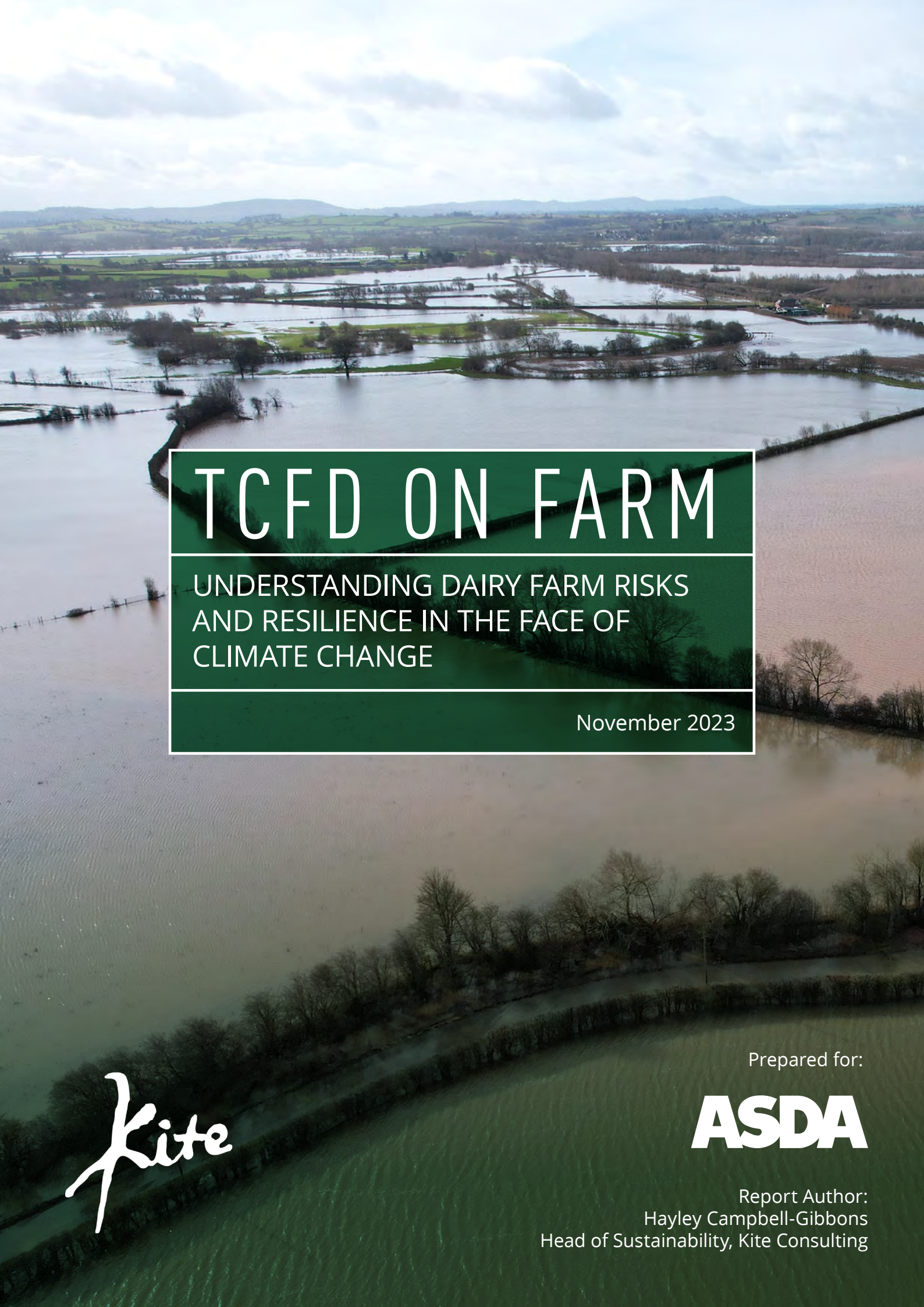

TCFD ON FARM

UNDERSTANDING DAIRY FARM RISKS AND RESILIENCE IN THE FACE OF CLIMATE CHANGE

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INTRODUCTION

Conversations and action on climate change in the food sector have, until now, focused largely on farming's impact on the planet and how to reduce it. With that train firmly in motion, it's time to change the conversation beyond simply understanding farming's contribution to climate change to understanding the risks climate change poses to food production.

This concept isn't new for other sectors of industry. Large private companies, such as supermarket retailers and major milk processors, are now legally required to report on the financial risks that climate change poses to the business and its investors, so called Climate Financial Disclosure (CFD).

Climate risks that companies are required to report on are classified as physical (such as the increased frequency and severity of extreme weather events), and transitional (such as those arising from the changes in technology, markets, policy, regulation and consumers).

By 2024/25 it is expected that climate financial disclosures will be extended to include an assessment of a company's contribution to climate related risks also; so called Sustainable Disclosures Requirement (SDR)[1]. This focuses on the company's climate impact, as well as risks.

You might say that farmers have had it the other way around. The supply chain has, until now, been almost exclusively preoccupied with farming's contribution to climate change - the SDR piece. Yet, few have considered the risks that climate change poses to farm businesses and food production - the climate risk piece.

To put it plainly, it's time for the principles of climate-related financial disclosure to be applied at farm level. Although, let's not call it this when talking to farmers. At farm level this is about climate resilience.

This report examines why the concept of CFD can and should be applied at farm level, examines the physical and transitional risks to a typical dairy farm and explains why a climate stress test should become an essential part of the climate toolkit.

> It's time to shift the conversation beyond simply understanding farming's contribution to climate change to understanding the risks climate change poses to food production.

[1] UK Sustainability Disclosure Standards (SDS) will set out corporate disclosures on the sustainability-related risks and opportunities that companies face. This will form part of a package of measures aimed also at reducing greenwashing and unifying UK sustainability reporting.

TCFD AND SDR: AN EXAMPLE AT A MILK PROCESSOR LEVEL[2]

TCFD: The Happy Cow Dairy Co. purchases raw milk from dairy farms that is processed to make pasteurised liquid milk. Due to the climate change impacts of animal heat stress, loss of forage caused by flooding, and higher feed prices due to a wet, late, poor harvest, their total milk pool volumes are declining. This causes supply chain issues as The Happy Cow Dairy Co can't process and deliver as much milk, nor can they forecast future volumes as reliably as in previous years.

SFD: As well as stating to its shareholders/ members that it can't procure as much milk, The Happy Cow Dairy Co. must also disclose that it is partly responsible for this situation, given that scope 3 emissions from dairy production account for over 85% of the company's overall carbon footprint, and is an evidenced contributing factor to UK climate change. In addition, there have been several water pollution incidents on suppliers' farms caused by flash floods and increased run-off. The company is partly responsible for this through its supply chain association. Positively, the carbon stored by and future removal potential of pastureland, trees and hedges across the supplying farms is a valuable asset in the ultimate goal of achieving net-zero carbon.

[2] Adapted from Small99.co.uk

WHAT IS CLIMATE-RELATED FINANCIAL DISCLOSURE?[3]

New mandatory climate-related financial disclosure regulation[4] introduced in January 2022, amending the Companies Act 2006[5], places requirements on certain publicly quoted and large private companies to incorporate climate disclosures in their annual reports.

For financial years starting on or after 6th April 2022, companies must now report on how the risks posed by climate change could have material impact on the value of the company and its assets.

These regulations have evolved out of the recommendations of the Financial Stability Board's (FSB) Task Force on Climate-related Financial Disclosures (TCFD), which is regarded as the most effective framework for companies to analyse, understand and ultimately disclose climate-related financial information.

Wide support for the taskforce's recommendations across large businesses, governments, stock exchanges and the investment community led the UK Government to adopt them as the basis for implementing mandatory climate-related financial disclosures across the UK economy (albeit with some adaptations to suit UK legislation).

The benefits for investors are that, by disclosing any material climate-related financial information, as well as a company's exposure to climate related risks and opportunities, investors will be better equipped to incorporate these risks into their investment and business decisions. The government's Net Zero Strategy, published on 19th October 2021, highlights the importance of these disclosures to inform investment decisions.

