2022

Climate Change and Food Systems: a North East Scotland Handbook

This handbook was commissioned by Professor Diana Feliciano as part of the ScotPEN Wellcome Engagement Award project: Food Systems in a Changing Climate

Produced by Iain Brown, 2022

Climate Change and Food Systems: a NE Scotland perspective

Contents

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This Handbook

This handbook has been developed to bring together information on climate change and food systems as a resource for schoolteachers when further integrating this topic into the curriculum. The aim is to help answer some of the big questions that both pupils and teachers might ask with a specific focus on what this might mean for NE Scotland and the schools involved in the ScotPEN project.

Introduction

Climate Change is probably the most important long-term problem of our times, especially for young people. It is also complex and often misunderstood. These notes highlight the major issues of climate change for food systems, both on land through agriculture and in the seas through fisheries.

The handbook therefore addresses some of the key concepts and how they can be communicated in schools, including:

- That climate change is occurring at a **global scale** but also that impacts vary at **local level**, as demonstrated for NE Scotland.
- Different local contexts also mean that **effective responses** to climate change should also vary at a local level too. Two main types of response exist, as explained below: reducing the greenhouse gases that cause climate change ('mitigation' responses) and managing the risks from climate change already occurring or expected to occur in future ('adaptation' response). Both are important and necessary.
- To think in terms of **Systems,** where different components are joined together in the real-world at different scales. Therefore, food systems link together agriculture and fisheries with climates, soils, and seas, but also people (farmers, fishers), communities, and methods of food production (meat, milk, bread etc.). Similarly, the climate can be thought of as a system, linking atmosphere, land and oceans with people and the natural world (biosphere). Changes in one part of the system therefore can affect the whole system, especially through **feedbacks** where the changes can become circular and self-perpetuating, leading to increased impacts (or potentially decreased impacts with negative feedbacks).
- To explore ideas of **Sustainability**, where problems of the present are not passed on and become even worse in the future, and that we live prosperously in a healthy natural environment.
- To also think in terms of systems when exploring different types of **responses for Food Systems** regarding climate change. This is to avoid indirect effects across the system where the problem is simply moved elsewhere or put off into the future.
- To explore different **graphical techniques** to understand climate change, such as graphs to follow changes through time, or maps to look at changes geographically.

1. WEATHER AND CLIMATE

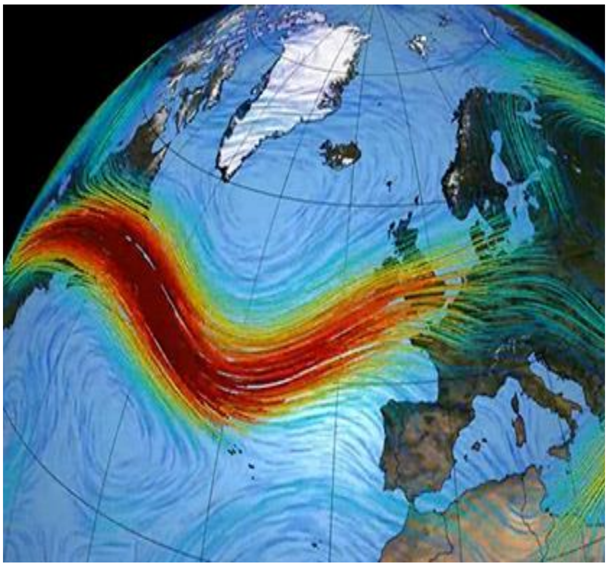
Q1.1 What is the difference between weather and climate?

Weather is the atmospheric conditions we experience every day – sunshine, warmth, cold, wind, rain etc. The science of weather is ***meteorology*** *(mainly physics, maths, chemistry)* which forms the basis for the computer models used to provide our daily weather forecast.

Climate is the general pattern of weather that occurs in a location over a longer time period (usually several years). It indicates the typical weather conditions we might expect each year during the seasons, both in terms of averages and extremes.
Differences between regional climates occur due to their position on the globe, including distance to the equator (warmer) or poles (colder), and adjacency to the sea (milder/wetter) or mountains (colder/wetter/windier). Other important influences including atmospheric circulation patterns (e.g. the 'Jet Stream') and ocean currents (e.g. the Gulf Stream), which move heat around the globe. Climate change is now altering these larger-scale influences and therefore our daily weather is also changing.

The science of climate patterns is ***climatology.*** Climatology and meteorology are used together to understand current changes in climate and weather, compared to the past, and how they will change further in the future.

The Jet Stream has a strong influence on our weather in Britain because it is a fast-flowing current of air at high altitude that forms at the boundary of warm (sub-tropical) and cold (Arctic) air. The spin of the Earth means the Jet Stream moves from west to east, generally meaning westerly winds (wind from the west). When the jet stream is directly over Britain it is usually windy and changeable, often wet as the jet stream picks up moisture and storms as it crosses the Atlantic Ocean before reaching Britain. Alternatively, the jet stream may be further south or north of Britain meaning we are in warmer or colder air, often more bringing more settled weather or several days.



The Jet Stream here positioned directly over Britain bringing strong westerly winds and potentially storm conditions (image: Crondallweather.co.uk)

More info on the Jet Stream at https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/wind/what-is-the-jet-stream

The Gulf Stream is a large ocean current that moves warm sub-tropical water from the Caribbean (Gulf of Mexico) northwards into the North Atlantic and eastwards (also due to the spin of the Earth) to reach across the ocean to western Europe. Extensions of the Gulf Stream therefore reach the west coast of Britain and in combination with the westerly winds of the jet stream is the reason for our winters usually being relatively mild (compared to equivalent locations such as Canada or Japan).

The Gulf Stream
(image: USGS)

More info at https://www.metoffice.gov.uk/weather/learn-about/weather/oceans/what-is-the-gulf-stream

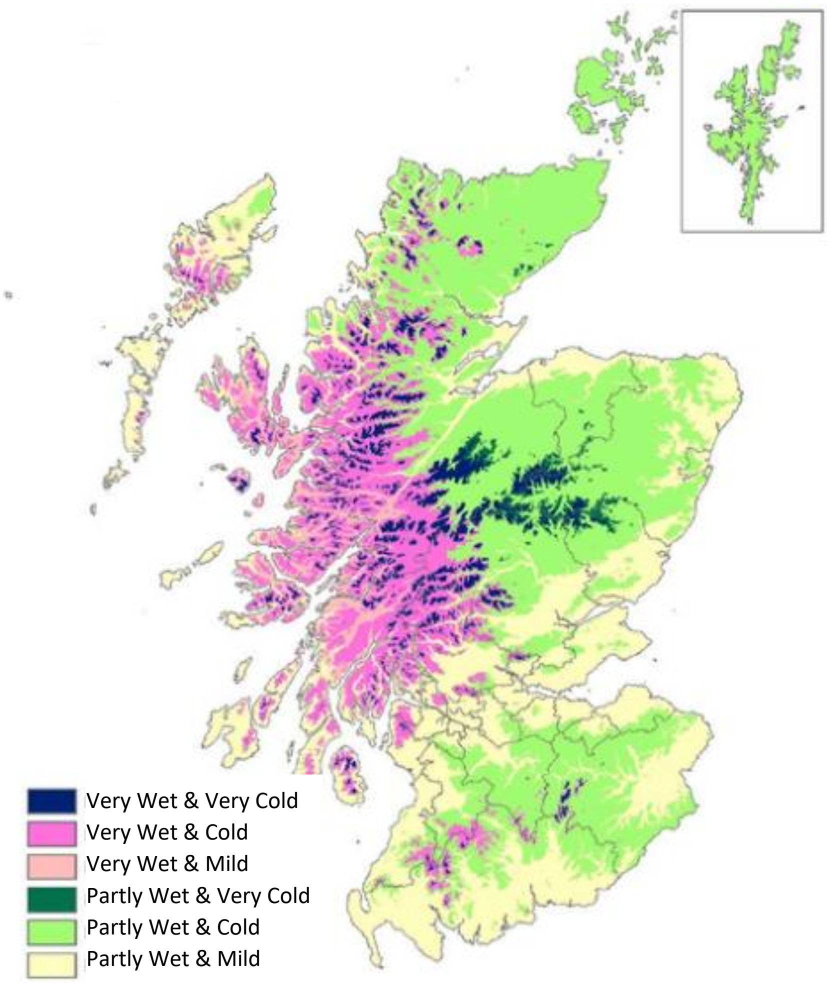
Q1.2 What is Bioclimatology and why is it important?

Bioclimate defines the local climate factors that influence living things such as soils, plants, and animals at a particular location, including crops that can be cultivated. Important factors are the length of the growing season for different plants, the availability of water, and the effects of wind. Bioclimatology therefore combines climate knowledge with biology and geography and is very important for ecology, agriculture, and forestry planning.

In Scotland, bioclimate factors are very variable but in the right locations the conditions are suitable for growing some cereals (barley, wheat, and oats), potatoes, some other vegetables and fruit, and grass (for livestock), but not other crops such as soya, rice, or avocados, which we have to obtain from other countries.

Although Scotland and the UK often have quite changeable weather conditions, our ***temperate oceanic*** climate (influenced by the jet Stream and Gulf Stream) means bioclimate conditions are normally quite mild compared to equivalent locations on the globe. However, some locations can be too wet and windy to grow crops, and it can be too cold in the mountains.

Bioclimate zones of Scotland



The main agricultural areas are in the 'Partly Wet & Mild' zone where it is warm enough to grow crops or grass for livestock, and usually with enough water but not too much. Some livestock farming (especially sheep farming) also occurs in the 'Partly Wet and Cold' zone together with other uses such as forestry.

Q1.3 How is the climate changing?

The impact of global climate change, caused by human influence, is now also affecting our local climates in Scotland. These changes will continue into the future, with the magnitude of change depending on how much we can moderate this human influence.

Climate change is usually measured against a reference period before the global Industrial Revolution that occurred in the late 19th century (although starting earlier in Britain). During this time average global temperatures have increased by 1.1C. As this an average, some locations have increased by a much larger magnitude, notably the Arctic because of the loss of ice cover. Most of the change has occurred in the last 50 years indicating a faster rate of change in recent decades. To show recent change, temperature differences ('anomalies') are often referenced to a recent average period. The graphs below show both changes for the global average and for the UK average.

