EUROPEAN GRADIENTS OF RESILIENCE IN THE FACE OF CLIMATE EXTREMES


Field site in Belgium with rainout shelters deployed in 2013 ©Sigi Berwaers

POLICY BRIEF

This policy brief is based on the results of the BiodivERsA-funded project 'SIGNAL' addressing the interaction of three major research areas, combined in ecology for the first time: biodiversity experiments, climate change research, and invasion research. The project made use of coordinated experiments in different climates across Europe, thereby increasing the scope and relevance of the results.

Extreme weather events and the presence of invasive species can act as pressures threatening biodiversity, resilience and ecosystem services of semi-natural grasslands and drive them beyond thresholds of system integrity (tipping points and regime shifts). On the other hand, biodiversity itself may buffer ecosystem functioning and services against change. Potential stabilising mechanisms include species richness, presence of key species such as legumes and within-species diversity. These potential buffers can be promoted by conservation management and policy adjustments.

KEY POLICY RECOMMENDATIONS

- **Local biodiversity should be actively stimulated or preserved across European grasslands** in order to increase the stability of ecosystem service provisioning, which is especially relevant as climate extremes are expected to become more frequent and intense.
- **Adjustment of mowing frequency and cutting height can help maintain or increase biodiversity.**
- **More explicit consideration of within-species diversity is warranted,** as this component of biodiversity can contribute to stabilising ecosystem functioning in the face of climate extremes.
- **Ecosystem responses** to climate extremes of similar magnitude can vary significantly between climates and regions, suggesting that **targeted policy requires tailor-made impact predictions.**
- **Invasive species'** ability to use climate extremes as windows of opportunity for establishment or for gaining competitive dominance varies significantly between climates and regions, suggesting that **targeted policy requires local impact assessment and specific management strategies.**
- SIGNAL adds to the recognition of the **value of biodiversity, especially in a context of climate change and associated climate extremes.** Its findings reinforce the need to **actively pursue the standards set out in the *EU Biodiversity Strategy*, and feed the reform of the *Common Agricultural Policy*.**

Context

The frequency and magnitude of extreme climatic events is increasing with ongoing climate change. Effects of these extremes on biodiversity and ecosystem functioning can be severe, *e.g.* reduced productivity or altered successional trajectories. On the other hand, some studies report high resilience of several ecosystem functions in the face climate extremes, which may relate to the characteristics of the system in question. Specifically, it has been suggested that more extreme rainfall regimes – including torrential rain events as well as severe summer drought - will affect ecosystems from mesic and xeric areas differently.

Increased plant species diversity is expected to generally increase resilience, although it is unclear if this theory holds under extreme weather events. There is also uncertainty about which aspect of diversity drives resilience the most. Pure species richness might be less important for the resilience of communities than the presence of certain key functional traits such as nitrogen fixation via legumes. Interestingly, within-species variability ('ecotypes') in the responses to extreme weather events has been shown to potentially exceed variability across species. Literature suggests that the introduction of ecotypes pre-adapted to future climate conditions may be an option for sustainable adaptation of managed ecosystems.

The rationale presented above outlines why **biodiversity has the potential to play a stabilizing role in a world expected to see ever more frequent and intense climate extremes.** At the same time, biodiversity is under threat, not only by the changing climate, but also by factors such as changes in land use and land management. Mowing techniques in the management of semi-natural grassland have been strongly altered over the last decades. Within SIGNAL, management schemes were analyzed in order to identify measures that promote the biodiversity of grasslands, as this could serve to buffer grassland services.

Another threat to biodiversity is the spread and establishment of invasive species, which is also expected to increase with climate change. **The presence of invasive species could alter the resilience of semi-natural grasslands against extreme drought events**, and drought events in turn may offer opportunities for invasive species to establish in semi-natural grasslands.

SIGNAL studied all of these factors in a pan-European project to determine both single-factor effects and interactions in order to gain deeper understanding about what affects the resilience of European grasslands and their provisioning of ecosystem services in the face of climate extremes.

Key results

1. Responses to drought of grasslands across Europe

SIGNAL studied the **impact of a locally-scaled meteorological drought on plant productivity by exposing grassland communities to experimental rainfall exclusion** (local 1000-year recurrence interval) at 10 field sites across Europe (from Belgium to Israel). **Aboveground biomass production in mesic grasslands appeared resistant to drought, while resistance was generally lower in grasslands at the more xeric sites.** At these drier sites, **rapid recovery implied high resilience, however.** We found **no clear correlations between drought effects and relative rainfall reduction**, mean biomass production or mean species richness per site. Changes in community composition were limited. We only recorded a site-specific significant increase in grass and sedge dominance in the year following the drought. In the Hungarian grassland, prior (natural) droughts had caused a mosaic of dominant vegetation types (grass, dicot or legume dominated) which significantly influenced the dynamics in the years following the SIGNAL drought. As such, the **presence of certain dominant plant groups before drought could be used to predict responses in the years following drought.**

2. Invasive species

Two distinct SIGNAL studies investigated the impact of the non-native invasive species *Lupinus polyphyllus* and *Senecio inaequidens* as an additional pressure for grassland biodiversity and ecosystem functioning in the face of drought. We tested whether land use change - here altered cutting frequency – could lead to facilitated settlement of invasive species under drought. We also manipulated plant species richness levels and species composition in mesocosms in four different countries (Belgium, Bulgaria, France and Germany) to disentangle the impact of biodiversity and drought on native plant and invader performance. Generally, SIGNAL results demonstrated high relative growth of the legume invader *Lupinus polyphyllus* under combined pressures of drought and competition, suggesting that **the spread of certain invasive species may be facilitated by extreme weather events**. For *L. polyphyllus*, its high resistance towards drought and competition may signal more or less unrestrained dispersal across large parts of Europe. Of note is that in our experiment, **the species diversity of the recipient community did not interact with invader presence to modify resistance or recovery to drought.**