For companies, a full assessment and disclosure by a business on what changing climate will mean for them, may help them make better plans for their organisation, operations, and people.

[3] BEIS, February 2022: Mandatory climate-related financial disclosures by publicly quoted companies, large private companies and LLPs Non-binding guidance

[4] The Companies (Strategic Report) (Climate-related Financial Disclosure) Regulations 2022.

[5] sections 414C, 414CA and 414CB

WHO DOES IT APPLY TO?

The disclosure requirements apply to companies or Limited Liability Partnerships (LLPs) that meet certain scope criteria including (for full list see note[6]):

- All UK companies[7] currently required to produce a non-financial information statement.
- UK registered companies which have more than 500 employees and a turnover of more than £500m.
- Large LLPs, which are not traded or banking LLPs, with more than 500 employees and a turnover of more than £500m.

More detailed size thresholds are included in the full guidance document, but overall the scope is intended to engage the most significant companies in economic and environmental terms in analysing and disclosing their climate-related risks and opportunities.

Companies are required to include disclosures on climate change related risks and opportunities, where these are material. The disclosures should cover how climate change is addressed in corporate governance; the impacts on strategy; how risks and opportunities are managed; and the performance measures and targets applied in managing these issues.

Climate related risks are defined as either **physical** or **transitional**; for example:

Physical risks: acute physical risks (e.g., higher frequency or severity of weather-related events such as winter storms, surge floods, hail and wildfires) and chronic physical risks (e.g., longer-term changes to weather patterns and associated sea-level rises, hot or cold waves and droughts). The range of geographical locations in which the company operates, and the extent to which those locations may be subject to identified risks should also be assessed.

Transition risks: Relevant climate "transition" risks across the spectrum of technology, policy, market and legal and reputational should be considered.

A description of the impacts and likelihood of each risk identified should be included.

For example: A milk processor may identify that one of its major plants and/or suppliers is situated in a location becoming more prone to flooding. The disclosures should state which sites/farms may be at physical risk, the importance of the production of that site/supplier to the business and the impact that a major flood in that area would have. A contingency plan should show if the business can source from alternative suppliers, whether flood defences are being improved or whether site relocation is being considered.

COMING SOON...

The Taskforce on Nature-Related Financial Disclosures (TNFD) is an international initiative that builds on the model developed by the TCFD. It has received international political support and recommends that from 2023 financial services firms and large corporates also disclose nature-related risks, such as negative effects on biodiversity and ecosystems[8].

In a dairy context this might include, for example, say in cow diets that contributes to deforestation, or is linked to land-use change; or poor slurry and soil management that may lead to pollution and erosion incidents. Equally, opportunities may exist, such as regenerative agriculture practices that enhance soil organic matter and carbon capacity; or habitat creation through agro-forestry and/or participation in the Sustainable Farming Initiative (SFI) scheme.

Overall, the approach will focus on reducing nature-negative activities to promoting nature-positive ones and will be aligned to the existing policy goals of no net-loss of biodiversity by 2030 and net gains by 2050.

The Environmental Audit Committee Chair has called on government to make TNFD mandatory for companies, like TCFD is. Although TNFD reporting is not yet mandatory, investors may start asking for corporate disclosures on nature impacts and start assessing their own exposure to biodiversity risk[9].

[6] UK companies that have more than 500 employees and have either transferable securities admitted to trading on a UK regulated market or are banking companies or insurance companies (Relevant Public Interest Entities (PIEs) / UK registered companies with securities admitted to AIM with more than 500 employees / Traded or banking LLPs which have more than 500 employees.

[7] UK Companies with an overseas parent company which reports on a consolidated basis must also disclose

[8] Deloitte.com

[9] British Retail Consortium (BRC.org.uk).

CLIMATE, AGRICULTURE AND THE DAIRY SECTOR

Farmers won't need reminding that the record-breaking temperatures seen in summer 2022 brought unprecedented numbers of heat-related deaths, both animal and human, wildfire incidents, crop losses and significant infrastructure disruption.

The Climate Change Committee's (CCC) Independent Assessment of UK Climate Risk report (2021) identifies climate change as one of the greatest risks to the UK food sector.

UK CLIMATE PROJECTIONS

In its latest UK Climate Change Risk Assessment[10], the Committee prepared an independent risk assessment setting out the latest evidence on the risks and opportunities to the UK.

The key UK climate scenarios and risks identified include:

- Later this century more of the rain in summer will come from short lived high intensity showers.
- Rainfall is expected to decrease in summer, but when it does rain it is projected to be more intense, by as much as 25%.

- A decrease in soil moisture during summers is projected, consistent with the reduction in summer rainfall.
- The UK could experience an increase in annual average temperature of up to 4˚C or more by the end of the century, depending on the success of global greenhouse gas reductions.

- The UK is expected to experience warmer, wetter winters and hotter, drier summers as the climate changes.
- The chance of extreme maximum daily temperatures will increase.

- Sea levels will continue rising.
- By the end of the century, the sea level in places around the UK is projected to rise between 0.29m and 1.15m.
- We can expect increases to extreme coastal water levels driven mainly by increases in sea level rise.

For agriculture specifically, the CCC's assessment concluded that climatic changes, especially wetter or drier conditions, could significantly impact on UK soil health leading to implications for agricultural productivity.

It suggests that agricultural productivity could be at risk under most future climate scenarios. This could be as a direct result of more extreme weather (namely extreme heat, flooding, drought, sea level rise or saline intrusion), or due to a greater number of pests, pathogens and invasive non-native species (INNS).

There could also be some opportunities for UK agriculture under a changing climate should new or alternative species become suitable for the UK, or due to longer growing seasons (if water is not a limiting factor).

These findings are supported by wider research which identifies increased agricultural and hydrological drought risk across the UK, as well as wildfires under the predicted hotter, drier conditions. In general, the risks associated with high temperature extremes will increase the most in southern and eastern England, but the rate of increase from a lower base may be greater further north and west. River flood risk increases particularly in the north and west. The demand for cooling energy on livestock farms will also likely increase because of prolonged warm conditions, whilst demand for heating energy will decline[11].

According to a Met Office study, the dairy sector is one of the sectors most likely to be impacted by UK climate change over the next thirty to fifty years[12].

Specifically, the study found that dairy cattle in parts of the South East may be exposed to heat stress for an extra two months per year, compared to around a week per year currently. In the South West, the UK region with the largest herd of dairy cattle (c.750,000 dairy cattle according to Defra figures), heat stress conditions are currently met around two-to-three days per year, but in the period 2051-2070, this could extend to around one month per year on average.

Other regions of the UK which are likely to see prolonged periods of heat stress in dairy cattle are the West Midlands and the East Midlands, which may both see increases of heat stress conditions of around a month per year on average using climate projections.

[10] Findings from the third UK Climate Change Risk Assessment (CCRA3) Evidence Report 2021

[11] Arnell et al (2021)

[12] Garry et al (2021)

A CLIMATE RESILIENT DAIRY FARM

It is vital that farms begin to incorporate climate change into their operations and business planning in the same way 'big businesses' do. Understanding how a changing climate will impact a dairy farm business, and understanding what can be done to manage it will be fundamental to producing milk successfully in future.

Warnings and evidence of climate change's current and mounting impact on the UK are numerous. Yet, there are no tools available currently to assess farm level climate risks and calculate business resilience in the UK[13].

The World Wildlife Fund (WWF) notes the lack of studies on the cumulative impact of environmental changes on livestock and crop sectors and has proposed that UK Government adapts the concept of 'stress testing' for a range of sectors to help inform policy related to natural capital, as well as sectoral economic metrics[14].

Currently, the only means identified of tracking and understanding emerging environmental risks affecting the food supply chain is the Defra-funded Met Office climate service on Food, Farming and Natural Environment. This service focuses on the impacts of climate change on farming, with the aim of informing policymakers on the future adaptation needed in the farming sector. This involves close collaboration with Defra and informs policy and action through Defra's 3-yearly UK Food Security Report and contributions to the National Adaptation Plan. The climate service also has strong links to the UK's Global Food Security Programme. The service also explores the climate sensitivities of UK plant pests and diseases, and provides estimates of when microclimate conditions might be suitable for known, invasive plant pests.

