Farmlytics

Extreme weather and its impact on farming viability in Wales

Extreme weather and its impact on farming viability in Wales' is an independent report produced by Farmlytics, commissioned by WWF Cymru

Foreword

WWF Cymru's aim is to help create a Wales where people and nature can thrive, for generations to come.

This aim is threatened by climate change. Global temperatures have been rising for over a century, speeding up in the last few years. Internationally it has been agreed we must work together to cap warming at 1.5 degrees, the limit at which we can halt the worst impacts of climate change. But even at 1.5 degrees there is likely to be deadlier hot spells, greater loss of biodiversity, longer droughts and more extreme storms. At just half a degree more, warming to 2 degrees puts far more of the population at risk of extreme weather and increases the likelihood of the planet reaching irreversible tipping points.

Regardless of how much this planet warms in the future, we know that our climate is already changing, in some cases faster than people and wildlife can adapt. People and nature in Wales are already feeling the effects.

We commissioned Farmlytics to produce an independent report to assess the recent impacts of a changing climate on farming and food production in Wales. Given that nearly 90% of land in Wales is utilised for farming, farmers are on the front line of climate change and are facing challenges to adapt and invest in climate-resilient systems. Their lives and livelihoods are directly affected by its impacts, and they are also vital to implementing many of the solutions we need to help prevent it.

The UK's first Food Security Report concluded that the biggest medium to long term risk to the UK's domestic food production comes from climate change and other environmental pressures. We wanted to understand what that impact looked like in real terms now in Wales.

The findings of this study show the significant impacts that a changing climate is already having on Welsh farming and food production, including dramatic negative financial impact. We also know that extreme weather events such as droughts and floods driven by climate change will likely become more common as our climate warms, intensifying the impacts that farmers feel in their pockets.

But we also know the solutions. Across Wales, the evidence shows that farmers which adopt nature friendly regenerative practices which enhance land resilience and enable them to better mitigate and adapt to droughts and floods are those best equipped to weather the storm of climate change. But support is desperately needed from Welsh Government and other actors to enable farmers to both properly mitigate and adapt to climate change. Investment is quickly needed in jobs, training and skills so that farmers are first in line to prosper from a transition that enables farmers in Wales to cope with a changing climate.

We hope this study will provide a useful contribution to future debate in Wales. We would like to thank Farmlytics for conducting this research and highlighting the challenges, as well as some of the solutions, to help the farming sector in Wales respond to the escalating impacts of a changing climate.

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Executive summary

In 2021, the UK's first Food Security Report concluded that: 'The biggest medium to long term risk to the UK's domestic production comes from climate change and other environmental pressures like soil degradation, water quality and biodiversity' (Defra, 2023d). The report also stated that losses of around £1.2bn each year (in England and Wales) were caused by issues such as soil erosion, degradation and compaction, reducing the capacity of UK soils to produce food.

The changing climate is already having an impact on Welsh farming and food production. Climate projections show that Wales will experience drier summers and warmer and wetter winters, with more unpredictable weather patterns. It's likely that extreme weather events will become more common as our climate warms, with farmers feeling the impacts in their pockets. Already over the last five years Wales has experienced several extreme weather events, including the 'Beast from the East' and heavy snowfall in 2018; summer drought in 2018 followed by Storm Callum; storms such as Storm Dennis in February 2020 and Storm Ciaran in November 2023; wildfires in south Wales during the summers of 2022 and 2023, and drought declarations in mid and south-east Wales during summer 2022. In 2023, Wales had one of the driest periods on record for May and June, followed by the third-wettest July in over 100 years.

Data from 2018, 2020 and 2022 provides illustrative examples of the financial impacts of the kind of severe weather Wales can expect in future. For example, in 2018, due to the impact of drought and floods on the growth of crops, grass and fodder in Wales, the total value of additional livestock feed bought in by farmers was estimated at £151m, and the estimated value of lambs lost was estimated at £23.8m. The impacts of weather on the ruminant livestock sector were estimated at £175m during 2018 alone – equivalent to 9% of the total Welsh agricultural output that year of £1.86bn. Similarly, reduced crop yields due to extreme weather during 2018 cost up to £4m, and poor crop conditions in 2020 cost £19.7m.

The drought in 2022/23 had similar impacts, with feed and forage costs rising to £265m above what would ordinarily be expected. However, some of this increased cost was likely to have been due to non-climate related factors such as rising fertiliser and energy costs.

The overwhelming majority of farmers interviewed for this study confirmed the climate was changing, with more unpredictable weather patterns, particularly during the spring and autumn. This is affecting farms in several ways, including through restricted growth of crops and fodder due to extreme drought or cold weather (meaning increased feed costs), livestock deaths due to cold weather or extreme heat (especially for newborn lambs), shortages of drinking water for livestock and irrigation water for crops, storm damage to agricultural infrastructure (e.g. buildings), and disruption to milk collections due to heavy snowfall and flooding. Farmers say this has led to longer feeding periods, shifts towards later lambing times, and shifts towards winter rather than spring cropping on arable farms.

The financial impact of extreme weather is significant for Welsh farmers, and is forcing significant numbers of them to change their farming systems in response. **Evidence from experts and farmers across Wales shows that those actively engaged with nature restoration, nature-friendly or more diverse farming practices are more resilient to extreme weather events.** Some of the latter report their land is less scorched than that of their neighbours during periods of extreme heat and water stress, and less prone to flooding. Greater tree cover, shelter belts and hedges mean animals are less exposed to heat stress and given greater protection in cold weather. Lower stocking rates mean fodder management is easier and

there is more resilience in the system. Rotational grazing can help maintain production while improving soil structure. Activities such as reducing synthetic fertiliser use, increasing crop rotations, water management (e.g. rainwater harvesting) and reducing tillage help to enhance soil health and fertility while increasing biodiversity. These types of measures are helping farm businesses become more resilient to the more frequent extreme weather events predicted as the climate changes.

Climate adaptation and mitigation support for farmers is currently insufficient. Finance was mentioned as a barrier to climate mitigation and adaptation by many farmers, as well as a lack of knowledge. Others spoke of the need for greater education on sustainable agriculture and on adapting to climate change. More nature-friendly farming can mitigate the impacts of climate change and help maintain farm incomes and food production within Wales. However, transitioning to nature-friendly systems requires investment, and it takes time to build resilience.

The findings highlight why we need a more diverse and resilient food and farming system, one that can withstand global and local climate shocks. They underscore the impacts of climate change on farmers and food production in Wales. They also highlight the impact on the wider supply chain and on the general public in terms of, for example, increased food prices due to the effect of rising energy costs and global temperatures.

Years featuring extreme weather events are likely to become the norm. **Climate-driven changes in weather are among the highest-risk future shocks to the food system in Wales.** Climate change poses huge risks to food security. In terms of Wales and the UK, a key area of concern is the fruit and vegetable sector, with imports largely sourced from climate-impacted parts of the world. However, a warmer climate could increase the potential for fruit and vegetable production within Wales. More diverse farming systems with mixed rotations could help lessen reliance on imports and exposure to climatic impacts on the supply of fruit and vegetables. Policies to encourage more small-scale fruit and vegetable production would also benefit rural employment as well as supporting public health goals.

This report focuses on the impact of climate change on farmers in Wales. Farmers are at the frontline, facing challenges to adapt and invest in climate-resilient systems. Support from both the Welsh government and the private sector will be critical in ensuring the transition to climate and nature-friendly farming supports resilient businesses and thriving rural communities.

There are actions that could help Welsh farms address the impacts of climate change. **Many of the farmers and experts interviewed for this study suggest that nature-friendly farming methods, such as regenerative and organic practices, can contribute to farm resilience.** These methods focus on building soil health, diversifying crops, and using agroecological approaches. While they may not eliminate the impact of adverse weather, they can enhance a farm's ability to cope with changing conditions.

Support for implementing nature-friendly practices is needed to drive the transition to a more sustainable and resilient farming system. Increased public and private finance are needed to help farmers mitigate and adapt to climate change. Many farmers state that they do not yet have enough information on the Welsh Sustainable Farming Scheme and whether it will help with climate mitigation and adaptation measures. It is vital that the Sustainable Farming Scheme embeds sufficient support to enable farmers to access measures for climate mitigation and adaptation.

Key areas for farm-level mitigation and adaptation should include:

- **Soil health:** Maintaining soil structure will provide better drainage, better water retention during drought, and reduced flood risk. There is a need for improved on-farm soil health monitoring for better management, along with testing soils for pH, texture, fertility, etc to make informed decisions. Other measures include avoiding heavy machinery, limiting livestock access on wet soils, maintaining soil cover (e.g. through cover cropping), and implementing reduced-till or no-till farming to help build soil organic matter and encourage soil organisms.
- **Tree and hedgerow planting:** Trees help reduce soil erosion, thereby reducing losses of water, and provide shelter for livestock especially during heatwaves. This can be achieved through support for agroforestry systems and planting shelter belts and hedgerows.
- Implement fire breaks between fields, hedgerows and woodland areas.
- **Greater crop diversity:** More diverse arable rotations are needed for climate and economic resilience. The inclusion of temporary grass and herbal leys will help with the integration of livestock into arable systems, and will help to increase the amount of plant and animal matter going back onto fields. Integrating livestock within arable rotations will allow manure and green composts to replace nitrogen-based fertilisers. Changing crop schedules and introducing a multiple cropping system (growing two or more crops in the same field, e.g. salads) can help to make the most of extended growing seasons.
- More diverse rotations and swards should be encouraged, for example putting legumes or herbs in reseeding leys. Deeper rooting forage species such as chicory can help to retain moisture in the soil and therefore maintain pasture. Sowing earlier and harvesting later can help to compensate for lower yields due to drought.
- Rotational grazing can support grass yields and reduce water runoff, maintaining moisture in the soil. Rotational grazing helps to prevent overgrazing and soil damage, and enables greater grass yields. It can cut veterinary bills and feed and fertiliser costs.
- **Investment in technology:** Sensors for monitoring soil and livestock can help improve management and boost resilience.

Support for investment in infrastructure

A lack of funding is a key barrier to adaptation to climate change. There is a need for investment in:

- Farm buildings to enable the housing of stock over the winter to rest grazing land.
- Slurry and manure storage to cope with wetter winters and reduce the risks of pollution.
- Drainage systems to cope with higher rainfall intensities.
- Flood prevention schemes.
- On-farm water management in terms of irrigation (to aid harvesting in dry ground), including rainwater harvesting and water storage reservoirs to enable farmers to cope with the reduced availability and reliability of summer rivers. Farmers need to take advantage of periods of heavy rainfall and store rainwater, as well as recycling water.
- Peatland restoration projects to enhance biodiversity and prevent flooding.

Data on sustainability and technology

There is a need to collect more farm-level data on environmental metrics. This is best collected by farmers themselves. It will help them to monitor their own progress and provide actionable insights into the sustainability of their own farms. Technologies to improve resilience include sensors that monitor essential components of farming such as soil parameters, livestock behaviour, production, and farm inputs and outputs. Precision agriculture is one way in which technology can be used to minimise inputs and maximise outputs. GPS systems can help farmers plant crops in the most efficient patterns to save time, fuel and costs. Drones and remote sensors can map areas of plant disease and other plant health parameters.

Improved training and education on sustainable farming

Improved agricultural education is seen as a key factor in helping the sector develop greater resilience. This includes a stronger emphasis on nature-friendly farming and soil conservation. Agricultural colleges need to focus more on sustainable farming and move the emphasis away from production-led agriculture. In addition, farm advisers need to upskill in sustainable farming methods.

Horticulture production

Measures are needed to support domestic fruit and vegetable production, especially among smaller-scale producers and as part of diversified farming businesses. For example, the Welsh government's Horticultural Development Scheme could be improved by ensuring that the minimum investment threshold is not a barrier to small-scale producers.

There is also a need for measures to encourage more home-grown food and gardening, and to provide more allotments in towns. This will help consumers to reconnect with food production, and will also support public health objectives.

Introduction

Background

In 2021, the UK's first Food Security Report concluded that: 'The biggest medium to long term risk to the UK's domestic production comes from climate change and other environmental pressures like soil degradation, water quality and biodiversity' (Defra, 2023d). The report also stated that losses of around £1.2bn each year (in England and Wales) were caused by issues such as soil erosion, degradation and compaction, reducing the capacity of UK soils to produce food.

The recent cost-of-living crisis has highlighted the volatility of global food prices and the impact of extreme weather on food price inflation. Alongside this, Russia's invasion of Ukraine in 2022 led to disruptions in global commodity markets, significantly affecting the cost of key farm inputs such as fertiliser and animal feeds, with global food prices spiking in 2022 (World Economic Forum, 2022). However, the high prices were exacerbated by drought and other poor crop conditions in the UK and elsewhere, highlighting the threat to food security posed by climate change.

Climatic events also had an impact on global food prices in 2022. For example, Brazil's agricultural GDP declined by 8% in the first quarter of 2022 due to a severe drought in the country's south caused by a rare triple-dip La Niña (Hanbury, 2022). El Niño and La Niña events are becoming more frequent, and it is predicted that these kinds of crop failures will become more frequent in future, with impacts on global food security.

Research aims and approach

This report explores the economic impact of climate-induced extreme weather events on Welsh agriculture. It highlights the risks the changing climate poses to Welsh agricultural resilience, and discusses some sustainable farming techniques that could help Welsh farms mitigate and adapt to it.

The report describes the risks Welsh agriculture faces if a transformative change is not delivered through the Sustainable Farming Scheme. More broadly, it aims to explore the perception that the most important aspect of food security is food production alone, particularly in light of the fact that the bulk of Welsh production is exported out of Wales.

A two-pronged approach comprising interviews and an economic analysis has been used to gather qualitative and quantitative data.

Interviews

Brief qualitative interviews were held with a range of farmers about observations they have made on their farms concerning extreme weather and its impacts, as well as some techniques and practices that have helped to mitigate against the worst effects of this weather. We have interviewed both farmers who use regenerative and nature-friendly farming practices and farmers who do not.

Economic analysis

Key questions for the economic analysis were:

1) What was the economic impact of key adverse weather events on Welsh agriculture over the past decade, broken down by agricultural sector? This considered the impact on livestock numbers, food and fodder supplies, and crop production.
2) Were these economic impacts buffered for those who use nature-friendly farming methods?
3) Can alternative agricultural practices support farm resilience and profitability for the future?
4) What potential future costs and impacts could be felt by agriculture and the wider supply chain as a result of these continuing extreme weather events?
5) How did this compare to non-weather events that have cost the agricultural sector, for example bovine tuberculosis, foot and mouth disease, and war in Ukraine?

The study quantifies the physical losses incurred by farmers as a result of the extreme weather events and the economic costs involved. A literature review of industry and media reports on the impact of extreme weather events in Wales over the last 10 years also informs the analysis.

Livestock and crop statistics from Defra, the Welsh government and the Farm Business Survey were used to quantify the losses to farmers during this period as a result of extreme weather events. Long-term trends in livestock numbers and crop yields were factored out of the estimates to indicate impacts specifically attributed to extreme weather events.

The key extreme events considered were:

- 'The Beast from the East' and heavy snowfall, 2018.
- Summer drought in 2018 followed by Storm Callum.
- Named storms such as Storm Dennis in February 2020 and Storm Ciaran in November 2023.
- Wildfires in south Wales, in summer 2022 and 2023.
- Drought declaration in mid and south-east Wales, in summer 2022.

Literature review

Introduction

Almost 90% of the land in Wales is dedicated to farming, with three-quarters of it kept as permanent pasture for livestock (Armstrong, 2016). However, climate change could drive significant changes to this pattern of land use.

In 2017, agriculture accounted for 0.8% of total Gross Value Added (GVA) for Wales, which is a higher proportion of the economy than it is for the UK as a whole (Welsh government, 2019). However, average Welsh farm holdings are 48 hectares (ha), smaller than those in England and Scotland, and the relatively low levels of intensive farming result in smaller incomes compared to similar-sized farms in England (Armstrong 2016).

The Welsh agriculture sector's output focuses heavily on livestock (51%) and livestock products (35%), mainly lamb, beef and milk (Armstrong 2016). Farmers are the largest group of land managers in Wales (Welsh government, 2019), and the contribution they make to the appearance of the Welsh landscape is often cited as an indirect but important way in which agriculture contributes to the Welsh economy by supporting other rural businesses such as tourism and hospitality.

The climate, as well as topography, severely constricts agriculture in Wales. The wettest months are October to January, while the driest are late spring to early summer. The annual average temperature varies with altitude, from 9.5-11°C at low altitudes to 3.5-7.5°C at higher altitudes (Welsh government, 2022c). Soils across most of Wales are at 'field capacity' (the point at which soil is fully saturated with water after excess water has drained) for over 200 days per year (Welsh government, 2022c). At higher elevations, this saturation time can rise to 250-300 days per year (Welsh government, 2022c). As a result, cropping options and opportunities to work the land are severely limited. There is evidence that land use and soils are already experiencing the impacts of climate change through extreme events like floods, fires and droughts (Natural Resources Wales, 2021).

Agriculture is one of the main contributors to greenhouse gas emissions, contributing 15.8% of Wales' total domestic greenhouse gas emissions in 2021 (StatsWales, 2023). Furthermore, the recently released State of Nature 2023 report found that one in six species in Wales is at risk of extinction (State of Nature Partnership, 2023). While sustainable agricultural practices have a central role in the restoration of biodiversity and carbon sequestration, certain practices have contributed to biodiversity loss, water pollution and soil depletion at a national scale. This has weakened the resilience of ecosystems and, thereby, their ability to recover from the kind of environmental shocks that are likely to increase with climate change. Increasingly frequent extreme weather events are making farming harder by affecting planning, yields and profits.

Examples of extreme weather impacts on agriculture include:

- Shortages of feed and fodder due to extreme cold weather.
- Restricted growth of crops and grass due to extreme drought or cold weather.
- Livestock deaths due to cold weather or extreme heat.
- Shortages of drinking water for livestock and irrigation water for crops.
- Storm damage to agricultural infrastructure, for example buildings.
- Disruption to milk collections due to heavy snowfall and flooding.

In 2023, Wales had one of the driest periods on record for the May and June period, followed by the third-wettest July in over 100 years. Wales has already experienced changes in its climate, and these are projected to continue and intensify. This report considers food security by looking at the impact of extreme weather on domestic Welsh food production, and disruptions throughout the supply chain. It also looks at the role of a resilient ecosystem in maintaining food production, and the potential for sustainable and regenerative farming practices to contribute to policy aims.

> **The UK climate continues to change, but UK temperature extremes are changing much faster than average based on 1960 to 2022 UK daily average maximum and minimum temperatures.**
>
> *(Kendon et al., 2023)*

Summary of key extreme weather events affecting Welsh agriculture

Storm Emma and the Beast from the East – 2018

The winter of 2017/18 saw heavy snowfall culminating in the March 2018 **'Beast from the East'**, which saw significant disruption to farming activities and food supply chains (BBC, 2018). South Wales and the West of England received significant snow, with 49cm at St Athan, South Glamorgan, and 25cm at Hereford (Met Office, 2023).

It was reported that the severe winter weather had an impact on livestock populations. Welsh lamb yields were down by 8% in 2018 on the previous year, and the total number of sheep and lambs recorded in June 2018 was down by 5% (HCC, 2018).

Heatwave – 2018

Summer 2018 was the joint-hottest summer on record for the UK. The highest temperature recorded was in Porthmadog, Gwynedd, where it reached 33°C on 28 June. Wales also saw the second-highest amount of sunshine out of all the countries in the UK, with 640.3 hours, 123% above average (Wales Online, 2018). During this period, an early summer heatwave caused wells and streams to dry up and created problems for livestock and crops. A crisis began to emerge for Welsh farmers, who started turning to their winter feed stocks and buying additional feed and straw (Wales Online, 2018).

Storms Ali and Callum – Autumn 2018

Autumn 2018 saw three significant storms. Storm Callum in October 2018 brought strong winds to the north of the UK and Wales, and 24-hour rainfall totals exceeding 100mm in parts of south Wales (Wales Online, 2018).

The 2019/20 winter was mild but wet, with February 2020 the wettest on record. Poor weather continued into the spring, followed by dry but sunny periods with farmers low on forage and bedding due to a long housing period and slow grass growth. Summer conditions improved with hot and dry periods allowing work to progress. Overall, the summer had less sunshine than average and an August heatwave. An unsettled mild and favourable autumn and winter followed, with no excessive pressures on housing or fodder stocks.

Storm Dennis – February 2020

Rainfall from Storm Dennis caused the most significant impacts, with flooding in parts of south Wales and England. Between midnight on the morning of Saturday 15 February and 10am on Monday 17 February, a Natural Resources Wales site at Crai Reservoir in Powys recorded 157.6mm of rainfall (Met Office, 2020). Several locations recorded significant portions of their monthly average rainfall totals during the event. The strongest wind gust – of 91mph – was recorded at Aberdaron in north-west Wales. The torrential rain and flooding caused significant disruption to farming operations, leading to submerged fields and flooded farm buildings.

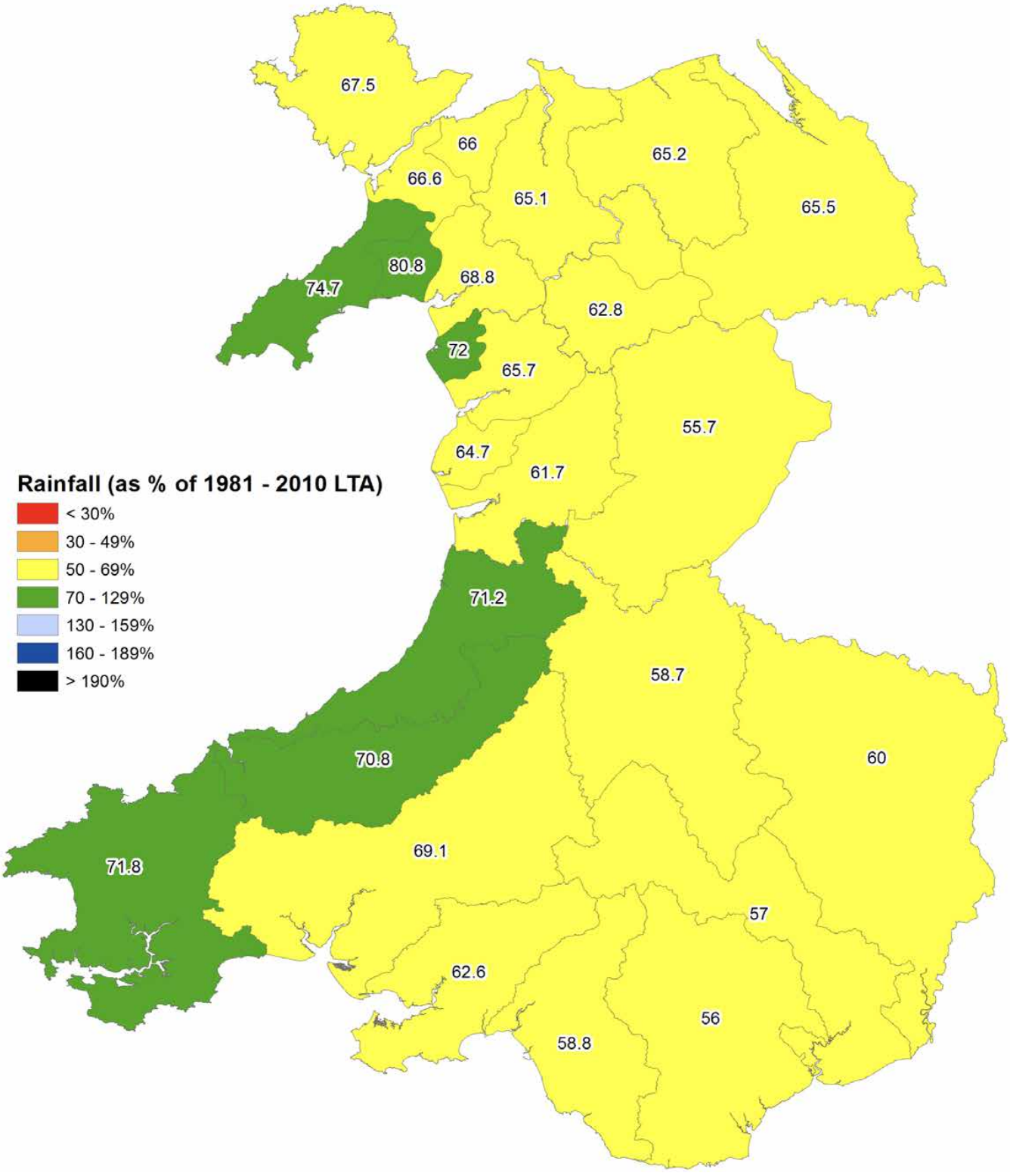
Storm Anwen – November 2021

High winds caused considerable damage to farms and forestry and led to loss of power in some parts of the country, leading the Met Office to issue danger-to-life warnings.

Drought – summer 2022

Low rainfall across Wales throughout 2022 saw drought declared in September 2022 (see Figure 1) and the driest seven-month period on record (Natural Resources Wales, 2023). In 2022 drought and record temperatures in the summer months put pressure on vegetable growers, with many key vegetable growing areas recording minimal rainfall from June onwards (Wilkinson, 2022).

