The impact of extreme weather events on Scottish agriculture

SAC CONSULTING

Part of Scotland's Rural College (SRUC)

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Contents

Executive summary

Extreme weather events are increasingly more likely and risk the profitability of Scottish farms. Already this decade Scotland has experienced extreme weather events including Storm Barra and Storm Arwen, alongside heavier and more persistent rain. Last summer Scotland experienced record-breaking temperatures and drought with significant water scarcity leading to SEPA suspending abstraction licenses in catchments for the first time. Previous research from WWF Scotland has highlighted the economic impact of extreme weather events on Scottish agriculture: in 2017-18 alone it cost Scottish farmers £161 million due to livestock losses and lower crop yields. Scotland has already experienced changes in climate, and these are projected to continue and intensify. The extent to which changes occur depends on our ability to reduce greenhouse gas emissions.

This project investigates farmers' views and experiences in relation to extreme weather events and whether alternative agricultural practices can support farm resilience and profitability for the future.

An economic assessment was also made using SRUC's Scotfarm model. This modelling shows that introducing nature-friendly farming methods can prepare farmers for a changing climate. Introducing measures such as maintaining a living root within the soil, minimising soil disturbance, maximising crop diversity on farm, keeping soil covered throughout the year, and if possible, integrating livestock into an arable system will help the majority of Scotland's farmers and crofters remain resilient and profitable to the frequency of extreme weather events caused by climate change.

Background

Sustainable production systems are essential for the future of Scottish agriculture, particularly as our climate changes and we experience variable and unpredictable weather events. Various land management approaches can be applied to develop sustainable production systems that enhance soil health, soil fertility and promote biodiversity. Research from WWF Scotland highlighted that extreme weather in 2017-18 alone cost Scottish farmers £161 million due to livestock losses and lower crop yields. Scotland has experienced record-breaking temperatures and drought during the summer of 2022 with significant water scarcity that caused SEPA to suspend abstraction licenses in catchments across Scotland for the first time. Therefore, this project investigates farmers' views and experiences in relation to extreme weather events and whether alternative agricultural practices can support farm resilience and profitability for the future.

Scotland has already experienced changes in climate, and these are projected to continue and intensify. The extent to which changes occur depends heavily on our ability to reduce greenhouse gas emissions contributing to climate change.

Kendon et al (2022) and the Met Office outline in 2021 can be summarised as;

- 2021 was slightly warmer than average for the UK overall (0.1°C warmer than the 1991–2020 average). 2021 (Figure 1) was the UK's ninth warmest summer and equal-third warmest autumn on record in series from 1884. In addition, 2021 included the UK's fifth driest April and second wettest May in monthly series from 1836.
- UK rainfall total for 2021 was 1,104 mm (95% of the 1991–2020 average). Much of western Scotland had less than 80% of average rainfall for the year, with other areas closer to average. It was also a relatively dry year for Shetland.
- Rainfall was broadly close to average (95% of the 1991–2020 average and 102% of the 1961–1990 average) though the western half of Scotland had a rather dry year (Figure 1).