At a supply chain and individual business level, stakeholders need to understand the risks that climate change poses to their operations, profit margin and sustainability in the medium and long term. If a key commodity, be it UK or internationally sourced, is likely to suffer shocks or significant change as a result of climate change impacts then what can the business do to mitigate against it? This last year could not have provided a more case-in point of the vulnerability of supply chains to sudden changes in supply.

Indeed, given the climate projections and predicted sensitivity of the dairy sector to climate risks, this is a question that milk processors also need to be asking themselves. Where is the milk pool distributed? What are the geographical risks as temperatures change? How affected are sites and logistics by rising sea levels and more frequent flooding?

WHO BENEFITS?

Using the TCFD's strategic risk framework at farm level enables several beneficiaries to pinpoint risks, respond appropriately and informs decision making. Those who would benefit from farm level climate resilience testing might include:

- **Individual farm businesses:** Planning ahead rather than responding reactively will help farmers with financial planning, forecasting, investment decisions, business continuity and potentially to demonstrate climate resilience to banks (a safer lending prospect), as well as the potential to access green finance.
- **Dairy processors and retailers:** For their own TCFD reporting and supply chain planning and forecasting, operational risk assessment and strategic plans.
- **Defra and Environment Agency:** Regulators and policy makers benefit from understanding climate risks and opportunities at farm/sector level.
- **Banks:** For assessing lending risks, and to satisfy their own disclosure requirements for climate risks within their client portfolios. Deloitte observes that there are no reliable tools for some sectors, and banks are likely to require specialist third party input in some areas. TCFD's updated guidance suggests that banks should forecast the financial impact that climate change could have on a client's operations within an estimated price range across several time horizons.

[13] Assessments at international, country level for particular crops exist (FAO / World Bank). US has created climate scenario tools to inform specific farm level decisions for arable crops.

[14] Cambridge Econometrics; www.camecon.com

HOW TO APPROACH A CLIMATE 'STRESS TEST' AT FARM LEVEL

A climate resilience test (or 'stress test' to use a banking analogy), looks at a common set of risks within the scope of an enterprise. It identifies the impacts the risks present and quantifies them at a business level (e.g. for a farm this may include operating profit / milk volume / value of outputs (ppl)). It also identifies options for increasing resiliency through mitigations and adaptations.

To be clear, this isn't about measuring carbon footprints, or reducing on-farm emissions. This is about understanding a farm's vulnerabilities, the threats that climate change may present, and ultimately preparing a farm business for the realities of more extremes in weather. The impacts of climate change on agriculture are not all negative of course, there may also be opportunities and climatic advantages to farmers in certain parts of the country.

Critically, whatever the impact, the 'stress test' will make farmers consider three crucial questions:

Q1. What risks does climate change pose to my farm business now, and over the next 5 years?

Q2. What would be the impact of that risk be to my farm area, animals and business?

Q3. What adaptations and solutions might mitigate the impacts or reduce the risk?

Once the risks and impacts have been identified, quantified and ranked in terms of likelihood and severity, with any mitigations costed, a bespoke climate risk assessment with a resilience score and mitigation guidance, and an action plan can be produced for the farm business.

There are several ways that this concept could be applied at farm level.

The simplest approach is a form of self-assessment with appropriate tools and prompts. Although in reality asking farmers to think about something that may happen in the future, when they are usually, and necessarily, focussed on the challenges of today, is difficult.

Another, and more active approach, is a guided discussion with individual or a group of farmers, using a step-by-step process:

Step 1: Select relevant climate hazards in a distinct geographical area.

Step 2: Explore climate risks presented to your farm/surrounding land area. Having selected your hazards, consider how they could affect the site.

Step 3: List the most important risks, the consequences if it were to happen and how they are being addressed. Impacts on finance, operations, infrastructure, land management and animals should be identified and quantified where possible. Then, spend time thinking about the likelihood of those risks occurring. A short, high level risk register is the output.

Step 4: After a summary discussion of the potential effects of the hazards, and any actions that can be implemented, consider relationships with other stakeholders (milk buyers, retailers, customers, regulators, consultants) who may be able to support efforts to increase resilience, or could be adversely affected.

APPLYING TCFD AT DAIRY FARM LEVEL

For the purpose of this report, macro level climate scenarios have been assumed in line with the latest Met Office forecasts. The scope is set at farm level, with some impacts likely to be industry-wide. Typical categories of physical and transitional risks are identified, along with the nature of the impact and potential mitigations.

Quantifying the economic impact of an animal disease and its management is generally more complex. In part because this depends on how prolonged and widespread is and the control measures required to manage or eradicate it

ECONOMIC IMPACT

Quantifying the value of impacts at farm level is difficult to do without access to financial business information. However, there are formulas and protocols that exist for calculating damage from weather related events and/or disease outbreaks events.

One example is the analysis of damage costs protocols used by the Environment Agency (EA) for the assessment of flood risk for agriculture. This methodology incorporates discrete categories - damage to arable, grass and other crops, to livestock enterprises and 'other' impacts at the farm scale. The scope of these costs is broadly defined as follows[15]:

- Flood costs for arable crops include loss of the value of output, additional inputs less any savings in uncommitted costs, such as harvesting and remedial work including land restoration and re-sowing crops.
- For grassland, the impact of a flood occurring in a given month is assessed in terms of the loss of animal feed, valued at substitute feed prices, less any savings in hay/silage making costs if relevant.
- Livestock costs include the cost of relocating and/or housing animals, including additional feed and bedding costs, increased morbidity/mortality and loss of sales.
- 'Other' costs include damage to field infrastructure (fencing, drains), utilities, machinery, buildings and contents, and the cost of clean-up.

The general formula for estimating the costs of a single flood event is therefore represented as:

FARM = ARABLE + GRASS + LIVESTOCK + OTHER

By comparison, quantifying the economic impact of an animal disease and its management is generally more complex. In part because this depends on how prolonged and widespread an outbreak is and the control measures required to manage or eradicate it (e.g. mortality rates, movement restrictions, milk withdrawals). The economics of disease outbreaks also largely depend on whether the disease is a 'notifiable disease', which then needs to be eradicated to allow trade of goods to continue[16], versus a disease that can be 'lived with'.

METRICS AND INDICATORS

There are several key metrics and indicators that may be used to assess and monitor a farm's exposure to climate related risks, and the business impacts. These include:

- Growing degree days are a proxy for the productivity of permanent grassland and the potential for annual crops. Growing degree days are calculated from daily average temperature with a threshold of 5.6˚C. The growing season starts once temperatures have exceeded 5.6˚C for at least five days.
- Days with high temperatures can limit growth (and at the extreme kill plants) and cause discomfort to livestock. For example, milk yields in dairy cattle fall if maximum temperatures exceed around 23˚C[17]. Temperatures of between 32 and 35˚C during the flowering and grain filling period lead to reductions in wheat yield.
- Drought is characterised by the Standardised Precipitation-Evaporation Index (SPEI), calculated over a six-month accumulation period, which correlates well with drought impacts on agriculture in the UK[18]. The drought indicator is the proportion of time that SPEI6 is below 1.5.
- Other agri-climate indicators for agriculture might include: growing season length, soil moisture deficit, soil organic matter/carbon, regional rainfall
- Business impact indicators for dairy farms include cost analysis, forage stocks and cow performance (e.g., yields, reproductive rates).