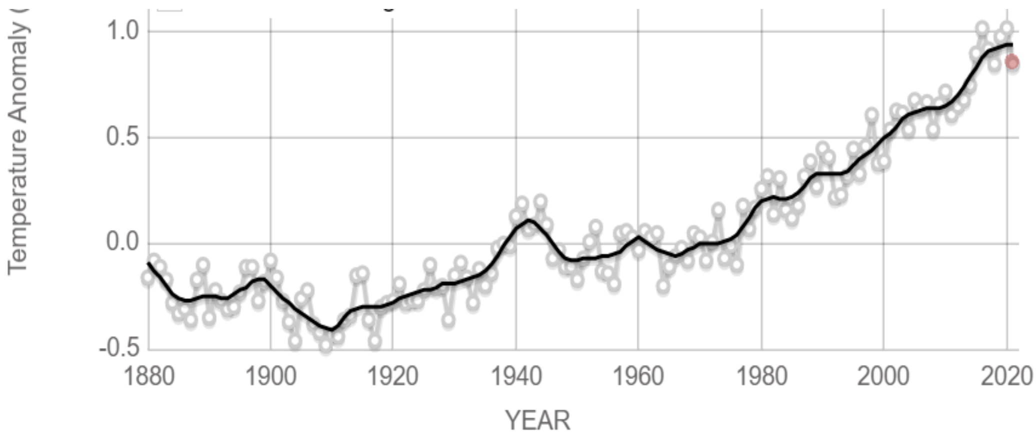


Figure 1 ***Global average temperature change since 1880 compared to the 1961-1990 average as an anomaly (source: NASA)***

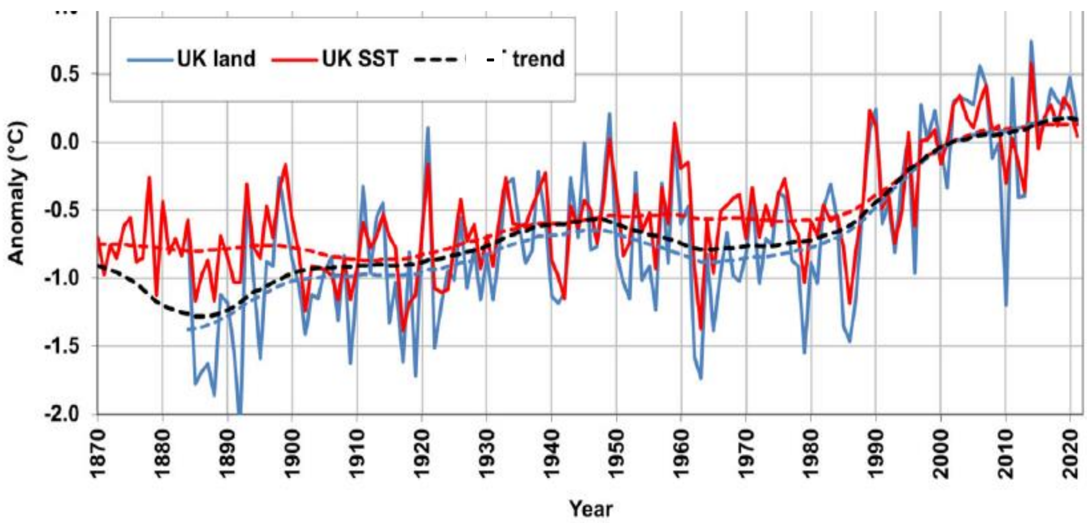


Figure 2 ***UK temperature variations and change since 1870 for land and sea surface temperatures (SST) compared to the 1991-2020 average ('anomaly') (source: Met Office)***

The map below shows how much warmer 2021 was for most of the globe compared to the 1961-1990 average period that is used to reference recent change.

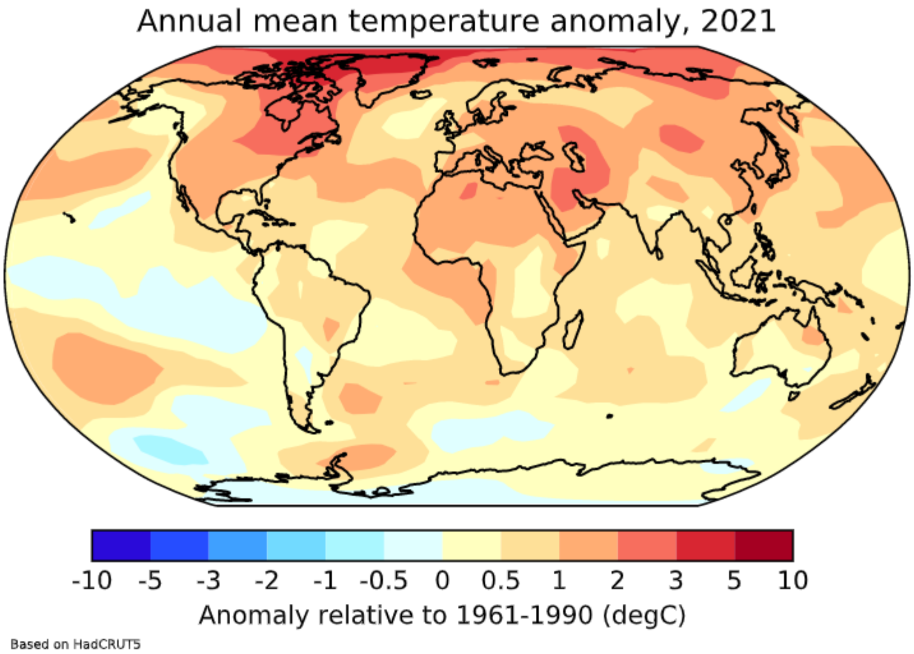


Figure 3 ***The global pattern of average temperatures in 2021 showing areas of greater warming (source: Met Office Hadley Centre)***

Q1.4 What about the sea?

The sea is also warming (see graph above). For the UK, average sea temperatures in the most recent decade (2012–2021) have been 0.7˚C warmer than 1961–1990.

Q1.5 What does this mean for our weather?

In simple terms, this means that although our weather continues to vary from day to day, we get more warm days and as occurred in 2022 more hot days that become a heatwave. Winters are not as cold as they were decades ago, therefore during most years there is less snow and ice. Although more rain is falling, it is also generally becoming more intense, so more rain falls in a shorter period of time.

Periods of more intense rainfall followed by longer dry periods seem to be related to changes in the atmospheric Jet Stream, which in turn is being influenced by a warmer Arctic and a lesser temperature difference between pole and equator. As the temperature difference is the driving force for the Jet Stream, then the reduced temperature gradient means that the Jet Stream is often becoming wavier, and the same weather pattern can persist for longer over an area compared to the past. However, there is also some evidence from the transition seasons (spring and autumn) that the Jet Stream is also becoming more intense over time, meaning there is potential for increased storminess.

Regarding the Gulf Stream, recent variations are more difficult to understand because we do not have good records of long-term changes in the oceans. However, the best evidence suggests that the

Gulf Stream will slow down in coming decades which is also likely to affect our weather whilst also have a major influence on marine life.

Q1.6 How do these changes in climate affect the Natural World?

Although many of us do not notice these changes much, some people do, especially farmers and fishers, because of their close contact with the natural world. This is because even small climate changes can have a big effect on plants and animals. Changes in the seasons mean that the growing season starts earlier in Spring, and this then affects other seasonal events that follow during the year. Similarly, changing rainfall patterns influence water availability or the frequency of flooding.

We can see these changing timing of the seasons in natural events. Although there is still a lot of variation from year to year, we also see a general trend over the longer term. In Spring, events such as plant budding/flowering, leaves on trees, or arrival of migrant birds such as the swallow or cuckoo are all occurring earlier. This can then affect events later in the year such as when berries are ripe on plants. or crops are most suited for harvesting, which may also occur earlier. However, some Autumn events are getting later such as leaf fall from trees, or the departure of migrant birds to other countries or different locations because of the warmer temperatures.

The scientific study of these changing events is ***Phenology,*** which everyone can join in with by recording their own local seasonal events. This can make a very good school project! One of the most popular annual surveys is Nature's Calendar which has now been running for over 30 years. The graph below shows the combined first flowering date for multiple species across the UK counting from January 1st, also showing particularly notable years that had early or late flowering. There is a lot of variation from year to year but also a clear trend towards earlier flowering. This means that the first flowering date is usually a month earlier than it was before 1980, typically occurring in April compared to May or June before. For NE Scotland, which is often later than the rest of the UK, for some flowers this may mean flowering now in May compared to June previously.

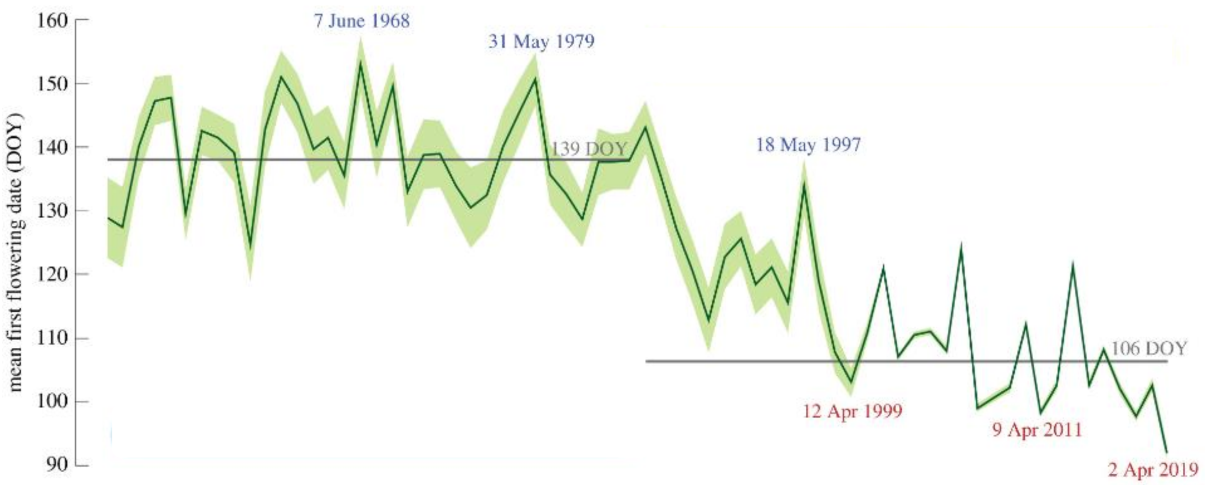


Figure 4 ***Average UK first flowering date (*****Büntgen et al., 2022**[1]**). Data** ***from Nature's Calendar project (https://naturescalendar.woodlandtrust.org.uk)***

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[1] Büntgen U, Piermattei A, Krusic PJ, Esper J, Sparks T, Crivellaro A. 2022 Plants in the UK flower a month earlier under recent warming. Proc. R. Soc. B 289: 20212456.

Q1.7 Why is climate change occurring?

It has been known by scientists since the 19th century that some of the gases present in the atmosphere can absorb heat energy and radiate this back to earth. These *greenhouse gases* act to maintain our planet at a reasonable temperature for life on earth (by comparison the moon with no atmosphere is very cold, about -18˚C!). The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water vapour (H_2O) – their heat absorbing properties can be confirmed with laboratory experiments.

Over the last 150 years, measurements have shown that the human race has been increasing the proportion of greenhouse gases in the atmosphere. This is particularly the case for CO_2 (increased by more than 50%) from burning of fossil fuels (coal, oil, gas). Amounts of CH_4 and N_2O have also increased, and these having a lower concentration in the atmosphere they have a stronger warming effect.

The science is therefore quite clear that more greenhouse gases in the atmosphere is the primary cause for global warming and climate change over the last 150 years (other influences such as changes in solar radiation and volcanic eruptions occur over shorter periods and are often referred to as natural fluctuations). Atmospheric water vapour is less directly affected by humans' activities but is indirectly affected because warmer air can hold more water vapour – this is therefore an example of a positive **feedback** where a small initial change can then lead to other changes and produce a greater impact. There are many types of feedback between the atmosphere, biosphere, and oceans that influence regional and local climates, and these have the potential to mean that climate change passes a certain threshold where the climate becomes increasingly unstable (sometimes referred to as 'tipping points').

Q1.8 How will the climate change in the future?

