Committee on Climate Change

Research to update the evidence base for indicators of climate-related risks and actions in England

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Final Report

12 April 2019

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CONTENTS

1 INTRODUCTION

1.1 Background

In order for the Adaptation Committee (AC) of the Committee on Climate Change (CCC) to report to parliament on progress in adapting to climate change in England, the AC uses an evaluation method based on a two-part framework. The first part relates to the assessment of analysis of trends in indicators of change that relate to climate change risks and adaptation. The second part is through decision making analysis to assess the extent to which low-regret adaptation measures are being taken up, and how long-term decisions are accounting for climate change.

The AC applies this framework across a number of defined 'adaptation priorities' to understand if there is a plan in place; whether actions are being implemented; and effects of actions in managing vulnerability. The AC use a set of metrics and indicators to assess and track changes in climate change risks and adaptation, whereby observed changes are monitored through time (using key data and information) across three core components of adaptation: indicators of risk, indicators of adaptation action, and indicators of climate impact.

There are a number of 'types' of indicator the AC use for their assessment of adaptation progress in England. These include: Action, Realised impact, Exposure, Risk, Vulnerability, Plan, Impact, Climate hazard, Hazard, and Realising opportunity.

To enable the AC to comprehensively apply this framework and provide an accurate update in its next progress report on the government's second National Adaptation Programme (NAP) in 2019, a number of the metrics and indicators that form the basis of this indicator set require updating.

1.2 Research purpose

This project reviews a subset of the AC's 200+ indicator set. This subset of 35 was identified by the AC as part of the procurement process for this project. ADAS were not involved with the selection of indicators selected. It is recognised that there may be alternative or other indicators that may also be suitable to demonstrate progress in adaptation, however these were not considered within the scope of this project.

The subset of indicators assessed by ADAS in this project provide supporting evidence to inform current understanding of adaptation progress being made in England. It is expected that these indicators will be used by the AC, alongside other indicators within the full AC indicator set, to inform the AC's 2019 report to government. The indicators assessed in the project are therefore not intended to be representative of the full progress in adaptation picture, or used in isolation. The purpose of this research is to provide updated indicators (within the context of climate resilience) to inform the AC of the current evidence base.

1.3 Approach

In total, 35 indicators of climate-related risk and actions are assessed in this report, across multiple sectors including the built environment, infrastructure, the natural environment, agriculture and forestry, people and health, and business. The data and information obtained came through a range of sources through consultation with stakeholders and industry representatives, and web-based searches.

For each indicator, a high-level description is provided and reference to the ‘type of indicator it is categorised as under the AC assessment (action, realised impact, exposure, risk, vulnerability, plan, impact, climate hazard, hazard, and realising opportunity).

1.3.1 Updated indicators

Where robust datasets were available, with suitable metrics to demonstrate change over time, indicators have been updated or developed to provide trends and allow interpretation of the data for climate resilience. For each updated indicator, we provide detail on the data sources and methods used, outline the trends and implications for climate resilience, and assess the robustness of the indicator as a measure of assessing climate-related risks and actions.

1.3.2 Updated evidence base

Where datasets or suitable metrics were not available to update or develop an indicator, the evidence base was updated instead. For each evidence base, we provide detail on the available information, which may include industry insight, ad hoc data, grey literature, maps etc. We do not attempt to assess the robustness of each evidence base, as a suitable metric was not available to interpret change over time, and thus provide an indicator.

1.4 Scope and interpretation of climate

The project scope was for England only. However for some indicators and evidence bases, disaggregated data was not available. In these instances, the data represented may include England, but not be completely attributable at a regional level (e.g. if data is for England and Wales, or the United Kingdom).

In this study we provide analysis of the available data and information. It is noted that some indicators are not purely climate driven, may not have a high (or any) sensitivity to climate change, and in fact require other drivers. Subsequently, indicators should be interpreted with caution.

2 UPDATED INDICATORS

2.1 Rate of development of properties in areas at risk of flooding

Description: *Rate of development of residential and non-residential properties in areas at risk of flooding*

Type: *Exposure*

2.1.1 Introduction

Rising sea levels and increasingly severe and frequent rainstorms caused by climate change mean that the risk of flooding could increase. Understanding where risk is increasing, and controlling the location of development is important. The Environment Agency (EA) recognise that locating property outside of the floodplain is a prime way to reduce flood risk. If this is not practical, siting new buildings in areas of lowest risk is the next best choice.

This indicator assesses the types of development that are being carried out at the different risk levels to understand changes and trends in exposure and vulnerability of property to flooding.

2.1.2 Data source and method

This method examines the impact of two different sources of flooding on properties, following on from work previously carried out by HR Wallingford (2015). The 'Risk of Flooding from Rivers and Sea' (RoFRS) and 'Risk of Flooding from Surface Water' (RoFSW). Both these datasets identify areas of High (each year, there is a chance of flooding of greater than 1 in 30), Medium (each year, there is a chance of flooding of between 1 in 30 and 1 in 100) and Low (each year, there is a chance of flooding of between 1 in 100 and 1 in 1000) flood risk.

Property data was provided by the latest OS AddressBase layer. This layer provides a classification code for each property, which provides information on the property type. Previous studies of properties at risk have classified properties into multi-coloured manual (MCM) codes: dwelling, retail, offices, warehouses, leisure, public buildings, industry and miscellaneous. Therefore, in order to maintain consistency with previous studies, the AddressBase codes were matched to an MCM code (see appendix A). Spatial analysis was then carried out to identify which (if any) flood risk area each property was within, and the local authority it was within, enabling summaries by local authority, MCM code and flood risk.

Flood risk data has previously identified all land at risk of flooding, irrespective of any flood defences. The latest RoFRS dataset used in this analysis takes into account flood defences and their condition. It is therefore not possible to compare the results with previous assessments that have not taken defences into account.

2.1.3 Trends and implications for climate resilience

2.1.3.1 Risk of flooding from rivers and sea

It is difficult to identify any specific trends in properties at risk of flood, as the flood risk layer used in this analysis (RoFRS) is different to that used in the previous analysis. The risk layer used in this analysis takes into account flood defences, where it is understood that in previous analysis, these were not included. There is therefore a decrease in residential properties in flood risk areas. There is however an overall increase in offices and warehouses in flood risk areas.

The percentages of the total numbers of properties per local authority that are in high, medium and low flood risk areas are shown on maps in Figure 2.1. The total number of properties in each risk area are reported in Table 2-1.