[15] Penning-Rowsell et al (2013), cited in ADAS (2014)

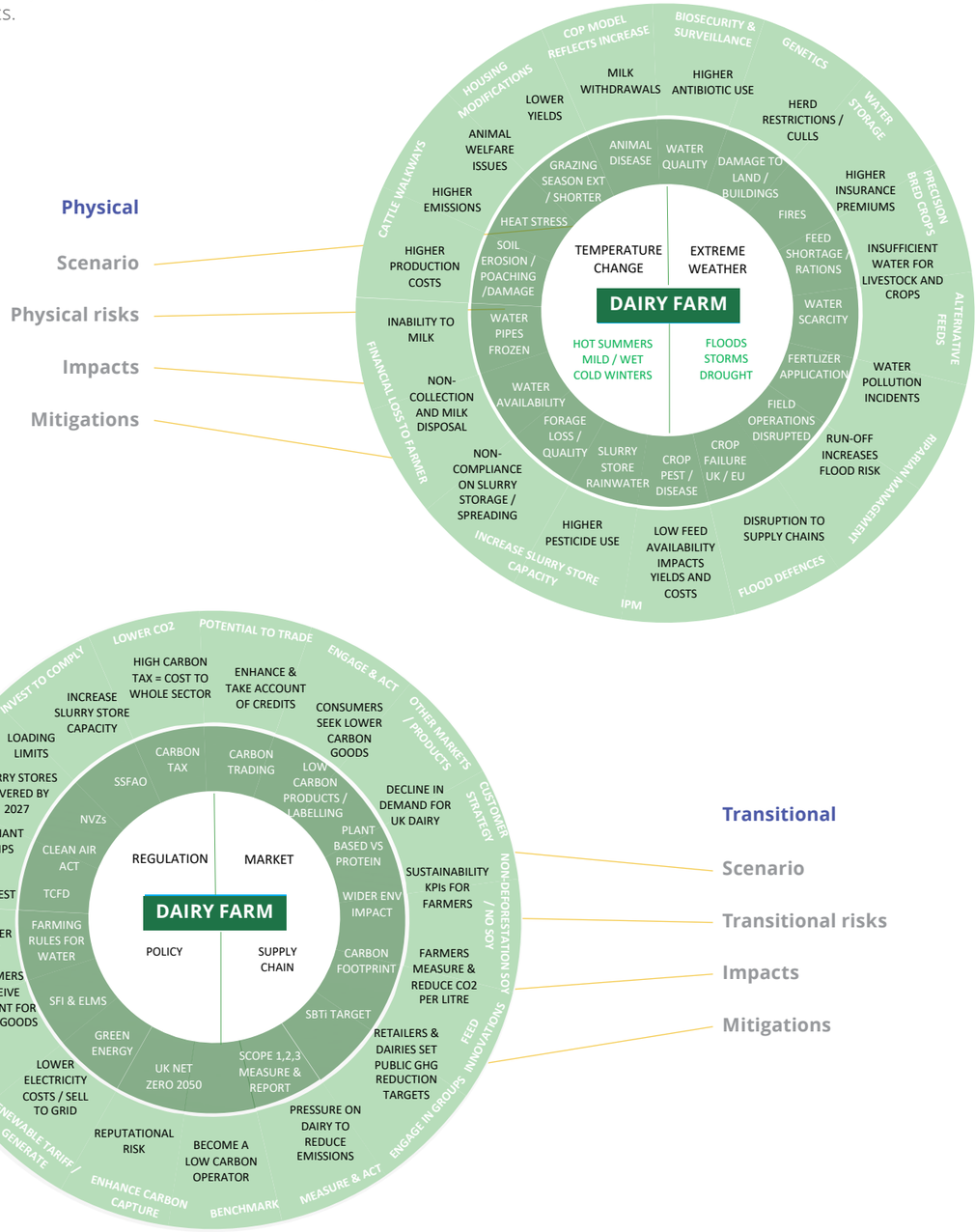
[16] The large-scale 2001 UK FMD outbreak provided some of the most comprehensive data available. It is estimated that this outbreak cost the UK livestock sector £3.1 billion with similar additional costs to the wider economy.

[17] Jones et al (2020)

[18] Parsons et al (2019)

CLIMATE RISKS AND IMPACTS TO DAIRY FARMS

The wheels below present a headline summary of the priority climate risks and impacts, with a more detailed qualitative analysis provided in the accompanying risk assessments.



PRIORITY RISKS

ANIMAL HEALTH AND WELFARE

Animal disease

There's no doubt amongst the scientific community that climate change will dramatically exacerbate how, what and why diseases occur in livestock. Some diseases are especially sensitive to climate change. This is particularly the case for diseases that are vector- borne, soil associated, water or flood associated, rodent associated, or air temperature/humidity associated[19]. These could be major outbreaks or smaller events.

In addition, climatic changes may influence the range and abundance of vectors and wildlife reservoirs, the survival of pathogens in the environment and an animal's response to a virus. There is also a risk to people from zoonotic infections that we currently aren't exposed to. We will also likely see a different spread in the current diseases we have geographically and temporally in terms of the months they affect animals.

Short, medium and long term mitigation and adaptation measures that can be used specifically in the livestock sector to minimize the impacts of climate change-associated livestock diseases include[20] capacity building to reduce overcrowding and improved shed ventilation, breeding for disease resistance, cattle vaccination and disease surveillance on-farm and at a national scale.

The UK Animal Plant and Health Agency (APHA) publish quarterly reports on cattle disease surveillance and emergence[21]. They also carry out testing. So, there is already a process in place to try to detect new disease early.

Heat stress in cows and calves

Temperature extremes (hot & cold) have a notable impact on cow health and performance at all stages of life. The thermoneutral[22] zone (TNZ) for dairy cattle is between 0.5˚C and 20˚C. As such 'heat stress' technically occurs at any temperature above this level.

In lactating dairy cows, heat stress negatively affects dry matter intake, milk yield, feed efficiency, fertility (through lower conception rates and increased risk of early embryo death) and water intake, with detrimental consequences to animal welfare, health and farm profitability[23].

There is also evidence that cows under heat stress will attempt to cope with high temperatures by reducing their activity and standing more, which may impact on lameness and rumination efficiency[24]. Acidosis (from panting and loss of CO2) can impact on butter fat output and impairs rumen function. In extreme heat conditions, animals can suffer from severe dehydration and death.

[19] Nejash, (2016)

[20] Betta et al (2016)

[21] https://www.gov.uk/government/publications/cattle-gb-disease-surveillance-and-emerging-threats-reports

[22] The range of environmental temperatures over which the heat produced by the animal remains fairly constant and the animal does not have to expend energy on cooling mechanisms (such as panting and sweating).

[23] Souza et al (2023)

[24] Chalcombe Ltd. (presentation)

The effects of heat stress on calves range from decreased gestation length leading to lower calf birthweights and weaning weights to reduced milk production in later life, as these calves never catch up (known as epigenetic effects, where the environment causes changes that affect the way genes work). Calves born after a period of heat stress also have reduced reproductive activity throughout their lifetime.

There is very little peer reviewed UK based research focused on heat mitigation. Most information is based on the experience of farmers in the USA, however, useful insights can still be drawn. For example, evidence suggests that the collecting yard is where dairy cows experience the most heat stress. A lactating cow will spend 15 to 75 min before milking in the holding pen adjacent to the milking parlour. One study found that increased milk production (0.8 kg/head per day) and a reduced body temperature occurred when sprinklers and fans were installed in the holding pen area[25].

Various genetic strategies are promoted for heat stress mitigation in cows, such as breeding for heat resistance[26] and genomic selection for improved feed intake (e.g. Cogent's Ecofeed claims to reduce water requirements as well as feed requirements whilst maintaining production). The UK Government has passed the Precision Breeding Bill, which legalises gene editing in plants (initially) and animals in the UK, and may bring further advances in breeding for climate resilience in animals.

Other strategies for mitigating heat stress in cows and youngstock include physical modifications of the environment (e.g. in Florida, fans automatically switch on at >21˚C and sprinklers at >22˚C). Sprinklers are one of the most common and effective methods to promote heat loss. They generate droplets that wet the cow's hair, coat and skin. Fans force air over the cow's body, causing evaporative cooling to take place on its surface. A combination of the two are widely considered the most effective means of cooling dairy cows.

