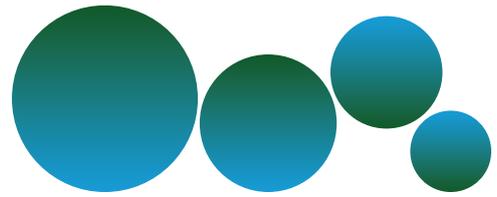


Rhwydwaith Ymchwil Cenedlaethol
i Ynni Carbon Isel a'r Amgylchedd Sêr Cymru

Sêr Cymru National Research Network
for Low Carbon, Energy and Environment



Science to Policy: Climate-proofing grassland productivity



Science to Policy:

Climate-proofing grassland productivity

Climate-Smart Grass was a Research Cluster that ran between 2013 and 2018 from the Sêr Cymru National Research Network for Low Carbon, Energy & Environment (see: www.nrn-lcee.ac.uk).

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Climate-Smart Grass investigated emerging climate change trends in the UK, their likely impacts on grassland productivity, and the applicability of new grass varieties in climate-proofing grazing resources.

This is a summary of the policy implications of both scientific review and original research undertaken by Climate-Smart Grass that fall within the remit of current and evolving Welsh policy.

Key recommendations

- **Irreversible damage occurs when flooding causes severe erosion** and soil washes out into watercourses. **Erosion can be prevented by assuring continual plant cover via planting flood-resistant swards or allowing natural regeneration of flood-resistant wild plants.**
- **Biodiversity supports recovery from flooding.** The mechanisms by which this occurs are not as yet fully understood, but it is likely that this is due to the effects of rooting diversities on soil porosity and the presence of naturally flood-tolerant plants.
- **Farmers need to be incentivised to modernise their grass seed mixtures using agri-environment schemes** (which currently include insufficient support for climate change mitigation). Specifically, **farmers should be paid to plant more flood-resistant swards in current and future flood-prone areas.** Without support, such an undertaking carries too much financial risk to farmers.
- **Climate-proofing grassland is financially sound.** Without intervention or sward changes, grazing land takes about 3 years to reset in the case of flood, 3 months for drought and 1 month for ozone, with costly implications such as replanting.
- **In some cases, the best climate change strategy would be to take land out of production or convert it to conservation grazing** (e.g. with ponies and cattle) **or woodland.**
- **Flooding in areas taken out of production could also accrue positive biodiversity effects:** for example, seeded grass swards would effectively 'drown' and potentially be replaced by rare, flood-tolerant plant species.



Background

The UK Met Office predicts that for most of the UK, extreme events such as drought and flooding will occur more frequently in the future; with summers becoming drier, and winters wetter. These changes challenge the agricultural sector by impacting harvests, livestock nutrition, and sward condition. In the UK flooding already incurs annual losses of £10-25 million, and ozone damage (which forms on hot and sunny days) ca. £180 million. The environmental costs of flooding are also high as soil, pollutants, and nutrients are lost into watercourses, causing fish deaths, eutrophication, and acidification downstream. Climate-Smart Grass sought to answer the following key questions surrounding land use under changing climate:

- **Is the frequency of extreme weather events increasing in the UK?**
- **How resilient are grasslands to the combined effects of flooding, ozone and drought?**
- **Can economic setbacks be minimised with better grass varieties?**
- **What are the implications of climate change for greenhouse gas emissions from agricultural grasslands?**

Relevant Welsh Government policy strands

Well-being of Future Generations (Wales) Act¹

Outlines seven well-being goals including resilience (enhancing biodiversity & functioning, resilient ecosystems)

Environment Wales Act²

Includes key part such as I: Sustainable management of natural resources, and II: Climate change (carbon budgeting, emission targets).

Decarbonisation Programme

Develops pathways to ensuring 2050 net emissions are at least 80% lower than the 1990 baseline set in legislation. The Welsh Government is due to publish a 'Low Carbon Delivery Plan', drawing on the responses to the 'Achieving our low-carbon pathway to 2030' consultation³ in 2019.