The climate will continue to change in the future because most of the greenhouse gases we are releasing now (especially CO_2) will stay around for a long time in the atmosphere and continue to have a warming effect on the planet. However, the magnitude of change will depend on 2 crucial issues:

- The amount of greenhouse gases we release from now onwards and whether we can significantly cut back on these emissions by moving to alternative energy sources (for power, transport, food systems etc.)
- The capacity of the natural world to absorb some of the excess carbon from the atmosphere. Plants take in CO_2 during photosynthesis which accumulates in plant tissues as biomass. Dead plants and animals transfer organic carbon to soils and ocean sediments, whilst CO_2 is also naturally absorbed by the oceans. This natural storage capacity has limits but it can be enhanced by actions in the right places (e.g. tree planting; wetland restoration; coastal and marine habitat restoration). This can help slow down the rate at which greenhouse gases build up in the atmosphere and therefore reduce the magnitude of climate change.

There are important uncertainties related to these 2 issues. We do not know whether, and by how much, countries will abide by international agreements to reduce greenhouse gases (see below).

Also, the limits on the capacity of the natural world to store carbon are not fully understood and these limits will also be affected by how much the climate changes now and in the future.

Q1.9 What is the importance of 'Net Zero'?

Many countries are aiming for a future pathway in which the release of greenhouse gas can be balanced by the carbon storage capacity of the natural world. This would mean that the concentration of atmospheric greenhouse gases would stabilise. This is the **NET ZERO** pathway. Scotland is aiming to reach Net Zero by 2045, and the UK by 2050, although we are currently a long way off this pathway at present.

Q1.10 What is the role of international agreements?

Climate change is a global issue because all of the planet is affected. Some countries, notably more developed industrialised nations, have contributed more than others regarding changes in atmospheric greenhouse gases. Conversely, some countries are already more severely affected by climate change, including small island nations threatened by rising seas, and African, Caribbean, or Asian countries experiencing extreme heat, storms, and drought. Consequently, climate change is also an issue of fairness, equity, and international responsibilities between countries.

The United Nations takes the lead on developing international agreements on climate change and sustainability. Under the UN Framework Convention on Climate Change, regular meetings of countries (i.e., the 'parties') are scheduled to try and agree on pathways to resolve the global climate crisis, these are the Conference of the Parties (COPs).

The United Nations 2015 Paris Agreement from Cop21 states that countries will collaborate to keep global average temperature changes below 2˚C compared to pre-industrial levels and make additional efforts to keep this change to 1.5˚C. However, despite pledges by countries to reduce greenhouse gases (including declared commitments to deliver 'Net Zero'), much more needs to be done to convert these pledges into the reality of verified actions. The current position is that global average temperatures will probably increase by 2.5- 3.5˚C, and possibly as much as 4˚C, unless pledges are turned into meaningful actions and then followed up by continuing actions to keep reducing greenhouse gases from now until 2050.

The United Nations 2021 Glasgow meeting (COP26) made some further progress on implementing the Paris Agreement, but significant barriers remain (COP27 in Egypt again only made limited progress on these). The UK and Scotland have so far made good progress on reducing their greenhouse gas emissions, but often this has occurred through developments that were already occurring (e.g., phasing out of coal). In addition, some of the reduction in UK greenhouse gases have occurred because we have transferred their production to other countries, but we still use and consume the end-products. For energy sources, a major transition to renewables (wind, solar, hydro, wave) is already way, but some other important greenhouse gas sources, notably in transport and **agriculture** have made much less progress. **Food** systems as a whole (including transport etc.) are now estimated to contribute **35%** of the UK greenhouse gases, and this proportion is increasing as other contributors are declining.

Q1.11 What does this mean for North-East Scotland?

Future predictions of climate change are usually provided as a range of values that depend on assumptions about the key issues described above.

For example, for **ABERDEENSHIRE,** temperatures on the hottest day on record reached 31˚C. This occurred in Aboyne during the heatwave in 2022.

If, in future, countries can meet their pledges consistent with the Paris Agreement and further develop these to meet the Net Zero target by 2050 or earlier, then the hottest summer days could be limited to about 32°C. The rainiest day could also be limited to an increase of 30% more rainfall than now.

However, if pledges are not kept and we continue on the current pathway, then the hottest summer days by 2050 are likely to exceed 35˚C and the rainiest days could be 50% wetter than now. It is also very likely that the climate will be much more volatile so that droughts are also more frequent in some years. As a consequence, the range of climate change impacts will unfortunately be much more severe on this pathway and much of these impacts will fall on future generations.

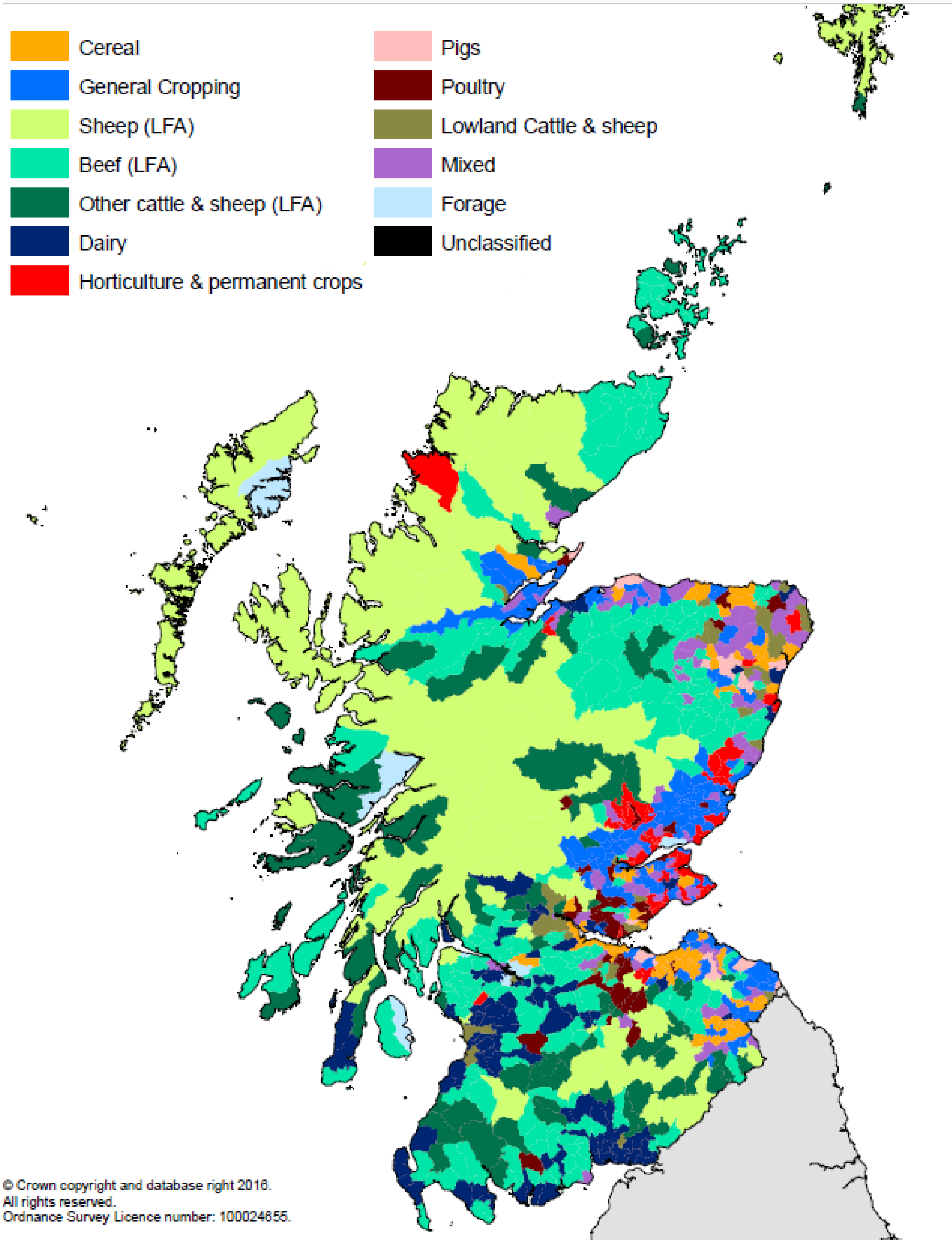
2. FARMING AND CLIMATE CHANGE

Q2.1 What food do we produce from farming locally?

The UK is about 65% self-sufficient in producing its own food and the remainder is imported. The main produce are cereals (notably wheat, barley, oats), potatoes and some other vegetables, beef, lamb, and dairy products. Most fruit is imported.

In Scotland, the better-quality land is mainly in the east and is primarily used for arable crops, particularly cereals. Livestock farming based on grassland is more common in the west where it is wetter.

The main farm types in Scotland (dominant farm type per parish)



source: Scottish Government

Much of the arable land in NE Scotland produces cereals. Barley is the most common crop, although much of this is used by the drinks industry (malt whisky etc.) rather than for food, and similarly with wheat. The quality of the crop can vary from year to year depending on the weather, especially regarding warmth and moisture. Potatoes and other vegetables are also produced on good quality arable land and some places grow local fruits such as strawberries and raspberries. Oil seed rape is grown to produce vegetable oil.

Good quality pastureland in NE Scotland is used for beef production although some locations also specialise in dairy produce (milk etc.), particularly around Aberdeen. In the hills and usually on lesser quality pastureland, sheep are more common. Some locations are now also specialising more in chicken and pig production.

In the past, mixed farming with both crops and livestock on the same farm was very common, with animals fed using fodder crops (turnips etc.) and animal manure used as fertiliser for the crops. Today this is much less common, and farms tend to be more specialised. Arable farms use large amounts of artificial fertiliser to grow crops and many livestock farms use imported feeds (notably soya from South America) to supplement or replace grass.

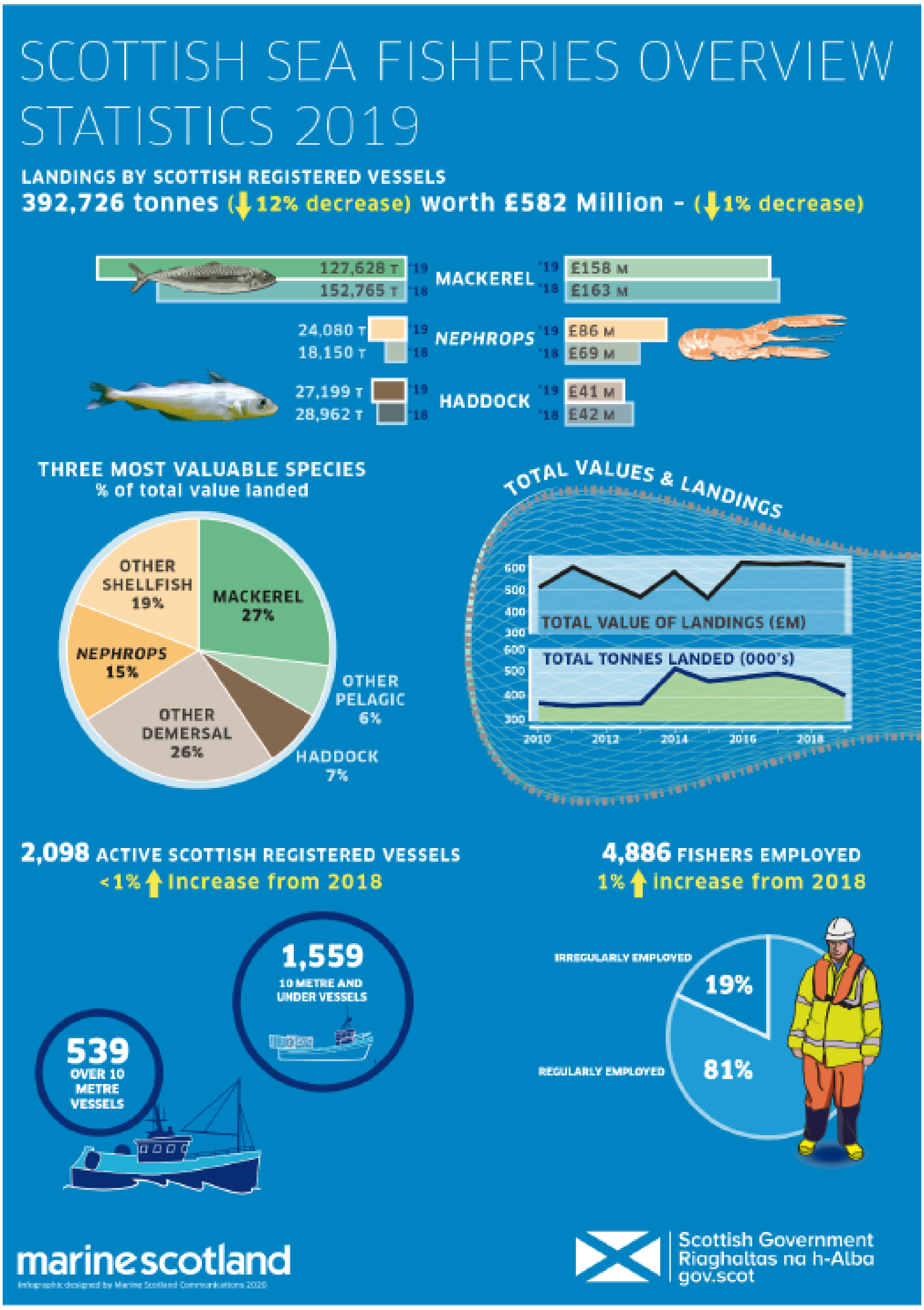
Figure 5 ***Arable land (mainly cereals) at harvest time: the Garioch (Inverurie area), one of Scotland's most fertile areas***