It should be noted that sprinkler and fan cooling systems generate large volumes of water that must be processed (potentially around 216 litres/cow per day). This would be dirty water that would then need to be stored/ spread appropriately. They also require electricity and maintenance. Fans don't feature in the majority of UK dairy sheds currently (although are becoming more popular), so would be a large investment for most dairy farmers. As an alternative, tunnel-ventilation barns can reduce the impact of heat stress on cow body temperature[27] and and are already widely used in UK cow sheds.

Another consideration is bedding material, which is usually selected based on economic feasibility, cow comfort, cleanliness, and udder health. However, few producers consider the thermal comfort that bedding material provides. The bedding material in a dairy farm should form part of a heat abatement strategy. For example, lower temperatures have been reported for limestone (25.9˚C) and sand (26.9˚C) compared with wood shavings (28.6˚C).

AHDB states the priorities during hot weather are in-calf and first-calved heifers. They are more sensitive to periods of under-feeding due to their own requirements for growth, as well as their growing calf's needs. During dry periods, providing straw in fields will act as an indicator of the need for additional feed. If straw intake exceeds 2kg per head per day, supplementary feeding will be needed to maintain condition and performance. Under-feeding heifer replacements may result in liveweight targets not being met – they need to be at least 65 per cent of mature bodyweight at first service. This may have consequences in terms of serving age[28]. Tailored nutritional and feeding strategies aimed at sustaining sufficient dry matter intake (such as the addition of bicarb and yeasts) can also help with the challenges of ruminal acidosis.

One key mitigation to prevent health stress in unborn calves is to cool in-calf cows for the entire dry period. Evidence shows that cooling also increases the efficiency of colostrum absorption as heat stress accelerates gut closure.

Cold stress in cows and calves

The UK has a temperate, maritime climate and as such tends to experience minus Celsius temperatures for prolonged periods of time. When persistent cold temperatures and frosts occur, water availability becomes a huge issue. Lactating dairy cows can drink around 120litres a day and frozen water and/or pipes can present an issue on farm very quickly.

There is also a lot of surface water in cows' every day environment and icy conditions under hoof can increase slips and cow mortality. Farmers need increased labour during these times to help mitigate risks by getting water flowing again and putting materials such as sand down to help counteract icy walkways.

Generally, however, the impact of extreme cold temperatures on dairy herds is more apparent in youngstock. The highest calf mortality rates are recorded in winter and cold temperature is the most significant factor in cause of death. Calves have a Lower Critical Temperature (LCT) of 10˚C. Below this temperature calves will lose weight as they require higher maintenance feed levels[29].

Slower growth rates in calves due to cold conditions means that they will take longer to reach their target weight for reaching reproductive ability, which incurs a long-term cost to the farmer. Cold stress also makes calves more susceptible to disease, especially pneumonia, which in turn increases the use of antibiotics.

Mitigation options for protecting calves from cold stress, include vaccination and improvement of the calf's environment, feeding higher quantities or concentrations of energy density milk replacer in the winter months, use of calf jackets (widely done in practice, but evidence to support their benefits is inconclusive) and space heaters in hutches and sheds[30].

[25] Collier et al (2006)
[26] Carmickle et al (2022)
[27] Dikmen et al (2020)
[28] AHDB REF: Effects of hot weather on cattle

SOILS, FORAGE AND LAND MANAGEMENT

Soils

There is increasing evidence of the negative impacts of changing weather patterns, particularly those involving increased and decreased rain periods, on soil resources.

Future projections indicate that hazards such as heavy rainfall or wind (leading to erosion) and drought (leading to increased soil moisture deficits, peatland drying and potentially the degradation of soil microbial communities) will exacerbate the loss of soil resources.

The current rate of erosion is estimated at 2.9Mt/yr in England and Wales with productivity losses estimated at £40million/yr. Severe degradation of soil quality would be very likely to have long-term, potentially irreversible, implications particularly given the critical importance of soil in underpinning biodiversity, providing high-quality farmland and a range of ecosystem services[31].

There are two key themes that will help resilience to prepare farms for these eventualities. The first is preparedness to maximise forage stocks during good growth periods, to help weather poorer conditions; in other words 'make hay when the sun shines'. This includes good storage facilities for both crop and slurry, as well as access to machinery and labour on demand.

The other area is looking at 'carbon for soils' not 'soils for carbon'. Organic matter is a key indicator of soil health and has a crucial role to play in water storage, drought and flood resilience and reducing the likelihood of compaction, erosion and soil run-off on saturated ground.

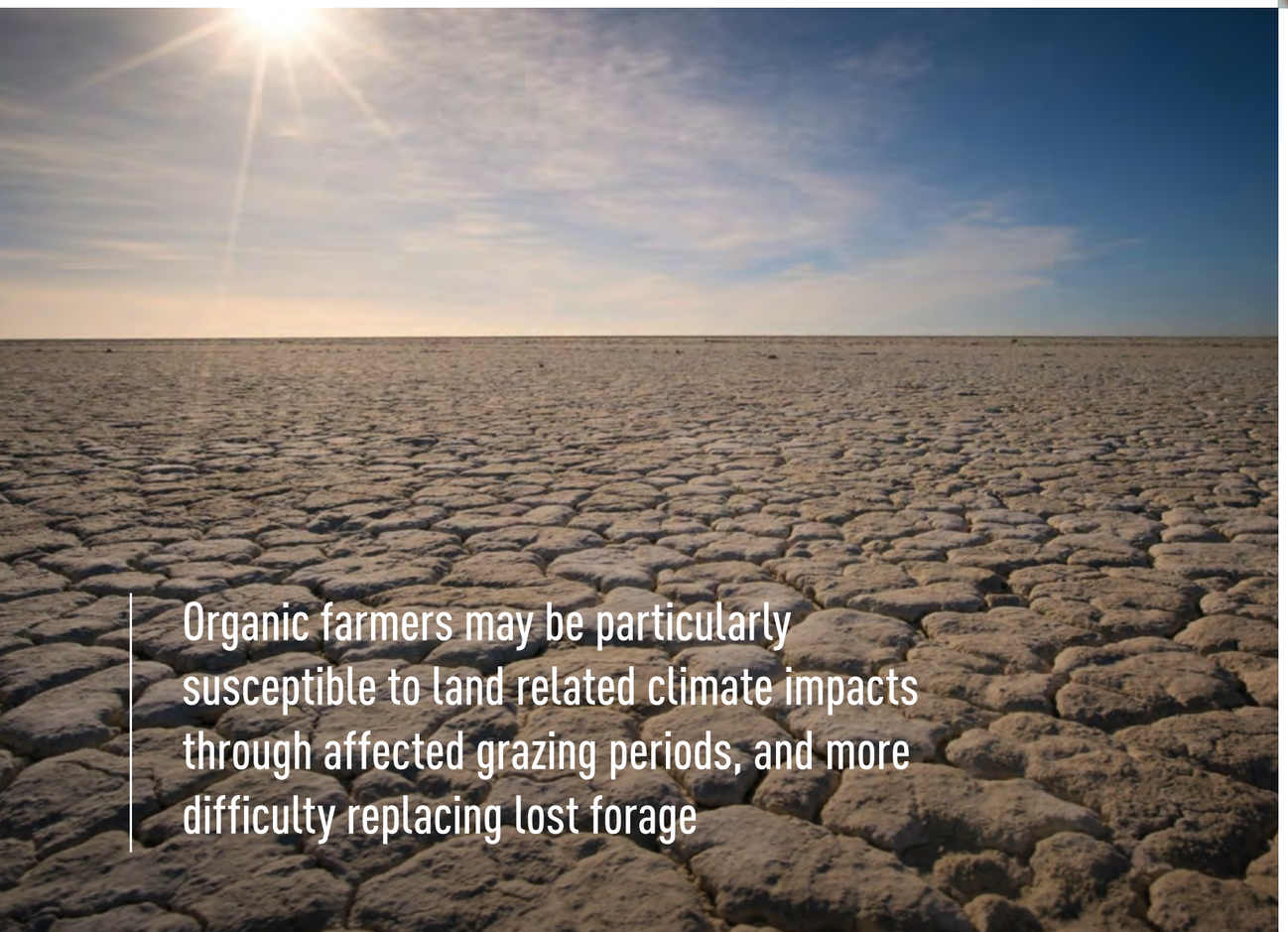
At a national scale, beneficial actions in the next five years to aid mitigation and adaptation include more investment in national-scale soil monitoring programmes and monitoring of different management interventions; improved advice for land managers together with payments that incentivise improved soil health and increased uptake of precision farming technology.