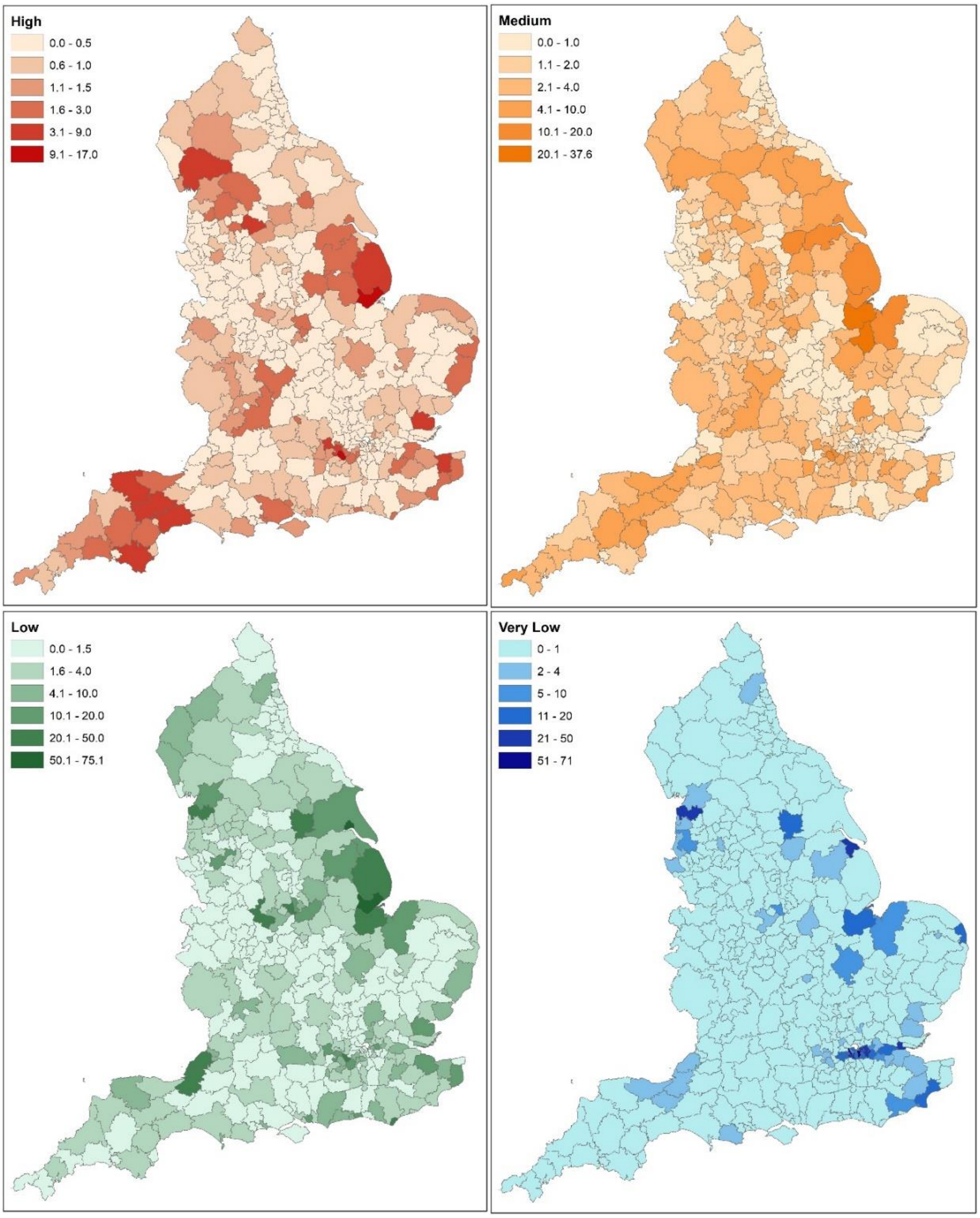


Figure 2.1 - Percentage of properties in each Local Authority at High (a), Medium (b) Low (c) and Very low (d) risk of flooding from rivers and sea in England. Source: ADAS for the CCC.

Table 2-1 - Number of properties at risk from flooding from rivers and sea for England by property type. Source: ADAS for the CCC.

Property type	High Likelihood of flooding	Medium Likelihood of flooding	Low Likelihood of flooding	Very low Likelihood of flooding	Total
Dwelling / Residential	133179	497440	875062	599047	2104728
Retail	9317	26777	39833	22319	98246
Offices	10405	30374	40580	34361	115720
Warehouses	15419	39815	55336	24023	134593
Leisure	8989	9246	14970	6389	39594
Public Buildings	2971	7954	11534	5473	27932
Industry	3239	7780	7730	3673	22422
Miscellaneous	14058	22974	32366	22564	91962

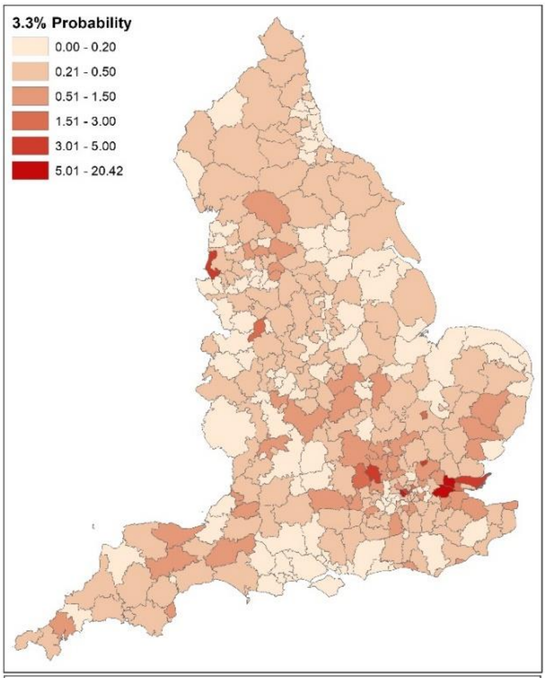
2.1.3.2 *Risk of flooding from surface water*

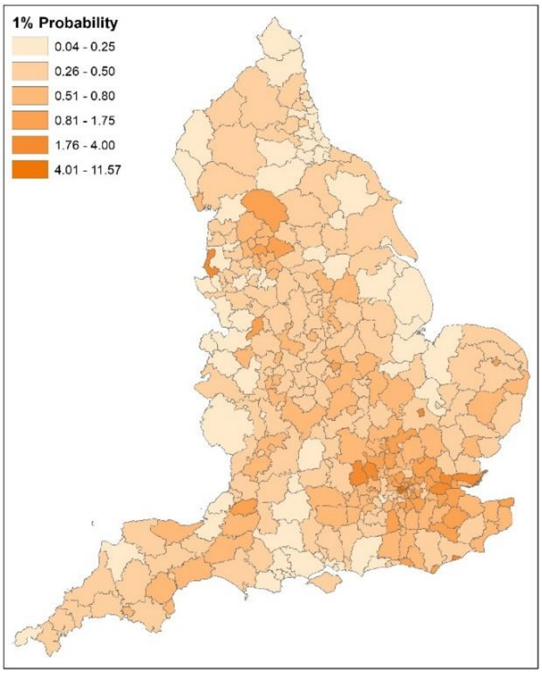
As with the analysis for the risk of flooding from rivers and sea, the analysis for the risk of flooding from surface water is likely to yield different results to those in previous analysis, due to the method of allocating the MCM Code to the AddressBase classification. Table 2-2 shows the number of properties at risk at each risk level.

Table 2-2 - Number of properties at risk from flooding from Surface Water for England by property type. Source: ADAS for the CCC.

Property type	3.3% probability	1% probability	0.1% probability	Total
Dwelling	25,512	148,202	705,858	979,572
Retail	5,168	6,983	33,771	45,922
Offices	4,584	7,371	30,363	42,318
Warehouses	5,955	7,658	38,443	52,056
Leisure	1,619	1,576	7,974	11,169
Public Buildings	2,577	3,334	14,127	20,038
Industry	3,380	3,574	12,579	19,533
Miscellaneous	12,887	13,357	48,098	74,342

Across all of the risk levels, the south-east consistently has a high percentage of properties at risk of surface water flooding (Figure 2.2).





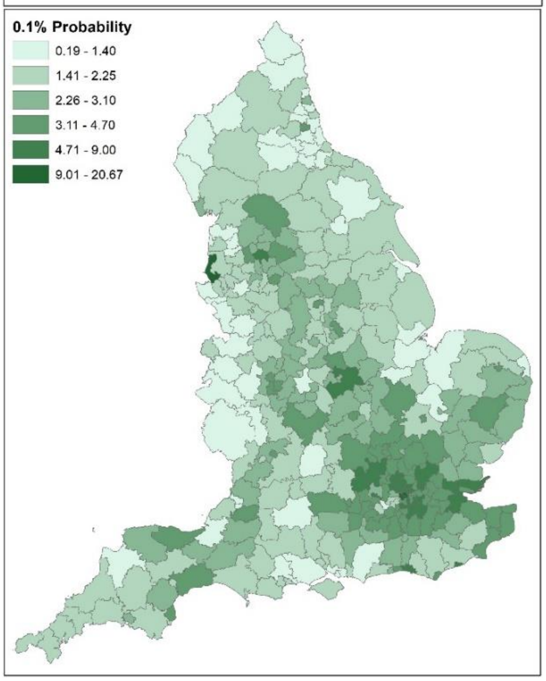


Figure 2.2 - Percentage of properties in each Local Authority with a 3.3% (a), 1% (b) and 0.1% (c) probability of flooding from surface water in England. Source: ADAS for the CCC.