Figure 6 ***Pasture and livestock farming, Orkney***

Figure 7 ***Upland hill farming (mainly sheep), Glenlivet***

3. FISHERIES IN SCOTLAND

Q3.1 What type of fish are caught in Scotland?



Fish landed in Scotland are mainly caught in the northern North Sea (as far north as Shetland and Norway) and in the Atlantic waters offshore of the Hebrides and west coast mainland. The 3 main categories of fisheries are:

Pelagic fish – which live neither close to the surface or the bottom of the sea. Mackerel is the main pelagic fish caught now, with herring also being fished in lesser numbers (the herring fishery was much larger in the past, especially in NE Scotland, but suffered from overfishing – see below). Other fish caught include blue whiting and horse mackerel.

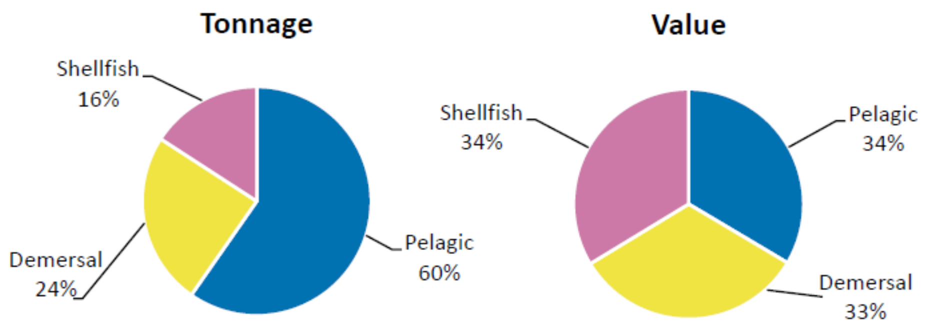
Demersal Fish – these are bottom-feeding fish and include the traditional species of haddock and cod, together with newer species such as monkfish. Other demersal fish caught in Scottish waters include ling, hake, plaice, skate, saithe, sole, megrim, whiting, turbot, John dory, and pollack.

Shellfish – the majority of these are Nephrops (lobster family) but also include Scallops. These fisheries are of high value but much of the catch is exported to other countries. Nephrops caught in creels in inshore fisheries typically represent a smaller tonnage of landings but can have a value more than three times that of trawled Nephrops.

Edible crabs, velvet swim crabs and lobsters make up a small proportion of overall value landed by Scottish vessels but are important for Scotland's large inshore fleet. Other shellfish include razor fish and whelks, with squid also included and increasing in terms of overall catch size.

Fisheries landings in Scotland

Pelagic fish are generally of lesser value compared to demersal fish and shellfish, therefore despite a greater volume of fish caught the overall value is about the same for all 3 types.

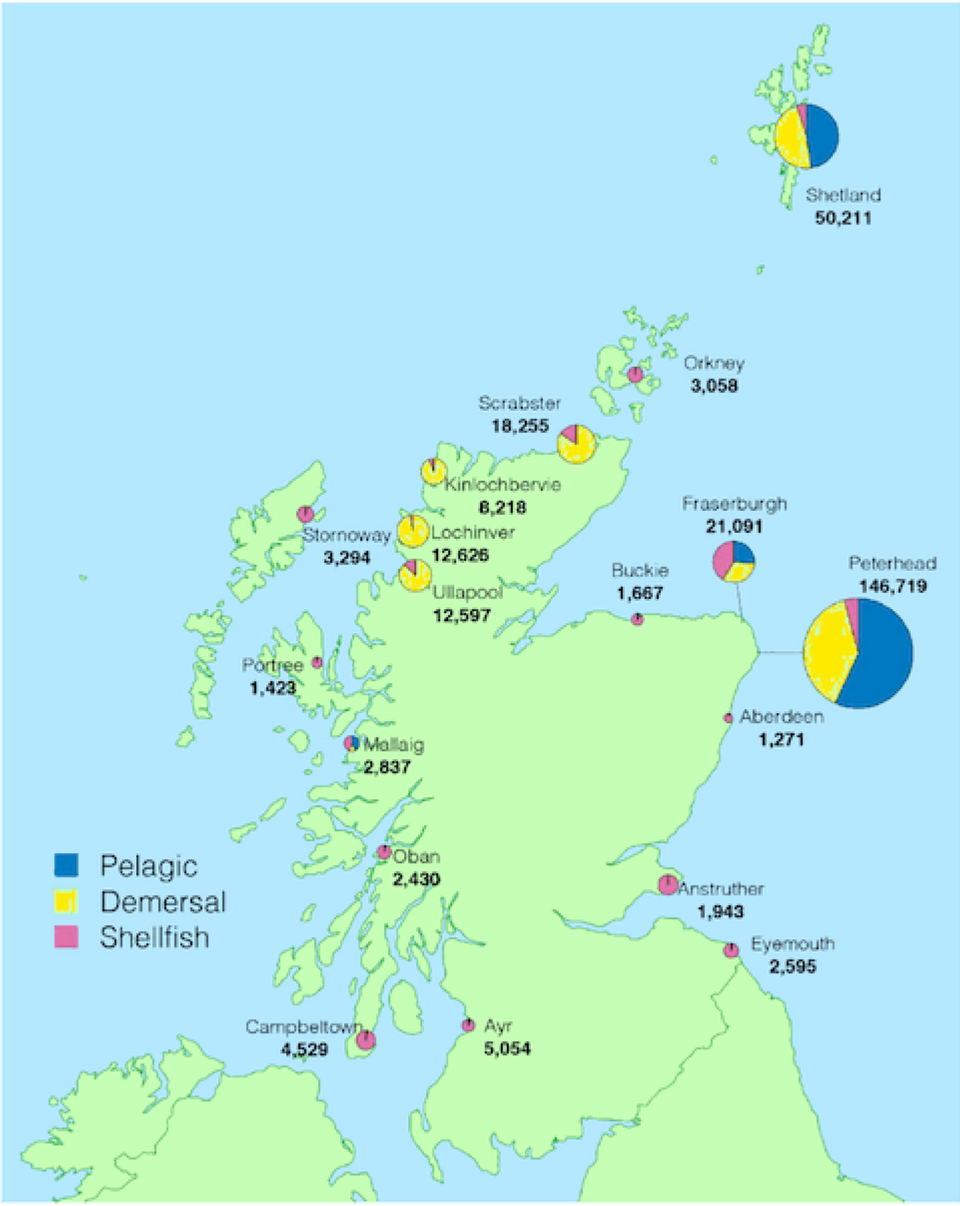


2019 summary

Q3.2 Were are the fish landed in Scotland?

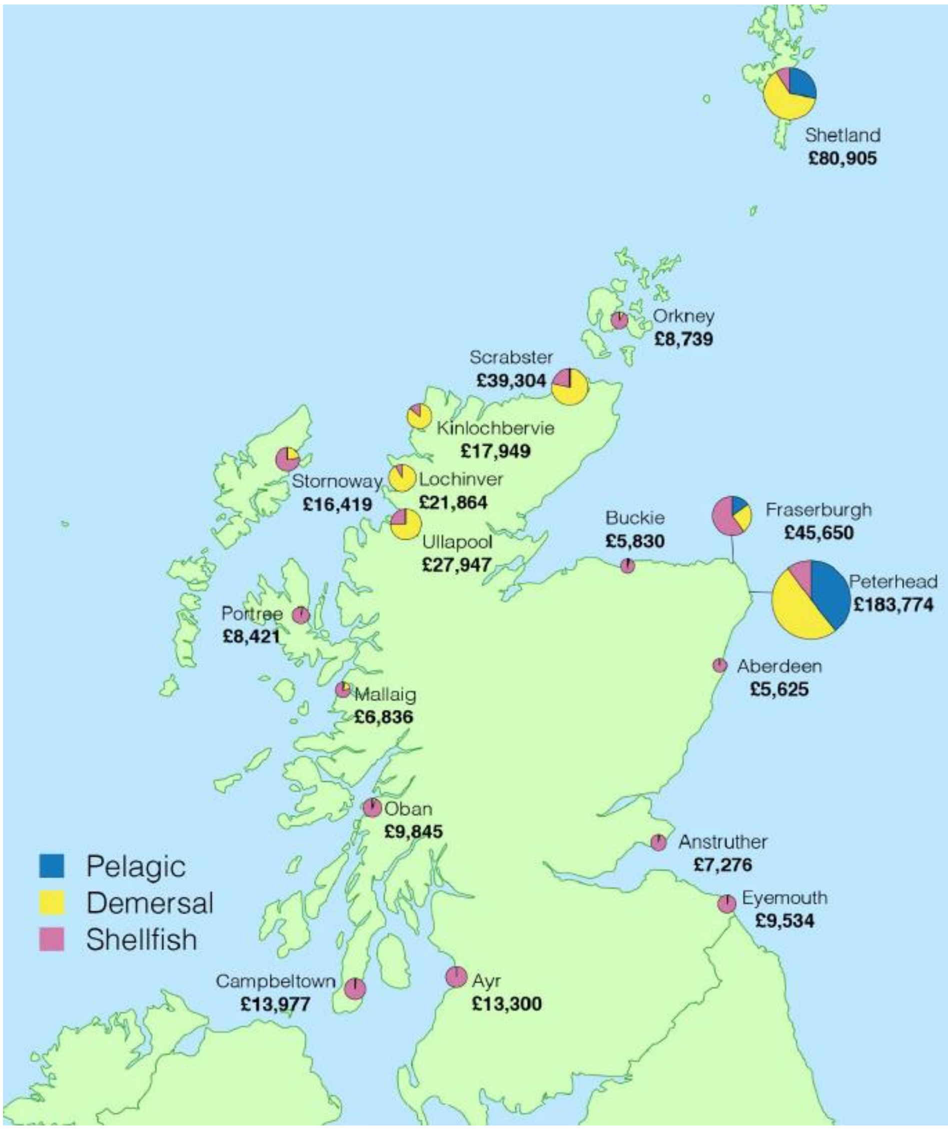
Fish landings are summarised by fishing districts. **Peterhead** is by far the biggest fishing port and district in Scotland, followed by Shetland and then **Fraserburgh**. Peterhead mainly handles pelagic fish whereas the Fraserburgh district ports (**Fraserburgh, Whitehills, Rosehearty, Gardenstown, Pennan, Portsoy and Macduff)** also handle a sizeable proportion of shellfish and demersal fish. Further west along the coast, Buckie is also an important fishing port, and some fish are landed at Lossiemouth. Fish are also still landed at **Aberdeen** although this is now mainly used by the oil industry, and further south fish are landed at **Catterline, Johnshaven, Gourdon, Stonehaven and Montrose.**

Volume of Fish Landings Scotland 2019 (in tonnes)



Source: Scottish Government

Value of Fish landings Scotland 2019 (in £ thousands)



Source: Scottish Government

Q3.3 How sustainable are fish stocks?