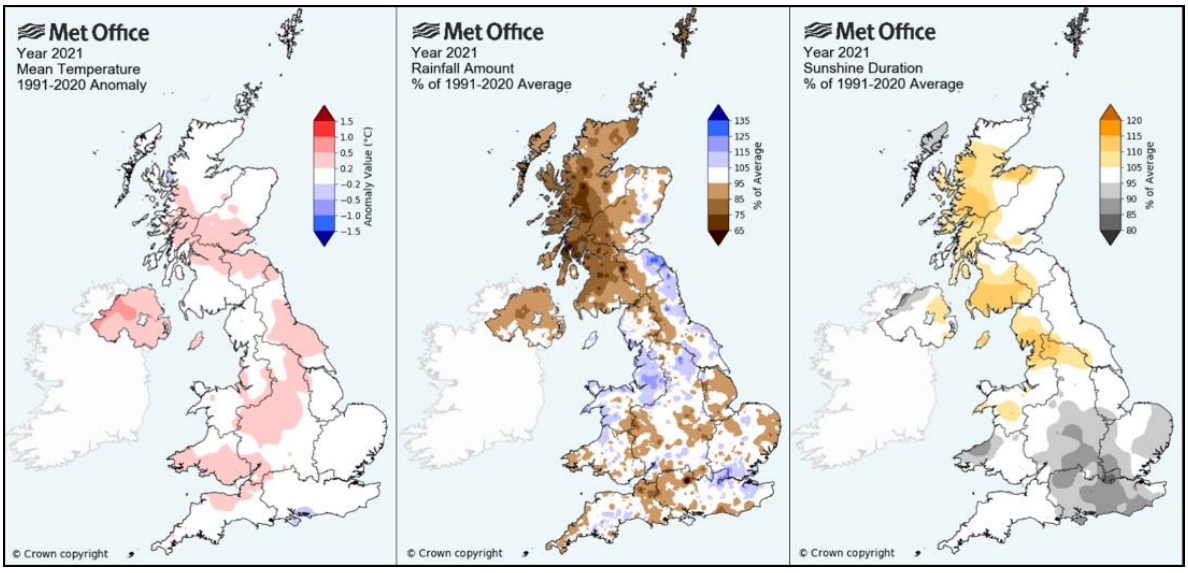

Figure 1. Met Office monthly climate summary 2021

Extreme weather events

Extreme weather is typically categorised as a weather event that significantly differs from usual or average weather patterns. Examples of common UK extreme weather events include:

- Flooding:
  - Large volumes of additional water. In the UK this commonly originates from heavy rainfall or rain over a long period of time. Other causes include melting snow, high tides or river levels and storm surges.
- Heat and drought:
  - Hot weather (relative to the expected conditions) over an extended period of time is termed a heatwave and can be accompanied by high humidity. Times of high temperatures in addition to a lack of rainfall can lead to droughts conditions.
- Storms
  - Typically applied to severe atmospheric events, currently, however, there is no official meteorological definition[1].

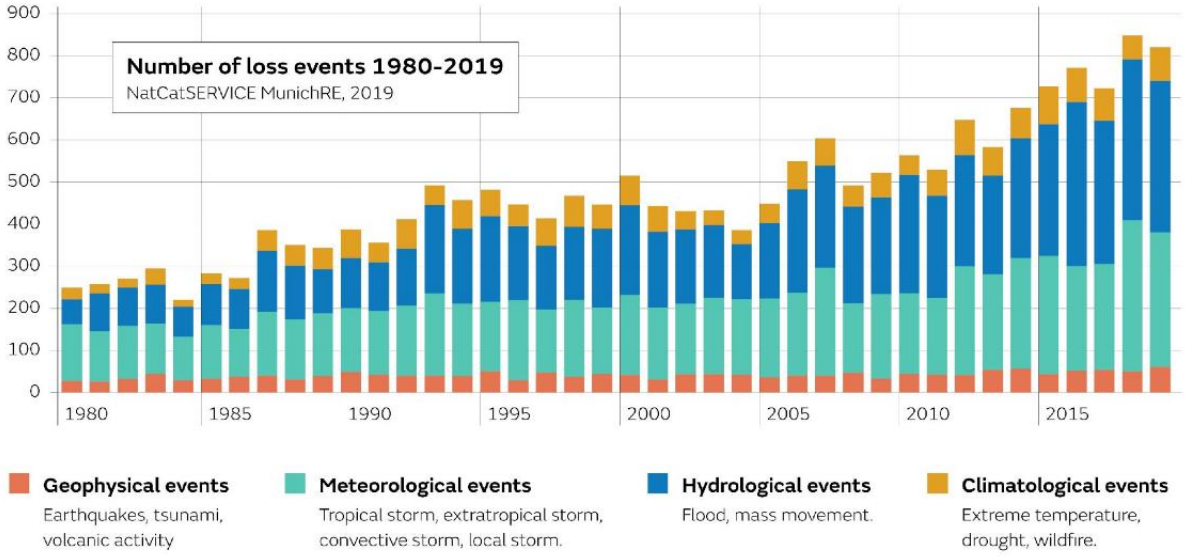

Figure 2. Met Office diagram highlighting the increased frequency of extreme weather events experienced in the UK between 1980 and 2019

Met Office records show that these events are becoming more frequent (see Figure 2), with notable extreme events affecting Scotland during 2021 and 2022 outlined below;

Exceptionally mild New Year, 30 December to 2 January 2022:

During this period, the UK experienced, in tandem, the warmest New Year's Eve and New Year's Day on record, with temperatures reaching 15 to 16°C. This was a results of air flow from Tropical Maritime Air from the Azores.