There has also been an increase in all property types in the 3.3% probability risk level between 2014 and 2018, shown in Table 2-3.

Table 2-3 - Percentage change in properties at risk of flooding from surface water between 2014 and 2018. Source: ADAS for the CCC.

	3.3% probability	1% probability	0.1% probability
Dwelling	36.0	-33.3	-12.8
Retail	68.2	-11.5	13.5
Offices	179.2	66.1	96.5
Warehouses	1214.6	575.9	736.8
Leisure	344.8	78.3	198.0
Public Buildings	253.0	65.8	93.6
Industry	97.5	-6.7	-6.5
Miscellaneous	3927.2	1838.6	1850.4

Flood Map for Planning

Analysis was also carried out to calculate the number of properties within the Flood Map for Planning Zones. These results are displayed in Table 2-4.

Table 2-4 - Percentage of properties in each flood zone (numbers for each zone have been calculated individually). Source: ADAS for the CCC.

	Percentage of properties (%)	
MCM No.	**Zone 3**	**Zone 2**
MCM_0	5.7	8.2
MCM_2	8.5	12.9
MCM_3	9.5	14.8
MCM_4	9.6	14.5
MCM_5	13.0	16.5
MCM_6	7.1	10.3
MCM_8	9.6	13.2
MCM_9	10.1	14.1

2.1.4 Robustness of indicator

In this analysis, AddressBase classification codes had to be converted to MCM codes (used in the previous analysis by HR Wallingford (2015). This amalgamation into MCM categories may have some differences to the methods used previously, since details on previous classification was not available.

Furthermore, a different fluvial flood risk dataset has been used. This may result in different risk extent, and the dataset takes the impact of flood defences into account, which will result in changes in the numbers of properties classified as at risk.

2.2 Area of impermeable surfacing in urban areas

Description: *Area of impermeable surfacing in urban areas*

Type: *Vulnerability*

2.2.1 Introduction

Areas covered by artificial impermeable surfaces are at risk of flooding as excess water cannot soak away into the soil. Impermeable surfaces can also contribute to a greater risk of flooding in the lower catchment due to increased run-off. As urban areas become more built up due to in-filling and building on urban brownfield and greenspace, this risk can increase due to the increased area of impermeable surface per unit area.

However, it also recognised that all new major development will have to demonstrate how surface water runoff will be managed to either 'greenfield runoff rates' or a reduction over existing rates of runoff through an appropriate surface water management strategy. As such, runoff rates should be the same or less following development. This could potentially reduce flood risk, or perhaps displace it somewhere else (i.e. natural environment).

This indicator uses a regularly updated source of detailed mapping from Ordnance Survey to track the relative proportions of manmade and natural surfaces in the urban environment as an indicator of vulnerability to surface water flood risk.

2.2.2 Data source and method

The 'Topography' layer of Ordnance Survey's MasterMap product (the most detailed digital mapping available nationally) records the surface material of each land parcel as "Natural", "Manmade" or "Multiple". The area categorised as "Manmade" is assumed to be impermeable. The "Multiple" category represents domestic gardens, which is assumed to be a mixture of permeable and impermeable surfaces. A methodology was developed by HR Wallingford (2012) to estimate the impermeable fraction of this category based on urban creep research under the assumption that estimated urban creep rates could be applied to these areas to determine the potential likely increase in intra-urban impermeable areas. The same method has been used for this indicator update.

Data was sourced from HR Wallingford (2012) for 2001, 2008 and 2011 data and ADAS (2017) for 2016 data. 2018 data is new analysis as part of this project.

To define the urban (built-up) area, up-to-date OS AddressBase premium data was used to calculate the property density per 1km grid cell. Two methods were used to define the urban area:

- Method 1 - uses a property density of > 500 properties per 1km cell to identify the urban area. This method is comparable to previous impermeable calculations dating back to 2001.
- Method 2 - larger areas of greenspace within cities and towns were missed by method 1. Therefore this improved approach takes account of the values of the neighbouring cells by taking an average of the central cell and its surrounding eight cells. This smooths the values, better defines the edge of urban areas and accounts for city centre greenspace. The original mask using > 500 properties per 1km cell was added to the revised mask to ensure inclusion of smaller settlements that would be missed by the revised method. This method is comparable to previous impermeable calculations carried out in 2016.

The urban creep method (Gill et al., 2008) used the property density to assign a housing class to each grid cell (Table 2-5). The impervious fractions of the "Multiple" areas were then estimated per housing class by adding the annual creep (quantified at differing housing densities by Gill et al. (2008)) to the impervious flat fraction of the 2001 baseline (Table 2-6) and then adding this the impervious pitched fraction to get a total impervious fraction.

Table 2-5 - Mean address points per hectare for each housing class. Source: Gill et al. 2008.

Urban classification	Mean address points/ ha	Class break
High density residential	47.3	37.1
Medium density residential	26.8	20.8
Low density residential	14.8	

Table 2-6 - Baseline data for surface type percentages of domestic gardens by housing class in 2001. Source: Gill et al. (2008).

Classification	Pervious	Impervious pitched	Impervious flat
Low density	57.3%	16.3%	26.4%
Medium density	42.7%	29%	28.3%
High density	15.6%	50%	34.4%

2.2.3 Trends and implications for climate resilience

The area of built-up areas covered by impermeable surfaces is shown for both methods of urban area calculation.

2.2.3.1 Method 1

Area of impermeable surfaces is shown for the current analysis (2018) and previous results (ADAS, 2017; HR Wallingford, 2012) for comparison in Table 2-7 and Figure 2.3. Since 2016, there has been an increase in urban area, and the impermeable fraction within this has seen an increase. This is reflected in the increase in areas of both manmade area and the multiple (impermeable) area.

Table 2-7 - Area of built-up areas covered by impermeable surfaces as estimated using OS MasterMap and using assumptions of urban creep (Method 1). Data sourced from HR Wallingford (2012) for 2001, 2008 and 2011 data and ADAS (2017) for 2016 data. 2018 data is new analysis as part of this project. Source: ADAS for the CCC.

Thousand ha	2001	2008	2011	2016	2018
Manmade	384	398	401	429	451
Multiple (impermeable)	94	142	163	160	170
Fraction of total	*0.37*	*0.42*	*0.44*	*0.44*	*0.45*

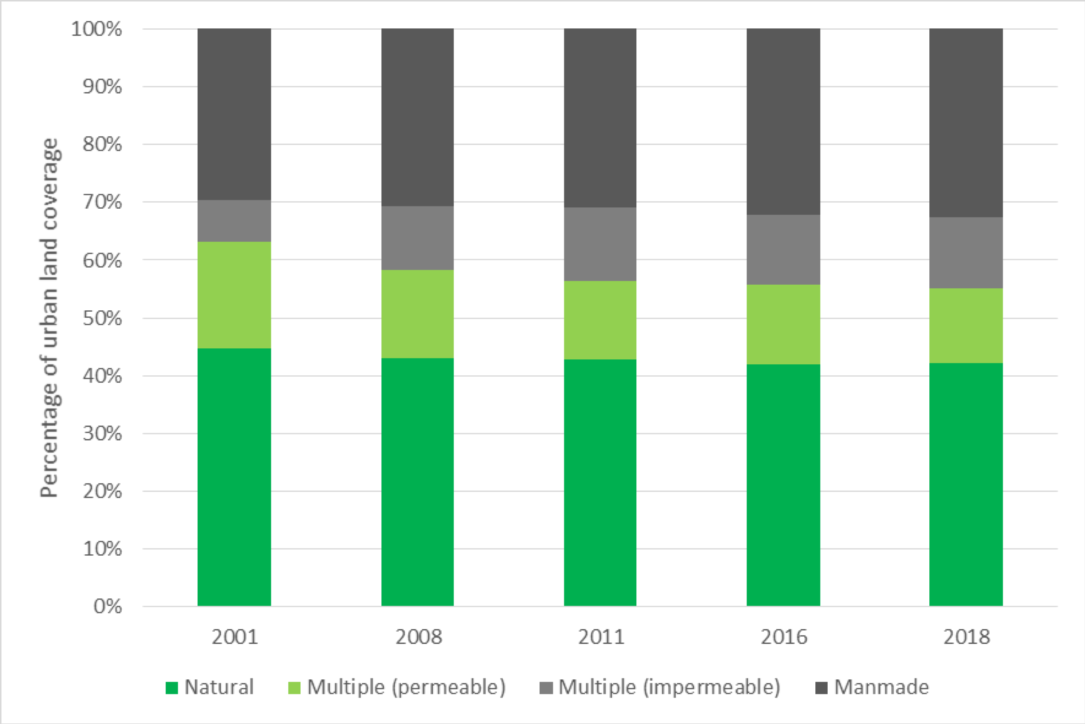


Figure 2.3 - Changes in percentage of permeable and impermeable area in urban areas in 2001, 2008, 2011, 2016 and 2018 (Urban areas defined using method 1). Data sourced from HR Wallingford (2012) for 2001, 2008 and 2011 data and ADAS (2017) for 2016 data. 2018 data is new analysis as part of this project. Source: ADAS for the CCC.