Figure 1.
March to September 2022 rainfall in Wales (as % of 1981-2010 average)



Taken from Natural Resources Wales (2023). Dry Weather Updates.

According to the Farm Business Survey, a dry, mild spring limited grass growth and a long, dry, warm summer gave ideal harvest conditions although yields were poor, particularly for forage. A warm autumn gave good forage growth and a mild, dry and early 2023 spring eased pressures on winter forage. The spring weather led to good lambing and finishing conditions. However, many farms were still short of fodder, which led to forced forage purchases and premature stock sales (Aberystwyth University, 2023).

Climate projections for Wales

The Welsh climate is already changing, and projections suggest that in future Wales will see more intense rainfall and more flooding in low-lying and coastal areas, along with hotter, drier summers (Natural Resources Wales, 2021).

These more frequent and intense extreme weather events will impact the ability of British farm systems to maintain or increase levels of food production (Osborne and Evans, 2019). A summary of the key projections from Natural Resources Wales is presented in **Appendix 1** on page 59.

The projections foresee more extreme warm days, milder and wetter winters, less snowfall and frost, and lower groundwater levels. These changes are likely to bring the following risks:

- Increased risk of death and illnesses during periods of hot weather.
- Changes to soils, biodiversity and landscapes due to warmer, drier summers.
- Reduced river flows and water availability during summer months, affecting water supplies and aquatic ecosystems.
- Increased risk of flooding, affecting people, property and infrastructure.

The report also highlighted the following opportunities:

- Increased grass growth, allowing for a potential increase in livestock production.
- Increased potential for cropping in some areas.
- Potential benefits for tourism, including opportunities for farm-based tourism.
- Reduced deaths and illnesses due to cold weather.

Climate change and food security

The definition of food security has evolved over the past 50 years, having expanded from a focus solely on producing enough food (as a result of food shortages following World War II), to cover other elements such as accessibility, access, utilisation and stability, which have been important for shaping policy (Clapp et al., 2022).

Recent decades have also seen an increasing awareness of important challenges that affect hunger and malnutrition, including food security issues that are driven by growing concentration within food supply chains, as well as climate change and other ecological pressures.

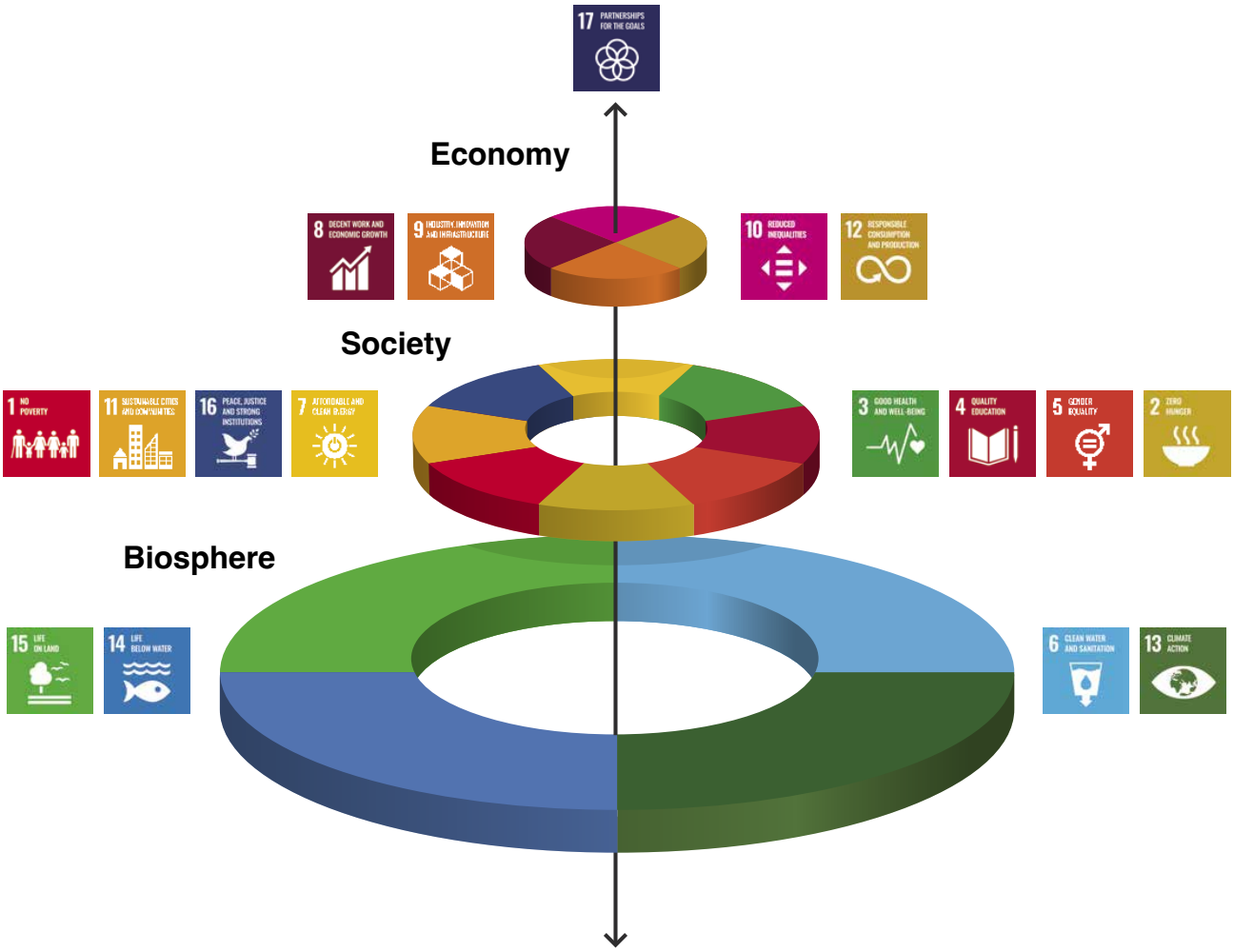
Extreme weather and climate change have an impact on the stability of food production. Problems such as biodiversity loss and soil degradation further reduce the resilience of our agricultural systems, affecting overall food security. In 2023, shoppers faced fruit and vegetable shortages due to unprecedented high temperatures in southern Spain, while the start of the UK growing season was late due to cold, overcast weather. The conditions led to some retailers limiting customer purchases of some items. For example, one retailer limited purchases of peppers, cucumbers and tomatoes to three units per person (Butler, 2023).

With half of the UK's food imported from overseas, worsening climate impacts both at home and abroad threaten our food security (Hess and Sutcliffe 2018). The UK is the third-largest importer of fresh fruit and vegetables in Europe (CBI Ministry of Foreign Affairs, 2022). Over a quarter of UK food imports – 9.8 million tonnes worth just over £16bn – came from the Mediterranean region (Energy and Climate Intelligence Unit, 2023). Spain – which is experiencing some of the worst climate impacts in the region – accounted for 7% of total food imports, worth £4bn (Energy and Climate Intelligence Unit, 2023). Other water-scarce countries such as Egypt and Morocco supply much of the fruit and vegetables sold in the UK (Hess and Sutcliffe, 2018), and they have also recently experienced severe crop yield declines due to drought (The Grocer, 2023).

Agriculture relies on clean air, water and nutrients provided by natural processes and cycles to support crops and livestock. Thus, any degradation to natural capital poses a threat to the UK's food production (Defra, 2023d). Human activities driving greenhouse gas emissions and climate change also pose significant risks to production and food security. Food production is dependent on natural processes, and therefore ecological resilience is fundamental to food security and the future of agriculture in Wales.

The Sustainable Development Goals (SDGs) were developed by the United Nations to tackle the world's big challenges. Food is important to several of the SDGs including SDG1 (No Poverty), SDG2 (Zero hunger) and SDG3 (Health and wellbeing) (Rockström and Sukhdev, 2016). The 'wedding cake' model (see Figure 2) theorised by Rockström and Sukhdev at the Stockholm Resilience Centre demonstrates how these goals stack up, with the societal and economic goals on top of the foundational layer. This foundational layer comprises all the SDGs that create a healthy planet, demonstrating our dependence on our biosphere for all the other goals. This vision is a move away from treating social, economic and ecological development separately. It demonstrates how the stability and resilience of our climate and environment underpins food security, which is dependent on healthy ecosystems.

Figure 2.
The 'wedding cake' model



Taken from Rockström and Sukhdev (2016)

Impact on food security in Wales and the UK

According to the most recent UK Food Security Report:

> **"The UK has diverse and longstanding trade links that meet consumer demand for a range of products at all times of the year. Trade is dominated by countries in the EU, and it is too early to say what effect leaving the EU might have on that trade"**
>
> *(Defra, 2023d).*

However, the UK's food system has been challenged by recent global events such as the Covid-19 pandemic and the war in Ukraine.

In addition, there are food system externalities that are not currently directly accounted for by food-producing businesses or consumers, such as natural capital degradation, biodiversity loss, production-related ill-health, and diet-related disease. It has been estimated that for every £1 UK consumers spend on food, additional external costs of 97p are incurred (Fitzpatrick et al., 2019). The 2021 UK Food Security Report also stated that:

> **"The biggest medium to long-term risk to the UK's domestic production comes from climate change and other environmental pressures like soil degradation, water quality, and biodiversity"**
>
> *(Defra, 2023d).*

Increasingly volatile weather patterns will have an impact on food production in particular years. For example, heavy rainfall and drought at critical periods in the growing season led to wheat yields being down by 40% in 2020; however, they recovered in 2021 (Defra, 2023d).

According to the Sustainable Food Trust:

> **"A UK-wide transition to sustainable and regenerative farming practices could produce enough food to maintain and potentially even improve current levels of self-sufficiency, provided we ate differently, ate less, and cut food waste"**
>
> *(Barbour et al., 2022).*

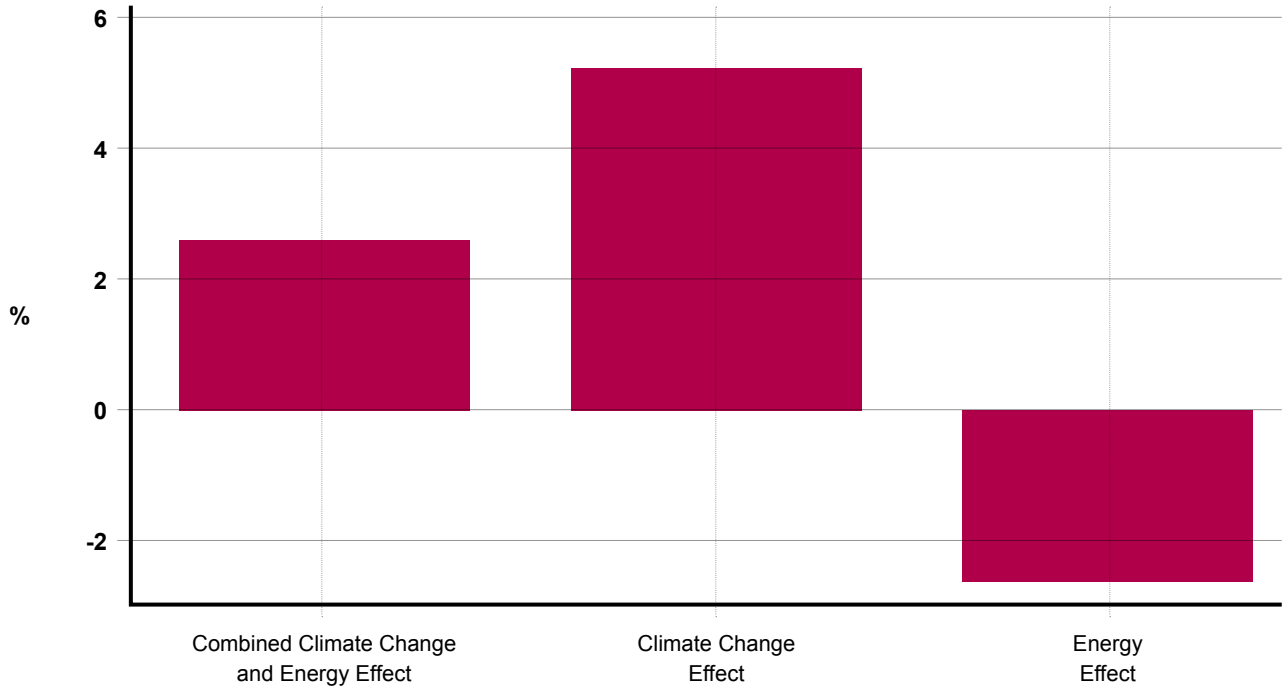
This could help tackle the climate, nature and public health crises we currently face.

Household food costs

A recent study by the Energy and Climate Intelligence Unit (ECIU) showed that the cost of energy inputs and extreme weather accounted for the largest share of the rise in food prices experienced in the UK in 2022 (Lloyd et al., 2023).

The ECIU study also estimated that the combined effect of energy costs and global temperatures on UK food prices in 2023 would increase average consumer food prices over the year by 2.7% (Lloyd et al., 2023). This equates to an increase of £2.8bn in the nation's food bill, or an average increase of £97 per household (Lloyd et al., 2023).

Figure 3.
Effect of climate change and energy costs in 2023 on UK food price inflation



Taken from Lloyd et al. (2023)

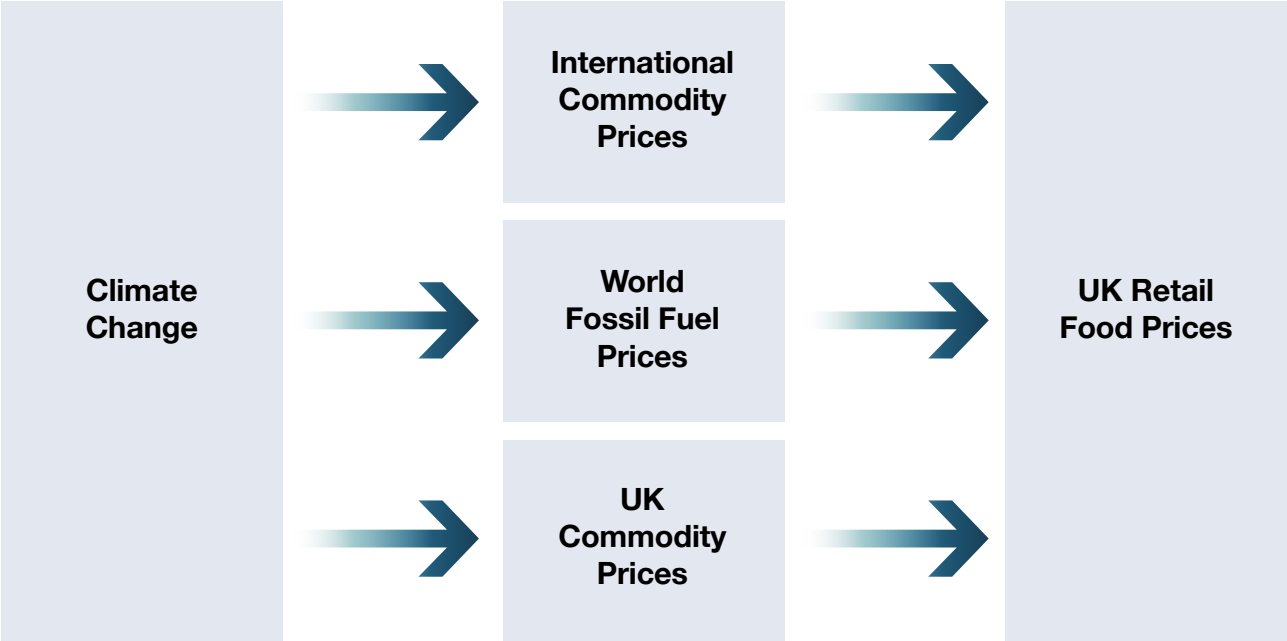
The breakdown above shows that climate change was projected to add 5.3% to food price inflation in 2023 (equivalent to an increase of £5.5bn in the national food bill, or £192 per household), whereas the fall in energy prices worked to offset inflation by 2.6% over the same period (equivalent to a reduction of £2.7bn in the national food bill, or £95 per household). The net effect of these opposing changes was to increase food prices in 2023 by an estimated 2.7% (equivalent to £2.8bn in total or £97 per household) (Lloyd et al., 2023).

The combined impact of energy costs and climate change across 2022 and 2023 led to an average increase in household food bills of £605, with climate costs accounting for 60% of this increase, or £361 per household (Lloyd et al. 2023) Thus, the impact of climate change was partially offset by the reduction in energy costs in 2023. However, with global temperatures in 2023 exceeding previous records, climate change continues to have an impact. Assuming food price inflation averages out at around 15% in 2023, Lloyd et al. estimate that around one-third of the increase (the 5.3% reported above) will be attributable to the extreme weather induced by climate change both within the UK and elsewhere.

According to another estimate, in 2022 the average UK household saw a £400 increase in annual food costs because of climate impacts and fossil fuel price volatility (Energy and Climate Intelligence Unit, 2023).

UK retail food prices are affected by many factors; however, global weather shocks are key driving forces for international commodity and fossil fuel prices, as well as for UK commodity prices, all of which have a direct impact on UK retail food prices (see Figure 4).

Figure 4.
The transmission of global weather shocks in UK retail food prices



Taken from Lloyd et al, 2023.

Self-sufficiency and food security are not the same thing. International trade can in some instances reduce the risk of food insecurity because global production is more stable than that of individual countries which may be adversely affected by extremes. Diverse food supplies from multiple trading partners can potentially reduce the risk of exposure to climatic shocks.

A recent study has found that countries with high source diversity have moderate exposure, but for countries reliant on domestic production there is wide variation in the degree of risk of food insecurity. Sourcing from a diverse range of sources will increase resilience to both climatic and non-climatic supply shocks (Bebber et al., 2023).

There is much less information on the impact of climate change beyond the farm gate. However, several potential impacts can be identified (Falloon et al., 2022):

- Increased volatility in supplies and quality, which can impact the food processing sector since it is dependent on consistent supplies.
- Heat and cold can affect the health of workers across the food chain.
- Disruption to transport and infrastructure; for example, disruptions to milk collection during snowstorms.
- High temperature and humidity can lead to increased spoilage and problems from toxins – highly perishable foods (such as fruit, vegetables, meat, dairy and fish) are particularly vulnerable to climate hazards during storage and transport.
- Spikes in consumer demand – warm weather drives up the demand for barbecue food, salads and fresh fruit, but supply will also be affected through heat stress (Falloon et al., 2022).

Welsh farm policy

The UK's departure from the European Union meant the EU's Common Agricultural Policy and the Basic Payment Scheme (BPS) subsidies that were paid to farmers under that policy needed to be replaced. In August 2023, Wales passed the Agriculture (Wales) Act into law – this is the first time Wales has been able to design its own legislation for farming payments.

The Act provides a framework from which future agricultural decisions will be made. It focuses on four sustainable land management objectives that work to pay for sustainable food production while also reducing the impact of farming on nature and the climate.

As of 2025, the Sustainable Farming Scheme (SFS) is set to gradually replace the BPS. It aims to reward farmers for managing their land sustainably, such as by improving water and soil quality as well as storing carbon. Within the latest consultation document, the four sustainable land management objectives of the SFS are:

- To produce food in a sustainable manner.
- To mitigate and adapt to climate change.
- To maintain and enhance the resilience of ecosystems and the benefits they provide.
- To conserve and enhance the countryside and cultural resources and promote public access to and engagement with them and sustain the Welsh language and promote and facilitate its use (Welsh government, 2023).

Economic analysis

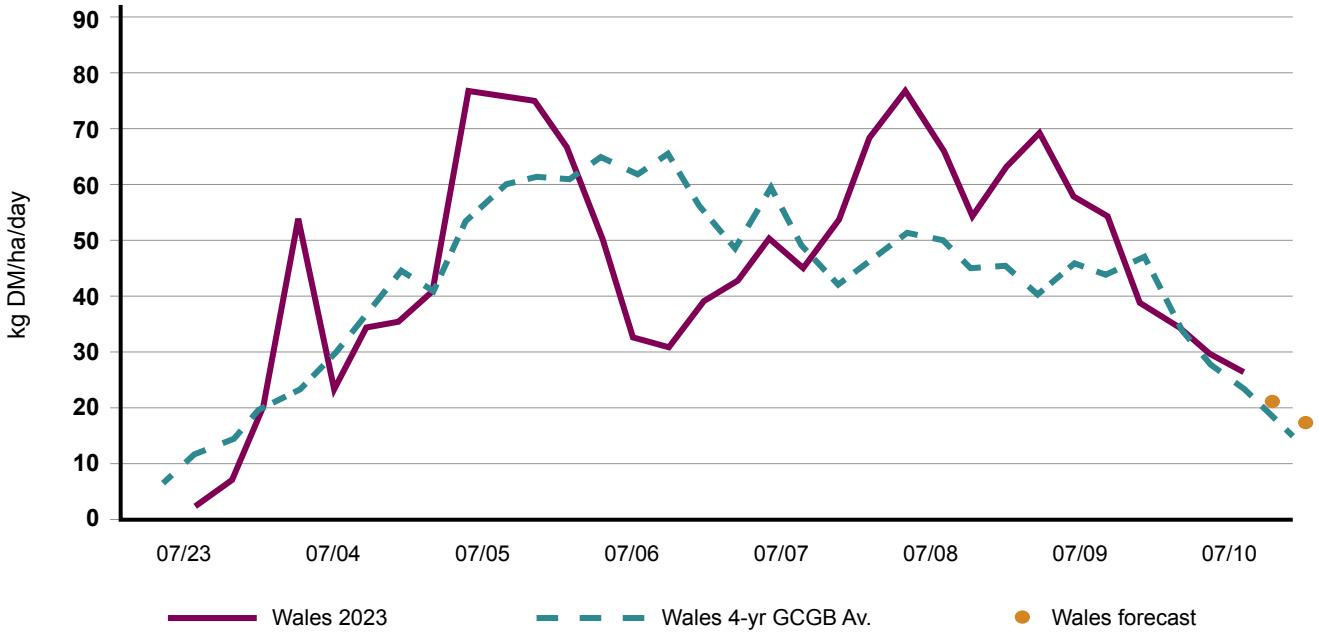
Our economic analysis aims to quantify the impact of key weather events on Welsh agriculture using a comparison with the long-term average.

Extreme weather events particularly affected Welsh agriculture during 2018, 2020 and again in 2023. However, it's important to note that the impact of drought in 2022 and 2023 was exacerbated by global events such as the Ukraine war and increased energy costs affecting the cost of farm inputs such as fertiliser. Therefore, higher than expected farm costs during 2022 were not solely due to climatic events.

Impact on fodder supplies

Grass growth and fodder production is highly seasonal in Wales (see Figure 5), with peak growth in spring and limited growth over the winter period. Very often during dry conditions in the summer there is a dip in grass growth before a late summer or autumn 'flush' as rain returns. Sheep and cattle farmers rely on conserving fodder for feeding over the winter by producing adequate hay and silage during the spring and summer period.

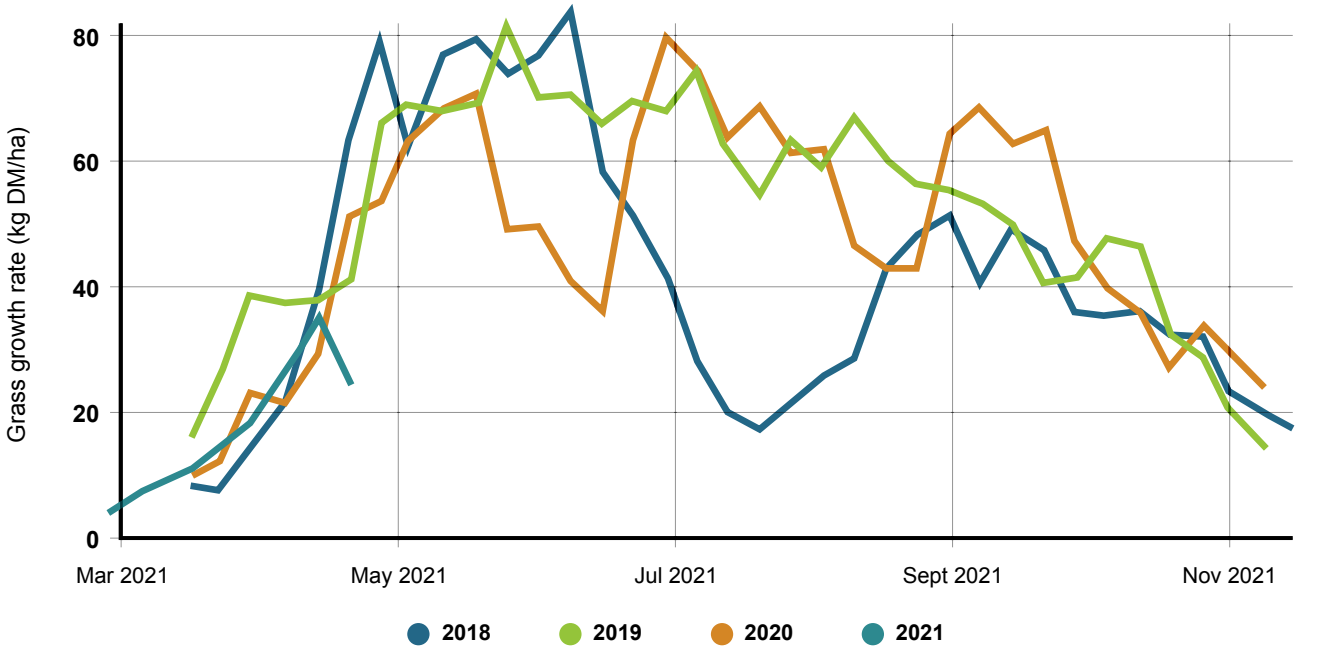
Figure 5.
Seasonal pattern of grass growth in Wales



Taken from Grass Check GB (2023)

The period from 2018 to 2021 saw some significant variations in the seasonal pattern of grass growth. Drought during the summer of 2018 had a severe impact on grass growth, with daily growth rates well below the seasonal norm (see Figure 6). This led to increased feed, forage and bought-in concentrate costs across all grazing livestock farms. However, in 2020, grass growth during the spring fell to 60% of its normal level due to unusually dry conditions (CIEL, 2020).