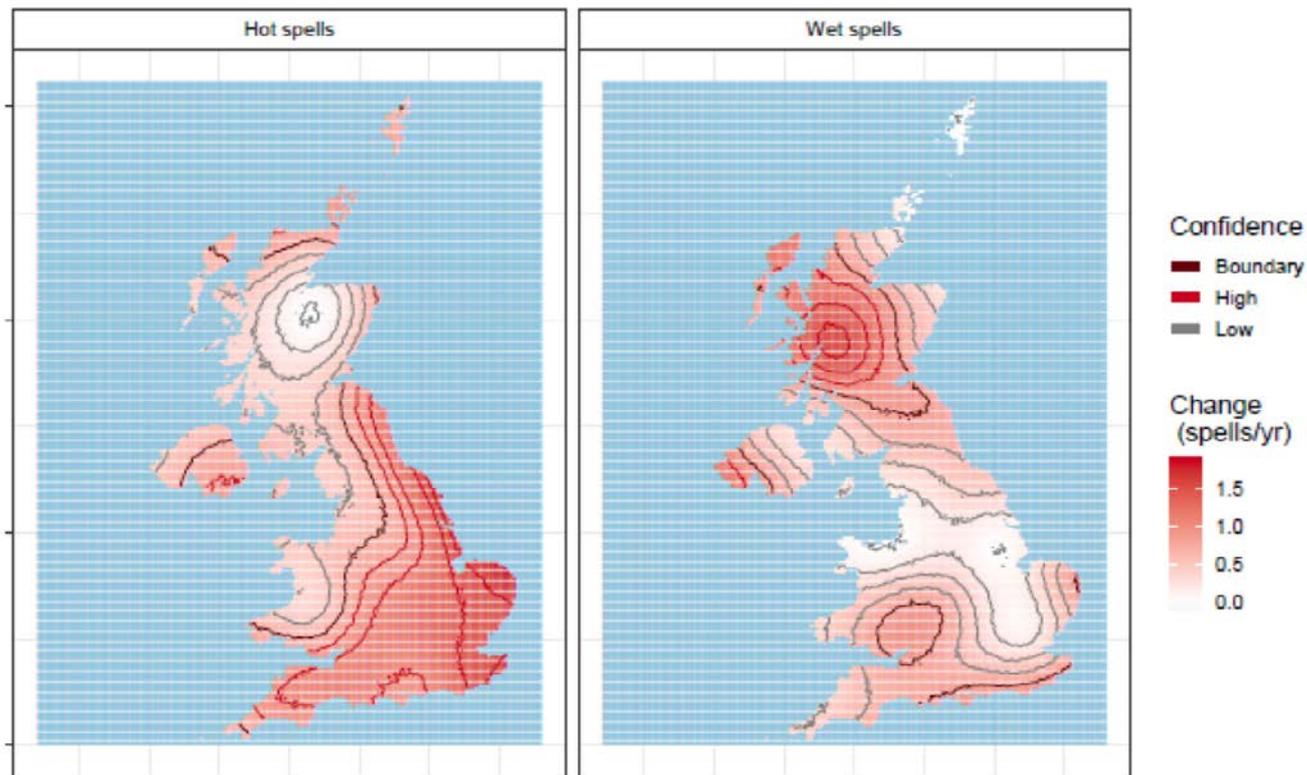


Figure 1

Changes in the frequency of spells of extreme hot and wet weather in the UK between the time periods 1961-1988 and 1989-2016, based on 5 km grid data. The contours represent confidence in the results: the grey side of the boundary reflects uncertainty in the change detected, whereas the red side contains significantly different frequencies. Figure: Emma Wiik (NRN-LCEE).

UK Climate change trends

Climate-SmartGrass analysis has confirmed that hot and wet extremes are becoming more common in south/mid-Wales (Fig.1), suggesting an increased likelihood of flooding and heatwave events. Their analysis also predicts that dry spells will increase in the south/mid-Wales region, which when coupled with elevated temperature, may increase drought susceptibility.