[15] Penning-Rowsell, et al (2013), cited in ADAS, (2014).

[16] The large-scale 2001 UK FMD outbreak provided some of the most comprehensive data available. It is estimated that this outbreak cost the UK livestock sector £3.1 billion with similar additional costs to the wider economy.

[17] Jones, et al. (2020)

[18] Parsons et al. (2019)



Organic farmers may be particularly susceptible to land related climate impacts through affected grazing periods, and more difficulty replacing lost forage

Feed, forage and bedding

In the UK, harvest pressures this season have affected UK feed wheat prices and volumes. In addition, the competition from the renewables sector for crops is having a significant impact on feed supply and demand. Analysts estimate that up to 50% of the UK's maize and wheat harvest has been sold for bio-fuels.

In 2017, the Scottish Government commissioned a report on the unfavourable harvest conditions, and their effects on straw and forage availability, pricing and the agricultural sector. That summer rainfall was above average across most of Scotland and much of England, (particularly northern arable areas including east Yorkshire). Conditions made it difficult to harvest cereal crops and to allow straw to dry out fit for baling, resulting in lower availability and higher prices. Making silage became difficult from mid-summer onwards and many farms had a reduced or lower quality stock of silage going into winter.

The knock-on effects of the poor silage and straw harvest included an expected loss of livestock condition, reduced calving rates and reduced livestock growth rates. In addition waterlogged fields may have experienced soil structure damage that would limit crop yields and take time and cost (drainage/re-seeding) to remedy.

The study identified a range of strategies that farmers may adopt to reduce straw use and minimise the risk of future higher costs, which included greater outwintering of stock, use of alternatives to cereal straw such as sand, woodchip and rapeseed straw, and more use of long-term agreements between livestock and arable farmers, including 'straw for muck' deals, bringing more stability to straw supply and price.

A transitional market risk for farmers to understand and adapt to is the impact of weather-related and political events on UK and international feed markets. Global weather events and feed price and availability [particularly maize and feed wheat] are closely interlinked, and heavily influence dairy farms. There are concerns that this year's El Nino event will affect production volumes in the southern hemisphere; in particular Argentina and Brazil, limiting availability, and prompting farmers to switch to using soy, at lower cost and higher availability.

competition from the renewables sector for crops is having a significant impact on feed supply and demand.

Flooded land

The effects of floodwater can be devastating and widespread, as witnessed during the floods of winter 2014 when the UK suffered a spell of extreme weather, with a series of very large winter storms battering the country. Much of the UK suffered from extensive flooding after January 2014; this period saw the highest rainfall on record, with particularly pronounced effects in the Thames Valley and West of England. The resulting flooding was a combination of fluvial, pluvial and groundwater flooding with an element of coastal flooding in some areas[32].

The floods impacted on the agricultural sector through damage to or loss of established crops (grass and winter-sown arable crops), inability to access land to manage crops or drill new crops, damage to stored crops and forage stocks, costs of movement and/or feeding of livestock, damage to infrastructure and costs associated with the clean-up operation. Typically, the type of impacts which can be induced by flooding and waterlogging will vary to a large degree depending on type of grassland, soil type, duration of flooding and flows and sediment deposits.

In terms of herd management, rapidly rising water levels can cut off access to livestock and mean they can't get to safe lying areas or food. If fields are prone to flooding then, where possible, AHDB advises farmers to move livestock ahead of time to fields with suitable drainage and an area where animals can stand out of the mud or damp.

Water contamination after flooding is a serious risk to livestock. AHDB advises providing stock with a fresh trough of clean water, or emptied and cleaned existing troughs, to discourage stock from drinking from floodwater. It may be necessary to test microbiological quality of water at the point of supply for contamination.

Equally, herd health can be compromised after flooding and farmers should be vigilant about the risk of hypothermia in livestock that have been standing in deep flood water for prolonged periods in cold conditions without access to food. Stress and poor access to feed during flooding will increase the risk of metabolic diseases, such as grass tetany, milk fever and ketosis. Farmers are advised to monitor cows regularly to check for abnormal behaviour that can be a sign of metabolic disorders, and to supplement dairy cows after calving with calcium and magnesium[33].

Natural flood management is a key mitigation for managing flood events and water levels at a catchment level. Practices, such as increasing soil infiltration, ditch management, buffer strips and storing water can reduce the frequency of flooding for high probability fluvial events (for example, less than a one in twenty-year return period) and have a beneficial impact on slowing the flow of flood water downstream[34].

It should be noted that protection against flood damage is not automatically included on farm insurance policies and farmers need to regularly review what they have protected. There are no standard products in the UK that cover crops in the ground or movable property in the open, such as stacks of silage bales, meaning if bales are at risk, the only protection is finding a site that is less vulnerable. Flood damage to farm buildings and their contents can be protected, as can tractors and farm machinery through a comprehensive policy[35].

It should be noted that protection against flood damage is not automatically included on farm insurance policies and farmers need to regularly review what they have protected

[32] ADAS (2015).
[33] AHDB Advice to Livestock Farmers Affected by Flooding; AHDB.org.uk
[34] Dales to Vale Rivers Network (2017).
[35] fwi.co.uk/business/compliance/which-rules-are-relaxed-when-farmland-is-flooded

Pests, pathogens and invasive non-native species

Climate change is also increasing the risk of impacts from pests and pathogens, due to warmer and wetter conditions especially in the winter months. For example, warmer temperatures result in increased over-winter survival rates of pests.

According to the latest CCC assessment, pests, pathogens and invasive non-native species (INNS) present serious risks to agricultural productivity, with consequences for livelihoods and businesses. One such example is the Septoria tritici blotch which costs UK wheat growers alone around £100-£200 million per year in yield losses.

Current risk assessments by plant and animal health agencies provide some adaptive capacity that acts to reduce the risk to a lower level, but most do not give explicit reference to long-term future climate change including considerations of scenarios up to a 4˚C world.

One obvious adaptation is through the use of breeding technologies to improve resilience along with the use of more diverse plant and livestock species and varieties.

BUSINESS, INFRASTRUCTURE & SUPPLY CHAIN

Logistics

In recent years prolonged cold snaps have made roads impassable across large swathes of the country. For the first time in corporate memory, tanker drivers in Somerset were unable to reach certain producers due to flooding in Spring 2023. In February 2016 Storm Dennis left roads impassable and many dairy farmers in Wales were unable to have their milk collected. In recent years some dairy farmers have been forced to dump milk due to driver shortages affecting milk collections. In short, logistics can be sensitive to sudden shocks, and dairy farmers have little control over this.

The only mitigating actions available at farm level are to increase milk storage facilities so that farmers can carry two days of milk on farm, and to take out insurance for non-collection and disposal of milk.

Environmental regulation

At a policy level, the introduction of several new and impending environmental regulations poses serious risks to many dairy farms that face large financial investments or non-compliance.

In a soon to be published report, Kite estimates the total cost of environmental regulatory compliance to British dairy farmers over the next ten years at over £1.85 billion. This is driven by the need to meet Nitrate Vulnerable Zones (NVZ) requirements, a possible investment in slurry store covers by 2027 to comply with the Clean Air Act (1993), and Silage, Slurry and Agricultural Fuel Oil (SSAFO) pollution control regulations.

Net zero and the rise of plant-based

From a market perspective, the drive for net zero presents opportunities for dairy farmers. Carbon footprinting and emissions reduction plans drive on-farm efficiency and, in doing so, reduce production costs/increase margins. In addition, the climate commitments made by large retailers and dairy companies presents a long-term opportunity for dairy farmers to provide the carbon removals needed by the supply chain to meet their net-zero targets.