Figure 6.
The seasonal pattern of grass growth in the UK 2018-2021



Taken from Corfield (2023). The Weather Proof Farm.

Impact on livestock numbers and production costs

Extreme weather events affect livestock farms through increased losses and through extended periods of supplementary feed, either from summer drought which affects grass growth or extended periods of feeding during the winter.

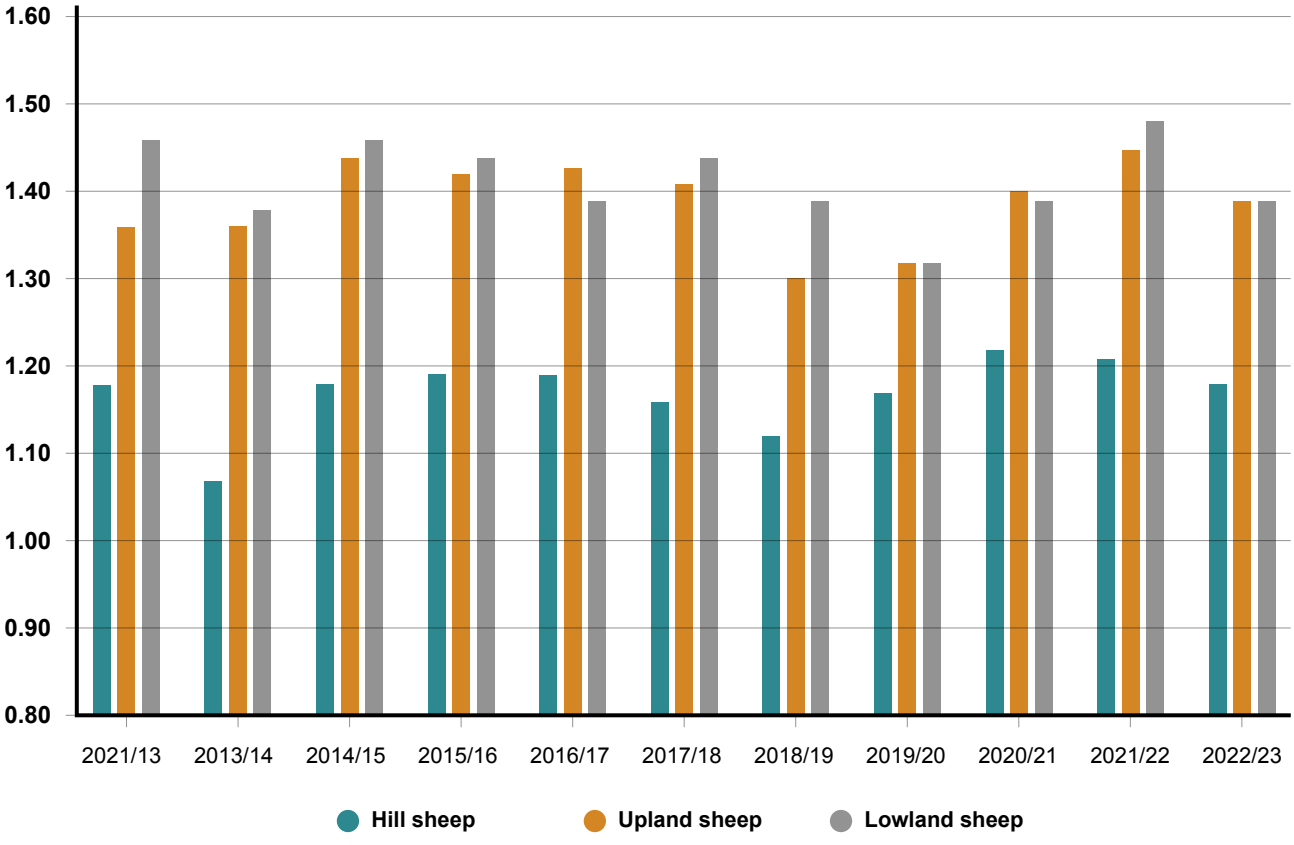
Sheep

In addition to the impact on feed costs, the sheep sector has also been affected by losses due to extreme cold weather, particularly during the spring lambing season.

Lamb losses

Extreme weather during 2018 and 2020 had an impact on Welsh sheep numbers, with increased losses of newborn lambs and a reduction in the number of lambs reared per ewe (see Figure 7).

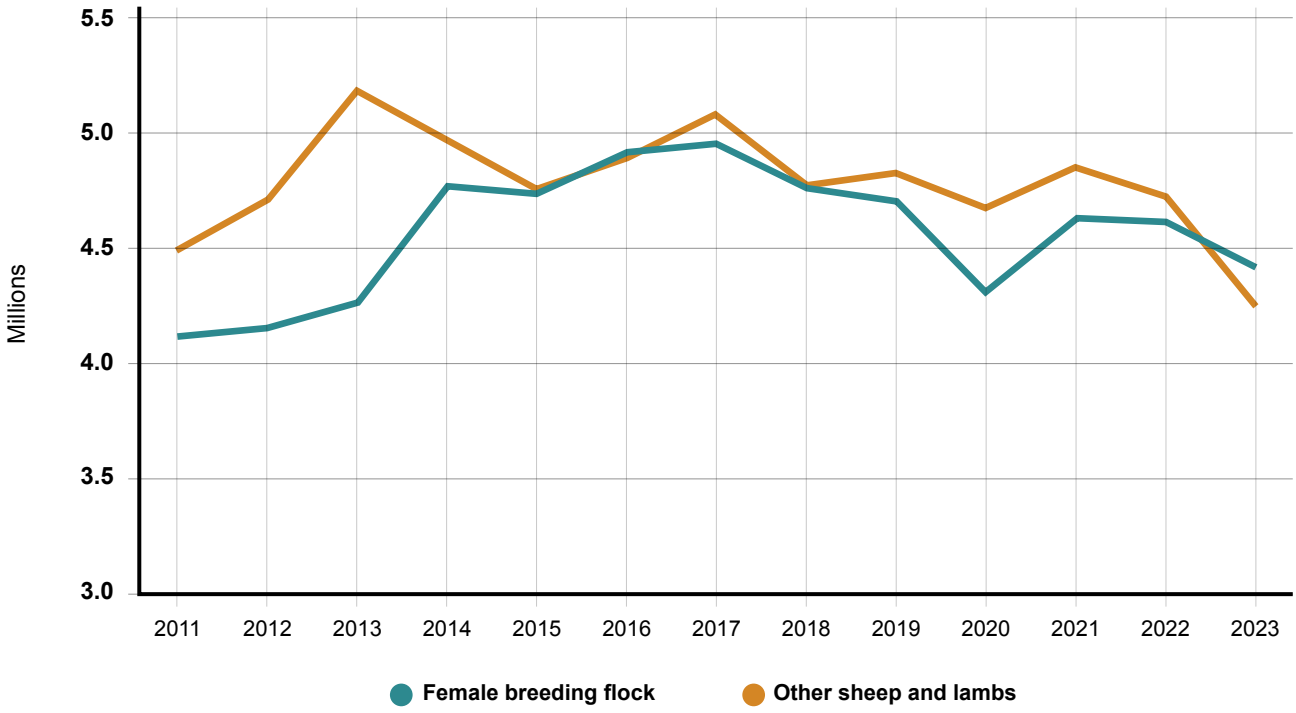
Figure 7.
Lambs reared per ewe 2012-2022



Data from Wales Farm Business Survey 2012-2022.

Losses in 2018 led to reduced sheep populations in 2019 and 2020 as there were fewer lambs being reared on farms, and fewer replacement females entering the breeding flock the following year, with a sharp decline in ewe numbers from just under 5 million in 2017 to 4.3 million in 2020 (see Figure 8).

Figure 8.
Welsh sheep population 2011-2023



Data from Defra Livestock Populations in the UK (Defra, 2023c).

The impact of extreme weather on the number of lambs reared was estimated by looking at the 10-year trend and the deviation from that trend in specific years where extreme weather events occurred (see Table 1). For example, based on a 10-year trend in the Farm Business Survey data, hill ewes would be expected to have reared an average of 1.2 lambs per ewe in 2018; however, the average numbers actually reared were 1.12. It is likely this was due to the extreme cold weather and snowfall during spring 2018, which we thus estimate led to losses of an average of 0.08 lambs per ewe.

Table 1.
Estimates of extreme weather impacts on lamb losses in 2018 based on Farm Business Survey farm performance data

Enterprise Type	2012/13	2017/18	2018/19	2022/23	10 Yr. Trend	2018 Based on Trend	2018 Actual	% Difference
Hill	1.18	1.16	1.12	1.18	0.00%	1.2	1.12	-3.4%
Upland	1.36	1.41	1.30	1.39	0.22%	1.4	1.30	-8.0%
Lowland	1.46	1.44	1.39	1.39	-0.49%	1.4	1.39	-3.0%

Data from Wales Farm Business Survey 2012-2022.

Thus, for an average flock of 609 breeding ewes this would equate to 49 fewer lambs worth £51.89 per head, and a loss of £2,542.

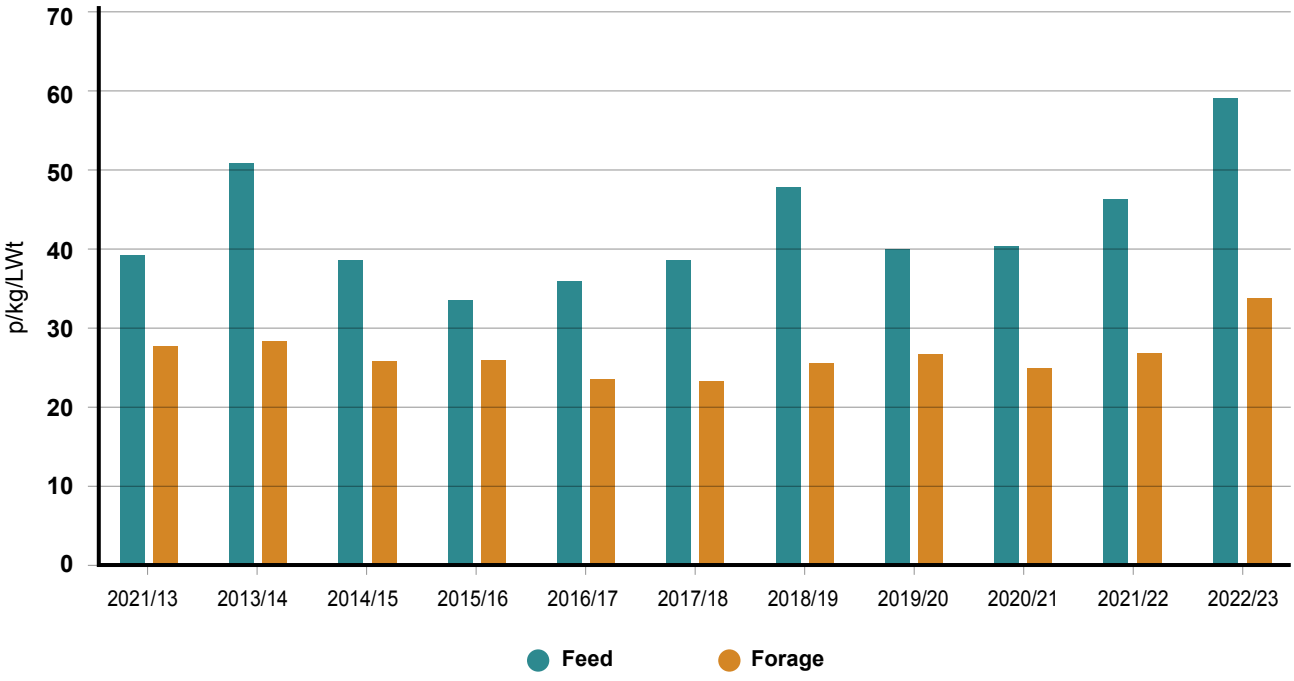
Estimates of increased feed costs

The Farm Business Survey contains data on forage costs per ewe for hill, upland and lowland sheep farms; extreme weather has an impact on these costs through increased bought-in forage and prolonged feeding periods. Overall feed and forage costs per ewe, suckler cow or dairy cow is presented in **Appendix 2** on page 61. The 2022/23 period saw a 10-year high in forage costs per head for all types of sheep farms, upland suckler farms and dairy farms. This was due to a combination of increased fertiliser costs and poor weather conditions. Concentrate and bulk feed costs per head were also at a 10-year high for hill and lowland sheep, hill suckler and dairy farms.

During 2018/19 there was an increased need for concentrate and bulk feeding, especially for suckler cows, due to cold weather in the spring and drought conditions over the summer. In 2018 the concentrate and bulk feed cost for lowland sucklers was £219.36 per head compared to a 10-year average of £154.35, while for upland sucklers it was £190.31 per head compared to a 10-year average of £154.22 (see **Appendix 2**). Feed costs on dairy farms were also above the 10-year average.

The Farm Business Survey also presents data on finished lamb forage and feed costs in terms of cost per kg liveweight. The data (see Figure 9) indicates spikes in these costs during poor weather conditions during 2018 and 2022 (with the additional impact of increased fertiliser and animal feed costs).

Figure 9.
Lamb forage and feed costs 2012-2022



Data from Wales Farm Business Survey 2012-2022.

By looking at the deviations above the trend in feed and forage costs in years such as 2018 and 2022, we can estimate the additional costs due to climate events (see **Appendix 3**, page 63). Projected costs per head based on a 10-year trend are compared with the actual costs per head to provide an estimate of the additional costs due to climatic events and other factors.

For example, forage costs per ewe in 2018 for hill flocks were 15% higher than expected (£1.50 per ewe), upland flocks 8% higher (£1.29), and lowland flocks 15% higher (£1.89). In 2022 during a drought year these figures were 10% (£1.38), 14% (£2.85) and 3% (£0.42) respectively.

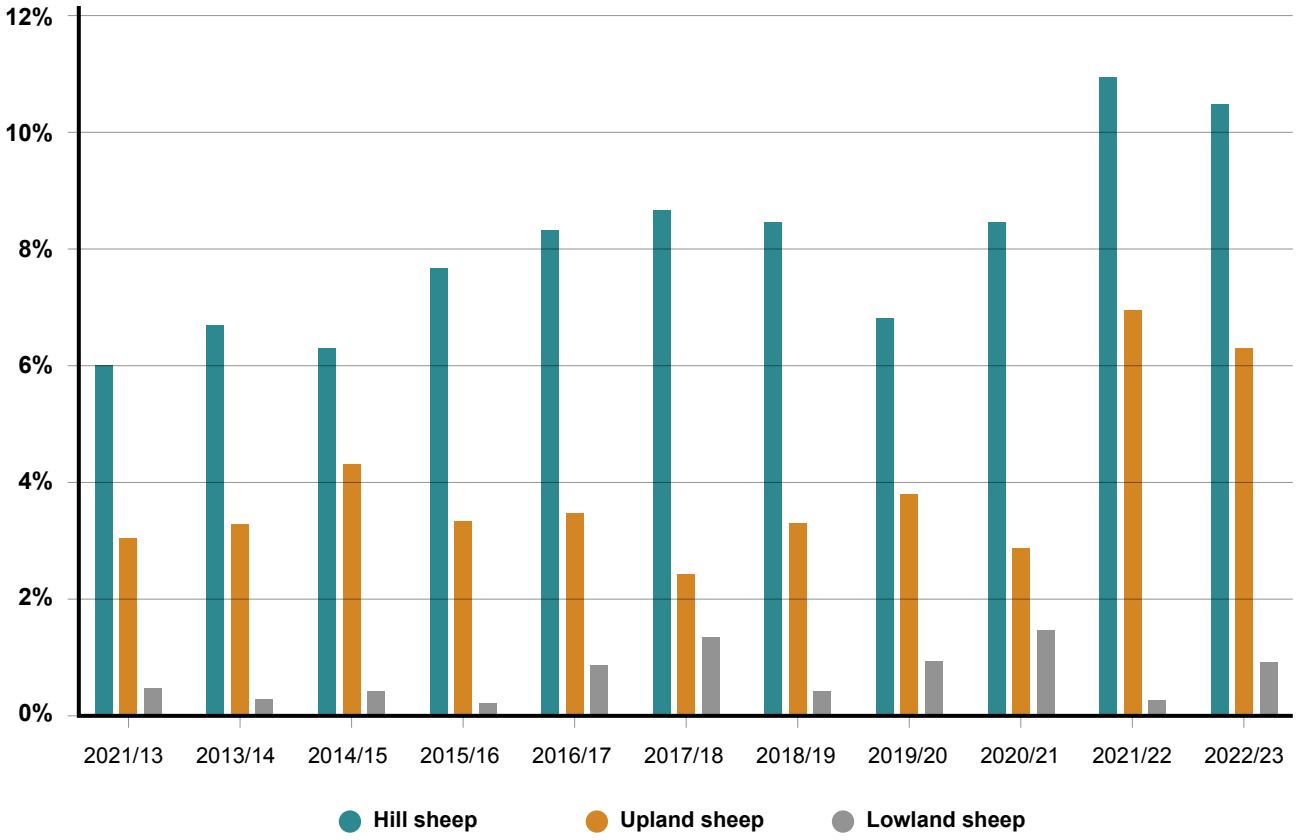
Similar estimates for concentrates and bulk feeds are also presented in **Appendix 3.** Concentrate costs per ewe in 2018 for hill flocks were 7% higher than expected (£1.07 per ewe), upland flocks 12% higher (£2.16), and lowland flocks 15% higher (£2.74). During the drought of 2022 these figures were 27% (£4.94), -2% (-£0.41) and 7% (£1.89) respectively.

While these deviations from the trend cannot entirely be attributed to climate events, they represent the kinds of impacts we could expect to see on sheep feed costs during years of bad weather.

Store versus finished lamb sales

The proportion of lambs sold as stores by value has trended upwards on hill and upland sheep farms over the last five years (see Figure 10), which could be an indicator of pressure on fodder and feed supplies.

Figure 10.
Store lamb sales as a % of total sheep output



Data from Wales Farm Business Survey 2012-2022.

Cattle

There is little evidence that extreme weather has a direct impact on Welsh cattle numbers in terms of losses due to exposure etc, as is the case for sheep. However, there are significant impacts in terms of feed costs, with increased price volatility seen over the last five years.

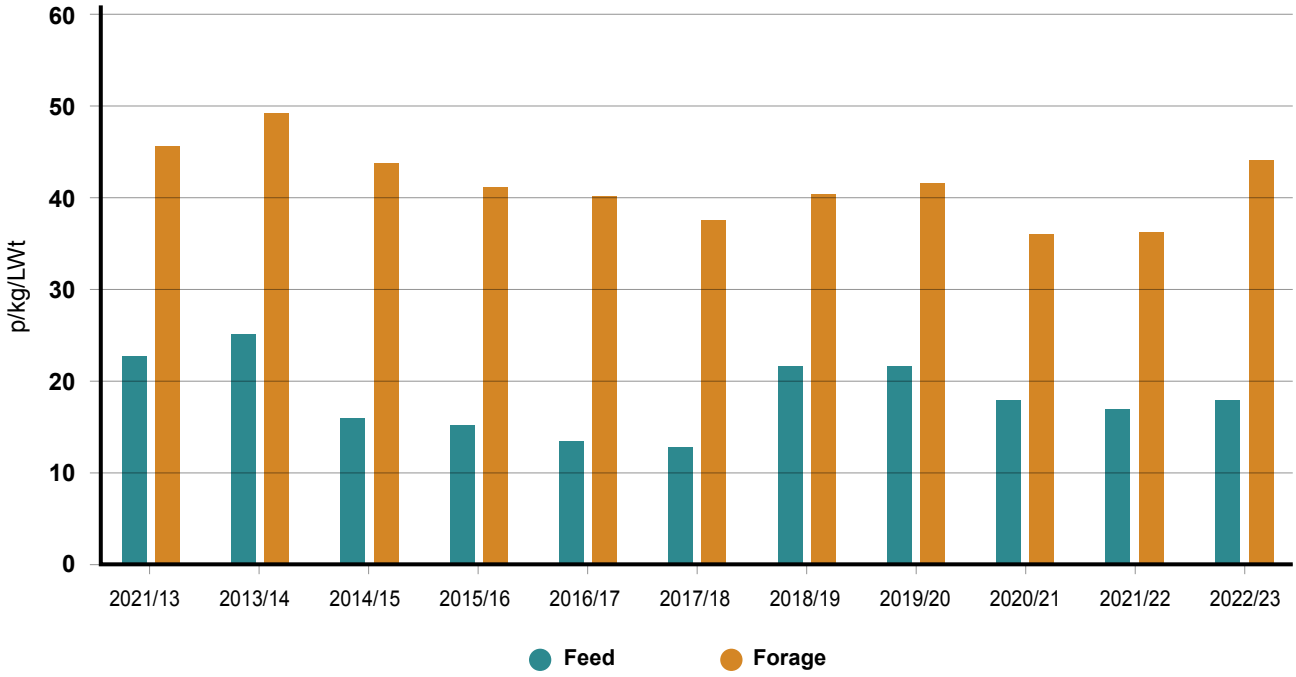
Estimates of increased feed costs

Compared with an estimate based on a 10-year trend, forage costs in 2018 for hill suckler herds were 5% higher than expected (£8.31 per cow), upland herds 13% higher (£24.30), and lowland herds 25% higher (£34.55) (see **Appendix 3**). In 2022 during a drought year these figures were 11% (£17.95), 11% (£22.03) and 30% (£52.88) respectively.

Similar estimates for concentrates and bulk feeds are also presented in **Appendix 3.** Concentrate costs per cow in 2018 for hill herds were 27% higher than expected (£47.09 per cow), upland herds 23% higher (£36.12), and lowland herds 87% higher (£101.88). In 2022 during a period of drought these figures were 27% (£57.38), 17% (£24.44) and 21% (£35.31) respectively.

While these deviations from the trend cannot entirely be attributed to climate events, they represent the kinds of impacts we could expect to see during years of bad weather on beef feed costs.

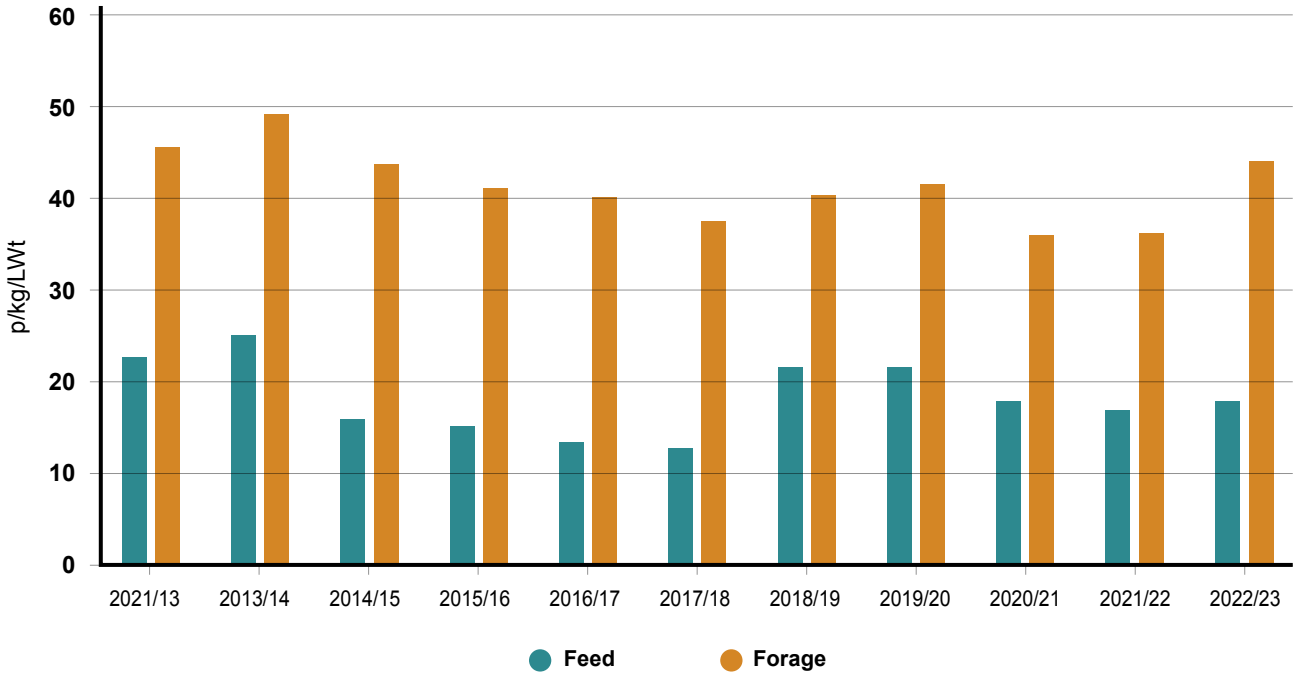
Figure 11.
Finished beef feed and forage costs



Data from Wales Farm Business Survey 2012-2022.