[1] https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/storms

Storm Barra, 7 to 8 December:

Storm Barra resulted in wind gusts of 69-81mph in the UK, predominantly in the coastal regions. Generally, these winds would be classed as severe, however, in Ireland the Met Eireann issued a red warning for wind in Counties Kerry and Cork. The storm resulted in severe disruption, with power outages in Ireland which impacted the ability to, and time to resolve, the repercussions of Storm Arwen the previous month.

Storm Arwen, 26 to 27 November:

Storm Arwen has been classed the most powerful and damaging winter storm in the past decade. The storm brought gusts of 69 to 98mph, which caused death and destruction around the UK. The storm resulted in thousands of trees being felled and millions of homes experiencing power loss and damage. There was substantial impact to infrastructure with road and buildings damaged, along with severe disruption to public transport.

Heavy and persistent rain, 26 to 31 October:

Heavy and prolonged rainfall impacted northern England and southern Scotland. The impact resulted in properties being flooded, though the impact was reduced to due current flood defences in situ, however, over 40 were still affected. There were major travel restrictions with railway lines unpassable and roads flooded. In Hawick, plans were put in place to evacuate local residents if the rain persisted as the River Teviot continued to rise.

Extremes of temperature, late March to early April:

During March 2021 the UK experienced unusually milder weather, with some weather stations recording their warmest March day on record. This was subsequently followed in April, due to an Arctic Maritime Airmass from a strong northernly wind, by dramatic temperature drops, up to 15° in places. This resulted in wintery showers leading to travel disruptions throughout the UK.

Snow and low temperatures including storm Darcy, 7 to 13 February:

Storm Darcy brought severe cold weather to the UK, which caused major disruption. The storm brought bitterly cold air flow from eastern Europe leading to night-time temperatures dropping to -10 to-15°C in certain areas, with Braemar reaching -23°C, the lowest UK temperature since 1995. Fatalities, travel restrictions and school closures affected many areas around the UK.

Storm Christoph, 18 to 20 January:

Storm Christoph brought unusually wet weather to northern England and North Wales, with certain areas experiencing the wettest three-day period on record. The impact from the storm resulted in mass evacuations being implemented as towns were flooded and rivers continued to rise. In addition, there was damage to infrastructure, including a bridge over the River Clwyd being swept away.

Alternative management practices – Regenerative agriculture

Alternative management practices (commonly described as regenerative agriculture) are promoted to help build resilience. Alternatives to traditional agricultural practices need to be developed within Scotland to better support farmers as the local climate changes. Regenerative agriculture takes a holistic approach to farm management that focuses on restoring the health of agricultural ecosystems, thereby enhancing the ecosystem processes that underpin production (e.g. nutrient recycling, natural pest control, pollination services and water regulation). Healthier and more diverse ecosystems are more resilient to shocks, and as such regenerative agriculture has the potential to prepare farms for a changing climate.

Regenerative agriculture, particularly in arable systems, strongly draws on five principles of soil health (Figure 3) alongside context and knowledge[2]. The five main principles for regenerative agriculture are: maintaining a living root within the soil, minimising soil disturbances, maximising crop diversity on farm, keeping soil covered throughout the year, and if possible, integrating livestock into an arable system.

