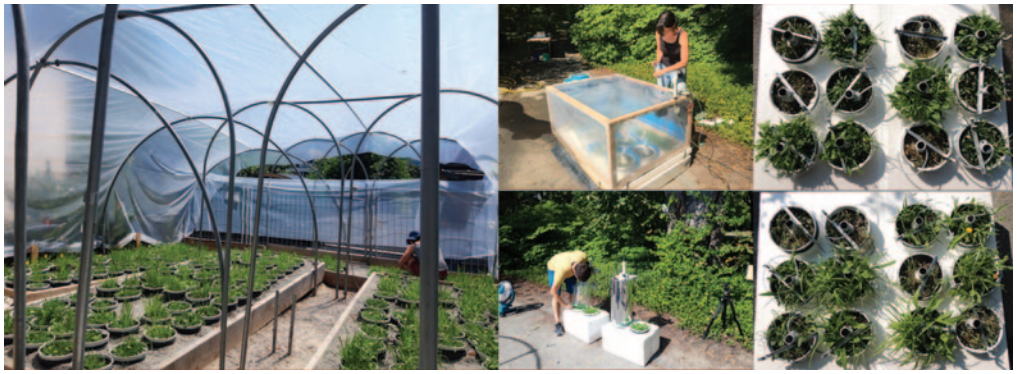


FIGURE 1: Grassland recovery dynamics after drought.



From left: Experimental set-up of mesocosm experiment used to study drought legacies; measuring grassland carbon dynamics; and, plant communities exposed to different drought intensities.

Conclusion

To understand how grasslands will respond to more intense droughts, and what the long-term consequences will be for grassland ecosystem functioning, we need to look below ground and consider plant–soil microbe interactions. The answers are blowing in the wind, but the solutions are likely under our feet.

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