Data from the Farm Business Survey indicates that feed per kg liveweight costs for beef finishing enterprises rose sharply following 2018, which is likely to be due to extreme weather-related impacts (Figure 11). Similarly, feed costs per kg liveweight for store cattle also rose in 2018 (see Figure 12).

Figure 12.
Store cattle feed and forage costs



Data from Farm Business Survey 2012-2022.

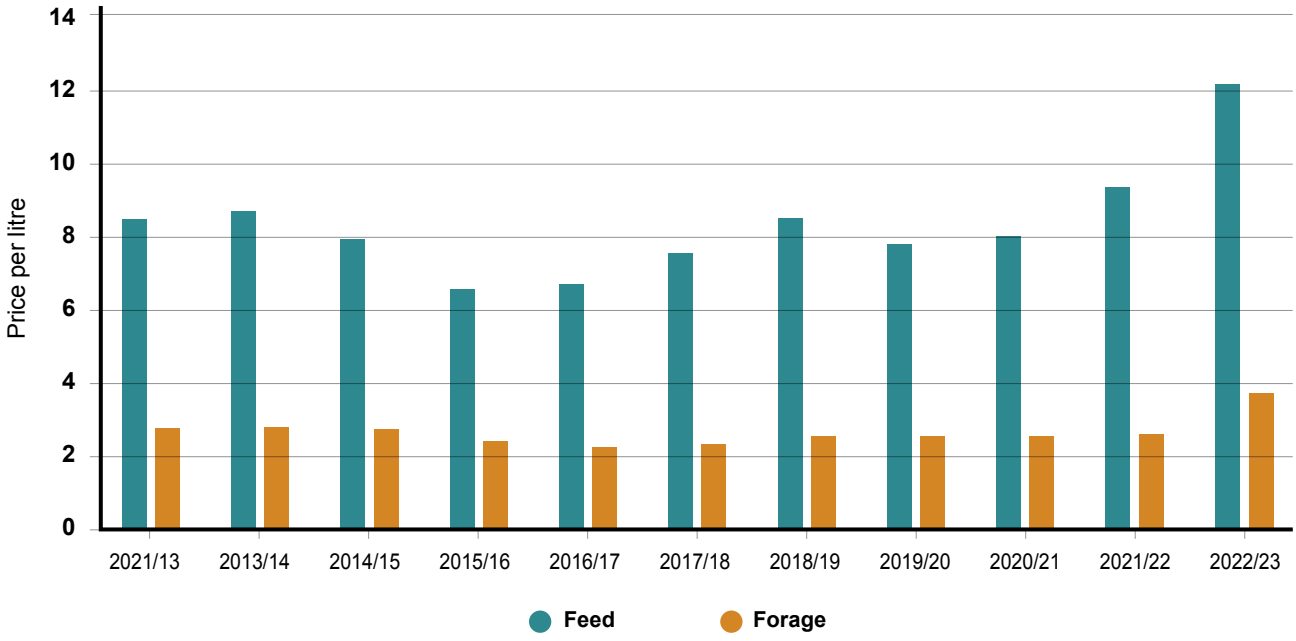
Dairy

As with the beef sector, the key impacts on dairy are in terms of increased feeding periods and the need for additional bought-in feed.

Estimates of increased feed and forage costs

Feed and forage costs per litre of milk produced rose sharply in 2023, as a result of climate impacts on feed prices, but also energy and fertiliser costs as a result of Russia's war in Ukraine (Figure 13). The impacts in terms of feed and forage costs per cow are shown in Figure 14 and Figure 15.

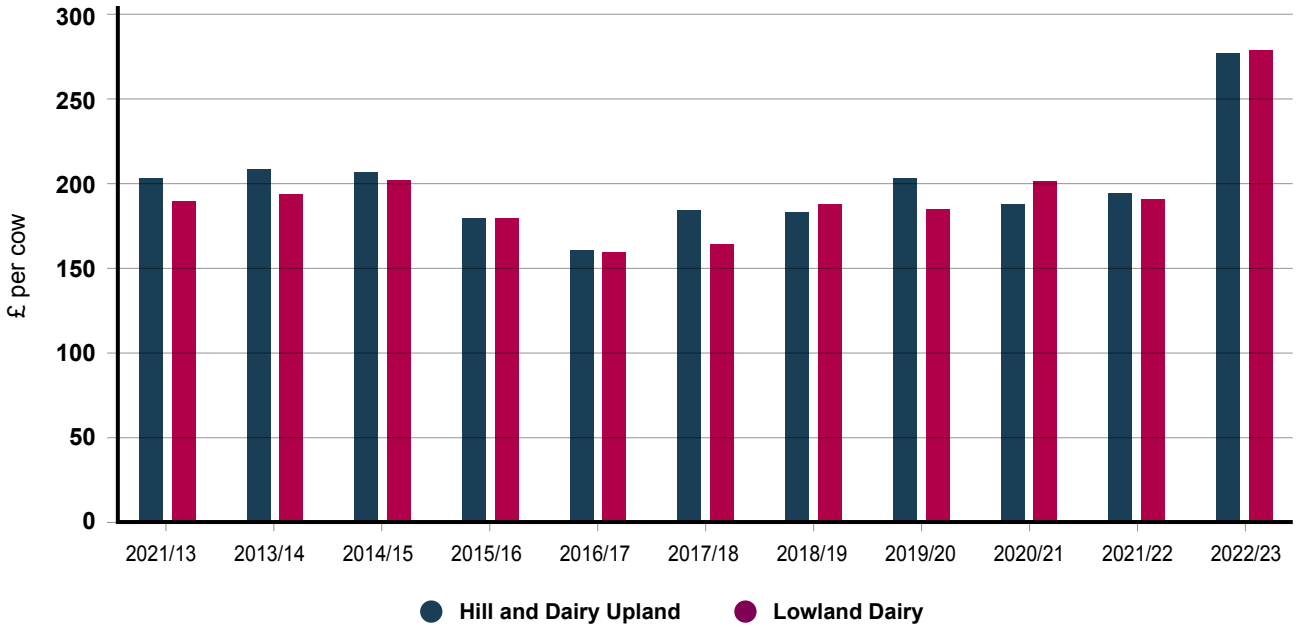
Figure 13.
Feed and forage costs of milk production



Data from Wales Farm Business Survey 2012-2022.

Compared with an estimate based on a 10-year trend, forage costs per dairy cow in 2018 for lowland dairy herds were 13% higher than expected (£22.15 per cow), but there was little deviation from the norm for hill and upland herds. In 2022, however, these figures were 43% higher (£83.96) for hill and upland dairy farms and 46% higher (£87.43) for lowland dairy farms. This reflects the rises in fertiliser prices during 2021-22.

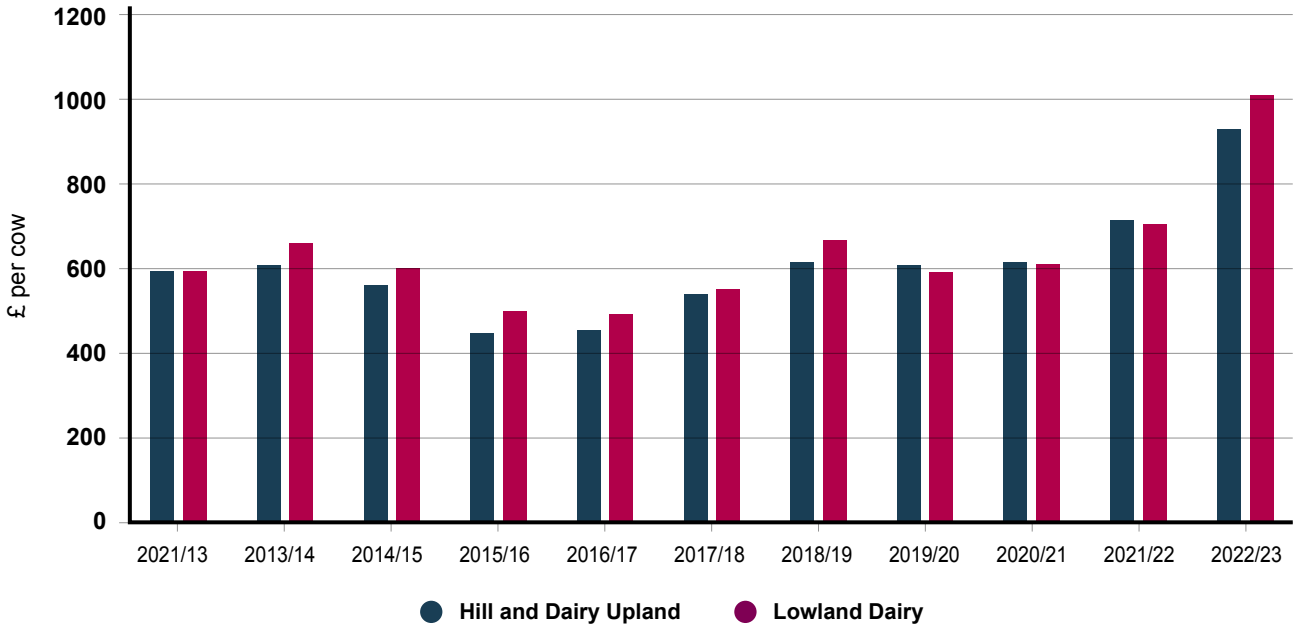
Figure 14.
Forage costs per dairy cow



Data from Wales Farm Business Survey 2012-2022.

Similar estimates for concentrates and bulk feeds are presented in **Appendix 3**. Concentrate costs per cow in 2018 for hill and upland herds were 12% higher than expected (£68.25 per cow), and for lowland herds 18% higher (£103.45). In 2022 during a period of drought these figures were 27% higher (£202.50) and 40% higher (£290.34) respectively.

Figure 15.
Concentrate costs per dairy cow



Data from Wales Farm Business Survey 2012-2022.

Estimates of total increased feed costs and animal losses

By using the estimated climate-related increase in feed costs and losses per animal and using average flock and herd sizes from the Farm Business Survey, we can estimate the impact for an average farm and for Wales as a whole, given overall livestock numbers and farm numbers.

The calculated estimates of increased feeding costs in 2018 and 2022 by farm type are presented in **Appendix 4** on page 666 . The results per farm and the aggregated totals for 2018 and 2022 are summarised in Tables 2 and 3. For 2018, the total value of additional livestock feeding and forage expenses due to extreme weather in Wales is estimated at £151.3m. The value of lambs lost is estimated at £23.8m, with the total estimated losses due to extreme weather in the ruminant livestock sector estimated at £175m – equivalent to 9% of the £1.86bn total Welsh agricultural output that year (Welsh government, 2019).

Table 2.
Aggregate estimated value of lamb losses and additional feed costs due to extreme weather 2018/19

2018/19	Average value of lambs lost per farm	Additional feed and forage costs per farm	Additional lambs lost total	Additional feed and forage costs total	Total additional costs/losses
Hill cattle and sheep	£2,524	£2,674	£10,915,095	£11,560,555	£22,475,650
Suckler cows		£1,108		£4,790,990	£4,790,990
Breeding sheep	£2,524	£1,566	£10,915,095	£6,769,566	£17,684,661
Upland cattle and sheep		£3,135	£5,445,335	£5,889,805	£11,335,140
Suckler cows		£1,752		£3,292,545	£3,292,545
Breeding sheep	£2,898	£1,382	£5,445,335	£2,597,260	£8,042,595
Lowland cattle and sheep		£9,643	£263,039	£10,481,799	£10,744,837
Suckler cows		£2,865		£3,114,439	£3,114,439
Breeding sheep	£242	£6,778	£263,039	£7,367,359	£7,630,398
Dairy		£12,940		£32,906,108	£32,906,108
Dairy cows		£12,686		£32,259,381	£32,259,381
Breeding sheep	£44	£254		£646,727	£646,727
Other		£1,412	£720,686	£20,568,749	£21,289,435
Suckler cows		£26		£383,306	£383,306
Breeding sheep	£49	£1,386	£720,686	£20,185,443	£20,906,129
Total			**£23,773,213**	**£151,253,477**	**£175,026,690**

In 2022/23 there was no significant increase in lamb mortality against the trend. However, due to drought conditions during the summer of 2022 there was increased supplementary feeding, with total feed costs for livestock farmers in Wales being £265.7m above what would be expected in a typical year – equivalent to 14% of the £1.939bn total agricultural output (Welsh government, 2022a).

However, it should be noted that 2022 was also characterised by other factors, such as increased energy and fertiliser costs (which also impacted on the forage costs reported in the Farm Business Survey).

Table 3.
Aggregate estimated value of additional feed costs due to extreme weather, 2022/23

2022/23	Additional feed and forage costs per farm	Additional lambs lost total	Additional feed and forage costs total	Total additional costs/losses
Hill cattle and sheep	£4,875		£21,321,556	£21,321,556
Suckler cows	£1,130		£4,942,076	£4,942,076
Breeding sheep	£3,745		£16,379,480	£16,379,480
Upland cattle and sheep	£2,052		£3,993,779	£3,993,779
Suckler cows	£1,208		£2,351,040	£2,351,040
Breeding sheep	£844		£1,642,739	£1,642,739
Lowland cattle and sheep	£2,681		£3,134,574	£3,134,574
Suckler cows	£2,028		£2,371,314	£2,371,314
Breeding sheep	£653		£763,260	£763,260
Dairy	£77,923		£112,286,674	£112,286,674
Dairy cattle	£77,821		£112,139,874	£112,139,874
Breeding sheep	£102		£146,800	£146,800
Other	£177		£2,771,568	£2,771,568
Breeding sheep	£142		£2,225,020	£2,225,020
Suckler cows	£35		£546,548	£546,548
Total			**£265,694,745**	**£265,694,745**

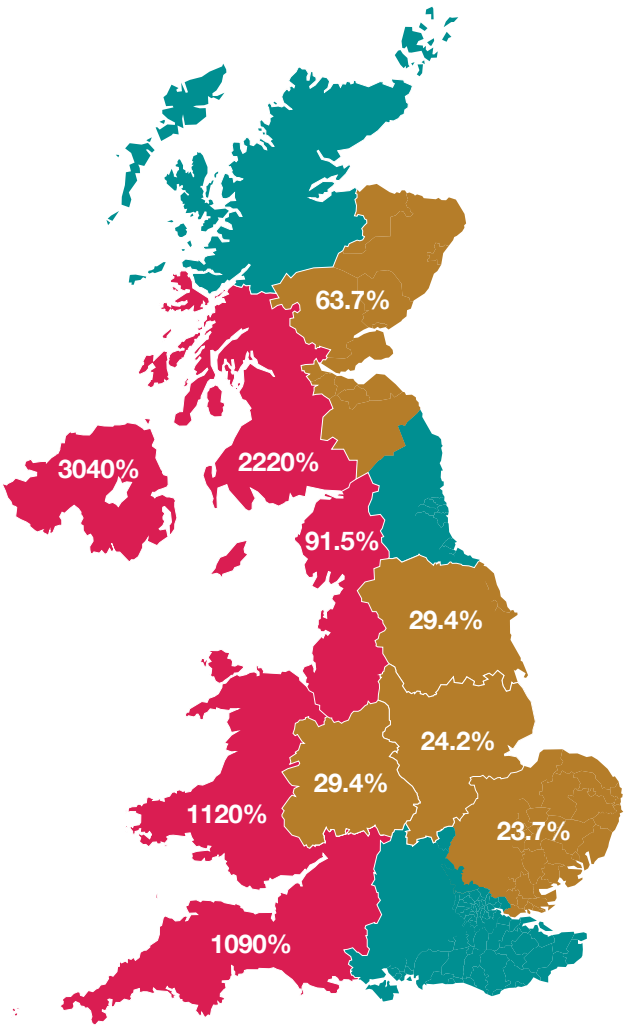
Impact on livestock disease pressures

Vector-borne diseases may expand due to climate change as they are the most sensitive to climate drivers. For example, in recent years, tens of thousands of farms in northern Europe have been affected by bluetongue, a vector-borne disease of livestock. The outbreak has led to the deaths of millions of animals, with a huge financial cost (Jones et al., 2019). It is forecast that by 2100 the bluetongue risk will extend further north, and the transmission season will extend by up to three months, with larger outbreaks (Jones et al., 2019). Thus a one in 20-year outbreak at present-day temperatures will become typical by the 2070s under the highest emissions scenario (Jones et al., 2019). That said, restrictions on animal movements could be sufficient to prevent the worst outbreaks (Jones et al., 2019).

Heat stress in livestock

In a warmer climate there is likely to be an increased risk of heat stress in livestock. Figure 17 indicates increases in risk for the future climate (2051-70) compared with current climate (1998 to 2017) for thermal heat stress in cattle (red) and potato blight (brown).

Figure 17.
Increases in risk in 2051-70 compared with 1998-2017 for thermal heat stress in cattle (red) and potato blight (brown)



From Defra, 2023a.

It was reported that more than 80 million chickens died before reaching slaughter weight in the UK in 2022, potentially due to heat stress, with mortality rates of nearly 7% being the highest in a decade (The Guardian, 2023). This compares with 64 million chickens that died prematurely in 2021 – a large part of this spike is likely to be due to heat stress (Defra, 2023b).

Pasture-based systems such as those found in Wales are particularly vulnerable to environmental factors (Foskolos and Moorby, 2018). Rising summer temperatures will lead to an increased risk of heat stress and loss of production on dairy farms in particular. In addition, by 2100 the average UK dairy farm is projected to lose between £2,000 and £6,000 in average years, and £6,000 and £14,000 in extreme years (Foskolos and Moorby, 2018).

Impact on crop production

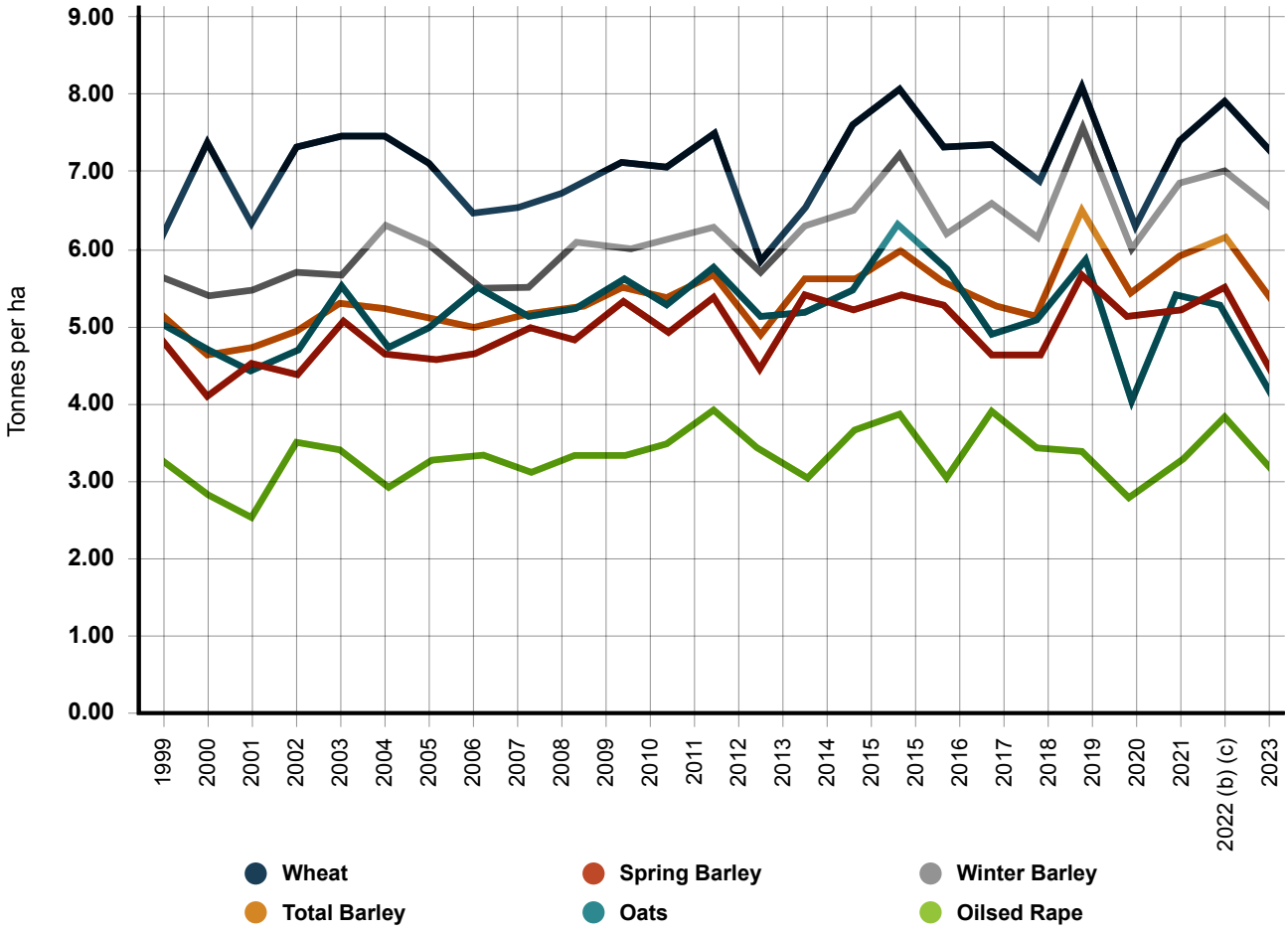
Crop production is not a major activity on the majority of Welsh farms, accounting for only 6% of agricultural output in 2022 (Welsh government, 2022b). However, in lowland areas mixed arable/livestock farming can be significant. The following section will consider the potential impact of extreme weather in 2018 and 2020 on the Welsh arable sector.

Cereals and oilseeds

Across the UK, due to unusual weather patterns linked to climate change, wheat yields in 2018 were 7% below the 2016-20 average, and 17% down in 2020 (Defra, 2023d). Data on Welsh cereal and oil seed yields indicates reduced yields in 2018 and 2020; after 2018 there was also a significant shift away from spring barley (Defra, 2023a).

Crop yields in Wales were lower than usual in 2018 and 2020 (see Figure 19). The 2018/19 winter was relatively mild and was followed by a fine spring. This meant crops were established into good seedbeds, so they initially thrived. However, this was followed by a wet autumn with localised flooding, which delayed the harvest and fieldwork. In 2020, extremely dry weather during the summer also had an impact on crop growth.

Figure 18.
Welsh arable crop yields 1999-2022



Data from Defra, 2023c.

Estimates of crop losses and costs

It is likely that reduced crop yields in 2018 and 2020 were due to poor weather conditions, while reduced application of fertiliser (due to costs) contributed to reduced yields in 2023. Thus 2018 and 2020 stand out as two years in which extreme weather had a significant impact on Welsh arable production. Based on a 20-year trend using Defra data, wheat production in Wales was calculated at 15,000 tonnes below trend in 2018, which was worth £2.6 million. Overall, crop output in 2018 was £4 million below the trend.

Table 4.
Potential impact of extreme weather on Welsh arable production in 2018

	Production (tonnes)					
	Average 2013-23	2018	On trend	Estimated loss (tonnes)	Value per tonne	Value of loss (£)
Wheat	162,850	152,308	168,209	15,901	£164.60	£2,617,321
Winter barley	50,740	47,167	51,618	4,451	£163.20	£726,374
Oats	25,832	24,789	25,244	456	£129.90	£59,203
OSR	16,731	15,961	17,855	1,895	£350.00	£663,089
						£4,065,988

In 2020 wheat output was 66,802 tonnes below trend, with output down by £12.4 million.

Table 5.
Potential impact of extreme weather on Welsh arable production in 2020

	Production (tonnes)					
	Average 2013-23	2020	On trend	Estimated loss (tonnes)	Value per tonne	Value of loss (£)
Wheat	162,850	134,732	201,534	66,802	£185.90	£12,418,496
Winter barley	50,740	44,976	66,784	21,809	£139.00	£3,031,431
Oats	25,832	19,448	27,932	8,484	£117.70	£998,602
OSR	16,731	8,317	17,769	9,452	£350.00	£3,308,032
						£19,756,562

Thus, we estimate that losses to Welsh arable production due to extreme weather conditions in 2018 were as much as £4 million, and £19 million in 2020. Although Wales is not a major arable producer, these losses could have significant impacts in terms of the local supply of animal feed in areas such as the Vale of Glamorgan and Pembrokeshire.