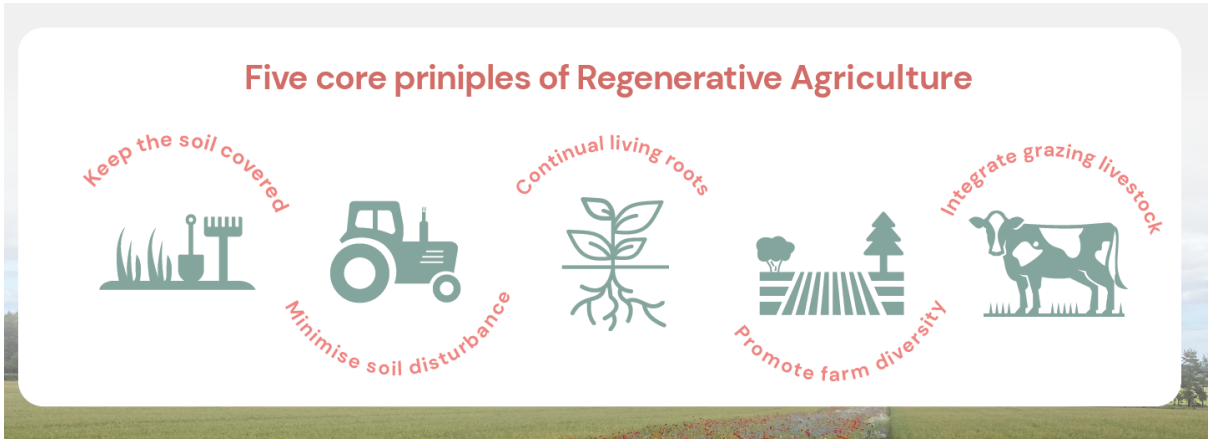

Figure 3. The 5 principles of regenerative agriculture

These principles put soil health at the centre of agricultural practices. Soil health is one of the most important factors to consider as healthier soils provide a robust base to all other agricultural processes, particularly in times of climatic stress. Living roots and soil coverage will prevent erosion and reduce nutrient leaching, while also increasing soil infiltration allowing for better water capture and higher soil moisture levels. Reduced tillage can help to improve soil biodiversity while maintaining soil structure and increased aggregate stability. Promoting crop diversity is encouraged to support healthier soils as microorganisms that prefer different root systems can establish in the same areas at the same time. Adding livestock to an arable system (where possible) can help to improve soil structure and plant/microbial biodiversity through organic nutrient additions through manure deposits. This can be achieved by allowing the grazing of cover crops or temporary grass ley, to help maximise additives while limiting damage to important crops.

The changes that are often implemented from these principles have benefits ranging from increased ecosystems services, such as higher water infiltration, more nutrient cycling

[2] Brown, G. (2018). Dirt to soil: One family's journey into regenerative agriculture. Chelsea Green Publishing.

and increased biodiversity, as well as economic benefits involving reduced inputs and less labour. In addition to the five principles of 'regenerative agriculture', it is important for farmers to consider methods that limit the negative impacts experienced from extreme weather ranging from drought to flooding. Practices such as limiting evaporation from livestock troughs or increasing rainwater capture through the introduction of gutter storage or on farm scrapes/ponds could help minimise groundwater extraction. Flooding protections, such as improved drainage or increase livestock provisioning, can help lower damage to fields and allow for a quicker reintroduction of livestock to fields without hurting soil health.

Project outline

This project investigates farmers' views and experiences in relation to extreme weather events and whether alternative agricultural practices can support farm resilience and profitability for the future. In addition, a simple economic assessment was made using SRUC's Scotfarm model. The outputs of the project are discussed below.

Case studies

Johnnie Balfour, Balbirnie Home Farms, Fife

Has your business been impacted by weather related events in the past 5 years?

Balbirnie farm has not really experienced drought but certainly had spells where it was warmer than usual or expected. The farm has experienced flooding in certain areas and there is the potential for field drains to become overwhelmed and overflow. However, all our fields have cover and so we didn't experience any soil loss and luckily our cattle were not affected as we had already started mob grazing by then - our infiltration rates are generally ok, and our cattle got moved quicker due to the ground being wet. Increased ground cover, cover cropping, and giving ground time to rest leads to the soil being able to hold on to moisture and increases its capacity to cope with wet periods.

Since we started with mob grazing and giving ground time to rest, we've noticed that our grass grows quickly and our fields stay greener for longer, probably as they can access moisture for longer.

It's too early to tell whether the investments made (fencing and animal supplies to enable animals on fields = big cost) will pay back, but I definitely feel and see that the farm is more resilient and moving towards reducing tilling has helped that.

What regenerative practices have you introduced on your farm?

Regenerative agriculture is not a set of practices but is overarching principles. Just because you plough a field once in six or eight years, doesn't mean you're not regenerative. For example, mob grazing is just a practice than allows you to fulfil the principles of regenerative agriculture. I do feel that there's sufficient information and knowledge available on regenerative agriculture, but it's down to the individual to look for it.

How do you feel that changing weather patterns will impact agriculture in Scotland over the next 10 years? What do you think the biggest threat to Scottish agriculture will be over the next 10 years?