Changes are also already significant in many other regions of the UK. For example, the eastern parts of the UK have experienced more hot days and less cold days than before, and Scotland has had an increase in wet and warm extremes.

The effect of flooding on environmental parameters and agricultural yield

Plants drown when flooded. Within 48 hours of being waterlogged, plants begin to suffer from oxygen deprivation, leading to reduced nutrient uptake and growth. Lack of oxygen also leads to chemical changes in soil including changes in gaseous emissions and the formation of compounds toxic to plants, such as manganese, hydrogen sulfide and acetic acid⁴. Some of these changes are reversible, but greenhouse gas emissions and nutrient losses are not. These losses need to be quantified in order to inform land management practices in a changing climate.

Greenhouse gas emissions

The UK is required by law to reduce its carbon emissions by at least 80% by 2050, which is incorporated into the Welsh Government decarbonisation programme. The UK Climate Change Committee (CCC) accepts that these targets may be challenging to achieve in Wales due to a disproportionate share of 'hard to reduce' emissions from agriculture and industry. It follows that any advances in these sectors would be much welcome, as indeed the CCC recommends that farming policies are put in place "to reduce emissions that move

beyond the current voluntary approach and ensure that any replacement of the Common Agricultural Policy contains support for emissions reduction and removals."

Methane and nitrous oxide form when oxygen is scarce, and are both substantially more potent greenhouse gases than carbon dioxide (CO₂) (over 100 years, methane is 34, and nitrous oxide 298 times more potent than CO₂). Short-term events that cause pulses of methane or nitrous oxide, therefore, can have disproportionately large impacts on the overall greenhouse gas emissions of land. Flooding is likely to increase such pulses because it causes oxygen starvation.

Climate-Smart Grass tested the effects of weeks-long floods on grass yields and field greenhouse gas pulses at different temperatures⁵. Findings from this research included that the harmful effects of multi-week flooding on field greenhouse gas emissions are worst at high temperatures; suggesting that summer floods are a greater risk for greenhouse gas emissions than winter ones. Despite CO₂ emissions decreasing during the flood phase at all temperatures, the combined global warming effect of all greenhouse gases (CO₂, methane and nitrous oxide) was higher for flooded fields compared with their unflooded counterparts⁵.

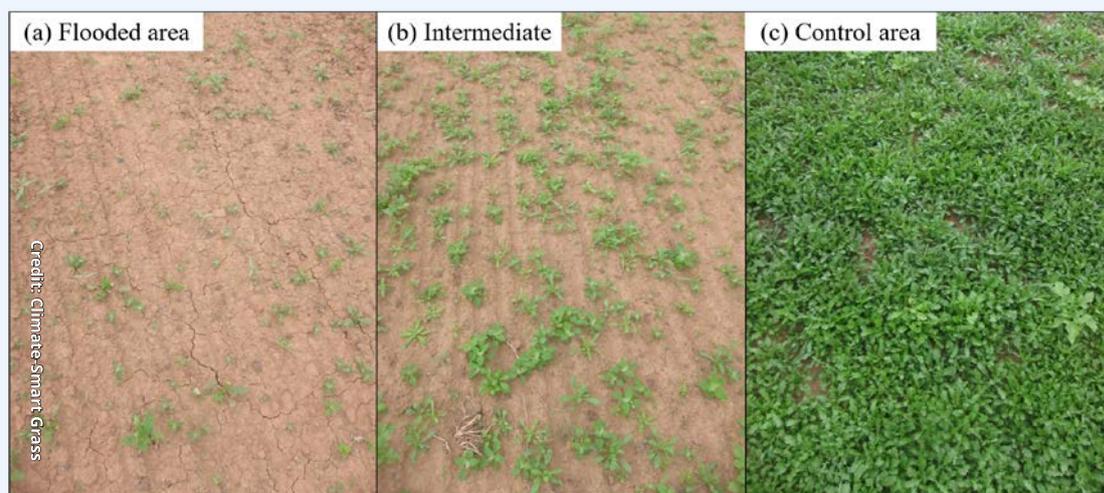


Figure 2

Whereas grass is resilient against flooding in winter, arable crops - as shown above, can suffer considerable losses from winter floods. Climate-Smart-Grass observed a 19-34% loss in arable crops from winter flooding across 15 sites in the UK (in Somerset, Worcestershire, Herefordshire and North Wales).