2.2.3.2 *Method 2*

Area of impermeable surfaces is shown for the current analysis (2018) and previous results from 2016 (ADAS, 2017). The 2018 data is calculated using the same method as the 2016 data. Results are shown in Table 2-8 and Figure 2.4.

Table 2-8. Area of built-up areas covered by impermeable surfaces as estimated using OS MasterMap and using assumptions of urban creep (Method 2). Data sourced from ADAS (2017) for 2016 data. 2018 data is new analysis as part of this project. Source: ADAS for the CCC.

Thousand ha	2016	2018
Manmade	498	509
Multiple (impermeable)	184	180
Fraction of total	*0.38*	*0.40*

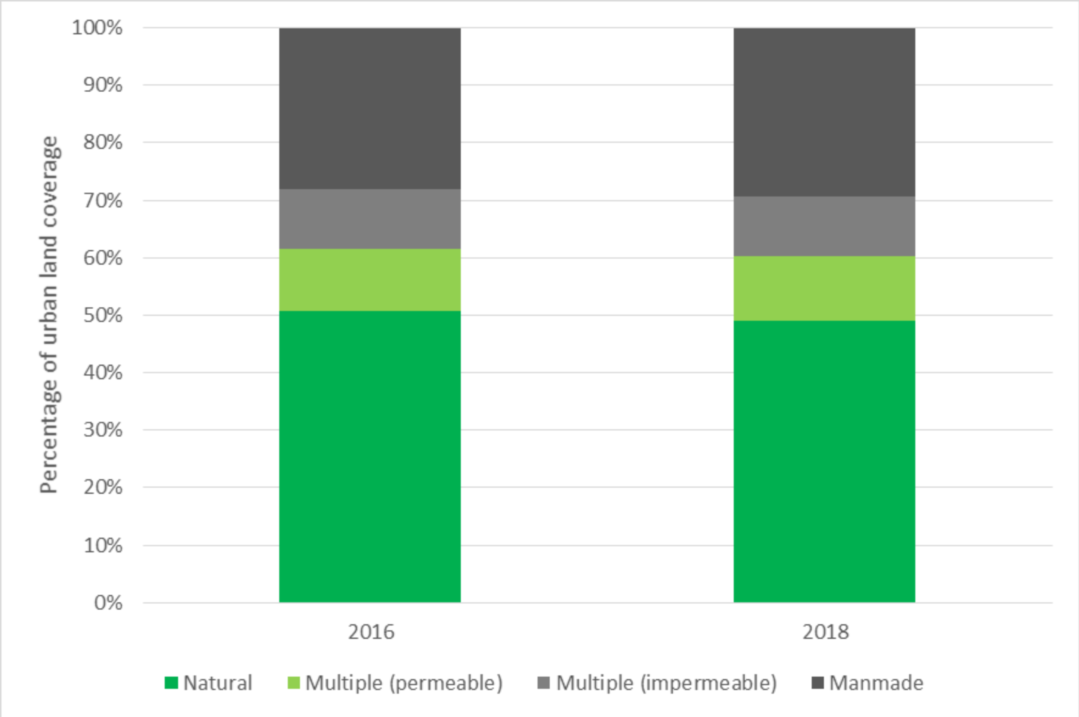


Figure 2.4 - Changes in percentage of permeable and impermeable area in urban areas between 2016 and 2018 (urban areas defined using method 2). Data sourced from ADAS (2017) for 2016 data. 2018 data is new analysis as part of this project. Source: ADAS for the CCC.

As with the first method, there has been an increase in the overall impermeable area fraction; however the impermeable area of the multiple category has actually decreased slightly since 2016. The impermeable fraction is lower in both years compared to Method 1 due to the inclusion of more urban greenspace.

2.2.4 Robustness of indicator

Ordnance Survey MasterMap is considered to be the definitive source of highly-detailed geographic data of Great Britain. This indicator is therefore robust in terms of the mapping used to represent impermeable surfaces, however an estimate has to be made of the impermeable fraction of the 'Multiple' surface type based on research into urban creep. This may lead to under- or over-estimation of impermeable area, but should be consistent across years.

The address point database used for definition of housing classes is different to that used previously (OS Address Point dataset has been superseded by OS AddressBase). Comparisons between data after 2016 and earlier years should therefore be made with caution.

2.3 Area of urban greenspace

Description: *Area of urban greenspace*

Type: *Vulnerability*

2.3.1 Introduction

Greenspace within urban areas can provide a sustainable means of storing or dissipating flood water or run-off following storms.

This indicator is closely related to 2.2, which assesses the area of impermeable surfacing in urban areas, but provides the opposite perspective in that it tracks change in the natural/ semi-natural areas within towns and cities.

2.3.2 Data source and method

The method used was similar to that used for 2.2, except that the area of greenspace in urban areas was estimated from the area of the "Natural" material plus the permeable fraction of "Multiple".

The 'Topography' layer of Ordnance Survey's MasterMap product (the most detailed digital mapping available nationally) records the surface material of each land parcel as "Natural", "Manmade" or "Multiple". The area categorised as "Natural" is assumed to be Greenspace. The "Multiple" category represents domestic gardens, which is assumed to be a mixture of permeable and impermeable surfaces. A methodology was developed by HR Wallingford (2012) to estimate the impermeable/greenspace fraction of this category based on urban creep research under the assumption that estimated urban creep rates could be applied to these areas to determine the potential likely increase in intra-urban impermeable areas. The same method has been used for this indicator update.

Data was sourced from HR Wallingford (2012) for 2001, 2008 and 2011 data and ADAS (2017) for 2016 data. 2018 data is new analysis as part of this project.

To define the urban (built-up) area, up-to-date OS AddressBase premium data was used to calculate the property density per 1km grid cell. Two methods were used to define the urban area:

- Method 1 - uses a property density of > 500 properties per 1km cell to identify the urban area. This method is comparable to previous impermeable calculations dating back to 2001.
- Method 2 - larger areas of greenspace within cities and towns were missed by method 1. Therefore this improved approach takes account of the values of the neighbouring cells by taking an average of the central cell and its surrounding eight cells. This smooths the values, better defines the edge of urban areas and accounts for city centre greenspace. The original mask using > 500 properties per 1km cell was added to the revised mask to ensure inclusion of smaller settlements that would be missed by the revised method. This method is comparable to previous impermeable calculations carried out in 2016.

2.3.3 Trends and implications for climate resilience

2.3.3.1 Method 1

The area of built-up areas covered by permeable surfaces (greenspace) is shown for the current analysis (2018) and previous results (ADAS, 2017; HR Wallingford, 2012) for comparison in Table 2-9. The results show that the permeable fraction of built-up areas has decreased between 2016 and 2018 to an estimated 55%.

Table 2-9 - Area of built-up areas covered by greenspace (permeable surfaces) as estimated using OS MasterMap and using assumptions of urban creep (Method 1). Data sourced from HR Wallingford (2012) for 2001, 2008 and 2011 data and ADAS (2017) for 2016 data. 2018 data is new analysis as part of this project. Source: ADAS for the CCC.