The sustainability of fish stocks measures whether the number of fish caught at present can be continued at this level into the future without a major decline in fish populations. This information is based on catch levels and fish reproduction rates, now also being updated to allow for the impacts of climate change. Sustainability of fisheries varies considerably between different fish species and also the location where they are caught. The Marine Conservation Society publish the Good Fish Guide which gives advice on fish and from where they are sourced in terms of whether that fishery is sustainable. This is based on a regular assessment of existing fish stocks relative to the volume of fish that are caught. The Good Fish Guide indicates where fish stocks are in danger of overfishing and therefore potentially lost for the future.

You may see the MCS logo at your local fish & chip shop. MARINE CONSERVATION SOCIETY | Good Fish Guide

Sustainability of Fish Stocks: The Herring Fisheries in NE Scotland

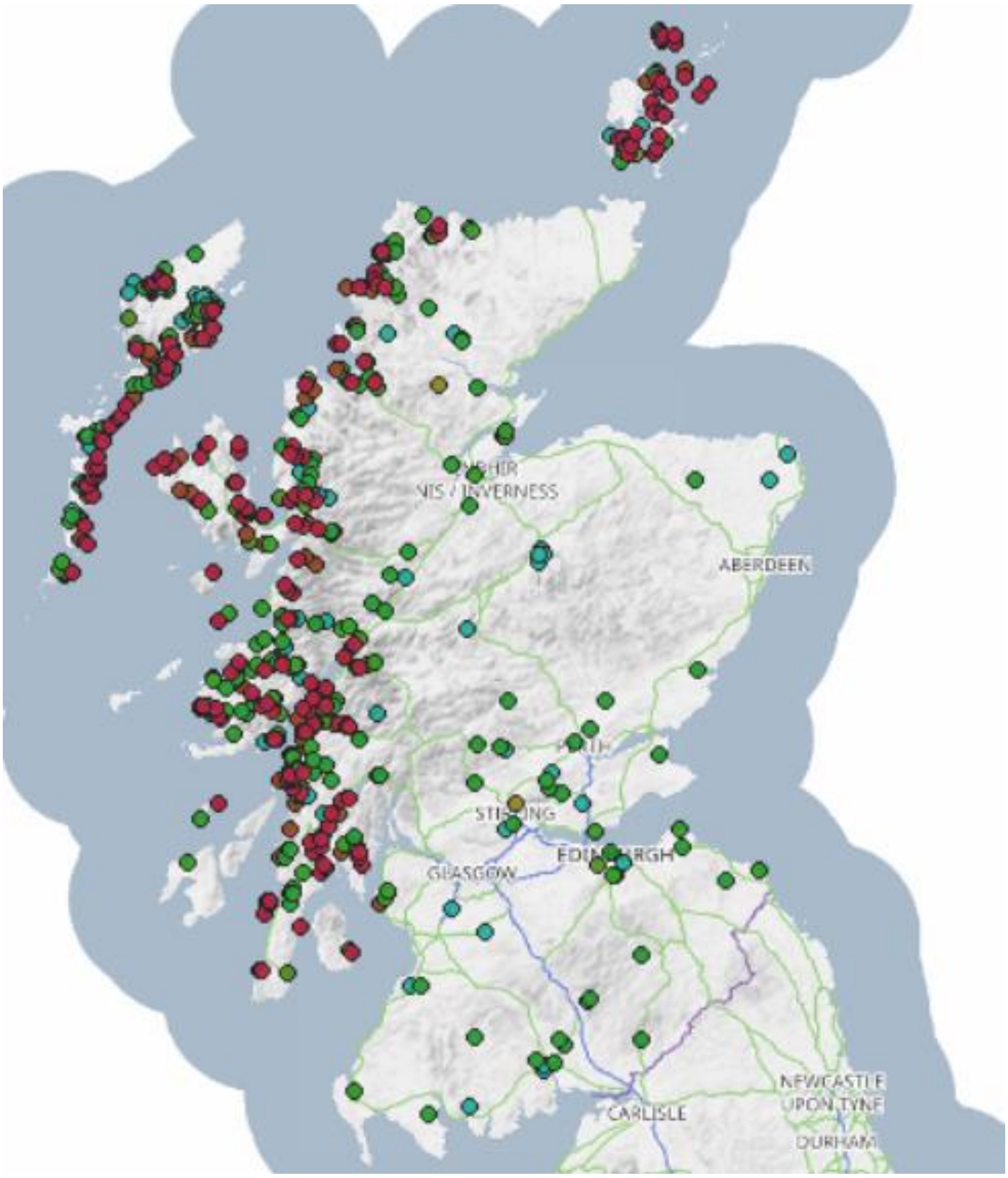
Figure 8 ***Fraserburgh harbour in the 1880s (source: Scottish Fisheries Museum, Anstruther)***

A lesson from the past on the sustainability of fish stocks is provided by the herring fisheries. These had a crucial role in the cultural history of NE Scotland but suffered a very severe collapse, particularly in the 1970s, due to overfishing. Some recovery has occurred since then, but the fishery is still much smaller than it was then.

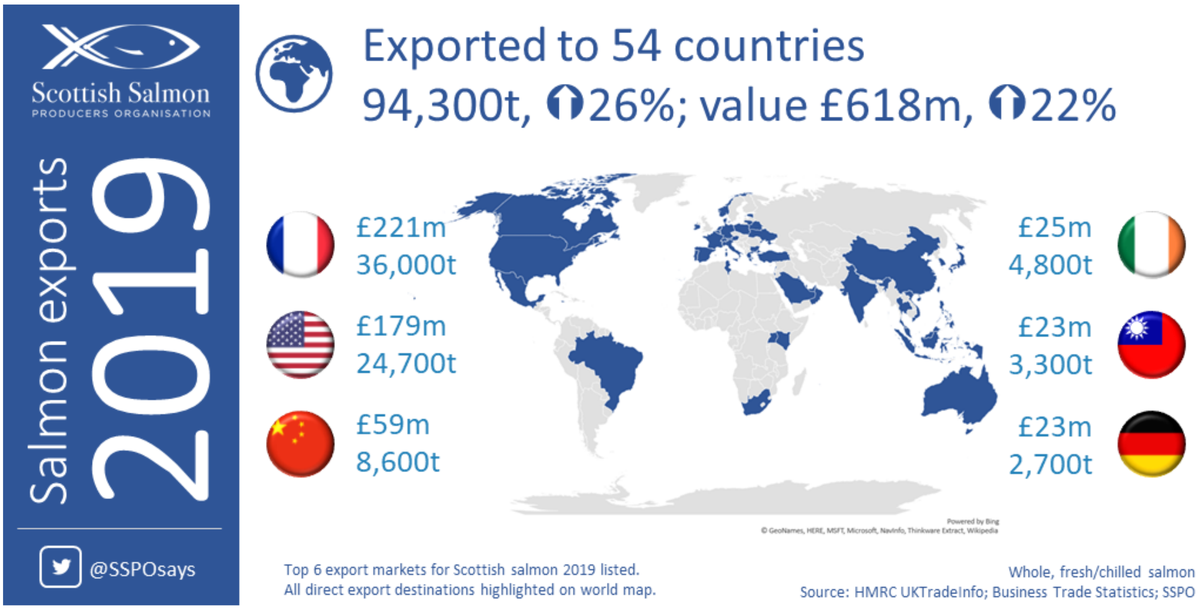
As with many fish, herring have a relatively complex life cycle and this is a key consideration is understanding fish populations, reproduction rates, and the likely effects of climate change. Young fish larvae spend their first winter drifting towards nursery areas in the North Sea that include the Moray Firth and Firth of Forth, although in some years the sea conditions mean many do not reach the nursery areas. Some of the herring in the North Sea nurseries also originate from the north and west coasts of Scotland. As they grow, the juvenile herring move offshore, eventually joining the adult populations that migrate to feed and spawn in the western areas of the North Sea. For these reasons, the number of fish varies from year to year, and a sustainable catch quota needs to be regularly adjusted to match these variations. Climate change is now further altering these migration patterns.

Aquaculture

At present, aquaculture is mainly based on the west coasts of Scotland and in the Northern Isles, although the Scottish Government have plans to double production by 2030. Most production is farmed salmon, usually in the se although some freshwater sites also exist, whilst some locations also specialise in shellfish production.



***Aquaculture and fish farm sites in Scotland [(http://aquaculture.scotland.gov.uk/](http://aquaculture.scotland.gov.uk/)**)*



Atlantic salmon

4. IMPACTS OF CLIMATE CHANGE ON FARMING FOOD SYSTEMS

Q4.1 What are the impacts of climate change on farming and food production?

Based upon both present and expected future changes in our climate that we described above (section 1), the following issues are identified for the farming and agri-food sectors:

4.1.1 Heat stress and heatwaves

As the climate warms, we are getting more hot days and longer sequences of hot days occurring as a heatwave, as occurred during 2022 in Britain when we had record high temperatures. If temperatures become too high at critical times of the year, for both crops and livestock, this can cause heat stress. For example, cereals can be negatively affected by heat stress at the time of flowering (early summer) which reduces photosynthesis and damages grains and leaves. This results in lower yields at harvest time, affecting farmers' incomes together with consequences for food supply and higher food prices. During 2022, many areas of the world that grow wheat have had negative impacts from high temperatures and as a result produce such as pasta have become much more expensive. Livestock can be especially strongly affected when heat and high humidity occur together, and this can result in reductions in daily milk production from dairy cattle.

4.1.2 Water shortages and drought

Another feature of recent climate change is that farmers are reporting that rainfall in their local area is occurring more irregularly compared to the past. This means that there can be lengthy dry spells with no rain, especially in summer, followed by episodes of intense rainfall. A notable recent year was 2018 when it was very dry in summer in NE Scotland. As a consequence, soils and ponds dry out and rivers become very low. Plants and animals require a regular supply of water therefore shortages can cause major problems for farmers. It takes an average of 1500 litres of water to produce one kilogram of cereal grain. High-value crops such as fruits, potatoes, and salad vegetables require even larger amounts of water to maintain their quality. Livestock can become more vulnerable to heat stress when less water available.