There are many challenges for farm businesses, in particular how to further reduce the use of synthetic inputs and findings ways to reach net zero. Future farm industry challenges are to ensure that the subsidies get to the right people and businesses. There are a lot of exceptionally good farmers that pull the national average up, however, there are still some not willing to engage and are not practicing good conventional farming. At the moment its propping up an industry where some are not doing their bit.
We can't predict the future, but we should invest the time to be prepared for variable weather.

Jock Gibson, Edinvale Farm, Forres

Has your business been impacted by weather related events in the past 5 years?

The main issues we experience is dry weather, particularly the prolonged dry spell in 2018. Paddock grazing system was used at the time and always managed to keep grass in front of cattle and never burned off. Other fields were struggling much more.

Last year had long periods of dry with some very heavy rain events. Neighbours were struggling with keeping grass as well. Heavy rain events are being managed better in their system than others - drains were not as filling up as much. Keeping grass covers taller without really short grazing.

Last year, we stopped using synthetic fertilizer and now use organic manure which seems to have led to better rooting depths allowing for increased soil water retention (just an observation, no scientific evidence!). We would not describe our farm as regenerative, however we are trying to head towards a more organic direction, pasture only livestock farm. Cutting out the fertilizer has led to increased resilience in terms of the farm managing droughts and extreme weather.

Have you noticed any subsequent changes to your farm from new practices that you did not anticipate?

Periods of the grazing calendar are greener than other surrounding farms. Our grass is green in February while others are brown, soil temperatures are up, and moisture contents are good and so the grass is good. When we compare against the UK Grass Check Program, our grass growth rates are near the top 5/6 of all beef and sheep farms involved pretty consistently.

What regenerative practices have you introduced on your farm?

Farmyard manures are generally used in reseed areas, no additives done to the existing grass leys, relatively little inputs lots of clover included in the mix. They will play with higher stocking densities on taller covers with longer rest periods, looking into outwintering cattle, strip grass and then silage added in ring feeders, thinking about removing the 2nd cut of silage and leaving it to grow.

How do you feel that changing weather patterns will impact agriculture in Scotland over the next 10 years? What do you think the biggest threat to Scottish agriculture will be over the next 10 years?

The challenge of winters being warmer and wetter instead of cold and dry. Growing conditions are deteriorating faster. Outwintering will become more challenging than it has been in the past. The policy surrounding climate change will be a worry, I don't think there will be enough detail in future policy to outline what the agriculture industry will have to do to change. There is conflict within government as to how people should be farming and whether people should be farming at all. There is a lack of confidence in people making the decisions, and so Scottish agriculture is not adapting quick enough. England and some European countries are changing faster but not necessarily in the right

direction. We need to have policy in Scotland that balances food production, climate change and biodiversity enhancement.

Sam Parsons, Balcaskie Farm, Fife

Has your business been impacted by weather related events in the past 5 years?

The main issues we've experienced recently on our farm are:

- *Explosion of pests from lack of cold spell this winter, could potentially be a real problem*
- *Livestock struggling with heavy rain, from not thriving to increased issues with poaching*
- *Maggots in sheep are occurring earlier and later in the season*
- *Long wet periods to long dry periods are leading to cereal root depth decreasing, leading to increased issue with the crop.*

What regenerative practices have you introduced on your farm?

Some of the regenerative agriculture practices we've put in place include;

- *No synthetic inputs - Organic*
- *Try to disturb the soil as little as possible*
- *Keep green cover on soil*
- *Mob grazing - we Introduced this to prolong the grazing season. They were struggling before with wetter and milder winders*
- *Using older cereal varieties – these have better rooting structures and are more resilient to dryer periods*
- *Have diversity in our rotations e.g., herbal leys everywhere they can - Increases grass root structure, which in turn allows for water to be taken up in wetter seasons and utilised in drier seasons. This reduces runoff and benefits soil health.*

Some of these practices have provided additional revenues, such as cover crops which either provide nutrients to the soil or can be used as fodder, so it's a win-win. We can decide on the use depending on what the season has delivered.

Overall, we feel that these practices have made the farm much more resilient to change. We feel that our investments have paid off and are working to reduce the negative impacts from changing climate.

Every day is a school day - mistakes have and are being made, but the way we now farm allows the ability to make these without huge initial investment. Initially we needed to invest to make the changes we have; however, we have the ability to trial and error without a huge investment just now. We feel we are more financially and climatically resilient."