A climate related market risk for dairy farmers and processors to be aware of is a potential decline in milk consumption as dairy alternatives grow in popularity. Although sales of such products have slowed during the cost of living crisis, protein diversification remains an active sustainability objective for several of the dairy sector's major customers.

> From a market perspective, the drive for net zero presents opportunities for dairy farmers

DAIRY FARM CLIMATE 'STRESS TEST' EXAMPLE

Scope: Farm level (hypothetical)

- Felixstowe, Suffolk.
- 300 Holstein cows, housed herd.
- 9000-10000k litre average.
- Rear own replacements.
- Land for silage and forage production.
- Low-lying land, fertile soil.

Climate Scenario and Hazards[1]: Felixstowe, East Anglia

The region supports a diverse range of habitats, from agricultural landscapes, wetlands and ancient woodland to heathland, rivers and a long low-lying coast that supports a wide range of freshwater, brackish and saline habitats, all interspersed with rapidly growing urban populations. Among these habitats are more than 40 sites that are designated as being of international importance. The landscape is more man-made than most in the UK due to the reclamation of land from the sea to create the Fens. The Fens and the Broads have some of the best and largest tracts of agricultural land in the UK including 58% of the country's grade 1 and grade 2 land.

Over 75% of land in the East of England is used for farming. This is reflected in the high number of food processing and related supply chain businesses in the region.

The East of England is known for its cereal crops (c.1.5 million ha), with farmers growing more than a quarter of England's wheat and barley. The East of England is a major region for horticulture, pig and poultry production.

Almost a third of England's potato crop is grown in the East of England and farmers in East Anglia harvest well over half the country's entire sugar beet crop - mainly in Norfolk, Suffolk and Cambridgeshire.

Key Climate Hazards

UK Climate Change Risk Assessment highlights 3 climate hazards pertinent to the East of England:

1. water scarcity
2. sea level rise
3. flood
4. temperature.

The projected climate change impacts on rainfall and river flow for the East Anglian region by the 2050s are for rainfall to decrease by 39% in the summer, but increase by 35% in the winter and low flows to be 81% lower, but peak river flows to be 35% higher.

Water Scarcity

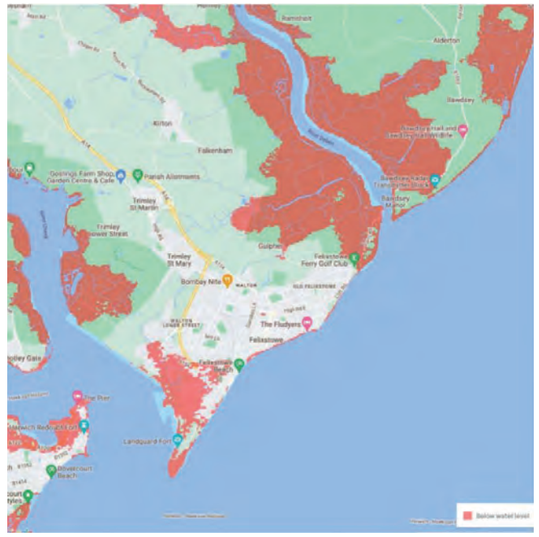
The East of England region is the driest region in the country. Annual rainfall (600mm average) is only 70 per cent of the national average and less than 20 per cent of the amount that falls in the Lake District. Dry spells are predicted to increase for the region, particularly in summer.

The agriculture sector holds 25% of East Suffolk's abstraction licences by volume, a quantity of 11 million cubic metres of water a year.

The region already faces significant water challenges, most of the East of England is recorded as being over abstracted or over-licensed at low flows. The region has several large reservoirs, two major water transfer schemes and a number of smaller river support schemes supplying rivers and groundwater aquifers. These transfers are crucial to the maintenance of public water supplies and also provide support for agriculture and the water environment, especially during drought periods.

Sea Level Rise

The East is a low-lying area with one-fifth of the region below sea level. There is also some of the fastest eroding coastline in Europe in Norfolk and Suffolk. The specific geology of the coastal areas (clay and sandstone) makes them particularly vulnerable to erosion.



Source: Climate Central

It is anticipated that the East of England could face dramatic increases in sea level of up to <0.54m by the end of the century assuming the high UKCP09 emissions scenario[2]. Shoreline Management Plans (SMPs) have been prepared; including Lowestoft Ness to Felixstowe Landguard Point, North Norfolk Shoreline Management Plan, and the Essex and South Suffolk Shoreline Management Plan.

The map shows where a water level of 1.0 meters above the high tide line could be reached through combinations of sea level rise, tides, and storm surge.

[1]All climate hazards and risks as cited in Climate UK's Climate Change Assessment for East Anglia and in accordance with the UK Government's Climate Change projections 2009 (UKCP09) scenarios and Met Office analysis.

[2]coastal.climatecentral.org

Flooding

Over 250,000 properties are at risk of flooding in the East of England; including warehouses, businesses and factories. This is based on a 1 in 1000 chance of flooding in any given year. In Felixstowe in 1953 a tidal surge, which was believed to reach 7ft 2in (2.1m), broke through the town's sea wall, causing mass flooding, loss of life and unprecedented damage to homes, businesses and farmland. Heavy rain and storm events are predicted to increase.

Temperature

The region is already exposed to some of the warmest UK conditions. Warm spells and dry spells are predicted to increase, particularly in summer. The hottest summer day in Felixstowe in the 30 years from 1991 to 2019 near was 34.7C.

If global average temperatures increase 2C above pre-industrial levels, the hottest summer day could be about 36.5C. If global temperatures rise by 4C, it could be about 40.8C. In the 30 summers from 1991 to 2019, there were 4 days above 25C per month on average. If global temperatures rise by 2C, there could be 10 days. With a 4C rise, there could be 18 days.

Farm Level Key Climate Risks 3, 5, 10 years:

RISK: Tidal flooding and storm surge where high quality agricultural land is located. Farm and surrounding land severely affected by the great flood of 1953 after river burst its banks. Storm events predicted to increase over next 5-10 years. Medium liklihood over next 10 years.

RISK: Availability of water for agriculture abstraction and boreholes under severe pressure. Currently abstract majority of water for livestock and feed-wheat / maize crop irrigation from borehole and abstraction licence. Availability under severe pressure. Dry spells in summer particulalry predicted to increase. High likelihood 3-5 years.

RISK: Summer overheating of milking cows and youngstock / increased disease risk within herd and from vector and airborne viruses. High liklihood over next 3 years.

RISK: Potential increased yields for current crops / grazing grass and new crops to grow (energy). Medium liklihood over 3-5 years.

Key impacts:

IMPACT: Saltwater cannot be used to irrigate crops or be consumed by livestock / Contamination of waterways from run-off causes regulatory breach = **£ FINES / LOWER YIELDS / RELIANCE ON MAINS WATER**

IMPACT: Maize and silage crop yields low, poor quality and possible failures / Welfare issues due to lack of water = **MILK YIELDS DECREASE / HIGHER PURCHASED FEED COSTS / WELFARE ISSUES ALL IMPACT PRODUCTIVITY AND INCREASE COSTS**

IMPACT: Reduced productivity and reproductive rates = **LOWER PREG RATE / YIELDS LOWER INCREASES COSTS AND REDUCES INCOME**

IMPACT: Potential increased yields / grazing grass and new crops to grow (energy) = **INCOME / GOOD FEED STOCKS**

Key mitigations

WATER: Better storage and use of excess winter rainfall to reduce relience on abstracted water. Field drainage works and to mitigate against saline intrusion. Think about installing an irrigation reservoir and adopting best metering practice.

LIVESTOCK: Invest in housing ventilation, reduce overcrowding, install fans & misters, minimise cows' heat exposure during peak heat periods and increase water availability.

FLOODS: Invest in drainage system for problem fields. Buy or lease new acreage with better drainage.

[1]All climate hazards and risks as cited in Climate UK's Climate Change Assessment for East Anglia and in accordance with the UK Government's Climate Change projections 2009 (UKCP09) scenarios and Met Office analysis.