Yield

- 6 Whereas arable crops can suffer considerable losses from winter floods (Fig.2), Climate-Smart Grass observed that grasses can be more resilient against flooding in winter.

Climate-Smart Grass's study investigating flooding-temperature interactions⁵, however, found that at higher temperatures, the harmful effects of multi-week flooding on grass yields increase. In trials of 8-week floods, 50% of yield was lost with flooding at 15°C and 95% at 25°C. This suggests, therefore, that climate change-driven increases in summer temperatures will increase the damage of multi-week flooding on both crop and grass yields.

Flooding also affects the plant community structure, as grass varieties are replaced by wet-tolerant nettles, dock, and plantain, which are not grazed by livestock. In a summer flood trial experiment, Climate-Smart Grass found that clover (high-value forage) only survived two weeks of flooding, and 12 weeks of flooding led to a 100% replacement of grass by non-forage plants⁶.

High temperatures speed up the metabolism of microbes as well as crops. This means that as temperatures rise, the rate at which chemicals required by plants are removed by microbes increases. The microbes also produce more toxic substances as the temperature increases.

To look at the impacts of extreme reversals of field conditions, Climate-Smart Grass also investigated the effects of flooding followed by drought. Their findings showed that the yield reduction caused by flooding followed by drought is much higher than the sum of them individually⁶.

Nutrient losses

Flooding increases on-farm nutrient losses, leading to increased compensatory fertiliser use and down-stream water quality issues. This occurs both as a combination of direct wash-out by flood waters alongside the effects of microbial processes that occur under soil oxygen starvation.

New grass varieties

Festulolium grasses, a hybrid between *Lolium* and *Festuca* grasses, have been bred to develop varieties combining high-sugar content (improving livestock weight gain and milk production) with environmental stress tolerance (e.g. deep roots to reach scarce water supplies).

Climate-Smart Grass expanded *Festulolium* variety tests from controlled conditions to the outdoors during the drought of 2018. They found that the deep rooting of *Festuloliums* does not in fact confer yield or tolerance benefits under prolonged water scarcity compared with traditional grasses. *Festulolium* grasses may have some benefits in milder droughts, however; suggesting the benefit of *Festuloliums* as components of seed mixes, where a diversity of varieties are available to grow depending on prevailing weather conditions.

This research suggests that further field trials are necessary to predict *Festulolium* performance.

Soil aeration as a grassland flood recovery strategy

Farmers are officially encouraged to artificially aerate soil after flooding in order to improve the return of nutrient and oxygen availability to plants.

Climate-Smart Grass tested three recovery methods of increasing soil porosity and drainage (sub-soiling, sward-lifting and aerating) following floods at two UK sites⁴. This study revealed little added benefit of these mechanical interventions on sward recovery beyond natural drying of the soil. In some cases, the use of subsoilers actually caused compaction resulting in a worsening of the situation and a delay in sward recovery.

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The over-arching mission of the Network was to promote excellent research within Wales into the sustainable use of natural resources for the provision of energy, water, food, and other ecosystem services. The Network was the catalyst to bring a diverse set of talented researchers and partners into new collaborations, in order to conduct innovative research that was highly pertinent on an international research agenda.

Four themes tie together all research funded by the Network:

1. Sustainable Intensification
2. Low Carbon Energy Pathways
3. Developing the Bio-Economy
4. Impacts & Mitigation of Climate Change and Human Activities

The core of the Network research was centred around 8 Research Clusters (supporting 18 Research Fellows and 12 PhD students) and 10 Returning Fellowships. The latter were individuals returning from extended career breaks. It also supported STEM outreach opportunities, public lectures and a diverse range of workshops and events on topical science issues. www.nrn-lcee.ac.uk

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