Establishment and spread of the non-native legume invader Lupinus polyhyllus into temperate grassland in Central Europe (Germany)

3. Biodiversity as a drought-mitigation factor

SIGNAL additionally investigated resistance and recovery to severe drought in a controlled and coordinated biodiversity experiment at five locations. **Across sites, biomass production was reduced by 30% in response to drought. Species richness improved recovery one year after the drought in low productive communities, while resistance was generally unaffected by biodiversity.** The number of plant functional groups had no significant effect on resistance or recovery, while legume presence likewise did not affect these components of ecosystem stability. Our data suggests that maintenance of ecosystem productivity and productivity-dependent ecosystem services for grassland communities happened mainly through asynchrony of species responses. As such, **biodiversity loss may reduce resilience in response to droughts and other climate extremes at least in some communities.**

In an accompanying study, SIGNAL experimentally investigated the effect of within-species variability on grassland production under drought and explored whether the presence of drought-adapted ecotypes improved the resistance of the plant community to drought. Experimental communities with different numbers of cocksfoot *(Dactylis glomerata)* ecotypes collected across a distinct climatic gradient were exposed to summer drought at four locations. **Drought promoted intrinsically smaller but deeper rooting ecotypes at the expense of larger ecotypes ('negative selection'). Greater within-species variability also led to alleviation of drought-induced senescence *(Fig. 1)*, at no cost to aboveground production. Ecotype richness can thus substantially affect both community structure and resistance to drought.**

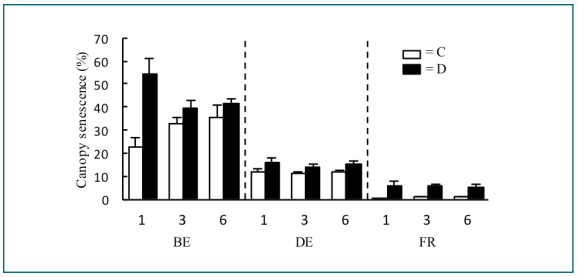

Figure 1: Mean canopy senescence + 1 SE of all mesocosms in control and drought treatments containing ecotype richness levels 1, 3 and 6 of Dactylis glomerata provenances in BE, DE and FR (n = 12) at the end of drought.

Adjustments of management techniques may be applied in order to preserve or increase diversity, as a measure to avoid the worst effects of climate extremes. Adjusting the mowing height was part of the design in the SIGNAL field experiment, with data showing inconclusive results. A SIGNAL **meta-analysis on mowing techniques suggests that land abandonment leads, at least initially, to a decrease in biodiversity.** Cutting at least once per year tends to stimulate diversity, although differences between one and multiple cuts are unclear. Furthermore, **the recent trend to cut lower above the ground level may actually increase diversity when comparing it with cutting higher above the soil, in contrast to our original hypothesis.**

Policy recommendations

- SIGNAL research has shown that biodiversity has positive effects on both the productivity of ecosystems and the stability thereof in the face of climate extremes. As such, measures to preserve or improve biodiversity should be actively pursued.
- The *EU Biodiversity Strategy* aims to halt the loss of biodiversity and ecosystem services by 2020. The conclusions from SIGNAL reinforce the notion that biodiversity is valuable, not only because it can mitigate some of the atmospheric CO_2 increases through increased productivity, but also because it may serve as an adaptation measure in agriculture, to stabilise production in the face of climate extremes. The latter is addressed in *Target3 ("achieving more sustainable agriculture and forestry")* of the *Biodiversity Strategy*: *"By 2020, the conservation of species and habitats depending on or affected by agriculture and forestry, and the provision of their ecosystem services show measurable improvements."* According to the mid-term report, the results are not keeping up with the aims, however.
- The newest *Common Agricultural Policy* reforms could lead to improvements in that regard. It explicitly stimulates farmers to adapt to challenges stemming from climate change and to pursue mitigation and adaptation actions (this includes building greater resilience toward climate extremes). One of the new policy instruments is the *Green Direct Payment*, which stimulates crop diversification and the development of ecological focus areas and permanent grassland. Another relevant measure is the requirement that at least 30% of the budget of rural development programs is reserved for measures that benefit the environment (also with respect to climate change). This could encompass promoting mowing strategies that benefit diversity, with SIGNAL demonstrating that abandonment of land management generally lowers biodiversity and that mowing regime and technique can be tools to preserve or increase diversity.
- Instead of focusing solely on increasing plant species diversity, SIGNAL results can serve as a stepping stone towards including within-species diversity in policy regarding ecosystem management. In SIGNAL experiments, higher numbers of pre-adapted ecotypes were able to buffer some of the adverse effects of climate change and climate extremes.
- Another target of the *Biodiversity Strategy* is related to invasive species, as expressed by *Target 5 ("combat invasive alien species")*. From SIGNAL research, we recommend close monitoring and management of existing invader stocks. Resurvey of establishment dynamics or population expansion after climatic extremes is needed. Targeted action in reducing local occurrence of invasive species is most efficient at periods of peak biomass production but before flowering and seed set.
- Resistance and recovery of ecosystems are not affected to the same extent by biodiversity. This is important with regards to priorities of land management: biodiversity may be more beneficial with regards to recovery than with regards to resistance.
- Finally, SIGNAL shows that the dynamics of drought impacts can differ significantly between locations. In some regions, the vegetation demonstrated higher resistance, in others lower resistance was compensated by fast recovery (increasing resilience). Mitigation and adaptation measures should therefore be tailored to the climate and region in question.

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