Other weather-related challenges to farming

Flooding

The prolonged flooding of farmland can lead to grazing land becoming inaccessible, and extreme flooding may also pose a risk to livestock. On arable, flooding may lead to land becoming waterlogged at critical times of year, impeding cultivation and planting.

Wind damage and tornados

A number of named storms in recent years produced high winds, which caused damage to farm buildings and property.

Wildfires

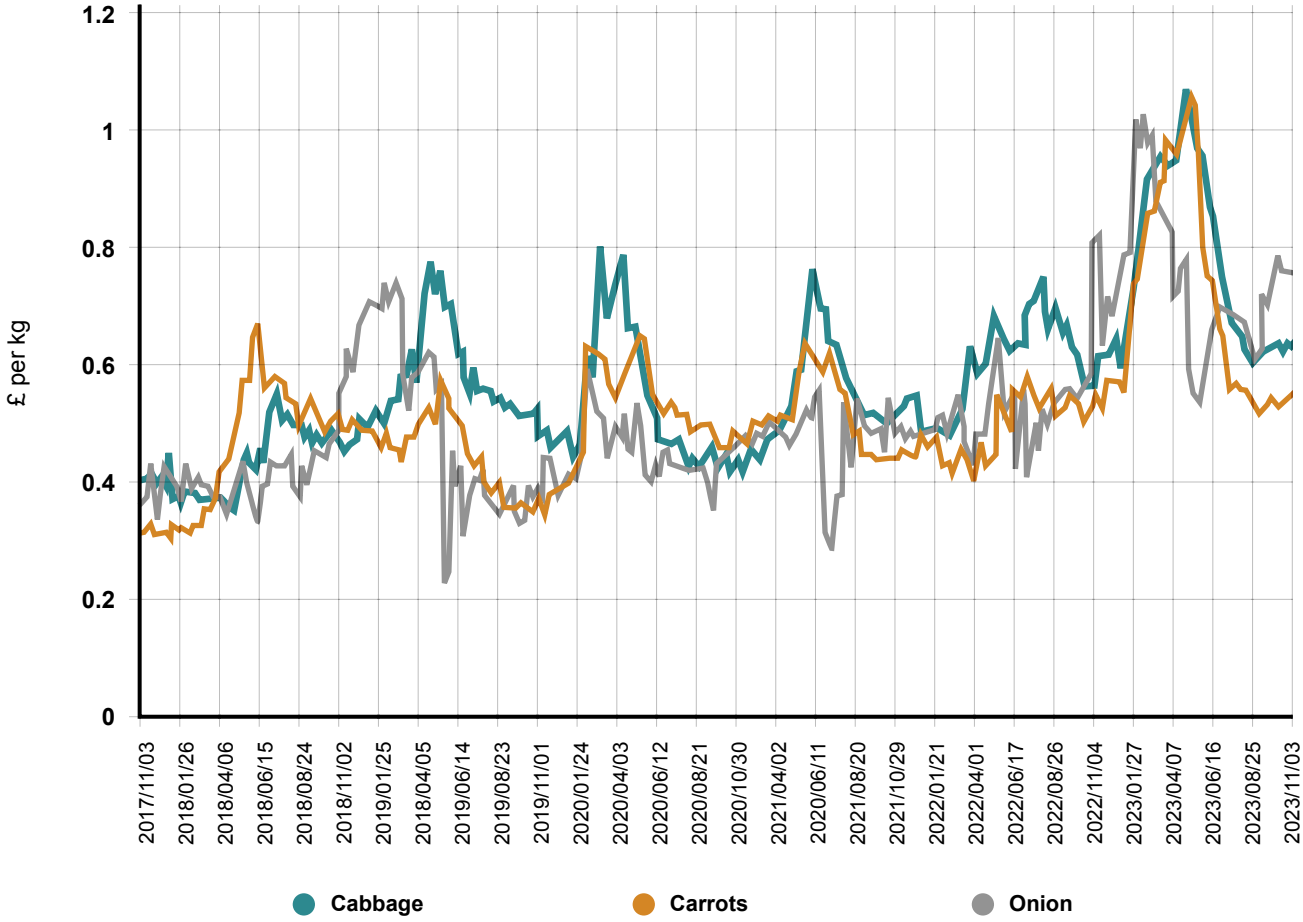
The increasing likelihood of long, dry periods is leading to fears that grassland blazes could escalate into forest fires in future (BBC, 2021a). Some common grazing areas in particular have become under-grazed, creating the conditions for increased fire risk (Welsh government, 2023).

In terms of wildfires, Wales is one of the most severely affected parts of the UK, and south Wales already suffers about 3,000 blazes a year (BBC, 2021b). Welsh firefighters report that wildfires are burning later into the year, getting larger, and causing more damage (BBC, 2021b).

Impact on food security

The horticulture sector is very small in Wales, and horticulture and cropping only accounts for 6% of total agricultural output (Welsh government, 2022b). However, the impact of climate on food security is largely seen through the retail and wholesale prices of some fruit and vegetables that have been volatile in recent years. For example, there was a significant spike in wholesale prices for some staple vegetables in 2023 (see Figure 19).

Figure 19.
UK wholesale prices for cabbages, carrots and onions 2017-23.



Data from Defra Wholesale Fruit and Vegetable Prices (Defra, 2023e).

In 2023, a spell of cold weather in southern Europe led to shortages of some salad products and vegetables in UK shops. This led to the spot price for some vegetables being two or three times higher than normal. For example, Dutch onions were £700 per tonne compared to a normal average of £250-£280 (Duncan, 2023).

However, climatic events do not always have a direct impact on retail prices immediately. According to the British Growers Association, in April 2022 retail prices for vegetables were in many instances lower than during the previous five years, despite rising input costs as well as drought (Wilkinson, 2022).

Mitigation and resilience

Regenerative and nature-friendly farming systems provide an opportunity for farmers to help mitigate and adapt to climate change, as well as improving resilience. Although the need for agriculture to adapt to climate change is well established, there is little UK research that explores how the risks associated with climate change are perceived by farmers, nor how farmers are adapting their businesses to improve resilience in the context of climate change (Wheeler and Lobley, 2021). Nature-friendly farming recognises the role that farming plays in not only providing food but also other public goods such as nature, flood prevention, carbon sequestration, and public access to the countryside (Nature Friendly Farming Network, 2023).

A 2022 survey of Welsh sheep and beef farmers showed that a large proportion of them were proposing to adapt their land management systems in order to become more efficient and sustainable. Over 70% reported that they were cutting fertiliser, with many looking to new methods of grassland management through reseeding or rotational grazing to ensure sufficient fodder without using additional soil inputs (Osborne-Sherlock, 2023).

A recent study looked at farms in England and Wales between 2005 and 2017 and linked them to climate data at a sub-regional scale (Harkness et al., 2023). The study highlighted that variability in temperature and rainfall reduces the stability of farm income and food production. Climatic variation is outside of the farmer's control, and the study found that farm management can have a larger effect on stability than climate under current conditions.

The study also identified three key aspects of farm management and policy that can improve stability:

i) increasing agricultural diversity;

ii) increasing the efficiency of agrochemical use; and

iii) agri-environmental management.

These management practices are associated with benefits to natural ecosystems, and may increase the stability of agriculture and food production while reducing negative environmental impacts.

Potential of regenerative farming practices

Nature-friendly farming methods, such as regenerative and organic practices, can contribute to farm resilience. These methods often focus on building soil health, diversifying crops, and using agroecological approaches. While they may not eliminate the impact of adverse weather, they can enhance a farm's ability to cope with changing conditions. There is no formal or widely accepted definition of regenerative farming, but regenerative agriculture is an approach to growing food that seeks to actively restore nature in the process. There are several principles to which regenerative farmers should adhere. They should:

- Avoid or limit ploughing or disturbing the soil, to maintain the soil structure and fertility.
- Always cover the soil with plant or organic cover through cover crops to prevent soil erosion and water loss.

- Keep live roots in the soil. This will feed the beneficial microorganisms that contribute to plant and soil health.
- Use crop rotations. This means growing a variety of crops, to increase biodiversity and resilience to biotic and abiotic stresses and shocks.
- Integrate livestock in arable rotations. This includes grazing ruminants as well as allowing chickens, pigs, geese and ducks to pasture freely. Manure will supplement the nutrient cycle and improve forage quality and allow a reduction in synthetic fertiliser use.

There is some evidence of high levels of awareness (>60%) and uptake (>30%) of sustainable soil management practices among mixed and arable farmers (Jaworski et al., 2023). It has also been reported that 92% of mixed and arable farmers stated they were practising sustainable soil management (Jaworski et al., 2023). Farmers combine practices in diverse ways and do not always follow the complete set of regenerative agriculture principles.

Drought resistance

Farming Connect highlights some key approaches to mitigate drought:

- Enhancing drought-resistant crops stands out as a pivotal measure for agricultural adaptation to climate variability, bolstering global food security.
- The complexity of drought resistance, stemming from multiple genetic factors, poses challenges for manipulation: leveraging new sequencing technologies holds promise in developing novel cultivars resilient to drought while maintaining high yields.
- Various management strategies, such as rainwater harvesting, succession planting, or transitioning to winter crops, offer avenues for farmers to navigate drought conditions (Williams, 2020).

Ryegrass is the most commonly cultivated grass in the UK as it is considered productive and well-suited to the local climate and farming systems (Williams, 2020). Perennial ryegrass (PRG) is the most popular as it is versatile, persistent, and long-lived. However, while PRG boasts good cold tolerance, it does not cope well with arid conditions (Williams, 2020).

Several management practices address drought and flooding (Williams, 2020). For example, sowing and harvest dates may vary depending on warmer springs and higher temperatures. Sowing earlier and harvesting later would help to compensate for lower yields due to drought (Richter et al., 2006).

Changing crop schedules and introducing a multiple cropping system (growing two or more crops in the same field; for example, salads) may help to make the most of extended growing seasons. Known as ‘succession planting’, this approach can help boost production through a variety of methods including planting different crops in succession, the same crop in succession, or at different maturity dates (Borchers et al., 2014). Farmers may also consider switching from spring to winter cereal planting, when rainfall is more reliable.

Water management

Managing water is important during periods of drought (Knox et al., 2010). Farmers would be better able to cope with the reduced availability and reliability of summer rivers by building winter water storage facilities. Improving water and energy efficiency through new and innovative technology can also help mitigate the effects of drought. In Wales, improving drainage systems and flood prevention projects to cope with higher rainfall intensities may be more applicable. Farmers need to take advantage of periods of heavy rainfall by storing rainwater, and also explore water recycling.

Maintaining soil structure allows for better drainage and reduces the risk of flash flooding. Testing soils on the farm and establishing key aspects such as pH, texture, fertility, drainage, moisture content, organic matter content, and nutrient status will allow landowners to make informed decisions when selecting crops to get the most out of their land.

Soil conservation

Healthy soils are essential for food production, in the fight against climate change, and to ensure biodiversity on our land. Across England and Wales, 4 million hectares of land are at risk of compaction, 2 million hectares are at risk of erosion, and up to 60% of our soils have lost their organic carbon (Defra, 2022). In 2010, soil degradation was estimated to cost the economy around £1.2bn annually (Defra, 2022).

The UK government has set a target of ensuring that all soils are sustainably managed by 2030 (Soil Association, 2016). However, changing how farmers treat their land is the biggest barrier. Many use agrochemicals as a quick fix for their depleted soils. As farmers are often competing with overseas suppliers with lower overheads, treating their land for pests and increasing its fertility with chemicals is a short-term solution (Soil Association, 2016). However, there is an urgent need to look at the longer term if we are to ensure a sustainable farming future.

How can soils be conserved across Wales?

The Soil Association has suggested seven key factors that can help regenerate soils and improve their nutrient composition (Soil Association, 2016):

1. Increase plant and animal matter going back onto fields – manure and green composts can replace nitrogen-based fertiliser.
2. Improve on-farm soil health monitoring – soil organic matter should be tested regularly and farmers who improve year on year should be rewarded.
3. Encourage soil organisms – some organisms build up soil and some release nutrients. Increasing soil organic matter and limiting pesticide use improves soil biology.
4. Cover up bare soils – exposed soils are vulnerable to erosion. Cover crops improve soil structure, aerate it, increase nutrient flow, increase biodiversity, increase carbon storage, manage droughts and floods, and improve water quality.
5. Plant more trees – trees lock away carbon and reduce soil erosion. The Welsh government has announced all farms must plant trees on 10% of their land if they are to be eligible for the new Sustainable Farming Scheme.
6. Reduce soil compaction – use lighter machinery, limit livestock access on wetter soils, implement reduced-till or no-till farming, and use correct tyre pressure.
7. Mix up crop rotations – use greater crop diversity in rotations with different root depths to take advantage of the varying nutrient profile of the soil. Include temporary leys for grazing livestock and consider growing legumes to improve soil organic matter (Soil Association, 2016).

Many of these factors rely on government commitment, either through financial rewards for farmers who take care of their soils or through enforcement measures.

Rotational grazing of livestock

Rotational grazing is the practice of regularly moving livestock from one field to the next. A field may be divided into sections and the animals moved between the sections daily, or whole fields may be used.

Although there is considerable planning required to effectively divide fields up – typically using electric fencing, as well as plumbing all areas into a water supply – there are many benefits to rotational grazing. Grassland is rested and is more productive because once livestock have been moved away it is allowed to fully recover before they return. This prevents overgrazing and damage to the soil. It also results in more grass yield, with an estimated 20% greater growth in rotational systems (AHDB, 2023).

Furthermore, the livestock provide nutrients for the soil from their dung, and they have regular access to the more nutritious, younger swards. Animals in rotational grazing tend to be healthier due to less exposure to mud, access to more nutritious grass, greater movement, and spending longer periods outdoors. This reduces costs in terms of veterinary bills, purchasing or making conserved feed, fertiliser use on the land, and expenses from indoor bedding, electricity and machinery use (Undersander et al., 2002).

The time that is spent moving cattle around the rotation is saved from not having to spread fertiliser and feed indoor cattle silage. One Welsh sheep farmer interviewed recently made the move from conventional grazing to rotational grazing and believes he will recoup the set-up costs in under two years (Farming Connect, 2016). Taking into consideration the dry matter, bedding and machinery that are used to house cattle, keeping cattle on pasture for an extra 30 days per year can save the farm up to £3,750 each year (Farming Connect, 2016).

A regenerative beef farmer was using rotational grazing and has used GPS mapping to plan out grazing a month in advance with small cells of 0.5 hectares and electric fences and roadways (Wheeler, 2023). Sward heights are measured every Monday, and the cattle are moved every day – with pasture being rested for 30-100 days. Due to improved management the grassland utilisation on the farm rose from 70% in 2019 to over 85% in 2021.

This kind of management, along with a more diverse sward and deeper roots, has meant that water infiltration is fast – which means that water runoff is reduced, and moisture is retained in the soil. During the drought of 2022 grass production on the farm was not adversely affected (Wheeler 2023).

Other technologies to build resilience

To build resilience in agriculture, it is important to monitor processes and production. This helps farmers, stakeholders and policymakers understand how different agricultural practices are performing, and allows them to make necessary changes. Technologies to improve resilience include sensors that monitor essential components of farming such as soil parameters, livestock behaviour and production, and farm inputs and outputs. Sensors and monitoring equipment can be tailored to individual farms, allowing farmers to make changes unique to them rather than relying on general advice.

Precision agriculture is one way in which technology is used to minimise inputs and maximise outputs. It can help to build resilience by enabling farmers to be more environmentally friendly and farm in a more precise manner (Agmatix, 2023). Examples of precision agriculture include:

- GPS systems – these help farmers to plant crops in the most efficient patterns to save time, fuel and costs. They ensure that there is no overlap when planting seeds or applying fertiliser, again saving time and money and reducing the environmental impact.
- Drone technology – can be used to gain a bird's eye view of fields and can map areas of plant disease and other plant health parameters. This saves the farmer from walking through the fields on foot.
- Water management – sensors installed in the soil determine if and when water is needed, preventing areas that do not need it from being overwatered. This saves water, protects soils and saves money.

Farmer interviews

Structured interviews

A total of 17 structured interviews were carried out with a range of farmers of different farm types across Wales in December 2023. Of these, seven were organic or farming with nature conservation as a key objective. It should be noted that these farms tended to operate a wider range of enterprises. The other nine were conventional or traditional family farms.

The interviews explored the farmers' observations concerning extreme weather and its impacts on their farms and businesses, as well as some techniques and practices that have helped to mitigate the worst effects of extreme weather. They were also questioned on perceived barriers to mitigating climate change, as well as about support and sources of information. The following section contains a summary of responses based on key sectors, while a summary of individual responses is presented in **Appendix 5** on page 68.

General observations

The overwhelming response was that the climate in Wales was getting more unpredictable, warmer and wetter, with more prolonged spells of wet or dry weather particularly during the spring and autumn. One sheep farmer from Ceredigion stated that: **"There are more extremes and longer spells of these extremes."**

Specific extreme weather events mentioned included the Beast from the East (2018), Storm Dennis (2021) and the drought of 2022.

Mitigation

Mitigation strategies tended to focus on risk management measures such as more diverse cropping, more diverse swards, and lower stocking rates.

Finance was the biggest barrier to adapting to climate change across all farming sectors. Farmers' incomes were being reduced by the impacts of climate change, but they had little finance to do anything about it. Time was also a factor. A farmer cannot take two to three weeks out of running a farm to develop a climate change strategy.

There was a general view that there was not enough information and detail on the Sustainable Farming Scheme (SFS) and how it could help them adapt to the impacts of climate change. Frustration was felt by some over the lack of information and delays in implementing the scheme. The conventional farmers interviewed tended to think that they would need to be compensated in some way before they considered adopting more nature-friendly practices, either through direct support or through the market. A beef and sheep farmer from Ceredigion commented: **"If we were asked to have fewer animals then we would need to be compensated for that, but if we were asked to change the way we farmed then a grant would be better."**

Many farmers interviewed believed they would not get sufficient support from government, and that support – not more red tape – was crucial. However, one respondent felt that the way the SFS was framed was really positive for the environment, but there was no detail yet. The actions and collaborative elements were positive, providing the ability to manage the microclimate in an area.

It was widely felt that policies and schemes needed to be less prescriptive and more flexible to suit individual farmers. There was a need for better advice on climate mitigation, and a need for advisers who know the farm and the system. Among nature-friendly and organic farmers there was a need for better agricultural education on sustainable farming. Agricultural colleges needed to focus more on sustainable farming, as there was still too much emphasis on production rather than sustainability.

Sector analysis

Hill/upland sheep and beef farmers

Impact

The farmers interviewed reported that grazing livestock were hit by adverse impacts on forage growth, quality and availability, which affected growth rates. In the hills and uplands there was exposure to the elements (snow, heavy rain), leading to lamb losses.

Wetter winters meant that livestock were creating more mud, and there were increased risks of field poaching (compaction by livestock trampling wet ground).

One farmer stated that he has not been able to reseed and cut silage because it has been too wet. The management of different jobs that rely on good weather has been challenging. He has needed to pay for contractors to come in to cut the silage so that he could then focus on reseeding. He also commented that there was so mud, which means more weeds grow, such as thistles the following season.

A number of respondents from hill and upland farms highlighted the risks posed by wildfires and the need for vegetation management. It was stated that the threat of wildfires will increase in the uplands if molinia grassland is not managed.

The weather was getting warmer and wetter but also less predictable, and farms in the hills and uplands still had to consider the potential for extreme cold weather during the winter period.

Barriers

Many schemes and regulations were too prescriptive. One hill farmer stated that the uplands are a good place for conservation if the right support is in place.

One farmer was a tenant needing permission to do things, which was a barrier: there was little point in investing in renewable energy supply, for example, as the tenancy was ending.

Mitigation/support

Mitigation strategies included changing to hardier breeds (more native or cross-bred breeds), lambing later, and reducing stock numbers to make resources (especially fodder) more manageable. Native breeds of cattle being kept included Hereford and Highland cross cows.

One nature-friendly hill farmer stated that retaining a traditional hefted flock was important as the sheep knew where to go in bad weather during the winter.

Maintaining hedgerows and wood plantations to provide cover for livestock was a common practice among these farmers. One conventional farmer stated that they would plant more trees if they could secure the SFS. They had already turned a marshy area into a lake to help manage water flows on their farm. One farmer in mid-Wales also stated that more support for peatland restoration was needed.

Mitigations among nature-friendly farmers also included going to a more traditional system, reduced stocking, and tree shelter belt planting.

Lowland sheep and beef farmers

Impact

It was again noted that there are more extremes and longer spells of these extremes, such as really long droughts and then months of rain. It was not as cold, but the winters are much wetter.

Cattle have been more affected by the worsening weather. Cattle enterprises were more vulnerable on these farms due to increased feed costs and the need to house during the winter to avoid poaching. However, cattle were an important enterprise in terms of diversifying the farm, and in promoting diverse grazing systems and habitats. If the weather was dry all through to October, then the cattle could stay outdoors. Because it was getting wetter cattle have been housed earlier. This has an impact on feed costs and slurry/manure storage. The rising price of straw was also having an impact. It was reported that some cattle have been allergic to the sun during hot weather, but this had not had adverse impacts on production.

Sheep were less impacted as they remained outdoors. However, it is likely that in severe weather additional supplementary feeding will be required. Sheep are not housed until then and will lamb later in the year when the weather improves.

One farmer reported an incident of storm damage: an isolated tornado cut the top off oak trees and knocked down a wall of the shed. They had to rebuild the shed, which was a significant cost.

One farmer in north Wales stated that flooding was becoming more aggressive, with more erosion impacting the productivity of grazing land. They had also lost lambs. One farmer cited concerns about building on flood plains.

Barriers

One farmer stated that their farm gets flooded, so if the river was dredged it would help their farming operations – but there is no way of contracting the right people to carry out work like that.

Another stated that it was hard to put sheds up due to financial and planning issues. If there are no sheds for livestock then they have to be out in the winter – this destroys pastures, and increases the risk of soil erosion and poaching of land.

Financing investment in buildings, slurry and manure storage was a significant barrier to adaptation for some.

Mitigation/support

Mitigation strategies included not grazing the wetter fields over the winter to avoid harm to both the grass and the livestock. One farmer had built a shed to provide shelter for the sheep: they poach in the winter so there is a need to protect the land.

The farms classed as nature friendly tended to have lower stocking densities and were trying to reduce reliance on bought-in feed as much as possible.

More diverse swards were also being used, for example by putting chicory in their reseeding leys. Chicory is anthelmintic and is good during droughts because it is longer-rooted.

One nature-friendly farmer stated that old-fashioned farming and using slow-growing traditional cattle breeds could reduce environmental impacts across the UK. Another stated that dry summers are difficult for cows, but since their stocking rate is low, they can manage it. If droughts were severe, it would affect how many cattle could be kept. The wet summers help the grass to grow, which reduces the need for concentrates. They are 100% grass-fed beef. The wetter fields sustain them during the droughts, and they can move the livestock down the hill if it is particularly dry.

Again, respondents stated that there was little information on the SFS. Some other schemes and grants encourage you to be more environmentally friendly but are too restrictive. Farmers stated that they were getting information on climate change from sources such as Farmers Guardian, weather apps, BBC Weather, and the Met Office.

Dairy farmers

Impact

Wetter weather meant longer housing periods with increased feeding costs, and increased pressure on the infrastructure of dairy farms.

Wetter and more erratic weather also affected when cows could be put out in spring, spreading slurry, and hedge trimming. The slurry cannot be spread when it is too wet as it will just run off fields, and the slurry stores fill up faster in wet weather. An uncovered store means a greater volume of slurry due to rainfall and a bigger problem. Building a cover or a new store costs money. New regulations on slurry were exacerbating this pressure as longer housing periods – either due to poor weather or a need to rest grazing – required greater slurry storage capacity.

Feeding in the sheds costs more and entails more time spent actively cleaning the cattle sheds – which would mean higher labour and fuel costs.

The farmers also reported infrastructure damage from storms, and poor silage due to adverse weather. One producer of replacement dairy cattle cited an incident of heat stress in young dairy cattle.

An organic dairy farmer had observed less standing water on their land compared with neighbouring intensive farms. This was presumed to be due to better management – resting the land over the winter, not overstocking, no use of fertilisers etc.

Dairy is at the mercy of the supply chain. The dairy industry is very volatile, it fluctuates regularly and widely. The farmers do not have any control over who they sell to. A conventional dairy farmer stated that to convert to nature-friendly or organic they would require compensation and financial incentives for specific changes towards nature-friendly practices. If they were asked to have fewer animals then they would need to be compensated for that, but if they were asked to change the way they farmed then a grant would be better.

Mitigation/support

Mitigation strategies on dairy farms included housing cattle for longer which meant reduced fertiliser use, enabled natural pastures, and allowed land to be rested over winter.