Many crops are supplied with additional water from irrigation during dry spells. However, long dry spells mean that there are limits on the amount of irrigation water available for farmers because the licensing system is intended to ensure there is enough water available for both people and the environment. These irrigation restrictions can therefore limit production of some crops whilst water availability restrictions can reduce the overall quality of crops, which in turn affects farm incomes and food supplies. Farm animals also require large amounts of water and therefore additional water tanks have to be provided when natural supplies run dry. With future climate change we expect more droughts to occur and these types of water-related problems to occur more often unless there are changes in farm management.

Figure 9 ***Crop irrigation***

4.1.3 Flooding and waterlogging

Rainfall events are also becoming heavier and more intense which is increasing problems with flooding. This is particularly a problem during winter when we have more rainy days but can occur at any time of year. A very severe example was Storm Frank which hit NE Scotland in December 2015, causing much damage to buildings and farmland. Flooding of farmland means that crops and even livestock may be lost if they cannot be quickly moved to higher ground. Even when not flooded, the land can remain waterlogged for long periods of the year. This means that farmers cannot access the land with tractors and other cultivation machinery because to do so would damage the soil and cause even more problems for the future that would limit production. Waterlogging also causes damage to crop roots and reduces plant growth, whilst livestock can be more vulnerable to pests and diseases that are more prevalent in wetter conditions (see below).

Figure 10 ***Flooding of cropland***

4.1.4 Pests and diseases

Warmer weather is meaning that formerly exotic pests and diseases are becoming more common on farmland. In many cases this is particularly due to the trend of milder winters which means that there are fewer ground frosts than in the past. For a farmer, frosts have the benefits of eliminating pests in the soil that prey on crops and livestock, or which transmit diseases. As a consequence of fewer frosts, we are getting more problems with pests and diseases. For example, liver flukes are a parasite that cause severe disease in sheep and cattle and can even spread to humans. Another example is bluetongue disease in cattle which is spread by midges. Similarly, there is now a much greater incidence of ticks in Scotland, which in addition to affecting animals can also prey on humans and are associated with the spread of Lyme Disease and encephalitis. Many crops are also affected by fungal diseases in warm wet weather, such as mildew and fusarium, or potato blight, which can all cause severe crop production losses.

Pest insects and other nuisance species from warmer countries can arrive in Britain through trade in seeds or food produce, then become established and spread due to the generally warmer conditions and lack of native predators. If this spread occurs rapidly and before preventative measures are in place, then pests and diseases can cause severe impacts on food production. A notable example is the Colorado beetle which is a major pest of potatoes.


Colorado Beetle


Potato blight

4.1.5 Soil Damage and Loss

Soils are crucial to farming because they provide the materials, nutrients, and moisture for plants to grow, including good quality grass for livestock. Farmers therefore know that it is good practice to look after their soils, but climate change is making this harder. This is particularly due to more intense wet and dry spells.

Heavy rainfall events can cause erosion of the soil meaning it is washed away into rivers and streams. Similarly, when soils are bare, strong winds can also cause soil erosion – this occurs relatively frequently in NE Scotland during the spring when strong winds can produce sandstorms from the bare fields, sometimes leading to roads being blocked by eroded soil.

Problems can also occur when farmers use machinery when soils are still wet and saturated, or there are too many livestock on the land. In these cases, the soil becomes compacted at the surface. This means there is less space for air in the soil which plant roots need to grow and access nutrients. It also means that rainwater cannot infiltrate into the soil, and it accumulates on the surface, causing waterlogging and further problems for field access by machinery.

Soils take a long time to form (hundreds of years). Loss and damage to soils therefore become a permanent problem that affects overall soil fertility and crop production. The organic material (humus) in the soil is particularly important for soil fertility and plant growth because it maintains the soil structure (including aeration for plant roots to function) and helps to retain the nutrients which plants need to grow effectively. Maintaining soil quality is therefore a crucial management issue for farmers.

Figure 11 ***Wind erosion of bare fields in Moray (source: BBC)***

4.1.6 Wildfire

Wildfires occur during dry spells when the vegetation is also dry and flammable. This occurs mainly during spring and summer. Due to climate change, we expect that the dry weather conditions conducive to wildfires will increase in the future. We are already seeing the early warning signs of this change, especially because the number of large wildfires is increasing. Although most wildfires occur on moorland and woodland, they can also occur on cropland and grassland. On agricultural land they can be started accidentally by machinery, such as by combine harvesters or striking stones during harvest-time in cereal fields, or by carelessness (cigarettes, barbeques etc.).

In 2018 which was a bad year, the insurance costs from wildfire on agricultural land reached £32 million in the UK. It is likely that the costs for 2022 will be even higher because there have been several large wildfires.

Figure 12 ***Wildfire in corn field (source: Claire Belcher)***

4.1.7 Changes in Food Crop Nutritional Value

Climate change appears to be impacting the nutritional value of some food crops. The implications are yet to be fully understood because climate is acting together with other factors, and it is likely that some crop varieties are more sensitive than others.

However, we do know that important food crops such as wheat are affected through changes in their protein content and in zinc and iron content. These constituents and trace elements in food crops contribute to the overall nutritional value of our diet because the human body requires basic amounts of these constituents to function effectively.

These impacts on nutritional value are a consequence not only of changes in warmth and moisture, but also increases in atmospheric CO_2 which affects plant photosynthesis and development of crop grains. A notable example is wheat because it is a crucial staple crop, used in everyday foods such as bread. Any changes in crop nutritional value can therefore have health implications, particularly for people who have specific dietary requirements. There are also signs that the nutritional value of grass is changing which can have implications for the nutritional quality of livestock products (meat, milk etc.) from animals reared on that grass.

4.1.8 Difficulties for Farm Planning

Farmers use advance planning to decide the crops they are growing and the number of livestock to manage on their land. However, the changing climate is causing increasing problems for farm planning, in combination with other factors (e.g., energy/fuel costs), because farmers see the weather becoming more unpredictable compared to the past. This means that their past experience of what works best on the farm through the year and how different field are managed is becoming less useful. For example, will next year be a relatively wet year or dry year, and what does this mean for the success of different crops or the quality of grass to rear livestock? Farmers are facing increasing challenges due to irregular weather patterns, such as a long dry period (sometimes becoming a drought) when water availability is a problem, followed by heavy rainfall when there is too much water and flooding can occur. In these circumstances, relying on just one crop can become increasingly risky but the general trend has been towards farm specialisation due to economic factors.

These difficulties are causing that the availability of some foods to becoming more volatile because they require consistent and stable weather conditions. In extreme circumstances, when availability is affected over larger areas, shortages can occur, and the price of these foodstuffs will increase.

4.1.9 Knock-on Effects - Human Health and Wildlife

Producing crops and animals for food is increasingly intensive on most farms. To maintain production, significant amounts of fertiliser are used (either chemical or organic fertiliser) and pesticides are usually applied to control pests and diseases. Unfortunately, without very careful management, fertilisers and pesticides can also be released to the wider environment beyond the farm. This is particularly a problem during water runoff from heavy rain (which is often becoming more frequent). Fertilisers and pesticide runoff from farmland can have serious implications for water quality, including both drinking water supplies and bathing waters, but also for wildlife in streams, rivers and lakes. In addition to direct toxic effects from pesticides, excess release of nutrients from fertilisers can cause large algal blooms in lakes and coastal waters, with risks to human health and to wildlife.

Although usually pesticide applications are carefully controlled to avoid people, release into the air can be toxic to wildlife beyond the target pest species. This is notably a problem for insects such as bees which are crucial for a healthy ecosystem. Similarly, if fertilisers are applied at the wrong time, large amounts of ammonia can be released to the air. When ammonia is combined with other pollutants in the atmosphere it can produce very harmful smog, especially for large towns and cities during hot and stable weather conditions when the pollution accumulates in the same place. This can be particularly harmful for people with respiratory problems and there is some evidence to suggest that it may have made the spread of Covid-19 worse in some locations.

Intensification of production systems on farms has also meant that less habitat is available for wildlife, such as field margins, hedgerows, and wetlands. Lack of food and shelter for wildlife, combined with the additional pressures from a changing climate, means that farm wildlife has decreased. Perhaps the most notable example of this has been the severe declines in many farmland bird species.

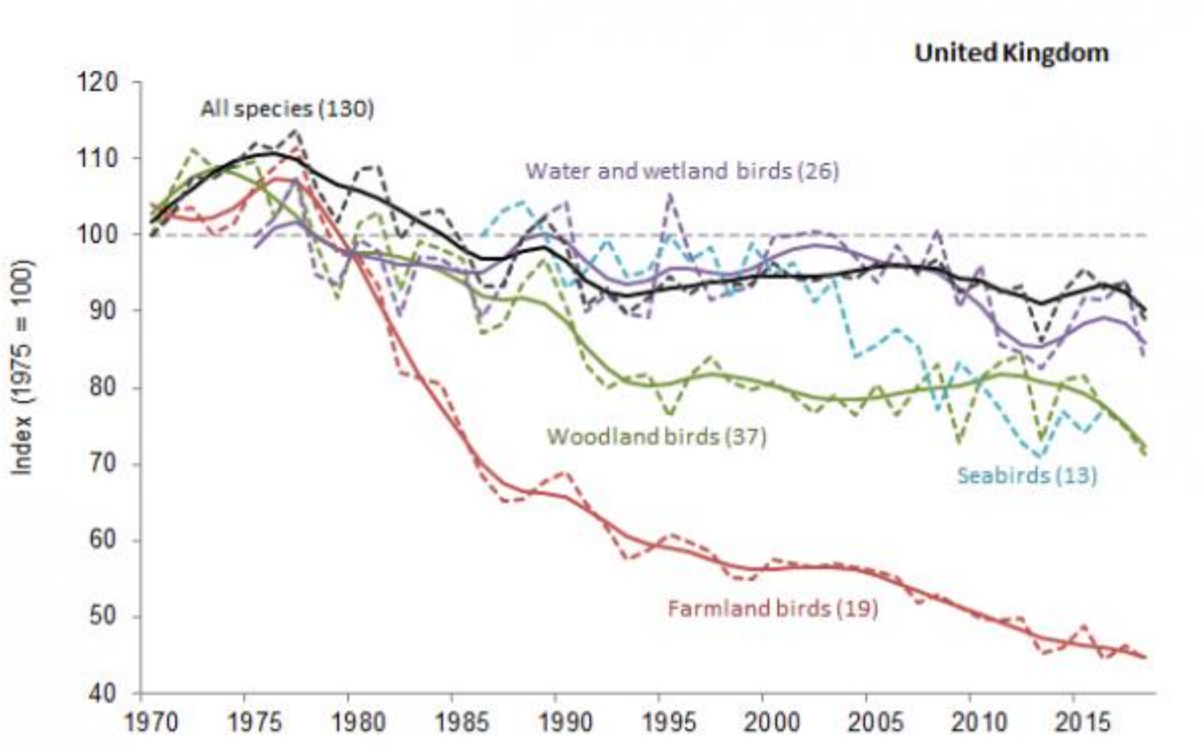


Figure 13 ***Indexes for changes in different bird groups in the UK (based on an aggregate number of species). Farmland birds have experienced the most severe declines in recent decades (source: UK Government)***

5. FARMING & FOOD SYSTEMS: WHAT CAN WE DO?

Farming needs to be able to change so that it is better able to adapt to changing weather and climate. It also needs to change its practices to reduce greenhouse gas emissions that contribute to climate change, consistent with the Net Zero 2045 commitment for Scotland.

There are a range of strategies that can help to achieve this and continue to supply food. However, if we also look more broadly across the food system, there is also a role for all of us as food consumers in also being involved in this transition, especially by changing the demand for different agricultural products.