Thousand ha	2001	2008	2011	2016	2018
Multiple (permeable)	240	198	178	185	179
Natural	581	559	554	558	583
Permeable fraction	*0.63*	*0.58*	*0.56*	*0.56*	*0.55*

2.3.3.2 Method 2

The area of greenspace is shown for the current analysis (2018) and previous results from 2016 (ADAS, 2017). The 2018 data is calculated using the same method as the 2016 data. Results are shown in Table 2-10.

Table 2-10 - Area of built-up areas covered by greenspace (permeable surfaces) as estimated using OS MasterMap and using assumptions of urban creep (Method 2). Data sourced from ADAS (2017) for 2016 data. 2018 data is new analysis as part of this project. Source: ADAS for the CCC.

Thousand ha	2016	2018
Multiple (permeable)	191	192
Natural	899	849
Permeable fraction	*0.62*	*0.60*

As with the first method, there has been a decrease in the overall impermeable area fraction; however the permeable area of the multiple category has actually increased slightly since 2016. The permeable fraction is higher in both years compared to Method 1 due to the inclusion of more urban greenspace.

2.3.4 Robustness of indicator

Ordnance Survey MasterMap is considered to be the definitive source of highly-detailed geographic data of Great Britain. This indicator is therefore robust in terms of the mapping used to represent permeable surfaces, however an estimate has to be made of the permeable fraction of the 'Multiple' surface type based on research into urban creep. This may lead to under- or over-estimation of permeable area, but should be consistent across years.

The address point database used for definition of housing classes is different to that used previously (OS Address Point dataset has been superseded by OS AddressBase). Comparisons between data after 2016 and earlier years should therefore be made with caution.

2.4 Incidents and delays to rail and strategic road network

Description: *Annual number and length of delays to rail and strategic road network caused by severe weather*

Type: *Realised impact*

2.4.1 Introduction

Severe weather, such as heavy rain and associated flooding, snow and ice, and strong wind can cause travel disruption to both rail and road networks. This can result in closures, delays and in some instances, severe and ongoing damage to key infrastructure.

Highways England (formerly the Highways Agency) are responsible for the operation, maintenance and improvement of England's motorways and major A roads[1]. National Rail is responsible for maintaining, renewing and enhancing the railway infrastructure. Network Rail both operate and develop Britain's railway infrastructure, including 20,000 miles of track, bridges, tunnels and viaducts; and thousands of signals, level crossings and stations. In addition, Network Rail also manage 20 of the UK's largest stations including Birmingham New Street, Manchester Piccadilly, Edinburgh Waverley, Glasgow Central, Leeds, Bristol Temple Meads and 11 in London[2].

This indicator looks at the annual number and length of delays to rail and roads caused by severe weather.

2.4.2 Data source and method

2.4.2.1 Road

Data for 2007 to August 2016 was used from the previous update of this indicator by ADAS (2017). This data was sourced directly from the Highways England and gave a breakdown of the number of reported incidents by weather type, as well as region, month, and lane impact duration in minutes. Weather categories included were: flooding; heavy rain; snow, ice and freezing rain; and strong winds.

The dataset for September 2016 to December 2018 was provided directly by Highways England in 2019. This data gave a breakdown of the number of reported incidents by weather type, as well as region, month, and lane impact duration in minutes. The weather categories included were: flooding; snow, ice and freezing rain; strong winds; and weather condition – other.

It is noted that there are slight differences in the weather categories included. This is because in September 2016, Highways England changed the way that incidents are recorded. This process included transitioning to a new system whereby weather events are recorded within the sub code field, rather than in the final incident classification. All five weather categories (flooding; heavy rain; snow, ice and freezing rain; strong winds; and weather condition – other) have been included in the analysis and the two datasets were combined to produce a full year of data for 2016.

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[1] https://www.gov.uk/government/organisations/highways-england

[2] https://www.networkrail.co.uk/communities/passengers/our-stations/

2.4.2.2 Rail

Data was provided directly by Network Rail for the years 2006-07 to 2017-2018. This included the number of incidents broken down by weather impact, as listed below, as well as the average time per incident event.

- Adhesion (e.g. seasonal impact of leaves on the line);
- Cold (e.g. ice on conductor rail preventing contact so electricity can't pass through to train, icicles on overhead lines or tunnel entrances, freezing of points which allow trains to move from one track to another);
- Flood (e.g. flooding from sea, river, ground or surface water);
- Fog (i.e. reduced visibility and speed restrictions);
- Heat (e.g. buckling of track, points failure, sagging of overhead lines, overheating in electric/signal boxes, problems with signalling connections etc.);
- Lightning (damage from strikes, electrical trips and outages, and impacts on signals and electrical equipment);
- Snow (snow and ice on tracks or key infrastructure);
- Subsidence (e.g. landslips, sink holes, subsidence of soils below track);
- Wind (e.g. debris and objects obstructing the track and overhead lines such as vegetation, fallen trees, trampolines, sheds, plastic bags; and speed restrictions caused by high winds).

It is noted that long term closures are not included in this data, so some large-scale incidents (e.g. subsidence, landslides etc.) may not be fully represented in the data.

2.4.3 Trends and implications for climate resilience

2.4.3.1 Road

A total of 1,439 incidents were reported by Highways England between 2007 and 2018 that resulted in the total closure, or carriageway closure of strategic roads, due to severe weather. The number of reported incidents due to weather fluctuated from 2007 to 2015, and increased substantially in 2016 to 2018 (Figure 2.5). This increase is likely attributed to the change in the way incidents were reported from September 2016, rather than a direct increase in the number of incidents due to severe weather.

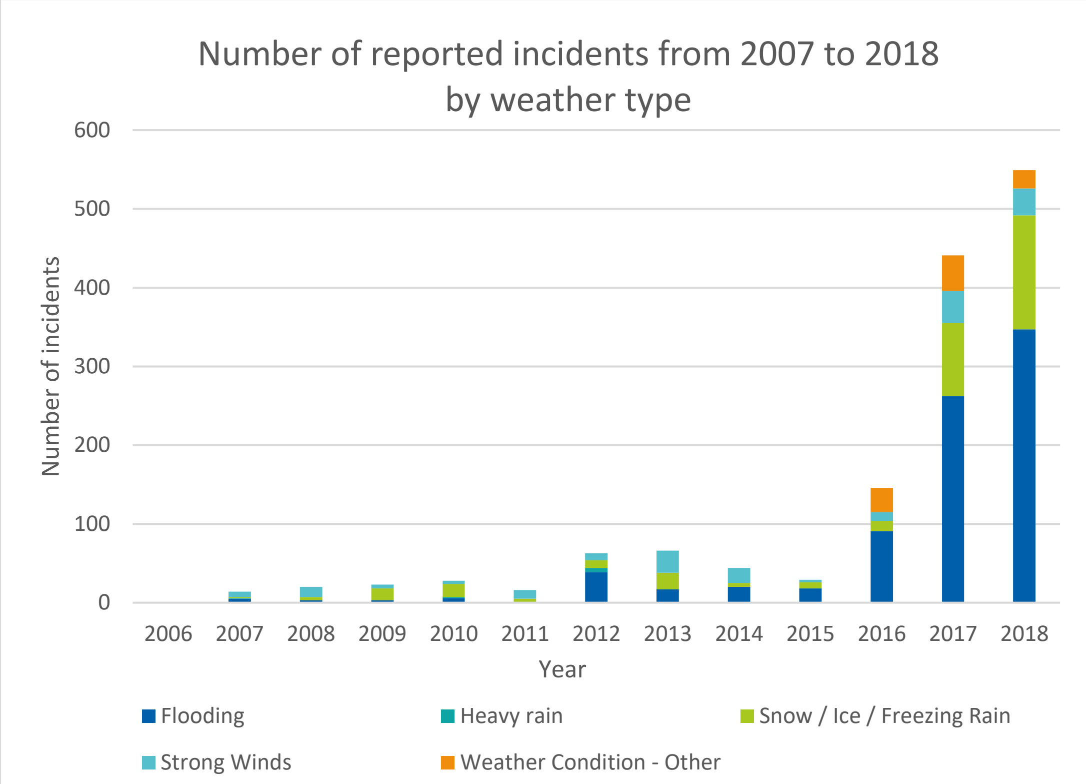

Figure 2.5 – The number of road incidents by weather type from 2007 to 2018 as recorded by Highways England. Note that the method to record incidents was changed in September 2016. Source: ADAS for the CCC.