Some farmers talked about going back to more traditional ways of doing things. For example, an organic dairy farmer from west Wales stated that land should be rested over the winter. In the early 20th century, cattle from west Wales were sent on trains to arable farms in England, providing manure into arable systems, and a break from grazing pastures in Wales – demonstrating their belief that land should be rested over the winter.

On this farm cattle were kept in from October to March/April, to allow grazing land to rest. Silage fields were rested after the third cut. The farm only applied farmyard manure made with woodchip compost, not slurry. As an organic farm, they had not used fertiliser in 25 years. In terms of pasture management, they did not plough to reseed pasture. Instead, they used an organic system with natural reseeding and feeding. They had tried using an aerator/subsoiler in the past, but it was very rare that they got the right conditions to use it.

On both conventional and organic dairy farms, cattle were being brought in earlier and let out later if the weather was wet. Both types were trying to make sure that there was enough silage.

One of the conventional farmers stated that new restrictions on slurry spreading meant that more investment was needed in the slurry store, as it was not big enough. Water was also getting in which increases the volume, therefore they need to expand it and put a cover on it.

Retaining hedgerows for shelter was seen as important on both the conventional and the organic farm, as well as the planting of shelter belts.

The conventional dairy farmer mentioned they are using new technology by using contractors who have up-to-date tractor technology to make better use of fertiliser and other inputs.

Information on climate change often came from other farmers by word of mouth. Other sources of information included farming publications such as Farmers Guardian, Farmers Weekly etc, and agricultural advisers.

Concerns were also raised about the complexity of government schemes and the associated bureaucracy. The organic farmer stated he does not want anything from the Welsh government and will not be in the scheme (SFS), as he'd had a bad experience previously with Tir Gofal, and schemes were generally too prescriptive.

Arable and mixed farmers

Impact

Arable operations were being impacted by drought during the spring which affected sowing and germination; and wet weather limited field operations, particularly for spring-sown crops.

In 2023 there had been a dry August and long period of dry weather in May and June – and it had been a lot worse in 2023 compared to 2022. The wet weather had impacted some of the pastures in the rotation and the ground had been scorched by the sun with little grass growth. This was followed by wet weather in the autumn which meant that not all crops had been sown. One farmer reported that they still had unsown seed in the shed.

One respondent stated that there had been a wildfire on their farm during the drought of summer 2022. As well as loss of fields, this had also threatened the farmhouse, which would have been a significant emotional as well as financial loss. The farmhouse had been saved by a marshy area of ground, illustrating the potential benefits of conserving this kind of habitat.

The proscriptive nature of some support schemes was cited as a barrier – for example, being bound by the rules of Glastir to practise spring cropping, while the pressure is to move to autumn-sown crops.

Mitigations

Mitigations to climate change for arable farmers included rotations and moving away from spring-sown crops and other crops which were deemed too risky, but also having a wider range of enterprises to spread risk. All the arable farmers interviewed also had other enterprises including livestock.

One organic farmer was building fertility using four-year leys then cereals, and was using lucerne in the rotation as it is deep rooting, provides good forage and is drought-resistant. He had noticed his fields had been less affected by drought compared to his neighbours.

One conventional farmer had considered regenerative farming, and they would advocate for minimum tillage where they could get away with it as it did help to conserve moisture. However, they had found that minimum tillage does not work everywhere – only on certain fields and soil types. They had lost 20 hectares of winter cereals by not ploughing and the fields had been waterlogged.

A mixed cropping and livestock farmer from the Vale of Glamorgan commented: **"We cannot change climate change. No one really knows what they are talking about. There is an element of climate change – but if we do not adapt, we will not survive."**

One of the nature-friendly farmers stated that nature recovery was a key part of their mitigation strategy. **"It's important for farmers not to be afraid of nature recovery,"** said a mixed farmer involved in nature recovery in west Wales.

One producer had diversified because pig production is a lot of work for a product that does not pay well. They retail their own pork to make savings on pork production, which allows them to control their price. In the wholesale market, they do not make enough.

Planting trees was again a key mitigation activity. One poultry producer stated that when they first moved to their farm, trees were planted as windbreaks and to provide shelter for the birds (about 20% of the farm is down to trees). The trees were also considered important for flood prevention on a wider scale.

Poultry sheds were being moved regularly to prevent bare soil and to give the soil a chance to recover. One small-scale producer interviewed used commercial breeds but reared the birds themselves from day-old chicks, to ensure the birds are adapted to the conditions on the farm.

In terms of training, one farmer stated that the Nature Friendly Farming Network ran good training days. Nature-friendly farmers tended to have more diverse farming systems and were collaborating through other organisations. Those who did not consider themselves nature-friendly would need a financial incentive to adopt nature-friendly farming methods. One respondent had tried to implement regenerative practices but was finding that it did not work on every field.

Horticulture and vegetables

Impact

Transplanting and the direct sowing of crops was very difficult in dry conditions. More irrigation was needed, which added to labour costs as more time was taken setting up sprinklers. It was stated that field-scale vegetables were becoming more challenging, as it was either too wet or too dry.

However, weed control was easier in a dry spring. Warmer weather means some crops grow quicker. For vegetable growers in north-west Wales, higher temperatures are not always a bad thing, but warmer winters meant that a lack of frost impacts on disease.

At times crop yields and quality were affected by water stress. For example, potatoes were more prone to scab if not properly watered. In the autumn of 2023, a substantial proportion of potatoes were not harvested due to the wet weather.

One producer operating a vegetable box scheme stated that they tried to source produce locally, first from the UK, then from Europe, and occasionally from outside Europe. Supplies were held up as a result of Brexit, but their experience during the pandemic was better than expected. However, there had been occasions when some fresh produce items were either unavailable to buy or were delayed due to adverse weather.

Mitigations

Producers had been investing in irrigation, to better cope with drought conditions. Other mitigations included ploughing as little as possible, not deep and as part of a rotation, and always cover-cropping. One vegetable grower stated that they kept their own seed as the crops will grow and be suited to the farm. They only planted when the conditions were favourable.

One small-scale vegetable producer in west Wales stated that there were no barriers to adapting to climate change if you were prepared to think out of the box. One producer had received support from the Welsh government's Horticultural Development Scheme. However, it required match funding, and the minimum investment threshold was a barrier to small-scale producers applying.

Producers selling directly to consumers felt that most of their customers understood constraints relating to seasonality. It was felt that consumers in general needed to be better educated about food, and the impact of seasonality and the impacts of climatic events on produce. Vegetable production is not a major activity in Wales; however, given the high proportion of imports to the UK that come from climate-sensitive areas, there is potential for an increase in small-scale and mixed cropping within Wales.

Expert opinion and additional contextual analysis

Expert interviews were also conducted to provide additional insight and context, and to cross reference to the responses of the farmers. Respondents included an independent nutritionist, a policy specialist from Hybu Cig Cymru, a university research group, and two university researchers. Summaries of key interview responses are presented in **Appendix 6** on page 84. A number of key themes that emerged in these interviews are outlined below.

Implications for farm policy

Many respondents felt that the Sustainable Farming Scheme needs to be more flexible and less prescriptive to enable farmers to be able to manage their farms appropriately, striking the right balance between nature and food production. Agri-environmental support should be results-based rather than a tick-box exercise. The Irish Agri-climate Rural Environment Scheme (ACRES) was cited as an example of a results-based support scheme, with farms being assessed using results-based score cards, and payment rates linked to a score out of 10 (Department of Agriculture, 2022).

Given that many farmers stated finance was a major barrier to mitigation and adaptation to climate change, the right support and funding mechanisms to support the transition will be crucial.

Data needs and data collection

Respondents spoke of a need to collect more farm-level data on sustainability; however, farmers should be engaged with this process to allow them to take ownership of it. Concerns were expressed over the idea of using satellite data to monitor agri-environmental performance.

Implications for advisers and agricultural educators

Improved agricultural education was seen as a key factor in helping the sector to develop greater resilience. This included a stronger emphasis on nature-friendly farming and soil conservation. It was also felt that many farm advisers had not kept up with trends towards sustainable farming, and were giving the same advice as 30 years ago.

Collaboration and information sharing

Many of the farmers describing themselves as nature-friendly or organic were actively engaged in discussion groups related to sustainability and sustainable farming. The decline of some aspects of traditional rural life and increased isolation had meant there were reduced opportunities for farmers to discuss issues like climate change among themselves.

Tree planting versus food production: the potential for agroforestry

Planting woodland, shelter belts and hedges was seen as an important mitigation and adaptation strategy. This was often done in conjunction with food production. At its core, agroforestry involves the combination of woody vegetation (e.g. trees and hedges) with crops and/or animals within the same landscape. As such, agroforestry is a form of mixed farming and encompasses a wide range of practices, including:

- Traditional agroforestry – long-established woody crops alongside food-producing livestock or crops.
- Innovative agroforestry – food and non-food biomass (e.g. bioenergy) and balancing resources alongside environmental conservation.
- Silvopastoral – trees with livestock grazing.
- Silvoarable – trees and arable cropping.
- Agrosilvopastoral – mixed farming crops and/or livestock with trees.

Adoption of new technology

The potential of digital technology was not raised by many respondents due to constraints on finance and costs. One of the farmer respondents stated that sometimes a job can become overcomplicated due to technology. Mitigation strategies focused on management and changing farming practices. New technologies mentioned in the context of more sustainable farm management included the use of cattle collars for better management of grazing and using contractors with the latest digital technology in tractors.

Fruit and vegetable production

One of the researchers in agroecology, water and resilience felt there was a need to encourage the provision of more allotments in towns and home-grown food. In addition, there was a need to encourage more diverse cropping systems. Climate change may benefit Welsh horticulture since a warmer climate will lead to plants growing faster, and a wider range of crops being grown. However, this will be dependent on farmers being able to manage the extremes of drought and intense rainfall.

Key conclusions

There is no one-size-fits-all solution to mitigating and adapting to climate change, and to meeting Wales's food security challenges. Nearly all the farmers interviewed had observed changes in weather patterns, with warmer, wetter winters and drier summers, and more prolonged periods of unsettled weather during the spring and autumn.

Incidents of extreme weather during 2018 and 2020 had significant economic impacts on Welsh farms due to increased feed costs, livestock losses and reduced crop production. In 2018, losses due to extreme weather in the ruminant livestock sector were estimated at £206.7m – equivalent to 11% of the total Welsh agricultural output that year.

In 2022/23 there was no significant increase in lamb mortality against the trend. However, due to the drought during the summer of 2022 there was increased supplementary feeding, with total feed and forage costs for livestock farmers in Wales being £265.7m above what would be expected in a typical year – equivalent to 14% of total agricultural output in that year. We also estimate that losses to Welsh arable production due to extreme weather conditions in 2018 were as much as £4 million, and £19 million in 2020.

Farm-level mitigations

Measures for soil health

Maintaining soil structure allows for better drainage and reduces the risk of flash flooding. Improved on-farm soil health monitoring is needed to enable better farm-level management and soil conservation. Testing soils on the farm and establishing key aspects such as pH, texture, fertility, drainage, moisture content, organic matter content and nutrient status will allow landowners to make more informed decisions when selecting crops and to get the most out of their land.

Other measures to conserve and support soil include:

- Avoiding the use of heavy machinery and ensuring tyre pressures are correct.
- Limiting livestock access and grazing on wet soils.
- Implementing reduced-till or no-till farming to help build soil organic matter and encourage soil organisms.
- Maintaining soil cover, for example through cover cropping.

Tree and hedgerow planting

Trees help to reduce soil erosion and provide shelter for livestock. Both organic and conventional farmers saw retaining and planting hedgerows for shelter as important, as well as the planting of shelter belts. However, there is a need to balance tree planting with maintaining agricultural production. This could be achieved through agroforestry systems, or by providing shelter belts and hedgerows.

Greater crop diversity

Greater diversity in arable rotations would provide increased climate and economic resilience. For example, crops with different root depths can take advantage of the varying nutrient profile of the soil. The inclusion of temporary grass and herbal leys would help with the integration of livestock into arable systems. This would help to increase the amount of plant and animal matter going back onto fields – manure and green composts can replace nitrogen-based fertiliser.

Less risky cropping

There is a need for more diverse rotations, and to move away from spring-sown crops and other crops that are deemed too risky. Also having a wider range of enterprises would spread risk. Changing crop schedules and introducing a multiple cropping system (growing two or more crops in the same field, for example salads) may help to make the most of extended growing seasons.

Diverse grazing

More diverse swards should be encouraged, for example by putting legumes or herbs in reseeding leys. Chicory is anthelmintic and is good during droughts because it is longer-rooted. Sowing earlier and harvesting later would help to compensate for lower yields due to drought.

Rotational grazing

Rotational grazing prevents overgrazing and reduces damage to the soil. It also results in greater grass yields. It provides access to more nutritious grass, and gives livestock more movement and longer periods outdoors. It cuts costs in terms of veterinary bills, and purchasing or making conserved feed and fertiliser. A more diverse sward and deeper roots means water infiltration is fast, so water runoff is reduced (reducing the risk of flooding) and moisture is retained in the soil.

Investment in technology

Technologies to improve resilience include sensors that monitor essential components of farming such as soil parameters, livestock behaviour, production, and farm inputs and outputs. Smart cattle collars and electric fencing have great potential to improve grazing management. Precision agriculture is one way in which technology is used to minimise inputs and maximise outputs. GPS systems can help farmers plant crops in the most efficient patterns to save time, fuel and costs. Drones and remote sensors can map areas of plant disease and other plant health parameters.

Other policy measures should consider the following:

Support for investment in infrastructure

Funding is a key barrier to adaptation to climate change, there is a need for measures to support investment in the following kinds of infrastructure:

- Farm buildings to enable the housing of stock over the winter to rest grazing land.
- Slurry and manure storage to cope with wetter winters and reduce the risks of pollution.
- Drainage systems to cope with higher rainfall intensities.
- Flood prevention schemes.
- Water storage reservoirs to enable farmers to cope with the reduced availability and reliability of summer rivers by building winter water storage facilities. Farmers need to take advantage of periods of heavy rainfall and store rainwater, and also practise water recycling.
- Peatland restoration projects to enhance biodiversity and prevent flooding.

Data on sustainability

There is a need to collect more farm-level data on sustainability. This is best collected by the farmers themselves, as it will help them monitor their own progress and provide actionable insights into the sustainability of their own operations.

Improved training and education on sustainable farming

Improved agricultural education was seen as a key factor in helping the sector develop greater resilience, including a stronger emphasis on nature-friendly farming and soil conservation. Agricultural colleges need to focus more on sustainable farming and move the emphasis away from production-led agriculture. In addition, farm advisers need to upskill in sustainable farming methods.

Barriers to adaptation

The biggest single barrier to mitigating and adapting to climate change and building resilience was finance, with many farmers saying they lack the resources to make increased investment in new infrastructure. Capital investment was particularly needed in the following areas:

- Water storage and irrigation.
- Housing for grazing livestock over the winter.
- Slurry/farmyard manure storage and covers for livestock yards.

However, at the same time, farm incomes were under pressure, with many farms lacking the financial and other resources to invest in mitigation measures. Other barriers to mitigation included a lack of information on more sustainable practices.

Nature-friendly farming

There is evidence that nature-friendly farming brings increased farm business resilience to the changing climate, as well as increased financial resilience. Some observations of the benefits from nature-friendly farmers included:

- Less waterlogging during wet periods.
- Land was less burnt off (or scorched) and water-stressed during periods of drought.
- More tree cover, shelter belts and hedges meant animals were less exposed to heat stress and more protected in cold weather.
- Lower stocking rates meant fodder management was easier and there was more resilience in the system.
- Rotational grazing could potentially maintain production while improving soil structure.

While nature-friendly farming can bring real benefits, these benefits are often only realised in the long term. For example, it takes time to restore soil structure or to establish hedgerows or shelter belts. Thus, support to implement nature-friendly practices is needed for the transition. Adopting nature-friendly farming practices could help Welsh agriculture to mitigate and adapt to the worst effects of climate change and help maintain livelihoods and food production. However, mitigation and adaptation require investment at a time when farm incomes are under pressure, and many measures are long-term, with farms needing time to build up resilience.

Food security

In terms of food security within Wales and the UK, as noted above, extreme weather including very cold as well as hot weather has a negative affect on livestock and therefore food produced. A key area of concern is also the fruit and vegetable sector, with imports sourced largely from climate-impacted parts of the world. However, a warmer climate may be beneficial for the prospects of some fruit and vegetable production within Wales. This might allow some farms to move toward more diverse cropping systems and increased horticultural production, which would help to generate rural employment. It could also align with public health objectives to encourage healthy eating.

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Appendix 2

Feed and forage costs

Forage costs (including fertiliser) £ per head (Data from Wales Farm Business Survey 2012-2022)

Enterprise	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	10-year average (2012-22)	10-year trend % p.a. (2012-22)
Hill sheep	11.15	11.46	12.20	10.97	10.34	9.73	11.39	12.45	12.85	13.12	14.72	11.57	1.64%
Upland sheep	17.07	16.60	16.76	15.80	15.19	15.69	17.21	17.63	18.62	19.80	22.95	17.04	1.49%
Lowland sheep	16.70	15.11	16.45	14.07	13.13	12.89	14.76	16.41	16.86	16.46	16.86	15.28	-0.14%
Lowland suckler cows	225.55	226.71	237.12	201.58	189.96	139.67	171.04	186.42	194.00	179.11	227.91	195.12	-2.28%
Upland suckler cows	209.60	205.46	183.90	166.04	179.19	185.43	208.88	169.63	162.36	200.17	221.28	187.07	-0.46%
Hill suckler cows	168.63	178.94	180.98	156.23	145.20	152.32	159.65	175.35	143.15	158.07	175.00	161.85	-0.64%
Hill & upland dairy	202.43	207.58	206.70	180.16	161.72	184.71	183.09	203.44	187.16	194.15	277.30	191.11	-0.42%
Lowland dairy	189.78	192.52	202.93	178.81	159.91	164.99	187.26	183.96	201.42	191.19	278.76	185.28	0.07%

Concentrates and bulk feed costs £ per head (data from Wales Farm Business Survey 2012-2022)

Enterprise	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	10-year average (2012-22)	10-year trend % p.a. (2012-22)
Hill sheep	16.73	18.77	15.07	13.39	15.03	15.39	16.61	14.41	16.04	18.43	23.55	15.99	0.97%
Upland sheep	20.15	23.85	17.32	15.76	16.94	17.60	20.06	17.30	21.52	23.84	23.83	19.43	1.70%
Lowland sheep	20.77	22.25	20.02	16.73	17.01	17.43	20.48	19.25	18.34	24.84	27.18	19.71	1.81%
Lowland suckler cows	191.39	146.51	137.19	130.14	128.16	118.79	219.36	132.44	168.24	171.25	204.67	154.35	-1.11%
Upland suckler cows	177.96	180.07	144.19	131.07	146.03	156.97	190.31	140.40	126.42	148.82	170.62	154.22	-1.77%
Hill suckler cows	208.12	238.80	199.27	165.15	173.81	173.42	220.66	189.12	190.77	209.95	267.51	196.91	0.09%
Hill & upland dairy	599.23	614.78	568.15	456.14	461.75	546.41	625.09	613.48	624.34	723.94	940.26	583.33	1.91%
Lowland dairy	599.57	672.49	606.55	509.05	500.19	562.24	675.69	594.55	625.77	715.14	1018.20	606.12	1.78%

Appendix 3

Economic analysis

Forage costs (including fertiliser) £ per ewe

	2012/13	2017/18	2021/22	2022/23	10 year trend	2018 based on trend	2018 actual	Difference from 2018	% Difference	2022/23 based on trend	2022 actual	Difference with actual	% Difference
Hill	11.15	9.73	13.12	14.72	1.64%	9.89	11.39	1.50	15%	13.34	14.72	1.38	10%
Upland	17.07	15.69	19.80	22.95	1.49%	15.92	17.21	1.29	8%	20.10	22.95	2.85	14%
Lowland	16.70	12.89	16.46	16.86	-0.14%	12.87	14.76	1.89	15%	16.44	16.86	0.42	3%

Forage costs (including fertiliser) £ per suckler cow

	2012/13	2017/18	2021/22	2022/23	10 year trend	2018 based on trend	2018 actual	Difference from 2018	% Difference	2022/23 based on trend	2022 actual	Difference with actual	% Difference
Lowland	225.55	139.67	179.11	227.91	-2.28%	136.49	171.04	34.55	25%	175.03	227.91	52.88	30%
Upland	209.60	185.43	200.17	221.28	-0.46%	184.58	208.88	24.30	13%	199.25	221.28	22.03	11%
Hill	168.63	152.32	158.07	175.00	-0.64%	151.34	159.65	8.31	5%	157.05	175.00	17.95	11%

Forage costs (including fertiliser) £ per dairy cow

	2012/13	2017/18	2021/22	2022/23	10 year trend	2018 based on trend	2018 actual	Difference from 2018	% Difference	2022/23 based on trend	2022 actual	Difference with actual	% Difference
Hill & Upland	202.43	184.71	194.15	277.30	-0.42%	183.94	183.09	-0.85	0%	193.34	277.30	83.96	43%
Lowland	189.78	164.99	191.19	278.76	0.07%	165.11	187.26	22.15	13%	191.33	278.76	87.43	46%

Concentrates and bulk feed £ per ewe

	2012/13	2017/18	2021/22	2022/23	10 year trend	2018 based on trend	2018 actual	Difference from 2018	% Difference	2022/23 based on trend	2022 actual	Difference with actual	% Difference
Hill	16.73	15.39	18.43	23.55	0.97%	15.54	16.61	1.07	7%	18.61	23.55	4.94	27%
Upland	20.15	17.60	23.84	23.83	1.70%	17.90	20.06	2.16	12%	24.24	23.83	-0.41	-2%
Lowland	20.77	17.43	24.84	27.18	1.81%	17.74	20.48	2.74	15%	25.29	27.18	1.89	7%

Concentrates and bulk feed £ per suckler cow

	2012/13	2017/18	2021/22	2022/23	10 year trend	2018 based on trend	2018 actual	Difference from 2018	% Difference	2022/23 based on trend	2022 actual	Difference with actual	% Difference
Lowland	191.39	118.79	171.25	204.67	-1.11%	117.48	219.36	101.88	87%	169.36	204.67	35.31	21%
Upland	177.96	156.97	148.82	170.62	-1.77%	154.19	190.31	36.12	23%	146.18	170.62	24.44	17%
Hill	208.12	173.42	209.95	267.51	0.09%	173.57	220.66	47.09	27%	210.13	267.51	57.38	27%

Concentrates and bulk feed £ per dairy cow

	2012/13	2017/18	2021/22	2022/23	10 year trend	2018 based on trend	2018 actual	Difference from 2018	% Difference	2022/23 based on trend	2022 actual	Difference with actual	% Difference
Hill & Upland	599.23	546.41	723.94	940.26	1.91%	556.84	625.09	68.25	12%	737.76	940.26	202.50	27%
Lowland	599.57	562.24	715.14	1018.20	1.78%	572.24	675.69	103.45	18%	727.86	1018.20	290.34	40%

Appendix 4

Aggregate livestock impacts

2018/19	Number of farms	Average livestock numbers	Additional forage costs per head	Additional concentrate costs per head	Production losses (lambs)	Estimated additional lambs lost per farm (head)	Value per head	Value of lambs lost per farm	Additional feed and forage costs per farm	Additional lambs lost	Additional feed and forage costs total	Total additional costs/losses
Hill cattle and sheep	4324		£10	£48	0.08	£49	£52	£2,524	£2,674	£10,915,095	£11,560,555	£22,475,650
Suckler cows		20	£8.31	£47.09					£1,108		£4,790,990	£4,790,990
Breeding sheep		609	£1.50	£1.07	0.08	£48.72	£51.81	£2,524	£1,566	£10,915,095	£6,769,566	£17,684,661
Upland cattle and sheep	1879		£26	£38					£3,135	£5,445,335	£5,889,805	£11,335,140
Suckler cows		29	£24.30	£36.12					£1,752		£3,292,545	£3,292,545
Breeding sheep		401	£1.29	£2.16	0.10	£40.10	£72.27	£2,898	£1,382	£5,445,335	£2,597,260	£8,042,595
Lowland cattle and sheep	1087		£49	£122					£13,543	£263,039	£14,721,121	£14,984,159
Suckler cows		21	£34.55	£101.88					£2,865		£3,114,439	£3,114,439
Breeding sheep		303	£14.76	£20.48	0.01	£3.03	£79.86	£242	£10,678	£263,039	£11,606,682	£11,869,720
Dairy	2543		£24	£106					£12,940	£0	£32,906,108	£32,906,108
Dairy cows		101	£22.15	£103.45					£12,686		£32,259,381	£32,259,381
Breeding sheep		55	£1.89	£2.74	0.01	£0.55	£79.86	£44	£254		£646,727	£646,727
Other	14569		£49	£122					£2,209	£720,686	£32,183,847	£32,904,533
Suckler cows		0	£34.55	£101.88					£26		£383,306	£383,306
Breeding sheep		62	£14.76	£20.48	0.01	£0.62	£79.86	£49	£2,183	£720,686	£31,800,541	£32,521,226
Total	**24402**									**£23,773,213**	**£182,962,317**	**£206,735,530**

2018/19	Number of farms	Average livestock numbers	Additional forage costs per head	Additional concentrate costs per head	Production losses (lambs)	Estimated additional lambs lost per farm (head)	Value per head	Value of lambs lost per farm	Additional feed and forage costs per farm	Additional lambs lost	Additional feed and forage costs total	Total additional costs/losses
Hill cattle and sheep	4374		£19	£62	--	--	--	--	£4,875	--	£21,321,556	£21,321,556
Suckler cows		15	£17.95	£57.38	--	--	--	--	£1,130	--	£4,942,076	£4,942,076
Breeding sheep		592	£1.38	£4.94	--	--	--	--	£3,745	--	£16,379,480	£16,379,480
Upland cattle and sheep	1946		£25	£24	--	--	--	--	£2,052	--	£3,993,779	£3,993,779
Suckler cows		26	£22.03	£24.44	--	--	--	--	£1,208	--	£2,351,040	£2,351,040
Breeding sheep		346	£2.85	-£0.41	--	--	--	--	£844	--	£1,642,739	£1,642,739
Lowland cattle and sheep	1169		£53	£37	--	--	--	--	£2,681	--	£3,134,574	£3,134,574
Suckler cows		23	£52.88	£35.31	--	--	--	--	£2,028	--	£2,371,314	£2,371,314
Breeding sheep		282	£0.42	£1.89	--	--	--	--	£653	--	£763,260	£763,260
Dairy	1441		£88	£292	--	--	--	--	£77,923	--	£112,286,674	£112,286,674
Dairy cattle		206	£87.43	£290.34	--	--	--	--	£77,821	--	£112,139,874	£112,139,874
Breeding sheep		44	£0.42	£1.89	--	--	--	--	£102	--	£146,800	£146,800
Other	15678		£53	£37	--	--	--	--	£177	--	£2,771,568	£2,771,568
Breeding sheep		61	£0.42	£1.89	--	--	--	--	£142	--	£2,225,020	£2,225,020
Suckler cows		0	£52.88	£35.31	--	--	--	--	£35	--	£546,548	£546,548
Total	**24608**										**£265,694,745**	**£265,694,745**

Appendix 5

Structured farmer interviews

Sheep and beef - Hill

1. Mixed hill sheep and beef farm, Powys. Organic/Nature-friendly	
Impact	• There are warmer wetter winters and drier summers. • Cattle are more susceptible and more difficult to manage.
Mitigations	• They used a hardier native sheep breed and lambed late (April into May) when weather was more likely to be favourable. • They retain a hefted flock – the sheep know where to go in severe weather. • Cattle collars could keep track of cattle and know how and where they are grazing. They can help improve vegetation management and map out where the cattle have been. • Hedges are really important shelter for the livestock, and they also provide berries and other things for the house. • Key mitigation measures include grazing cattle in plantations, vegetation management, and providing shelter.
Barriers	• Access to finance was a barrier to investing in mitigation. • Many schemes and regulations are very prescriptive. The uplands are a good place for conservation. • They were tenant farmers and needed permission to do things; little point in investing in say renewable energy supply as tenancy ending.
Support	• There is a need for advice and there is a need for advisers who know the farm and the system. • Policies need to be less prescriptive and more flexible. • They were hoping to get Heritage Lottery funding for peatland restoration.
Concerns	• The threat of wildfires will increase if Molinia is not managed. Wants to do more with peatland restoration. • There needed to be more support for peatland restoration.