Here are some of the options on how farming and agricultural food systems could respond to climate change and also contribute to the global agenda to live more sustainably, maintaining Earth's resources for future generations. These options can provide a good discussion forum for actively thinking what farmers and all of us can do to tackle climate change. Some might be considered more viable options compared to others, but will they deliver the outcomes we need to make an actual difference?

Option 1: New crops & crop varieties

This option is focussed on developing and growing new crops (or different varieties of crops) that are more resilient to the changing climate conditions (both now and in the future), whilst also contributing to the goal to reach Net Zero emissions. For example, this could include crops that can better withstand hotter weather and drought conditions whilst also requiring less of the fertiliser that contributes to greenhouse gas emissions.

Depending on their local circumstances, farmers may therefore consider growing more high-protein agricultural crops such as fava bean, buckwheat, hemp, pea, and lupin. Alternatively, instead of using traditional cereal crops such as wheat or barley, farmers may grow crops such as triticale which is a hybrid of wheat and rye that is more resilient against extreme weather conditions and crop diseases whilst also requiring less fertiliser.

One of the problems that has developed in recent decades is that we have become particularly dependent on just a few varieties of our key crops despite much diversity existing in their less common or wild relatives. These different varieties my look different but are often better adapted to extreme conditions, therefore growing more of these varieties can give better protection against future extreme events, such as droughts. Advances in crop breeding are also now creating brand new varieties of fruits and vegetables that may be more drought or disease resistant.

Discussion Points: This option requires that farmers have the skills and knowledge to grow the new crops or crop varieties, which may require information campaigns to share experiences and best practice, including from other countries where the crops are already grown regularly.

Option 2: New Technology and Precision Farming

The technology available for farmers is also rapidly changing. This includes the use of specialist sensors and robotics to replace traditional machinery. Precision farming uses these technological advances to target the application of fertiliser and pesticides with the aim of reducing their use and decreasing pollution to air and water. New bio-technology is also being applied through use of genetic modification (or genetic editing) to produce crops or animals that are more resistant to climate stresses and diseases, potentially also requiring less fertiliser and pesticide.

Very large-scale intensive technological development is now also occurring in specialist crop and animal farming systems where most of the production takes place indoors, sometimes also using artificial lights and recycled water. This also includes large greenhouses where the temperature and humidity are closely regulated for maximum productivity, or large intensive farms for livestock. Ultimately, this is also leading to development of 'vertical farms' in cities where production units are arranged upwards in specialised structures rather than across fields as normally happens. In these intensive production systems, the efficiency gains can mean reduced greenhouse gas emissions.

Discussion Points: For this option, farmers will need the skills to be able to use the technology correctly. New technology can also be very expensive and only affordable by large specialist farms, or potentially it may be acquired by a group of farmers together. In some cases, development of intensive production systems can raise animal welfare issues, whilst use of genetically-modifications is very controversial (currently banned in Scotland) because of ethical concerns and risks to the wider environment.

Option 3: Agroecology and mixed farms

An alternative to the high-tech approach to farming is provided by agroecology, which aims to better include natural processes, particularly by avoiding the use of artificial fertilisers which can cause water and air pollution, including release of the greenhouse gas nitrous oxide. This agroecology option includes a return to mixed farming in which both crops and animals are produced on the same farm. In the recent past, much of NE Scotland was occupied by mixed farming but this changed at the end of the 20th century towards more specialist farms. On a mixed farm, some of the crops (including grass) are used as fodder for the animals whilst the manure is used as an organic fertiliser for the crops. This can make the farm more flexible and adaptable whilst also reducing greenhouse gas emissions and reduced air and water pollution from excess artificial fertilisers. Organic farming also aims to follow the principles of agroecology.

Discussion Points: At present, only a few farms have moved back to a mixed farming system and to encourage larger changes would probably require additional government support. However, there are many farms (often small-scale) that have adopted an organic farming approach: these are certified to ensure quality standards and typically provide farm produce at a higher price to cover their costs. Cost therefore may be an issue, although if combined with local food initiatives (see below) this may be alleviated to some extent.

Option 4: Improved Fertiliser Use & Nitrogen Use Efficiency

In addition to precision farming (option 1), there are a range of other initiatives to improve use of fertilisers on farms if artificial fertilisers (as distinct from organic fertilisers such as manure) continue to be used. Particularly important from a climate change perspective is improved use of fertilisers regarding the nitrogen/nitrates they contain. Any nitrogen/nitrates not taken up by crop roots as nutrients can be released to the air (notably as the greenhouse gas nitrous oxide) or runoff into streams and rivers causing dangerous algal blooms and loss of biodiversity (also due to the phosphorous in fertilisers). Developments include slow-release fertilisers that aim to provide the fertiliser at the same rate that the plant can use it without producing a surplus.

An agroecology approach (option 3) to reduced artificial fertiliser use is to grow more legumes such as peas, beans, and lentils. Legumes have the distinctive ability amongst crops of being able to obtain nitrogen directly the soil through their root nodules, therefore can naturally contribute to soil fertility and therefore in the past were commonly used as part of crop rotations from year to year.

Discussion Points:
This option may also require government support to encourage more efficient fertilisers or a shift to use of more legumes on the farm. However, it is very likely that the costs involved would be much less than those that result from the damaging release of surplus nitrogen to water and air. Also as fertiliser is expensive (especially at the present due to energy costs in production) then reduced fertiliser use can actually reduce farm expenditure.

Option 5: Changes in Livestock Farming

As ruminants, cattle and sheep produce a lot of methane as they digest grass and other fodder. This is one of the main reasons that agriculture is a major contributor to climate change as methane is a powerful greenhouse gas. Much emphasis is therefore being placed on actions that may reduce methane emissions from livestock such as through changes in their diet, as for example through additives in their feed. The challenge is to develop effective actions that also improve production efficiency.

Discussion Points: For this option, it is important that any changes to livestock farming do not have a negative impact on animal welfare. Changes involving modified diets may be more difficult to apply to livestock that are free to roam outdoors, although there is potential for growing new varieties of fodder crops, such as high sugar grasses.

Option 6: Local food initiatives

Food from farming often involves complex chains of storage, transport, and processing that can occur over a large area, often including multiple countries. For example, some of the feed currently used for livestock comes from South America. Some of the produce from local farms is also transported considerable distances for processing then transported back to NE Scotland for sale in local shops. This transport is often represented as 'food miles' with the implication that a greater distance means higher carbon emissions from increased transport, although the full picture also depends on how much greenhouse gas was also released during farm production (including methane and nitrous oxide). We are often unaware of all these steps in the food production chain and even many of the people involved do not know the full chain, especially when a food product has multiple ingredients. For this reason, food systems have been estimated to contribute about 30% of overall greenhouse gas emissions.

A shift to more local food production with less transport would therefore be a good option to address this issue, particularly if the local farms are adopting good practices that reduce their environmental footprint and greenhouse gas emissions.

Discussion Points: Of course, Scotland cannot grow everything, and production also follows seasonal patterns but a good range of meat, vegetables, some fruits, and cereals can be produced. Local food initiatives such as farmers' markets also allow direct contact with the people who grow and produce the food. The advantages can therefore include a better knowledge of where food comes from and its value in the local economy.

Option 7: Reducing waste

It is estimated that overall, more than 30% of food is wasted in the UK. Reducing waste can therefore be a very good strategy to ease the pressure on food systems and farming. This could also have benefits for cutting pollution produced by intensive farming because less land and water would be needed. Reducing waste also makes food production more efficient and therefore can reduce greenhouse gas emissions per unit of production.

Reducing food waste requires target actions across the full production and processing chain to improve efficiency and storage. Particularly important is the hospitality and food service industry, and the role of supermarkets in the supply chain. It also requires all of us as consumers to be more careful in storing and using food. In addition, schemes such as redistribution of surplus food and recycling of food for related purposes (e.g., energy) are increasingly important. Recycling of waste is associated with the concept of the 'circular economy' so that waste outputs are actually treated as inputs to a related part of the production cycle, as occurs through the use of anaerobic digestors on farms to recycle manure and crop residues as energy and fertiliser.

Discussion Points: This option seems obvious but requires co-ordinated actions and incentives to make it work. Also, all of society need to be involved, not just the farmer.

Option 8: Changing what we eat

A potentially more radical option is to change our diet, depending on the degree of change. For example, moving to a more vegetarian diet because the livestock farming used to produce meat is currently the largest source of greenhouse gases from agriculture.

A related development is the increased availability of lab-grown food that imitates the taste and texture of meat.

Discussion Points: Some people are already doing this, but should everyone follow this path or should choice still be an important consideration? How do we develop the right incentives and also recognise the importance of livestock farming in local economies and communities?

Option 9: Integrated Pest Management

Farmers are experiencing more problems with pests and diseases, and this would normally lead to increased use of chemical pesticides with their potential toxic side-effects for farm wildlife. An alternative approach that is gaining more support is the use of biological rather than chemical controls using predators that prey on the nuisance species. The margins around fields, which may have trees, shrubs and other vegetation provide good habitats for these predator species. One example is beetle banks which are raised grass margins in arable fields.

Figure 14 ***Beetle bank in an arable field***

Discussion Points: This is another option that is likely to require government support and incentives because some of the approaches are less familiar to farmers, although some are also a reversion to traditional practices.

Option 10: Water catchments and Natural flood management

Farmers obviously do not want waterlogged and flooded fields; therefore, their normal response is to install drainage systems to remove the excess water. Throughout much of the 20th century, farmers could receive a government grant to install drainage to improve farmland productivity. However, there is now greater awareness of the problems that this can cause due to the transfer of water downstream in the water catchment. After heavy rain this can lead to both flooding downstream in towns and cities, together with increased water pollution problems from runoff of fertilisers and pesticides.

Now there is increased realisation that the best course of action is to try and slow down the runoff of water from farmland to help avoid flooding problems downstream. This may involve retaining the water on fields and in the soil, meaning livestock need to be moved and damage to crops may occur, which is a challenge to the farmer. However, the costs would be much less than flooding damage to houses and businesses downstream.

Discussion Points: If farmers can be adequately compensated for the damage and disruption then this provides a solution that can work for everyone, but it will require advanced planning to prepare for the events.

6. IMPACTS OF CLIMATE CHANGE ON FISHERIES

Q6.1 What are the impacts of climate change on fish-based food systems?

6.1.1 Warmer Waters and Fish Migration

Fish are very sensitive to water temperatures. Warming seas are causing the cold-water fish that we normally eat (cod, haddock etc.) to migrate northwards and they are becoming less common in their traditional fishing areas such as the North Sea. This is also a consequence of past problems from overfishing. Due to the introduction of catch quotas, fish stocks had often been slowly recovering from being severely overfished, but this is now being further disrupted by climate change.

Taking the place of the traditional species are warmer water species, such as gurnards, red mullet, sole that are also migrating north and becoming more common in our seas. As these species are new to our waters, there is limited information on their stocks and there are usually no fishing quotas set. This means that there are concerns that they could be overfished before they become fully established here, especially if mainly younger fish are caught.

Red mullet

6.1.2 Changing Fish Food Chains

The fish that we catch and eat are the larger fish that are predators of other smaller fish and plankton in the ocean food chain. As the seas get warmer, these plankton and smaller fish are also altering their life cycle and changing their distribution, and they have also often been affected by pollution or overfishing, such as intensive fishing of sand-eels for non-human consumption. These combined effects are causing complex changes to marine food webs, impacting both the larger fish and also other predators such as seabirds which are being forced to rapidly adapt to these changes. In addition to the impacts on fisheries, there have been sharp declines in seabirds such as puffins and guillemots which were much more numerous on UK coasts in the past.