CONCLUSION

Is there a case for applying the principles of climate-related financial disclosure at farm level? Quite simply, yes. Although, at farm level this is about climate resilience.

As this report shows, there are multiple and well evidenced physical and transitional risks posed by the impacts of climate change to a typical dairy farm. Agriculture is particularly sensitive to climatic conditions and will experience profound impacts on productivity and economic viability in response to weather related changes.

There are potentially significant commercial and competitive advantages to be gained by those businesses tackling the challenges. It would also benefit a range of supply chain stakeholders should a climate stress test become an essential part of the farm climate toolkit.

Addressing risks around weather and productivity should not be sidelined or considered a strategic exercise only for large corporates. It's a false economy for a business of any size not to understand and address them.

Demonstrating responsibility and preparedness when faced with external challenges will be paramount to long term business sustainability.

> The farmers that understand how changing climate patterns will affect future profitability, resource availability, investment needs and productivity will be the ones whose businesses have longevity

BIBILOGRAPHY

Arnell, N.W., Kay, A.L., Freeman, a., Rudd, A.C., Lowe, J.A. Changing climate risk in the UK: A multi-sectoral analysis using policy-relevant indicators. Climate Risk Management. 31 100265 (2021).

ASSESSING AND ADAPTING TO THE IMPACT OF PAST WEATHER EVENTS IN THE HORTICULTURE SECTOR. Case study: Royal Botanic Garden Edinburgh

Baker, R.E., Ayesha S.M., Miller, I.F., Rajeev, M., Rasambainarivo, F., Rice, B.L., Takahashi, S., Tatem, A.J., Wagner, C.E., Wang, L., Wesolowski, A. and Metcalf, C.J.E. Infectious disease in an era of global change. Nature Reviews Microbiology (2021).

BEIS, Mandatory climate-related financial disclosures by publicly quoted companies, large private companies and LLPs Non-binding guidance. February (2022).

Bett, P., Kiungaa, B.J., Gachohia, C., Sindatod, D., Mbothaa, T., Robinsona, J., Lindahlae, D., Grace Effects of climate change on the occurrence and distribution of livestock diseases. Preventive Veterinary Medicine. 137, 119–129 (2016).

Chamberlain, Tom, MRCVS, Chalcombe Ltd. A presentation on 'Heat Stress: Is it an issue for UK dairy cows?'

The Companies (Strategic Report Climate-related Financial Disclosure) Regulations 2022; sections 414C, 414CA and 414CB.

Carmickle, A.T., Denicol, A.C., Ferreira, F., Haimon, M.L.J., Hansen, P.J., Hernandez, F.S., Larson, C., Jensen, L.M., Pereira, J. Physiological responses of Holstein calves and heifers carrying the SLICK1 allele to heat stress in California and Florida dairy farms. Journal of Dairy Science, 105:9216–9225 (2022).

Collier, R.J., Dahl, G.E., and VanBaale, M.J. Major Advances Associated with Environmental Effects on Dairy Cattle. Journal of Dairy Science, 89:1244–1253 (2006).

Davidson, B.D., Dado-Senn, B., Padilla, N.R., Fabris, T.F., Casarotto, L.T., Ouellet, V., Toledo, I.M., Dahl, G.E., and Laporta, J. Late-gestation heat stress abatement in dairy heifers promotes

thermoregulation and improves productivity. Journal of Dairy Science. 104:2357–2368 (2021).

Dikmen, S., Larson, C. C., De Vries, A. & Hansen, P. J. Effectiveness of tunnel ventilation as dairy cow housing in hot climates: rectal temperatures during heat stress and seasonal variation in milk yield. Tropical Animal Health and Production, Volume 52, pp. 2687-2693 (2020).

Ezenwa, V., et al. Infectious Diseases, Livestock, and Climate: A Vicious Cycle? Science & Society. (2020)

Filho, L.W., et al. Climate Change and Zoonoses: A Review of Concepts, Definitions, and Bibliometrics. International Journal of Environmental Research and Public Health, 18, 893 (2022).

Fournel, S., Ouellet, V. & Charbonneau, E. Practices for Alleviating Heat Stress of Dairy Cows in Humid Continental Climates: A Literature Review. Animals, 7(5), p. 37 (2017).

Garry, F.K., et al. Future climate risk to UK agriculture from compound events. Climate Risk Management, 32, 7, (2021).

Godde, C.M., Herrero, M., Mason-D'Croz, D., Mayberry, D.E., Thornton, P.K. Impacts of climate change on the livestock food supply chain; a review of the evidence; Global Food Security 28 (2021).

Habimana V., et al. Heat stress effects on milk yield traits and metabolites and mitigation strategies for dairy cattle breeds reared in tropical and sub-tropical countries. Front. Vet. Sci. 10 (2023)

Hyde, R.M., et al. The effect of environmental temperature on average daily gain in pre-weaned calves: A randomized controlled trial and Bayesian analysis. Journal for Dairy Science. 105 (2022)

Hyde, R.M., et al. Quantitative analysis of calf mortality in Great Britain; Journal for Dairy Science. 103 (2020).

Impact of 2014 Winter Floods on Agriculture in England, ADAS UK Ltd.

Jones., et al. Bluetongue risk under future climates. Nature Climate Change www.nature.com/natureclimatechange (2019)

Kordowitzki, P., Mietkiewska, K.. Pareek, C.S. Effects of Heat Stress on Bovine Oocytes and Early Embryonic Development: An Update. Cells (2022).

Laporta, J., et al. Recent Contributions from Women Scientists to Animal Endocrinology: Pregnancy and Lactation / Environmental stress and the mammary gland / Late gestation hyperthermia. Animal Endocrinology (2021)

Miner, H. 'Don't Skimp on Dry Cow Cooling. Agriculture Research Institute Farm Report, July (2014).

Nejash, A. Impact of Climate Change on Livestock Health: A Review. Journal of Biology, Agriculture and Healthcare, 6. (2016)

Natural Flood Management Measures – a practical guide for farmers; Dales to Vales River Network. Based on 'Natural Flood Management Measures – a practical guide for farmers

(2017),' produced by the Yorkshire Dales National Park.

Penning-Rowsell, E.C., et al. Flood and Coastal Erosion Risk Management: A Manual for Economic Appraisal (2013).

Rutherford, N.H., et al. The effect of calf jackets on the health, performance, and skin temperature of dairy origin beef calves American Society of Animal Science (2019).

Straw and Forage Study A Review commissioned under the Scottish Government RESAS Policy

Underpinning: Special Economic Studies - 2017/18 Prepared by SRUC Julian Bell, Gillian Inman, Mary McDowell and regional SAC Consultants.

The reality of heat stress in dairy herds across the UK a field study Mark Scott Regional Technical Lead UK, Ireland & North West Europe, Cargill.

Semenza, J.C. Climate change and infectious disease in Europe: Impact, projection and

Adaptation;. The Lancet Regional Health – Europe, 9 (2021)

Souza, L.E., et al. Modelling the effects of heat stress in animal performance and enteric methane emissions in lactating dairy cows. Journal of Dairy Science, 106:4725–4737 (2023).

Summary of Climate Change Risks for the East of England. Climate UK (2012)

Tildesley, M.J., et al. The role of movement restrictions in limiting the economic impact of livestock infections. Nature Sustainability (2019).

UK Climate Change Risk Assessment (CCRA3) Evidence Report 2021

WEBSITES:

https://www.gov.uk/government/publications/cattle-gb-disease-surveillance-and-emerging-threats-reports

Cambridge Econometrics; www.camecon.com

www.fwi.co.uk/livestock/health-welfare/livestock-diseases/

www.gov.uk/government/collections/animal-disease-surveillance-reports#cattle

www.fwi.co.uk/business/compliance/which-rules-are-relaxed-when-farmland-is-flooded

www.gov.uk/government/publications/cattle-gb-disease-surveillance-and-emerging-threats-reports

www.adaptationscotland.org.uk

www.keepscotlandbeautiful.org/sustainability-climate-change/

www.Small99.co.uk

www.Deloittes.com

www.BRC.com

www.AHDB.org.uk