The highest number of recorded incidents was 549 in 2018, followed by 441 in 2017. In 2018, 63% of weather related incidents were due to flooding, with 26% due to snow, ice and freezing rain. These weather types were also the top cause of incidents in 2017, with 59% of weather related incidents caused by flooding, and 21% caused by snow, ice and freezing rain.

Incidents were more common in the winter months; with 48% of incidents between 2007 and 2018 occurring in December, January and February. Only 9% of weather related incidents occurred in the summer months of June, July and August.

Figure 2.6 shows that 24% of all weather related road incidents between 2007 and 2018 occurred in the North West of England (346 incidents), with 19% (279 incidents) occurring in the North East. The East Midlands experienced 70 incidents, which was the lowest number of incidents by region. It is noted however that these differences do not directly indicate some regions being more susceptible to severe weather-related road closures than others, rather it likely reflects the number of main trunk roads in each region.

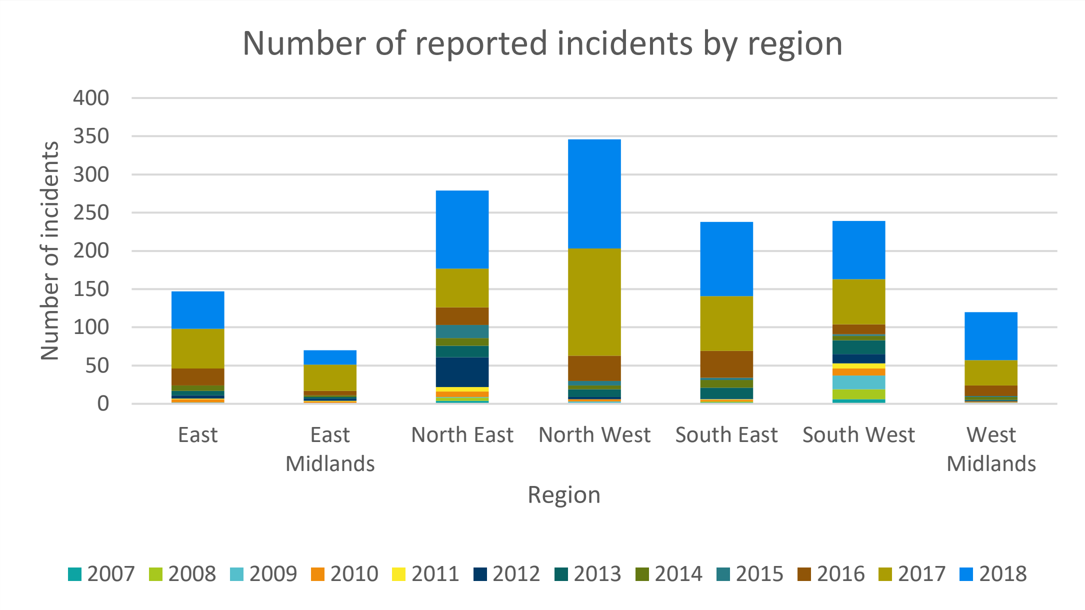

Figure 2.6 – The number of weather related road incidents by region from 2007 to 2018 as recorded by Highways England. Source: ADAS for the CCC.

Figure 2.7 shows the data provided by Highways England using the new recording system, implemented in September 2016. This graph shows that December 2017 and March 2018 and had the highest number of incidents, which were largely caused by snow and flooding.

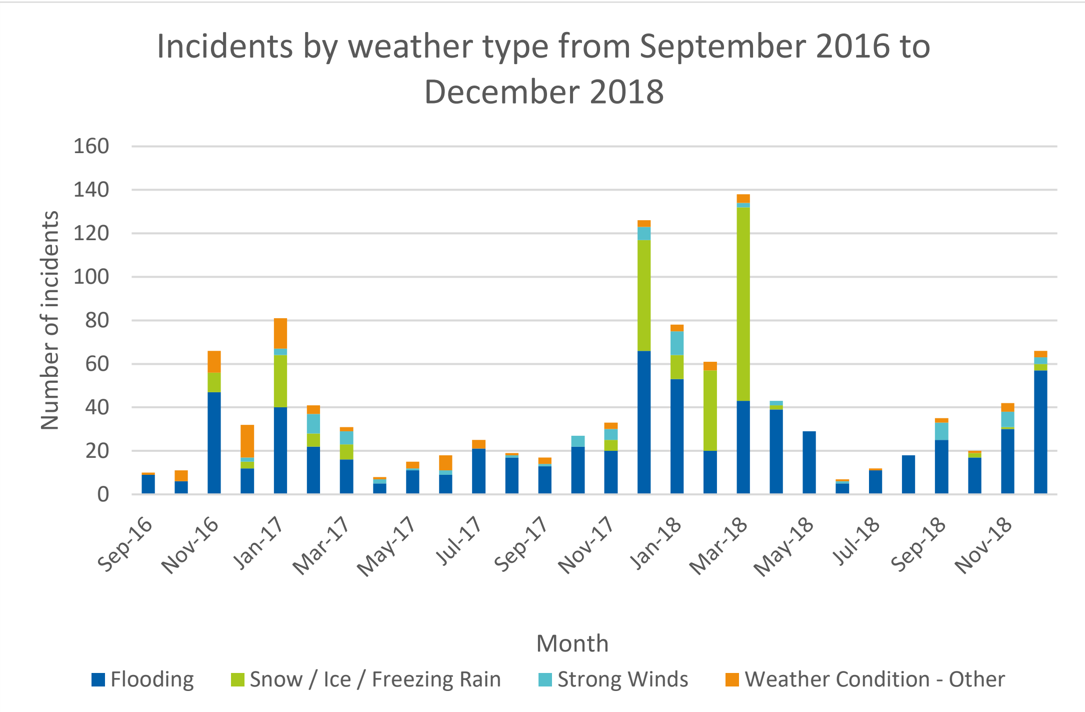

Figure 2.7 – The number of road incidents by weather type as recorded by Highways England from September 2016 to December 2018. Source: ADAS for the CCC.

In terms of the length of closures, 311,090 minutes of delay were recorded between 2007 and 2018, with 245 events where minutes delay were not recorded. Delay minutes indicate the length of time that a road or lane was closed, rather than the disruption that road users may have experienced, which could be much longer in some instances. For example, a closure of a dual carriageway for one hour due to snow would result in 60 minutes of delay on the Highways England incident log, but for the cars that may be stuck in tailbacks on the road, this delay could have been, for example 120 minutes, per car.

The total minutes delay by weather type is shown in Figure 2.8. 2018 experienced the highest number of delay minutes (84,876), followed by 2012 (49,594). Flooding accounted for 48% of all delay minutes from 2007 to 2018, with snow, ice and frozen rain accounting for 28%, and strong winds accounting for 21% of delay minutes.