Economic impact assessment

A SRUC based dynamic farms level economic model, ScotFarm[3], (Shrestha, 2022) was used for this study. The model is based on farming system analysis and includes biophysical and management relationships to link production to resource requirements, which are used to the optimal levels. For example, availability of land, labour and feed required to generate a given volume of different outputs are combined with data on the prices of inputs and outputs to calculate farm net profit as an objective function to be maximised. The net profit is the total revenue generated from all farm activities plus subsidy payments received by the farm minus variable costs *i.e.* input costs associated with farm activities and fixed costs (machinery costs, depreciation, repairs, fuel, electricity, labour, rent, tax and others running costs). The production coefficients used in this tool are generated from the farm level data inputs.

We used five farming systems: dairy, beef, sheep, mixed and arable farming systems, in this study. Farm data for these farming systems was taken from Scottish Farm Business Survey (Scottish Government, 2021). Representative farm data for an average farm in each of the farming system was used in the model. The model is run under a baseline scenario where farm activities follow the existing farm strategies for production without any changes introduced. The next step was to use farmers' experience/perception about the extreme weather in recent years and economic consequence on their farms. This information was gathered from a farmer survey conducted under this project. The perceived loss/gain in farm production and profits was used in the model to run an extreme weather scenario. The final step in the modelling process was to run the farms under the extreme weather effect plus potential regenerative management practices to examine if the regenerative practices had any impact on softening the consequences of extreme weather on farm economy.

Extreme weather

Farmers were asked about the impact of recent extreme weathers such as the heat wave in 2020, different storms in 2021 and 2022, as well as heavy rains in 2021. Farmers' responses to the impact of such weather on farm production ranged from -10% to -30% reduction in their production and profitability. Interestingly, one of the farmers (mixed farming system in Tayside) indicated to have +30% increase in production due to the heat wave in 2022. This analysis, however, focused only on negative impacts of the extreme weather.

[3] Further details available at:
https://www.sruc.ac.uk/download/downloads/id/3513/scotfarm_%E2%80%93_a_farm_level_optimising_model.pdf

Regenerative practices

The regenerative practices, which were listed by the farmers in the survey and were possible to use in the model are described below:

i. Arable farms – a combination of a cover crop, no tillage, set aside 10% land to maintain habitat diversity, 20% reduction in inorganic fertiliser and residue management. It is assumed that there is 10% reduction in production, there is a saving on use of no tillage and less fertiliser but additional cost on maintaining land for habitat diversity and income foregone on straw sale.

ii. Dairy, beef and sheep farms – a combination of setting aside 10% land for habitat diversity, 10% reduction in inputs and out-wintering. There is a 10% reduction in production, 10% savings on input costs and 20% savings on feed costs.

The extreme weather loss, regenerative practices, and assumptions used in the model are presented in Table 1.

Table 1. Extreme weather loss, regenerative practices and their assumption taken on different farming types.

Farming types	Weather impact on profit	Regerative practices	Assumptions	Extreme weather experience
Arable	-30%	Cover crop*	yield increased by 5%	Heavy rains 2021; Heat wave 2022
		No tillage*	yield reduced by 5%, input cost reduced by £103/ha	
		Reduced inputs**	20% redcution in costs	
		Habitat diversity**	10% reduction in production	
		Residue management*	loss in straw revenue	
Dairy	-10%	Habitat diversity**	10% reduction in yield	Heat wave 2022
		Reduced inputs**	20% redcution in costs	
		Outwintering***	20% reduction in costs	
Beef	-10%	Habitat diversity**	10% reduction in yield	Heat wave 2022; Storms 2021, 2022; Heavy rains 2021
		Reduced inputs**	20% redcution in costs	
		Outwintering***	20% reduction in costs	
Sheep	-30%	Habitat diversity**	10% reduction in yield	Heat wave 2022; Storms 2021, 2022; Heavy rains 2021
		Reduced inputs**	10% redcution in costs	
		Outwintering***	20% reduction in costs	
Mixed	-30%	Habitat diversity**	10% reduction in yield	Heat wave 2022; Storms 2021, 2022; Heavy rains 2021
		Reduced inputs**	20% redcution in costs	
		Outwintering***	20% reduction in costs	

Sources: *Glenk et al., 2017; **Lampkin et al., 2021; AHDB, 2016

Results

Under the extreme weather scenario, the dairy farms are estimated to reduce farm net profit by 19% (Figure 5). Although dairy farmers perceived a 10% reduction in farm production under the extreme weather, the model estimated higher loss in profit as farms are projected to adjust for loss in milk production. The inclusion of regenerative practices on farms allowed the farms to decrease losses on farms as the extreme weather is projected to reduce farm net profit by only 12% when these practices are adopted on farms.