2. Upland sheep, Pembrokeshire. Conventional	
Impact	• In dry weather they had noticed that the higher, top land and older pastures did not burn so much.
Mitigations	• They were using hardier breeds and crossbreds such as the improved Llyen and had started lambing later. They had changed breeds because they realised they needed a hardier breed. • They were also calving outdoors – this was going back to their grandfather's system of farming.
Barriers	• Policy was too prescriptive and the agricultural budget was not big enough. • Not enough finance was available to invest in the infrastructure for resilience.
Support	• It is not clear what they are doing with the SFS. • Welsh politicians were not interested in farming and visiting farms.
Concerns	• Gorse and scrub were building up on the mountain – a potential tinderbox during dry summers. • There was a need to hold water back on the farm; concerns over water for cattle; springs on the mountain drying up. • Delayed payments from supermarkets were having an impact on farm finance.

3. Upland sheep and cattle, Carmarthenshire. Organic/nature-friendly	
Impact	• There were more extreme weather patterns and more uncertainty. They used to be able to predict the weather. • Last three years have had to buy feed in, which they had tried to avoid. • Their turnover had been reduced by 15%, but their profit was up 10% due to reduced costs.
Mitigations	• They had a big challenge from the east wind as it dries everything out. Like having extra sheep. Buildings do stand up to the wind. • Does not buy in feed/fertilisers. Input costs add to the risk. • The key was keeping a mix of sheep and cattle, they also kept some ponies for conservation grazing. • Producing enough fodder was the biggest challenge. • The 'Beast from the East' had caused difficulties lambing – some sheep were in, some were out. • They used native breeds. Hereford cross dairy cows. Highland cross cows. • There is a need to use free resources on farm. Less reseeding and more natural pastures. Look in hedgerows and see what grows there. • Have tried herbal leys but they have not worked. • Used to grow swede/fodder beet, but it was too much risk. Too dry in spring and too wet in winter. • Maintain hedgerows, let them grow. Shelter for animals. • Historically farmers had been more savvy at locating buildings in sheltered areas to avoid storm damage. • Compared with 1947 or 1982/83 when they were stuck on the farm for weeks, climate getting warmer has some benefit. • Reported comment from bank manager: those farmers working more closely with nature have healthier finances.
Barriers	• Farmers have to produce what the market wants. Supermarkets have too much control. • There was a market penalty for native breeds. • Fear of failure was also a barrier. • No control over maintenance costs – machinery, repairs, etc.
Support	• It was seven years since Brexit – Welsh government needs to do something. • The government needs to address market failures. • The policy of producing cheap food will not be sustainable. • The farming unions are trying to protect a broken system. • They were involved with Nature Friendly Farming Network. • Support and education are needed for farmers, as well as consumers. • Agricultural colleges need to focus more on environmentally friendly farming.
Concerns	• The BBC has an agenda and gets the message wrong – for example industrial beef versus grass-fed. Need to eat less meat (less poultry, processed meat), but better quality. The vegan movement has corrupted young people. • Supermarkets make their money from bad food – processed food.

Upland

4. Upland sheep, Ceredigion. Conventional/traditional	
Impact	• The weather has become more extreme. Has not been able to reseed and cut silage because it has been too wet. Juggling the different jobs that rely on good weather has been challenging. Has had to pay for contractors to come in to cut the silage so he could then focus on reseeding. Shearing also requires good weather. • The winters were now a lot wetter. Sheep create so much mud which means more weeds grow such as thistles the following season. • With extreme weather, more contractors have to be paid. 'Beast from the East' – lost a lot of lambs because the ewes were stressed in the poor weather. A lot of premature lambing. • The Texel breed stress quite easily, for example if they overheat. He has lost some during the drought.
Mitigations	• Cross Texel sheep breed on the farm but would like to get a hardier breed. Lamb the Texels earlier in the season. • The weather fluctuates too much. The poor weather is not sustained: the following year it could be fine. Just going with the flow. • Maintain their hedgerows and wood plantations which provide shelter in the fields. • May plant more trees if they secure the SFS. Have turned a marshy area into a lake.
Support	• The information about the SFS is very limited. Talking about planting trees. What are the requirements; what are they paying for? Do they need to re-map the farm? It is not clear. • Word of mouth and read on Facebook and Farmers Weekly. • Would need a financial incentive to adopt sustainable or regenerative practices.
Concerns	• There are market fluctuations which the farmer has no control over. They sell through an agent. The larger lambs remain in the UK and the smaller ones are exported to the EU. • Concerned about new schemes. A lot of the previous work they have carried out on the farm – will that be eligible for the new schemes?

5. Sheep and beef farm, Powys. Conventional/traditional	
Impact	• Warmer and wetter. • Increased risk of flooding – low-lying land next to river. Sometimes they had to move animals away from flooding. Had lost one or two sheep.
Mitigations	• Not much specific. • Reduced stocking had cut cow numbers. • Parts of the farm planted to woodland to provide shelter, had maintained hedges.
Barriers	• There was a lack of finance for investment in new facilities and mitigation measures. • Needed more information on how best to adapt. • Lack of time to get things done.
Support	• No information yet on SFS. • Already had significant woodland areas on some marginal and steep parts of the farm. Had been within the Glastir environmental scheme in the past. • Trade press and the local graziers' association.
Concerns	• There was increased risk of flooding on the farm.

Lowland

6. Beef and sheep farmer, Welshpool. Conventional/traditional	
Impact	• No significant changes except it is getting wetter, so they are housing the cattle earlier. This has an impact on costs. Sheep have not been impacted; they remain outdoors. • Cattle have been more affected by the worsening weather. Sheep are not housed until then and will lamb later in the year when the weather improves. If the weather was dry all through to October, then the cattle could stay outdoors. The rising price of straw has hit them hard, as well as the cost of conserved feed.
Mitigations	• If the weather was poorer more often then they may consider making changes. • Dredging the river would help manage the changing climate and the threat of flooding. • They have built a shed to provide shelter for the sheep and to prevent poaching of grazing land in the winter.
Support	• The SFS has not been advertised enough. If the scheme were viable then they would consider applying. • Not interested in SFS because it is too restrictive. Always told what to do, when and where.
Concerns	• Concerned about building on floodplains; farmers are the ones who are expected to make the changes.
Other comments	• Have not considered implementing sustainable practices. They do not see the benefit in doing it. They are happy staying the same, and it is easier to remain as they are. • They (the farmers) want to produce top-quality products. They are happy with the supply chain they are part of. • They read Farmers Guardian every week to stay informed of any agricultural changes. • Weather apps, BBC Weather, Met Office. Have done hedgerow planting. Some schemes and grants encourage you to be more environmentally friendly and sustainable but are too restrictive. • Shows such as the Royal Welsh Show and the Winter Fair. Clubs such as Dorset Sheep Clubs.

7. Lowland sheep, Ceredigion. Conventional/traditional	
Impact	• There are more extremes and longer spells of these extremes, such as really long droughts and then months of rain. It does not seem to get as cold, but the winters are much wetter. • An isolated tornado that cut the top off the oak trees and knocked a wall of the shed down. They had to rebuild the shed which was a significant cost. They do not graze in the wetter fields over the winter due to the wet ground and damage to both the grass and livestock.
Mitigations	• Putting herbs (chicory) in their reseeding leys. They have planted chicory which is anthelmintic and is good during droughts because they have longer roots. So, when the grass burns off the chicory will still survive. Should also help with floods due to the longer roots.
Barriers	• It is hard to put sheds up due to no financial incentives, lack of grants, and the planning permission required. No grants to help renew old sheds. If there are no sheds for livestock, then they have to be out in the winter which destroys pastures and increases soil erosion and poaching of land.
Support	• Not interested in SFS because it is too restrictive. Always told what to do, when and where.
Concerns	• The rest of the supply chain does not seem to know what to do. The Welsh government talks about net zero but does not tell farmers how to get there. • Food production and self-sufficiency. Why are we importing so much? There should be more support for growing vegetables rather than trees and encouragement for more mixed farming which was better and less intensive.

8. Lowland beef and sheep, Ceredigion. Conventional/traditional	
Impact	• Stated does not believe in climate change, believes that the weather is just cycling through, and they are recurring patterns. The changing weather is just normal for them. • Loss of habitat is not due to climate change; it is due to certain species being protected and decimating other populations. • No effect of adverse weather on his farm.
Mitigations	• None. Being asked to grow 10% trees by the Welsh government is not feasible on the west coast. Only bracken and gorse grow there. He is changing his farm completely to make it more sustainable. • Cannot afford to put in an elaborate slurry system, therefore he is getting rid of his sheep and suckling cows and buying calves which he will sell as store cattle in the autumn. This will mean he will not have any cattle over the winter. • Some cattle have been allergic to the sun and have lost their fur. But other than that, no adverse effects of weather on production. Some breeds of cattle are less hardy.
Barriers	• The finance in agriculture is too low. There is very poor support from the government. Too many youngsters are leaving Wales and not being supported in running their family farms.
Support	• It was not advertised enough (the SFS) and therefore does not know enough about it. • Reads Farmers Guardian. Speaks to other farmers. • He joins a group of three farmers to share machinery.
Concerns	• The supermarkets have too much power. UK supermarkets only take about 19% of UK lamb. • The government is controlling too much of the supply chain and will not make changes if it does not make financial sense. They should have a scheme to retire older farmers. There is little encouragement for young farmers.

Dairy

9. Dairy farm, Ceredigion. Conventional	
Impact	• The weather is definitely wetter and more erratic. This affects when cows can be put out in spring, spreading slurry, and hedge trimming. The slurry cannot be spread when it is too wet as it will just run off farms and the slurry stores fill up faster in wet weather, uncovered store which means more volume. • Feeding in the sheds costs more and more time is spent actively cleaning the cattle sheds. Their farm is well drained. The river causes flash floods, but it drains away quickly. • There has been infrastructure damage from storms and poor silage due to adverse weather.
Mitigations	• Cattle are brought in earlier and let out later if the weather is wet. Trying to make sure there is enough silage. • The new restrictions on slurry spreading were meaning that over the winter farmers will not be able to spread at all; the slurry store is not big enough to hold that much for that long. Water is getting in which increases the volume, therefore they need to expand the store and put a cover on it. • Hedgerows have been kept. • They were using contractors which have up-to-date tractor technology.
Barriers	• Expense and difficulty finding funding for their farming practices. Funding schemes are not very well advertised. They have specific criteria which are not always suitable for certain farms. • Slurry tank cover. The farm is a relatively low input because it is quite small. Make their own silage to keep costs down.
Support	• The SFS is poorly advertised. There is uncertainty over the scheme – even the government does not seem to know what the requirements are. The announcement for the 10% tree cover on the farm – no one knows if this is on top of what farms already have. They had even asked the Welsh government and they did not know. If you knew what was coming, then you could plan around it. • Speaks to other farmers. Gets information by word of mouth and reads publications such as Farmers Guardian. Agricultural advisers visit the farm.
Concerns	• The immediate concern is the slurry tank and managing that. Clear financial support and clear targets that are achievable. • Dairy is at the mercy of the supply chain. The dairy industry is very volatile, it fluctuates regularly and by quite a lot. They do not have any control over who they sell to. • To convert to nature-friendly or organic would require compensation and financial incentives for specific changes towards nature-friendly practices. If they were asked to have fewer animals then they would need to be compensated for that, but if they were asked to change the way they farmed then a grant would be better.

10. Dairy Farm, St Clears. Certified organic	
Impact	• Weather is wetter and warmer, with spells of persistent rain and drier summers. • Had observed less standing water on own land compared with neighbouring intensive farms.
Mitigations	• Farms organically. • Cattle are in from October to March/April to allow grazing land to rest. Silage fields rested after third cut. • Use all farmyard manure, not slurry. Woodchip compost. Had not used fertiliser in 25 years. • Retains and maintains hedgerows, allows hedgerows to grow to provide shelter. • Had planted woodland (40 trees). Would graze if allowed to. • No ploughing or reseeding. Organic system with natural reseeding and feeding. • Had tried using an aerator/subsoiler in the past. Very difficult to get the right conditions to use it.
Barriers	• Obtaining finance to make necessary investments. • Bureaucracy – government schemes too prescriptive and difficult to apply for.
Support	• Stays informed on climate change through nature-friendly farming groups and observations on own farm. • At the turn of the 20th century, cattle from west Wales outwintered in England. The land was rested, and arable land received manure.
Concerns	• There is a need for better agricultural education on sustainable farming. Too much emphasis on production/industrial farming at agricultural colleges.

Mixed cropping and livestock

11. Mixed cropping and livestock, Vale of Glamorgan. Conventional	
Impact	• Dry August, long period of dry weather in May and June. A lot worse this year than last year. The ground had burnt off – scorched and vegetation had died. • It was now a lot more expensive to fatten cattle due to higher feed prices. • They had not got all their own crops in (sown) due to wet weather and seed was still in the shed. This was going to be a problem in 2024.
Mitigations	• They had considered regenerative farming. An advocate of minimum till where they can get away with it. Does not work everywhere – only in certain fields and soil types. • Regenerative farming is important to help conserve moisture. • However, had lost 50 acres of winter cereals by not ploughing. The fields are now waterlogged. • Does not spread artificial nitrogen on grass. Uses digestors and applies digestates in spring. • Not doing anything much different, but do not want to be a single enterprise farmer – between climate and market pressures, need to spread risk. • They have cut the suckler herd and now kept more store cattle as there was less risk. • Have to be efficient and gain scale. • Only maize and fodder beet are grown in the spring, and they are starting to avoid spring cereals as they are too hit or miss.
Barriers	• The challenges are the costs to run the slurry tankers but offset by reduced fertiliser bills. Does not think it works for everyone.
Support	• Personally, believe they will not get help from the government. They do not have the answer. • More support and advice are needed on what support is out there. Support needed not more red tape. Difficult to police grants – needs to make them fair. Grants intended to assist not make profit. • Does not think 2025 government policy for climate change will make much difference – the TB testing situation is not much better than 15 years ago. • Had applied for grants through Farming Connect. • Information from shows, for example Royal Welsh, Agronomists.
Concerns	• We cannot change climate change. No one really knows what they are talking about. There is an element of climate change – but if we do not adapt, we will not survive.
Other	• Changes to how weather warnings are reported. Every storm has a name. The world is now a smaller place – more knowledge of events elsewhere, not necessarily greater frequency or severity. • Every single business is different, average prices and costs do not reflect everyone. • Big and efficient or small farmers with no costs – but smaller farmers will be working harder. • Sells directly through own butchery – started to do a carbon audit. Wanted to do field-to-fork. Wanting to be more sustainable.

12. Mixed organic crops and livestock (cattle, sheep, pigs), Vale of Glamorgan	
Impact	• Have been there on the farm for 10 years. Since 2017-18 there had been long dry spells in early/midsummer. Settled periods of six weeks of dry weather. The opposite is true in spring. Last March/April it rained every single day. They were in habitat schemes and grew spring-sown cereals. Last year the spring crops were sown late, and the yields were down. The previous year, the opposite occurred. • Climate instability means you now cannot rely on nature. • Storm Dennis had damaged their polytunnels. • Animals do not like heat. They had observed neighbours struggling with lack of forage.
Mitigations	• The farming system had evolved into a climate system changing regularly. • Closed nutritional cycle, no bought-in inputs. Fertility-building leys, four years then cereals. • Drought management – cannot stop rain. Aim for 3-4 cuts of silage over the summer. Planting lucerne in rotation – deep rooting, good forage, drought-resistant. Look around, the local landscape is yellow – but lucerne is thriving. When putting in grass/clover leys look for drought resistance. • Reweighting to autumn sown. Cultivation late August/September. Management of staff/machines to cope. Able to plough if there is a break in the weather. Bigger/conventional operations around them have struggled. • Cereals are very sensitive to long dry spells. OK if well established, but long dry spells in spring stuntsgrowth and impacts yields. 6-10 weeks dry, then 6-10 weeks wet not helpful. • They were applying for small grant to trial biological sprays, although this was not particularly about climate change.
Barriers	• Finance – there was no money to invest. Income being reduced by impact of climate change, no finance to do anything about it. • Lack of resources – cannot take 2-3 weeks out of running farm to develop climate change strategy. • The system was built on goodwill – too many farmers were not paying themselves. • They were bound by Glastir rules to spring-sown crops but now faced pressure to grow more autumn crops. • Policymakers have lost trust of farmers.
Support	• The way SFS is framed is really positive for the environment but no detail yet. The actions and collaborative elements are positive. The ability to manage the microclimate in an area would be positive. • However, the Welsh government has lost the trust of farmers. • They had been supported by the Glastir programme. • They always look for capital grants to improve infrastructure. Will need to improve infrastructure for cattle manure. Will need to pay £30-40k to roof an area for dry manure. This time next year will have £75k less in income from the government. • Applied to Natural Resources Wales for funds for habitat management. • Have set up own farmer-to-farmer network – looking at soil types and how to protect soil. Talking to local entrepreneurs on green energy/green economy.

12. Mixed organic crops and livestock (cattle, sheep, pigs), Vale of Glamorgan (contd.)	
Concerns	• Had concerns over the future of support, and where the money is coming from. • Soil preservation and loss of soil. • Biggest challenge adapting systems to cope with extremes. At some point need to reduce exposure.
Other	• Extensive habitat management – Welsh government disappearing into fantasy. • Debate on Biodiversity Net Gain – but not formed yet. Wales will be different to England. • Role of supply chain – farms will adapt to climate change – evolution. Technical developments – different varieties/mixes. Must be knowledge elsewhere in the world. They had a good relationship with their current retailer, who has tended to look after farmers. Others will only do things if of benefit to them. No real partnership with small farms, and supply chain all based on shareholder value. • Direct selling hard work. Try and build community. Only sell retail, not wholesale. • Climate change an opportunity for farmers. Opportunity to shape farming systems.

Pig and poultry

13. Pigs and some beef. Smaller-scale, traditional	
Impact	• A lot wetter. The cows are brought in earlier, spending more money on conserved forages. Not much flooding because they farm on top of a hill. • No additional costs but there is more in terms of work. Because they are a family farm, they all work a bit harder to cope with the adverse weather such as bringing the livestock indoors earlier. • The cattle are harder to farm during the wetter weather due to extensive mud from wetter fields. They are brought in earlier.
Mitigations	• They are diversifying because pig production is not paying much and is a lot of work for a product that does not pay well. They retail their own pork to make savings on pork production. This allows them to control their price. In the wholesale market, they do not make enough. They already have huge numbers of mature hedgerows and mature trees. • Keeping hedgerows and hedge-laying. These techniques are traditional, the sustainable way is not a new thing. Take part in the Carmarthenshire Meadow Project annually – they conduct a survey each year that shows how diverse their land is.
Support	• When they went to fill in the application form for an expression of interest (for the SFS), there was a warning stating that it was all subject to change. You cannot agree to something when you do not know what it is about. • They farm traditionally. They do not use rodenticides because they know their harmful effect on the ecosystem. They have barn owls nesting on the farm. Mature trees and hedgerows. They do not want to forfeit any of that to bend to the rules and regulations of the scheme if that is what will be required. • Many of the government schemes do not consider anything you have already done. Announcing 10% of farmland must be covered in trees – is that in addition to what is already there? The government makes it difficult. • They stay informed through networks such as NFU, and Farming Connect. Also, publications like farming magazines. They feel more open to the information when it comes through trusted agricultural sources rather than things like the BBC. • A member of the NFU. Talk to other farmers but rarely about the environment. • Dry summers are difficult for the cows but their stocking rate is low so they can manage it. If droughts were severe, it would affect how many cattle could be kept. The wet summers help the grass to grow which reduces the need for concentrates. They are 100% grass-fed beef. The wetter fields sustain them during the droughts, and they can move the livestock down the hill if it is particularly dry.
Concerns	• The rules and regulations that are put in place for farmers. Such as a blanket tree rule of 10% land cover would have a severe impact on food production.
Other	• They retail their own pork because the supply chain takes too many cuts out of their profits.

Cropping

14. Arable (wheat) and Welsh black cattle for nature preservation	
Impact	• Drier springs and it has become wetter earlier in the winter. There are more extremes meaning the changing weather is more relevant to the farm and their farming operations than before. • The drought of summer 2022 was particularly challenging. Getting livestock out is getting later in the year because there is not enough food for them. • Continental breeds of beef and quick-growing cattle and high-producing dairy cows are not suited to our style of farming. They are less adapted to the high-fibre diet that the UK provides. • Ryegrass monocultures and improved pastures are hugely susceptible to climate change and adverse weather conditions. • Wildfire on the farm during the drought of summer 2022 – all arable farms were burnt through and all monoculture grassland. What stopped it from consuming the farmhouse was the marshy land. So, from a climate point of view, marshland has huge benefits. The wildfire during the drought could have destroyed the house. The effect was not quantifiable, it would have been a significant emotional loss as well as financial. Having peace of mind (e.g. having a more robust and sustainable farm that will cope with the changing climate) cannot be quantified but would be hugely beneficial.
Mitigations	• If there is an El Niño year then there is a knock-on effect which can hit hard, especially in Wales which is naturally wet anyway. • Getting cereal crops established after drought is challenging. When it is excessively wet trying to outwinter and plan for winter feed is difficult. Some of the land cannot support livestock during the wetter months. • They are continually trying to make their farm as diverse as possible by improving the natural habitat. Old-fashioned farming such as slow-growing cattle could reduce environmental impacts across the UK. • It is easy to carry on with intensive farming methods using chemicals and dealing with poaching of the land, but this is only a short-term solution and temporary fix.
Barriers	• Manage challenges of adverse weather by being adaptable. They make their adaptations so they can prevent the extinction of biodiversity, reduce the impact on climate, and farm in a sustainable way. • Establishing herbal leys which pull nutrients and water up which provides grazing when regular grass is low. • Keeping and maintaining marshy grassland is essential. It keeps growing when other grass has dried up. It improves the habitat but also livestock can thrive on it. Their Welsh black cattle do very well on their marshy land. Re-wetting some areas could help farmers cope with summer droughts. • On top of what they are already doing, they would like to continue creating a habitat that would be good for year-round grazing. They are involved in many conservation projects which improve their regenerative farming practices. • They have found they have saved on costs such as wormer by planting integrated parasite control measures. • Important for farmers not to be scared of nature recovery. • Many changes as discussed. Wildflower meadows, hedgerows, planting trees, wildlife corridors, maintaining marshy land, etc. • Sustainable management of the land and creating a biodiverse farm.