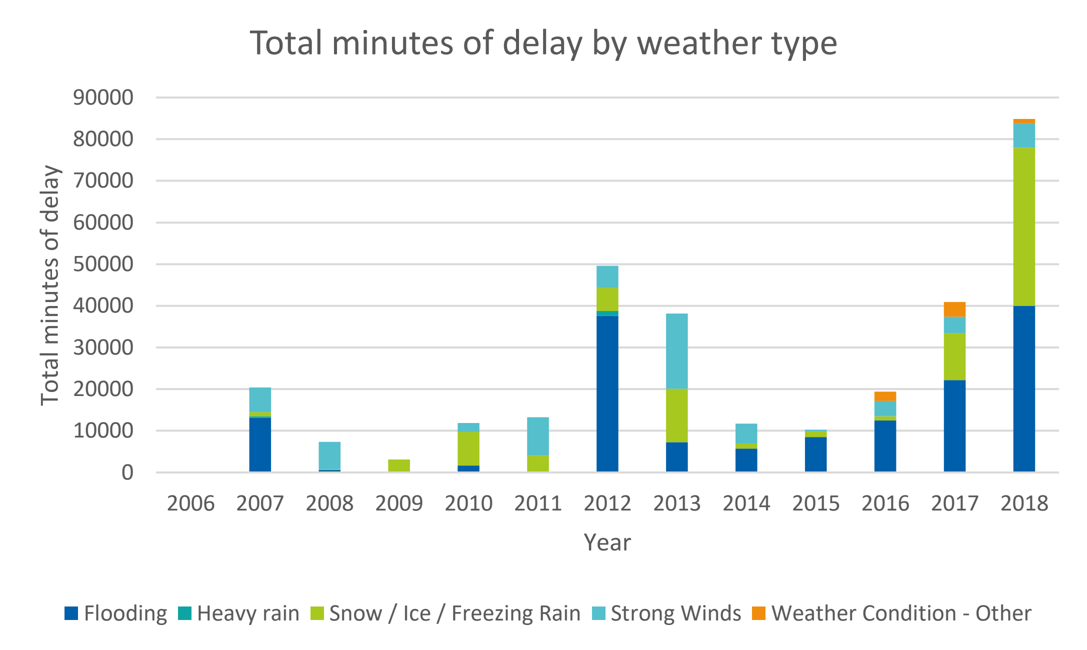

Figure 2.8 – Total minutes of delay caused by weather related road incidents by weather type from 2007 to 2018, as reported by Highways England. Source: ADAS for the CCC.

Whilst the number of recorded events shows an increasing trend over the time series, the average number of minutes delay per event shows a decreasing trend, as demonstrated in Figure 2.9. However, the latter part of the time series could simply be a product of the new reporting system rather than a decrease in the average length of delays, so these figures should be used with caution. The highest number of minutes delay per event were for flooding in 2007, when 13,118 minutes of delay were caused by five events of flooding. Despite Figure 2.5 showing 2018 and 2017 as having the highest number of recorded incidents, the delay time did not exceed an average of 311 minutes per event.

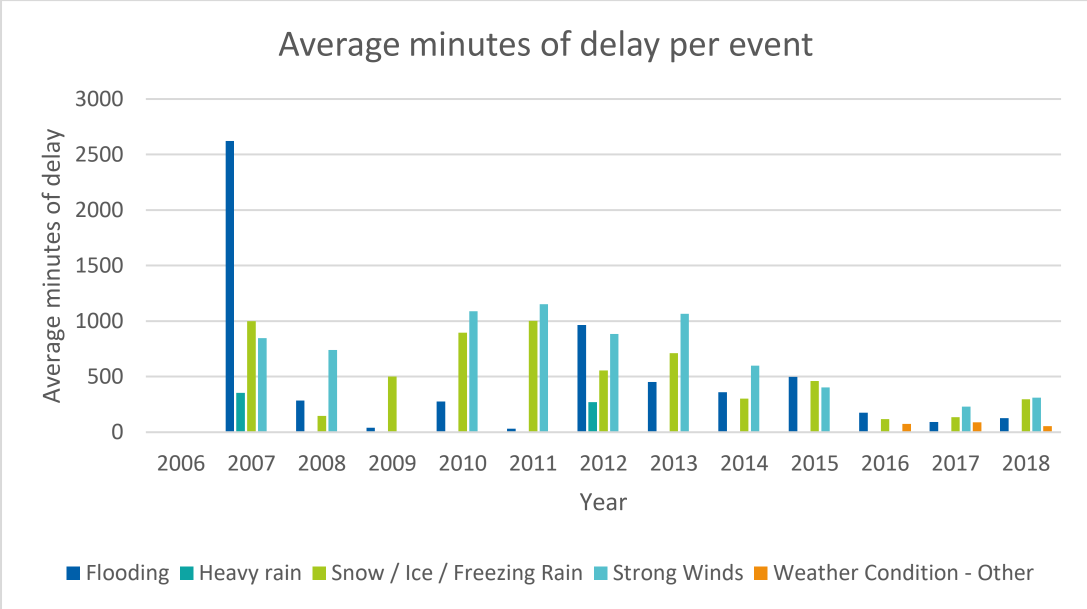

Figure 2.9 – The average minutes delay per weather related incident from 2007 to 2018 by weather type, as reported by Highways England. Source: ADAS for the CCC.

2.4.3.2 Rail

Adhesion accounted for 82% of incidents between 2006-07 and 2017-18, ranging from 73% in 2006-07, to 92% in 2015-16. As adhesion is a seasonal event rather than a severe weather event, and it accounts for such a large proportion of weather-related incidents, adhesion has been excluded from this analysis. This exclusion of adhesion is in line with the previous update of this indicator by ADAS (2017).

Figure 2.10 shows the total number of weather related incidents in England recorded by Network Rail by weather type. The number of incidents has fluctuated from 2006-07 to 2017-18. The highest number of incidents was in 2009-10 (4,670), where snow accounted for 50% of weather related incidents. The number of incidents were low during 2014-15 (1,766), 2015-16 (1,433) and 2016-17 (1,841). However, it is noted that the number of incidents is driven by the weather experienced within any particular year, and a lower frequency of incidents does not convey lower impact.

For example, 2009-10 and 2017-18 have a high number of incidents primarily because there were many small cold/snow related impacts. Conversely, 2014-15, 2015/16 and 2016/17 had more wet weather causing fewer, but larger incidents (e.g. large scale subsidence, flooding, and structural failures. Network Rail note that these larger events cause the line to be closed for longer - in some cases months to years, and the duration of these events does not get properly picked up in the data. As such, some years with fewer instances can actually have a greater impact and be more costly to Network Rail than years with higher instances that are smaller and less costly.

There were 37,820 weather related incidents in England between 2006-07 and 2017-18, of which wind accounted for 31% (11,551) of incidents, and snow 23% (8,527) of incidents.

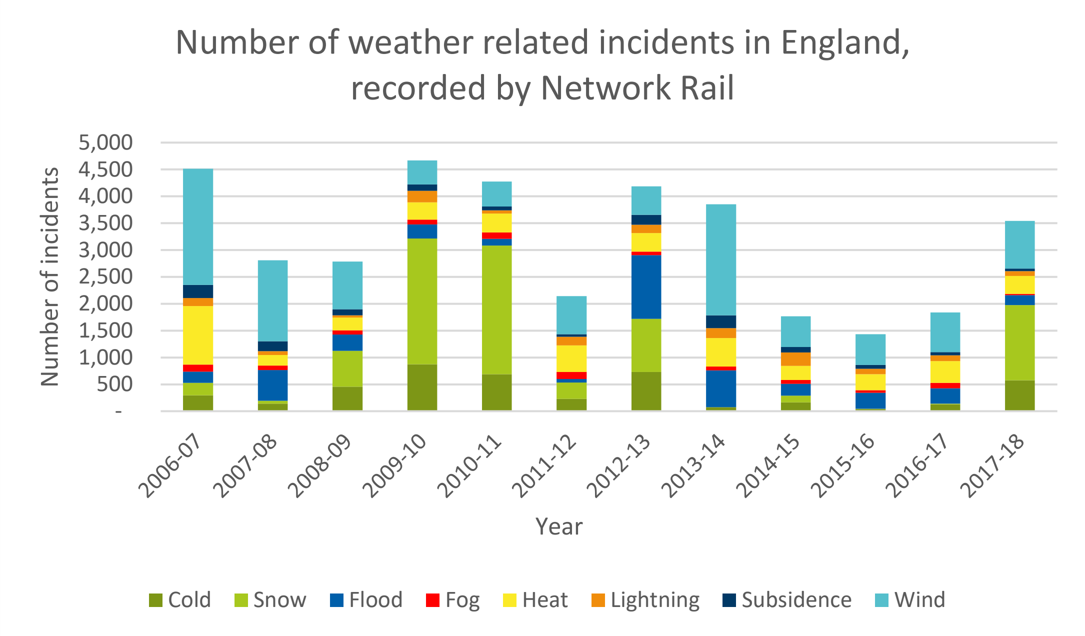

Figure 2.10 – The number of weather related incidents in England recorded by Network Rail between 2006-07 and 2017-18. Source: ADAS for the CCC.