Similarly, extreme weather is estimated to reduce farm net profit by 12% on beef farms. Including regenerative practices on beef farms has a very positive impact on farm net profit, which almost entirely removed the negative impact of extreme weather.

Sheep farms are estimated to have a reduction of 36% in farm net profit under the extreme weather scenario. These farms, however, show a lesser reduction in farm net profit (-22%) when regenerative practices are adopted on farms compared to when no such practices are adopted.

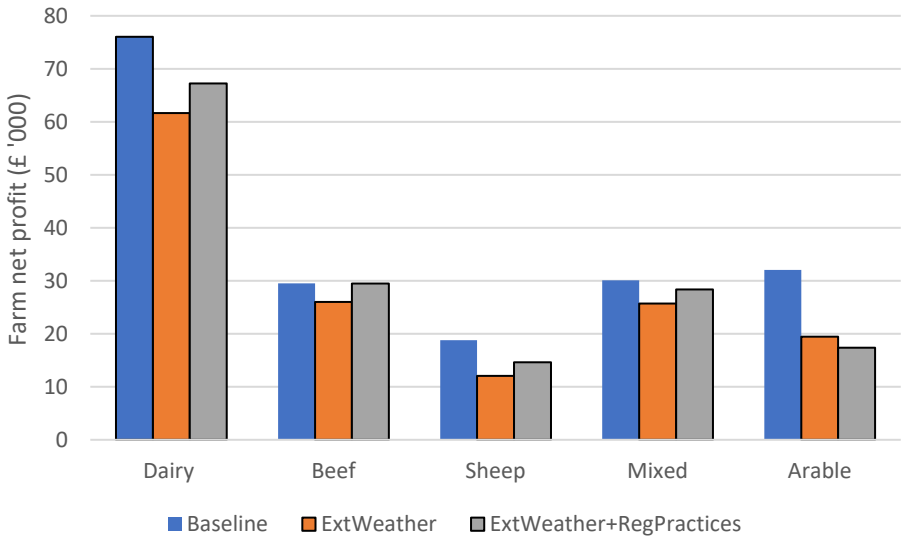

Figure 5: Farm net profit under the baseline, extreme weather (ExtWeather) and extreme weather with regenerative practices (ExtWeather+RegPractices) scenarios for different farming systems

The mixed farms are estimated to have a reduction of 15% on their farm net profit on average. These farms are projected to reduce their losses with only 6% reduction to their farm net profit when regenerative practices are allowed on farms.

The arable farms are projected to have to the largest reduction (-39%) in their net profit on average. The regenerative practices identified for arable crops in this study have higher implementation costs, hence, are estimated to reduce farm net profits further up to -46% as shown in Figure 5.

References

AHDB, 2016. Outwintering livestock on brassica and forage crops. https://ahdb.org.uk/knowledge-library/outwintering-livestock-on-brassica-and-forage-crops

Shrestha, S., 2022. ScotFarm – a farm level optimising model. ScotFarm - a farm level optimising model — SRUC, Scotland's Rural College

Scottish Government, 2021. Scottish Farm Business Income – annual estimates 2020-2021. https://www.gov.scot/publications/scottish-farm-business-income-annual-estimates-2020-2021/pages/12/

Glenk, K., Shrestha, S., Topp, K., Sanchez, B., Iglesias, A., Dibari, C. and Merante, P., 2017. A farm level approach to explore farm gross margin effects of soil organic carbon management. Agricultural Systems. 151: 33-46.

Lampkin, N., Shrestha, S., Sellars, A., Baldock, D., Smith, J., Mullender, S., Keenleyside, C., Pearce, B. & Watson, C., 2021. Preparing the Evidence Base for Post-Brexit agriculture in Scotland – case studies on alternative payments. NatureScot Research Report No. 1201.

WWF Scotland. The Economic Impact of Extreme Weather on Scottish Agriculture, 2019. https://www.wwf.org.uk/sites/default/files/2021-04/Impact%20of%20extreme%20weather%20on%20Scottish%20Farmers%202018%20FINAL.pdf