Guillemot

6.1.3 Impacts on Fish Life Cycles

Fish usually have a complex life cycle from larvae to juvenile to adult, and this is also being affected by climate change. A particularly notable example is Atlantic salmon which have for a long time had a high cultural importance in the rivers of NE Scotland. Young salmon are hatched and spend their juvenile years in rivers. They can then transition in river estuaries to living in saltwater and when they become mature adults they live in the sea, migrating to the Norwegian Sea to feed on smaller fish, but returning to spawn every year in freshwater rivers. Remarkably, for spawning they typically have the ability to return to the same river where they originally hatched.

However, changes in sea temperatures, salinity patterns, and ocean currents are now affecting migratory life cycle patterns. Where once, every year, thousands of salmon could be found in local rivers such as the Dee, Don and Deveron, now they are unfortunately very few. This is having wider implications too because of the importance of salmon fishing to local economies. It has been estimated that each salmon caught is worth about £1000 because of the number of people involved in supporting anglers (estates, hotels etc.).

6.1.4. Risks to aquaculture

Aquaculture is the managed production of fish and shellfish. In Scotland, this usually occurs using fish farms (predominantly salmon) or mussel farming in coastal seas. This industry has expanded considerably in recent years and the Scottish Government wishes to double production by 2030. The controlled aquaculture environments such as fish cages can mean that some of the hazards of the open seas can be reduced but problems still occur. Warming waters due to climate change can therefore be a challenge also for aquaculture and this might increasingly mean that production from traditional species is more limited in future, similar to the open seas. In addition, the controlled environment still has some risks from pests and diseases, and climate change is increasing the prevalence of some of these threats (e.g., gill disease in salmon). As with farming on land, use of antibiotics also has long-term implications as some pathogens are become resistant to the antibiotics meaning other forms of control become necessary.

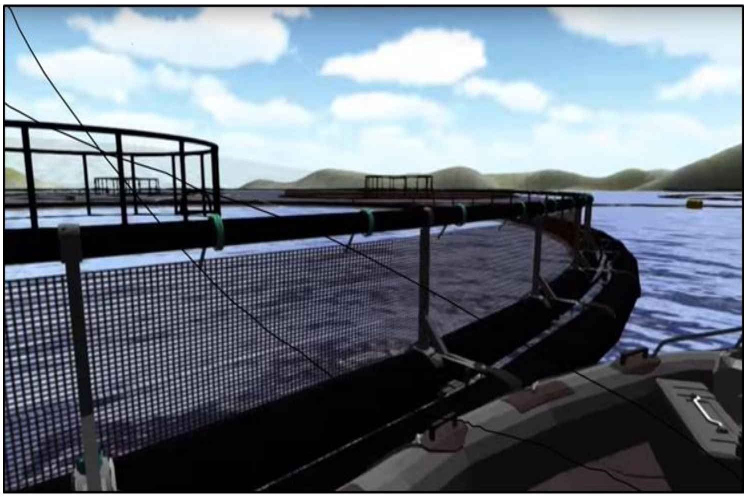


Figure 15 ***Fish farm cages***

7. FISHERIES: WHAT CAN WE DO?

For fisheries, the main climate change responses are those which keep fish stocks at a sustainable level. Regarding greenhouse gas emissions, the main contribution of fishing is through carbon emissions from transport as fishing boats have to usually travel large distances to make their catches. Therefore, measures to improve the sustainability and efficiency of fishing contribute also to reduced carbon emissions. Transport costs are usually less with aquaculture although some of the produces (particularly shellfish) are transported large distances to overseas markets.

Option 1: Keep habitats in good condition.

Significant change is already occurring in the seas and some degree of further change is inevitable. The open nature of the seas also means that we have less options to limit the effects of change. Probably the most important option we can further develop is to keep habitats and ecosystems in good condition, so that fish and shellfish can better adapt to changes. This particularly applies to the variety of habitats where different species find food and shelter but also maintaining the diversity of interactions between species that make up the food web. This means that the larger predator species continue to have a food supply, even if that food supply is changing. Some habitats are particularly important because they provide nursery grounds for young fish, and this might therefore be worth giving extra protection. For example, in Lamlash Bay (Arran, SW Scotland), there is now a trial 'no-take zone' meaning no fishing can occur there due to its wider importance.

Some marine habitats, such as saltmarshes and seagrass beds are also particularly good at capturing and storing carbon from the atmosphere as they grow and expand. Therefore, in addition to their ecological value, they can also provide a valuable means to respond to the cause of climate change by taking carbon dioxide out of the atmosphere.

Discussion Points: This option may require restrictions on fishing activities to allow habitats to recover and be restored. In many cases, this may also require international agreements and the co-operation of other countries.

Option 2. Better understand the seas and the effects of climate change.

There is much that we still do not know about the marine environment and how it will respond to climate change. This includes not only effects of warmer water but also changes in the composition of the seawater, including its salinity, oxygen content (which is affected by warming), and dissolved carbon content which is making seawater more acidic. Changes are also happening across the full marine food web. We therefore need more marine ecologists and fisheries experts to collect and analyse data to help better understand and respond to changes.

Discussion Points: This will require further investment in research and education to understand better the changing seas and to share the knowledge. Often fishers themselves have specialist knowledge of the marine environment from their experience at sea.

Option 3. Setting catch quotas.

To avoid overfishing, limits are placed on the number of different types of fish that can be caught through international agreements. These quotas can be controversial because they can affect fishers' livelihoods, but the aim is to base these on the best available science. If we can improve our knowledge of marine ecosystems and fisheries, including how climate change is affecting them and new species, then we can set better quotas that balance up the needs of fisher's livelihoods and the requirements to maintain a sustainable fisheries resource that is also there for future generations.

Discussion Points: The main challenge here is setting quotas that allow for the natural variability of fish stocks from year to year together with the additional pressures of climate change.

Option 4. Eat different fish.

As the traditional species that we eat (e.g., cod, haddock) decline in our local waters, we are likely to have to think more about new types of fish. At present, people in Scotland are usually slow to change their habitats and might need more encouragement to try new species that they have not experienced before.

For example, Fish and Chips in 20 years' time might mean something quite different than it does now. Or we might have to think much more about eating plants such as seaweed that are abundant in the seas and can be sustainably harvested.

Figure 16 ***Harvesting Seaweed***

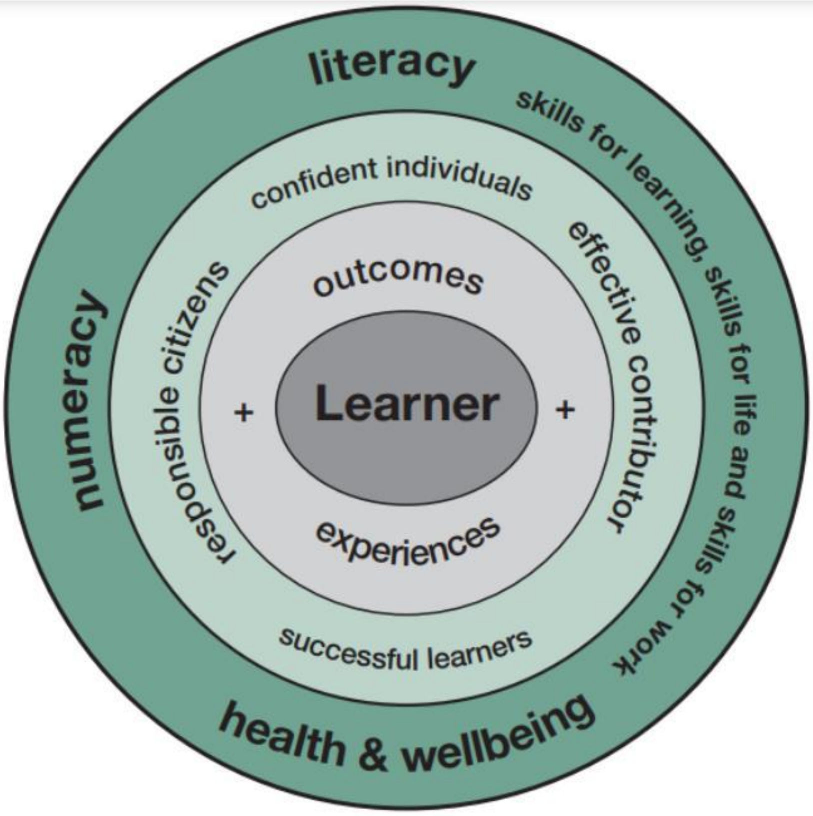
Discussion Points: This will require us to move away from the fish we normally eat to try new alternatives!

Option 5. Sustainable aquaculture.

There are big plans in Scotland to increase aquaculture production. This can provide a lot of local nutritious food to the population, including for NE Scotland. Production can also help to meet Net Zero climate change goals because aquaculture does not need to produce much greenhouse gas emissions. The challenge is how to do this in a sustainable way, so that expansion does not damage local marine ecosystems, and that it contributes to local communities. This is also important because many of the areas that could be used for growth in aquaculture are also important for tourism.

Discussion Points: The challenge for this option is to expand aquaculture production whilst improving its environmental footprint and not causing damage to the coastal landscape which is also often important for tourism.

8. HOW CAN THIS TOPIC BE FURTHER DEVELOPED THROUGH THE SCHOOL CURRICULUM?



Source: The curriculum for excellence

Both climate change and food systems are cross-cutting topics that can bring together knowledge and learning from different academic subjects. Moreover, solving our current problems requires skills and innovative thinking from many different backgrounds. A lot of emphasis is now being placed on joined-up systems thinking so that we can develop and implement effective responses and not merely move the problem elsewhere. Therefore, this topic is ideal for encouraging interdisciplinary systems thinking and to weigh up and consider different options, some of which may be quite radical. This can also encourage a strong focus on responsible citizenship and how we can all contribute (possibly in different ways) to delivering a sustainable future. It may also encourage children to define their own target outcomes themselves and then think about how we achieve these.

Science is obviously important in understanding the greenhouse effect and the role of greenhouse gases in changing our climate, together with the impacts on food and fisheries, which requires putting together the different links in the systems, both on land and in the sea. Interpreting the science in terms of concepts such as environmental, carbon or water footprints requires both numeracy but also to think about how we communicate these concepts, such as through food labels.

Clearly, there is also a strong link also with health and wellbeing, especially in terms of what we eat and where it comes from, but also lifestyles and our relationship with the changing natural environment. Sometimes the issues can seem complex and abstract, therefore learning can be enhanced by bring in lived experiences (either personally or through friends and family) and for field visits to farms, fishing ports, or other relevant locations. Local authority sustainability officers can help with this.

Fundamental to the topic is the need to both frame the issues locally and globally. In addition to local case studies, there is therefore important benefits to be achieved from also considering the implications for other countries, especially those that may be worse off than us, in terms of their history, geography, economies, and cultural contexts. The global dimension also brings in the role of the UN and international agreements. Shared local case studies in an international network can help with this.

Ultimately, to help understand the issues, pupils need to be able to access and critically interpret information from various different sources and subject areas. Projects are clearly an ideal mechanism to achieve this whilst also delivering individual and collective learning experiences through development of different skills. At community level, this is also being developed through greater emphasis on the role of storytelling and the role of the arts in asking questions and considering what we really need to do. Schools should therefore be able to connect with these initiatives, such as through universities, local authorities, or other organisations.