Cropping (contd.)

14. Arable (wheat) and Welsh black cattle for nature preservation	
Support	• There is a lack of knowledge of the SFS scheme. There are no clear guidelines surrounding the SFS. They do not know what will be paid for and when. They have seen other farmers reluctant to make any changes now because they are waiting to find out what changes will be funded by the scheme before implementing them. There has been a significant drop in income for farmers, and so they are already struggling and reluctant to make changes. • They stay informed through scientific literature. More support through Farming Connect would be beneficial. The creation of more cluster networks to inform them of changes and farming practices etc. Would be useful to have a trusted information system like Farming Connect, providing a go-to for farmers.
Support	• Collaborated through funded projects like the Nature Networks fund. Through this, they can engage with local farmers. Cluster networks and specialist interest groups. Farming Connect meetings and university student projects.
Concerns	• Many farmers have put long-term investments into the intensification of farming. This has come from previous generations; therefore, it is not easy to give all that up and start fresh. It requires money to change the farming practices. • There seems to be a lack of education for young farmers to use more sustainable farming methods. Farmers also need to want to change. It is a lifestyle job, so they need to be happy using the methods they use. • Would be beneficial to value land such as marshy land in terms of locking carbon away. Farmers would like to know what value some of their land has, but it is not always clear. • Terrified that we are not making the necessary changes fast enough. Deadlines and promises such as those made at climate conferences are not met. The government is not brave enough to make the changes needed as often sustainable farming does not fit with economic growth. • New innovative ways of farming should not be seen as competition to the traditional or current ways of agriculture. Bug Farm – farming insects is a new opportunity, not a threat.
Other	• If consumers are educated in sustainable farming practices, then more sustainable farming is likely to be achieved. This food needs to be available to households of all incomes. Educate the consumer to make a market for it in the first place. Schoolchildren need to be educated about it. Food companies need to actively source nature-friendly produce and shout about it. Both ends of the supply chain need to be tackled, from the government to the consumer.

Mixed farming

15. Mixed farm, livestock, cropping, woodland. St Asaph. Organic/nature-friendly	
Impact	• More flooding, more aggressive, more erosion. • Affects productivity of grazing land. Does not just deposit nutrients. Lambs lost. Fences lost and fields they cannot graze. • Winters getting wetter. January/February are the worst months. • Have had dairy heifers struggle with heat, and flies on the sheep.
Mitigations	• Woodlands protect the farm from extreme sun, and drought and hedges provide shelter. • They winter goats inside and other livestock are up the hill away from flooding. • Grazing managed sensitively. Always got a reserve and will stockpile grass. Surplus fodder is sold to larger neighbouring farms. • They were creating a basin in a field as a flood defence for the town. They were working with Natural Resources Wales and had raised money through crowdfunding (locals and customers) and had some Welsh government funding.
Barriers	• Investment needed. The climate is changing faster than we can manage. • As not in a protected landscape, funding is not available. • There is not enough education and training available for farmers to help with mitigation. • Farming Connect still focuses on productivity and does not see nature-friendly farming as proper farming. • Need for acceptance of the need to adapt.
Support	• Some details of the SFS would be nice. We still do not know what opportunities there are. Would like to see farmers rewarded for nature-based solutions. Need more landscape schemes. • Results-based payments are based on the Irish scheme. Scored out of 10. • The Nature Friendly Farming Network ran good training days. Work with Country Land and Business Association, WWF, Buglife, and Plant Life. Unions still focused on preserving the status quo.
Concerns	• Sometimes, we can overcomplicate the job with an overreliance on technology. Need for change in mindset. • Money not available from the government. • Concerned if no investment, there will be intensification.
Other	• Supermarkets and dairies have contracts in place and expect farmers to tick boxes, but not paid more. More investment from the rest of the supply chain needed. Need to help family farms stay in business, paying more and investing in nature-based solutions. • More education of the public is needed, for example public information boards in Bannau Brycheiniog explaining the role of grazing management and ecosystem services.

16. Small-scale cropping, livestock, vegetables, polytunnels. Ceredigion. Certified biodynamic	
Impact	• Climate has always changed. Increasingly more variable and changeable. The weather always impacts them. • Field-scale vegetables are the most challenging – conditions are either too dry or too wet.
Mitigations	• Planting trees has been a key mitigation activity. When they first moved there, they were put in as windbreaks. Trees are extremely important. About 20% of the farm is down to trees. Important for flood prevention on a wider scale. • Diversification as risk management and to help mitigate climate impacts. • The basics, keeping ditches clean. Look after soil and land. • Grass leys and rotations, look after soil microbes. • Poultry sheds moved to prevent bare soil and give the soil a chance to recover. • The poultry are fine in hot weather as they have woodland, shut-in sheds during cold weather, and naturally ventilated sheds. Commercial breeds but reared from day old. • Ploughing as little as possible, but not deep and as part of a rotation. • They always crop cover. • Composting is exceptionally important. • Keep their own seed as you know the crops will grow and be suited to the farm. They only plant when conditions dictate.
Barriers	• There are no barriers to anything if you are prepared to think outside the box.
Support	• Keeps an eye on jet stream forecast – three weeks ahead. UK is fortunate compared to climate impacts in other parts of the world. • Farmers need to be free to farm and be market-led. Farmers need to be paid fair price for food, then they would be able to take actions suitable for their own farm. Empowered to do the right thing. Every single farm is different. Not a fan of the grant schemes. • Smaller local initiatives need to be put in place. • Part of an experimental biodynamic group. • More encouragement for local food systems. • Schools need to teach children how important food is. The first thing you do is buy food – then if you have money left you go on holiday – not the other way around. • Subsidy should go to consumers to buy food.
Concerns	• Need to be more accepting of climate change and have an attitude of adaption. Plan stocking crop rotations for the worst and not the best. • Think about fixing soils, which are in a poor state globally. Then everything else will follow. Good soil structure means plants have oxygen.
Other	• Selling directly to consumers – to educate them on what can be grown and what is grown seasonally. It needs to be communicated that we can grow everything we need within the UK. • There was a need for a return to small mixed family farms, with livestock back on arable rotations. There was no need to import soya as we can grow all the beans we need in the UK. • Fortunate with location – on the coast but out of the way of flooding.

17. Mixed vegetable farm, Carnarvon. Nature-friendly	
Impact	• Been running for six years. Observed drier periods in the spring. May/June long periods with no rain. Transplanting and direct sowing crops very difficult. More irrigation is needed which adds to labour costs – time setting up sprinklers. • However, weed control is easier in a dry spring. Warmer weather means some crops grow quicker. For vegetable growers in north-west Wales higher temperatures are not always a bad thing. • A lack of frost has an impact on disease pressures. • At times crop yield and quality are affected by water stress. For example, potatoes are more prone to scab if not properly watered. • The odd winter gales cause a certain amount of wind damage, but cannot say if it is getting worse. • Trend toward wetter autumns. Wet autumn in 2023, a substantial portion of potatoes were not harvested due to wet weather.
Mitigations	• Have upgraded irrigation capacity. Booster pump and buffer tank. Irrigation concentrated on higher-value crops in polytunnels. • Scaling back potatoes – struggled to harvest all crops due to wet weather. Demand for irrigation. • Sell through a box scheme as have more control – and not bound by supermarket. • Have become more conservative in terms of choice of crops. Sticking with staples and crops known to work. But need diversity for vegetable schemes.
Barriers	• Money is always a limitation. Irrigation upgrades did not lead to great expense, but a new borehole would be out of reach to many small producers. • The potato supply chain is very conservative about the choice of variety. There is a need for new varieties – not just for climate change but emerging disease threats. Also, there are issues relating to appearance of produce.
Support	• Had received money for the Horticultural Development Scheme (HDS). Received a 40% match-funded grant. • Another round – HDS the timing of the grant window and application process was not very user-friendly. The level of match funding would put a lot of small, not so well capitalised producers off. • Had not claimed Basic Payment Scheme, although big enough to qualify. Under the impression any payment would not be worth the paperwork. • Part of Land Workers Alliance. Links into Organic Growers Association, local food hub. • Part of Wales horticulture training network. • More advice on coping with dry periods would be useful.

17. Mixed vegetable farm, Carnarvon. Nature-friendly (contd.)	
Concerns	• Volatility is the largest concern. • Some current crops are borderline, for example sweetcorn, but they like to include it in their vegetable boxes.
Other	• Almost all sales are direct to consumers through their vegetable box scheme. They considered themselves part of the organic movement but were not certified. Certification may help expand the business. • Customers are self-selective and understand seasonality. 100% own produce four to six months of a year. Customers tolerate seasonality. • Try to source produce locally. First from the UK, then Europe, occasionally from outside Europe. Supplies held up because of Brexit; their experience during the pandemic was better than expected. There have been a few occasions when some fresh produce items have either been unavailable to buy or delayed due to adverse weather affecting their availability or timely harvest. Generally, they have not noticed significant disruption to their supply chain. • If we do not produce in the UK, we are likely to have to source from somewhere else more water-stressed, for example Spain or Morocco.

Appendix 6

Structured expert interviews

Expert interview 1. Independent nutritionist	
Impact	• There has been a change in weather patterns. This has particularly affected harvest time. This year, farmers are finding that forage quality is poor purely due to poor weather (excessive rain and drought). This has an economic impact on the farmers as they will not be able to produce as much output on the same input. If they do, then it will cost them additional feed or nutrition. • Farmers have increased costs to cope with extreme weather. • Spring was very wet this year (2023) which affected when farmers could cut their grass. Summer became really dry which meant the grass did not grow as well as it should have. Many farmers are short of conserved forage for the winter – having to buy in silage rather than making it themselves. • The 'Beast from the East' had an impact on farmers because whatever food was outdoors disappeared under the snow overnight. The recent droughts have had the biggest impact. Due to poor forage quality, livestock are not doing as well, and with less output farmers are struggling to pay their bills. • Everyone is suffering – all animals out on pasture are going to be affected. But dairy seems to have struggled more. Sheep also – when ewes are flushed in the summertime in readiness for lambing because the food quality has not been there for them, the number of lambs scanned has been down. Again – less output.
Mitigations	• Growing brassicas on grassland. Many farmers are looking at growing vegetation that survives drought conditions. • A lot of people are now growing lucerne to improve nitrogen in the soil. People are becoming more aware of soil nutrition. Some farmers have not ploughed the land, only light tillage and seeding. The message of improving land is slowly getting through.
Barriers	• Only their mindset is preventing farmers from making changes. The next generation coming through is more open-minded to change. • No two farms are the same. What might work for one may not work for another. • They have noticed farmers are becoming more aware of soil management.

Expert interview 1. Independent nutritionist (contd.)	
Concerns	• Combination of local markets, publications like Farmers Guardian, and discussion groups (often monthly). The internet is starting to play a big role. Often have a mixture of ages and experiences at the discussion groups so multiple generations can benefit from them. Discussion groups are a good way for farmers to socialise, farming can be quite isolating at times. • Weather is out of the farmers' hands. Agriculture is not appreciated in this country. The general public does not know much about farming or where their food comes from. The message is not getting through just how hard farmers work and how much they produce for the country. • More support in the form of financial and management help (e.g. agricultural advisers) needs to be given. The Welsh government's agriculture budget has been slashed. • Suggest that a hub should be set up. Monthly meetings with people to speak about the different forms of help available to them.
Other comments	• Often supermarkets use milk as a loss leader just to get people into the shops. The supply chain needs to be more transparent and open.

Expert interview 2. Hybu Cig Cymru (HCC)	
Impact	• HCC Farmer intention survey, policy rather weather-related, but there are concerns. • The ground is often saturated during the winter, and then we go to periods of extreme heat.
Mitigations	• Discussed the HCC Farm intention survey – in 2023 some farms intend to restock. • More extensive forage-based systems are more resilient. Less reliance on bought-in fertiliser. • More varied swards. • Historically during bad weather, the store cattle market is flooded, but this has not happened recently. • Specific practices for drought management – more rotational grazing, more diverse grass leys, incorporating legumes, and simply giving the land a rest. • Rotational grazing can add 10% to productivity, and more diverse leys can speed up finishing rates. • There are also quality benefits in terms of carcass confirmation. • Greater emphasis on soil health is needed. • More farmers are resting land over the winter period. Traditionally, grazing livestock stock are sent away to arable farms.
Policy	• The supply chain will drive things quicker than policy and government. • Policy needs to change behaviours on farm. • The farm versus trees debate is not helpful. Potential for agroforestry and integrating trees into the landscape. Trees can provide shelter during extreme drought, storms etc.
Other	• Farming Connect promotes the importance of soil testing. A movement towards a higher level of soil testing. • Many farms, however, are still slow to react and embrace change, and we need to get them to understand the benefits.

Expert interview 3: Research Group: Agroecology, Water and Resilience	
Trends	• The climate is becoming more unpredictable; however, some aspects of climate change could be beneficial in a UK and Wales context. Warmer temperatures generally mean that plants grow better. This could be of benefit to some crop producers in Wales.
Vulnerabilities	• There was a lack of knowledge and awareness of sustainable practices.
Mitigations	• Mitigations included rotational grazing, resting land, tree and hedgerow planting. • Investment in water storage needed to cope with shortfalls.
Policy	• Support for action at the landscape level was needed rather than just for individual farms.
Technology and innovation	• There are few specific pieces of new technology which could be helpful with mitigation. Instead, improving management was key. Investment in new technology could be costly and would not be accessible to all producers.
Collaboration and knowledge sharing	• Farmers are becoming isolated and lack appropriate forums to discuss problems and issues related to the climate. This is not helped by the decline of many aspects of traditional rural life where farmers used to meet to discuss issues informally, for example village pubs, livestock marts, shows, etc.
Data and monitoring	• A need to involve farmers in collecting data and monitoring progress. They can measure their own progress and will buy into the process. • There were concerns over proposals by the Welsh government to collect agri-environmental data using satellites; it was felt this could be counterproductive.
Sustainable practices	• More diverse grazing is needed in the uplands with a range of species – cattle, sheep and ponies. • Simply going minimum tillage is not really sustainable farming.
Capacity building	• More ways for farmer communication are needed. Discussion groups, etc.
Global perspectives	• Irish environmental schemes were a good example of a beneficial scheme, where payments were based on outcomes. Farmers were provided with the choice of measures linked to payment rates, and they could choose their level of entry to the scheme.
Long-term planning	• In terms of food security, there was a need to encourage the provision of allotments in towns and more home-grown food as well as better education about food.

Expert interview 4: Researcher: enhancing ruminant livestock production	
Trends	• Weather is more variable; the winters are warmer and wetter, and the summers are cooler and wetter. There are more extreme events with floods and droughts. This poses big challenges for crop growers, especially when you are dependent on predicting what the weather is likely to be for sowing, field operations and harvesting. • As a result, some farmers are changing what they do, for example making haylage instead of hay. • Research on heat stress in cows, which is getting more prevalent. It is becoming more of an issue in the UK. Heat stress is most common outdoors without shelter, but also in large sheds even with ventilation because hot air is circulated. • Agriculture plays a big role in flood mitigation. There has been research into using more deep-rooted crops which are more resilient in times of drought but also help water infiltrate the soil with excessive rain.
Vulnerabilities	• Dairy cows are more susceptible to heat stress. But they also do not like cold and wet, so farmers have to bring their cows in more often during the winter months. Soil type is important because some soils are less prone to damage by livestock and therefore livestock can be kept outside longer. • The biggest crop in Wales is grass. Maize grows well in parts of Wales, but it is often too wet to harvest it. Farmers are going to have to adapt to the changing climate possibly by changing the way they farm and what they farm.
Mitigations	• Direct drills and no-tillage are being used instead of ploughing because it is too wet.
Policy	• The whole of Wales has just become a Nitrate Vulnerable Zone – limiting the use of nitrogen for farmers. No fertiliser is allowed during the winter, which is going to affect those using slurry tanks. The biggest challenge is the lack of funds for farmers to make the necessary changes to their infrastructure such as slurry tanks. • There is a lack of clarity over the SFS.
Technology and innovation	• Through formulating diets more efficiently, things like nitrogen loss and nitrogen run-off can be reduced. There are new varieties of ryegrass that can be grown more efficiently. • By measuring the outputs and performance of livestock, their impact on the climate can be monitored. For example, milk urea concentration can tell you how efficiently the protein in the diet is being used by dairy cows. • Defra is thinking about mandating feed additives that reduce methane production in dairy cows. It is important to develop and perfect different proxies to estimate methane emissions from livestock. For example, milk fatty acid profiles from dairy cows can be used to predict the amount of methane the cattle are producing and therefore their impact on the environment. • Personal interest in using hydrogen or ammonia to power vehicles and machinery on the farm. This would be a use for some of the waste produced on farms.
Collaboration and knowledge-sharing	• Many farmers are not receptive to scientific researchers. They are more likely to listen to other farmers. The collaboration is few and far between. Progressive farmers do listen including those who have an academic background, but many others are reluctant. So, it is difficult to get the message across. • Defra are using on-farm demonstrations to try and bridge the gap between academics and farmers.

Expert interview 4 (contd.)	
Data and monitoring	• There are low-cost technologies that could be installed on farms to monitor the emissions and efficiency of that farm. There are recommendations from the government for farmers to use certain products on their farms, but this is a generalised recommendation and not adapted to the specific farms. For example, by analysing slurry farmers will know how much nitrogen is in there and therefore how much to put on their fields. At the moment, they follow the guidance for the recommended amount. • Real-time soil analysis coinciding with real-time fertiliser application – some tractors have in-built technology that allows them to measure the N, P and K in the soil as it fertilises the field. It can then adjust the quantities of fertiliser as it goes along. This is more precision agriculture, reducing excessive use of chemicals and ultimately reducing the effect on the environment. • Portable NIR machines will tell you what your silage composition is and then an agricultural nutritionist can reformulate a diet based on the silage available for the cattle. Higher-end technology includes an automatic feed formulator, pecific for the individual cows on the farm. This costs money but it could help to increase yields.
Sustainable practices	• Sometimes intensive farming is less damaging to the environment. For example, if beef cattle are grown more intensively and reach slaughter weight quicker then they are producing less methane over their lifetimes. This means that they have less of an impact on the environment. In Wales, it is mostly upland sheep farming which is not conducive to intensive farming.
Capacity building	• As a researcher, we need more funding. This allows more research into the best agricultural practices and ensuring food security across Wales. • Farmers also need to be recording more data and using that data efficiently and effectively. If you do not measure your farm outputs and production, then you cannot manage it. • If farmers gather data such as lamb birth and growth rates, cattle milk yields and composition, and dietary parameters, then they need to understand it and be able to use it. This can be used to adapt to climate change as they will be able to see what works best and when.
Global perspectives	• Interested in using crops from other countries to feed our livestock. The latitude some of these plants grow at has changed. Some grasses like miscanthus and napier grow at lower temperatures than in their native climates. If we struggle to grow ryegrass then we can look at growing different species.
Economic impacts	• Over 80% of agricultural GDP in Wales is based on ruminant production because Wales grows grass and ruminants are the only animals that eat that grass. If farmers do not adapt, then they will go out of business. There are fewer options in Wales because the land and climate are geared towards grass and livestock farming.
Long-term planning	• Planning authority measures need to allow more use of things like wind turbines and solar panels.

Expert interview 5: Researcher: uplands, ingestive behaviour in livestock, nutrient supply from forages.	
Trends	• Greater drought conditions are affecting grasslands. Upland soil and improved grassland have thinner soil and therefore it dries out very quickly. Some species of grass do better than others, and legumes do better than grasses. Waterlogged soils make the management of land difficult and, therefore, affect efficiency and sustainability. Whether it affects food security yet is hard to say. • There is a shift in the seasonal weather patterns. Wales appears to be getting pulses of weather conditions, weeks of heavy rain and weeks of drought. So, you are not getting any respite from adverse weather.
Vulnerabilities	• Grassland is vulnerable due to the shallower soil. Some grass species have longer roots and can be used to improve the infiltration rate of rainwater as part of water management and reduce runoff from the land. If uplands can be used to soak up a lot of the rainfall, then they can reduce the risk of flooding. • It is a mistake to think about food security on its own. Land should instead be multifunctional. Grassland is productive but also need to think about carbon storage and the resilience of land, as well as water management. A more holistic approach is required. • Grass is the cheapest form of feed for livestock, but adverse weather means animals are being brought indoors earlier which is costing the farmers more in terms of electricity, bedding, and conserved feed. • Native breeds of animals are more resilient to the bad winter weather both physically (e.g. their coats) and behaviourally (e.g. use shelter more effectively). But they are not coping so well in the hotter summers. All livestock are going to need more shelter. • The adverse weather is going to put more pressure on some types of animals, for example cattle drink a lot more than sheep. During the droughts, water supplies have dried up meaning that farmers spent a great deal of time filling large containers in the fields. Very time-consuming.
Mitigations	• Agroforestry is a combination of growing trees alongside growing livestock. Just planting trees takes the land out of production and therefore impacts food security, but if you can graze livestock or grow rows of crops in between the trees then the land is helping in food security. • Have secured a grant to implement a small agroforestry trial. The trees will provide shelter and shade, carbon storage, increasing biodiversity gain. Grassland mixtures with longer roots can help during times of flood and drought.
Policy	• Current agricultural policies are poor. The SFS is unclear but has huge potential. Farmers do not know how the transition is going to work. Farmers need to be able to plan 5 or 10 years ahead.
Technology and innovation	• Scientific research uses expensive equipment to make measurements, but you can get low-cost sensors now, connecting to your own network. This type of technology can play a big role. Sensors and monitoring systems are quite common in the dairy industry, but 80% of Wales is upland farming. • Simple measurements like soil and air temperature and moisture could let farmers know the best time to put fertiliser on or when there is a particular risk from certain parasites etc. At the moment, weather information comes from just three Met stations across Wales, but having sensors on individual farms would make data more specific to each farm. Farmers would be making decisions about their own fields more effectively. • Sensors can be used more, especially wearable technology. This can be used to track animals and keep an eye on livestock such as picking up on their health through their movements and behaviours on the farm.

Expert interview 5 (contd.)	
Collaboration and knowledge-sharing	• Information is shared directly with farmers. Before Covid, open days were used to share research with the farming community. Using Farming Connect and unions to try and get messages out. • Some agricultural advisers are preaching farming practices from 20 to 30 years ago. Some have links to companies and therefore try to push a particular product.
Data and monitoring	• Data-driven decision-making by individual farmers and monitoring farm practices and production. The baseline information about climate change for Wales is terrible. We do not know where we are starting from, and therefore cannot determine which direction we are heading in. • There is a focus on peatland and farmland is being forgotten. There has been a lot of money spent on models and decision support packages without any real data to drive that. There has been data collection regarding biodiversity, but productivity and climate change have not been targeted. The climatic information is not being collected and analysed.
Sustainable practices	• If being sustainable is capturing nutrients better from soil to plants and from plants to animals, then by being more sustainable there are lower emissions because more of those nutrients are turned into products. Reducing methane intensities, for example methane per kg of weight gain or per litre of milk, is much more meaningful than focusing on the total amounts. • On grasslands, the data is from indoor situations and controlled environments. Deeply sceptical about carbon calculators because they have huge variation in them. There is not enough validation for carbon calculators. • Economic and environmental sustainability should go hand in hand.
Capacity building	• It is essential to have a lot of high-quality research. Decades of research has gone into improving agricultural productivity and now the goalposts are changing. The ability to collect quality data for policy and the models that are trying to predict different climate change scenarios. We need to know where we are and what our mitigation strategies are doing so that we know what is going on. • There is a poor connection between policymakers and researchers in Wales.
Global perspectives	• Nowhere doing it particularly well. The unpredictability of the Welsh weather makes it difficult to adapt. Having lots of different options on the farm helps to manage the different types of risk.
Economic impacts	• There are going to be more extremes in weather with more unpredictability and therefore less ability to plan for things. Farmers will become more reliant on government support to cope with bad years. • To overcome the unpredictable and changeable weather patterns, farmers need to include more diversity on their farms. Having different species (crops and/or animals) means that there is likely to still be income when some things fail. A diverse farm means that farmers are more prepared for the unexpected.
Long-term planning	• Need better monitoring on farms and across Wales. There needs to be a 20-30-year plan, but plans like agricultural ones are driven by politics which only foresee the next five years. Politicians are driven by their election campaigns and cannot make promises further into the future. • In England, there is a land-use framework which includes a long-term strategy with stakeholders involved. In Wales, there needs to be an independent strategic review and monitoring.