The total number of minutes delay due to weather incidents by event type is shown in Figure 2.11. The longest delays were in 2013-14, when 2,132,714 minutes delay were recorded. Wind incidents accounted for 54% of this delay time. 2011-12 had the lowest number of minutes delay due to weather incidents, followed by 2014-15 and 2015-16. It is noted however that the dataset does not pick up larger events (that were typical in these years of low delay minutes) that caused the line to be closed for long periods of time - in some cases months to years.

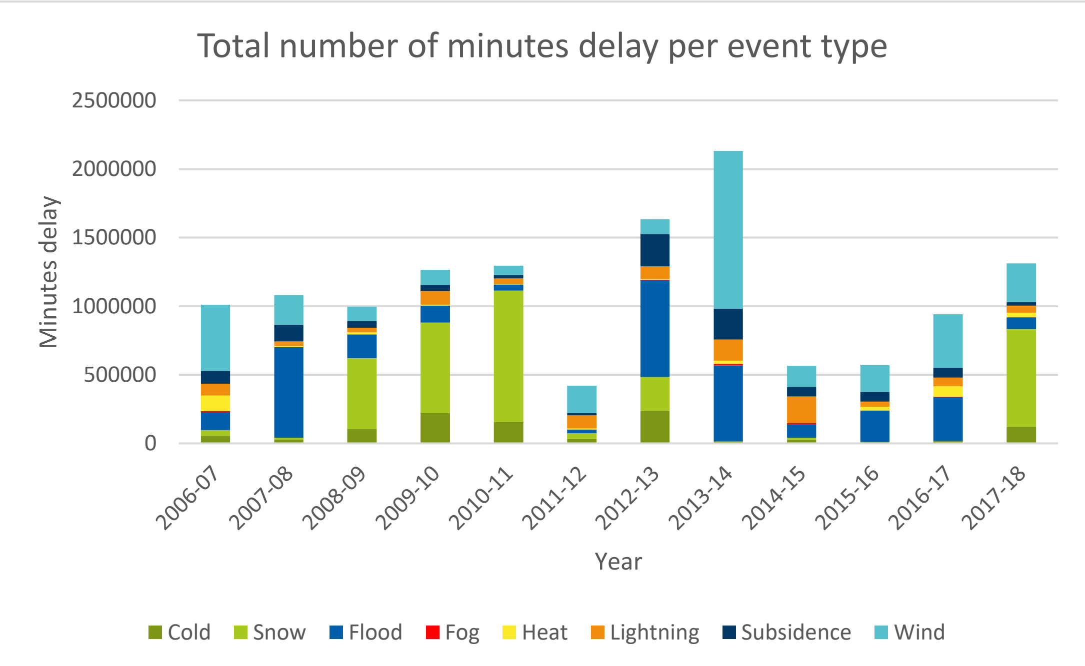

Figure 2.11 – The total number of minutes delay per type of weather related incident in England recorded by Network Rail between 2006-07 and 2017-18. Source: ADAS for the CCC.

Average minutes delay per event from 2006-07 to 2017-18 was highest for subsistence (672 minutes), followed by flooding (643 minutes) and lightening (608 minutes). Fog and heat caused the least disruption, with an average of 46 and 58 minutes delay per event respectively, shown in Figure 2.12.

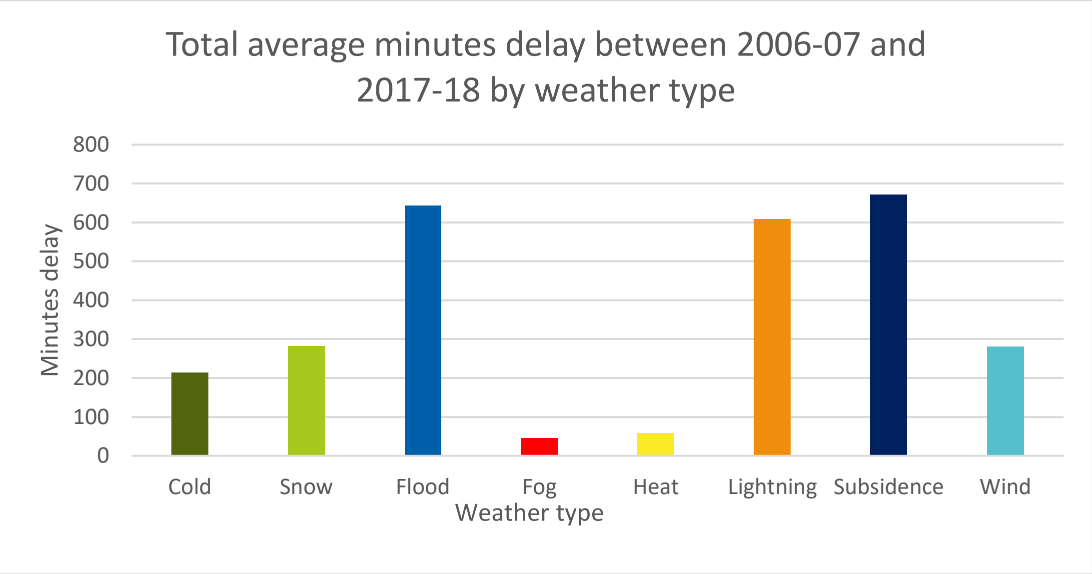

Figure 2.12 - The total average minutes delay between 2006-07 and 2017-18 by weather type as recorded by Network Rail. Source: ADAS for the CCC.

2.4.4 Robustness of indicator

2.4.4.1 Road

In September 2016, Highways England changed the way that incidents are recorded. This included transitioning to a new system whereby weather events are recorded within the sub code field, rather than in the final incident classification. The data used in the previous update of this indicator finished in August 2016 (ADAS, 2017). The updated data provided in this update by Highways England runs from the 4th September 2016 to the end of October 2018.

This has resulted in a small number of changes. For example, the new system has added an additional category of 'weather condition – other' and removed the 'heavy rain' weather category. This means for the years 2016, 2017, and 2018, there are slight differences in the categories recorded. Furthermore, there is a gap of data from 1-3 September 2016. It is unclear as to the reason for this, but could be that any incidents occurring from the 1-3 September inclusive could have been omitted from the dataset, or that no incidents were reported during the first three days of September.

2.4.4.2 Rail

The dataset provided by National Rail is considered robust. The data runs until March 2018 to provide data for the 2017-18 financial year. Data for 2018-19 will be available in April 2019.

2.5 Total annual spend on resilience measures by all water companies

Description: *Amount of actual investment in resilience measures by water companies*

Type: *Action*

2.5.1 Introduction

To ensure that water resources are managed properly and that the water companies controlling water supply are financially sustainable, annual performance is monitored by Ofwat. This includes checking that the water companies can continue to deliver services to customers, and that planned investment in services is delivered as promised. Ofwat are required to act in accordance with the UK Government's strategic priorities and objectives which, in the 2019 Price Review (PR19), included securing long-term resilience: *'Ofwat should challenge the water sector to plan, invest and operate to meet the needs of current and future customers, in a way which offers best value for money over the long term'*[3].

In 2018, Ofwat requested all water and sewerage companies, and water only companies in England and Wales to submit PR19 Business Plans setting out what the company intended to deliver for customers and the environment in the period 2020 to 2025[4], including investment around resilience, i.e. expenditure to manage the risk of providing consumers an appropriate level of service protection in the face of extreme events caused by hazards that are beyond their control (e.g. extreme weather).

This indicator assesses the annual total investment on resilience by all water companies in England and Wales.

2.5.2 Data source and method

Data used within this analysis was sourced from Ofwat, it was obtained through various submission tables from the water companies:

- For 2008-09 to 2010-11, data was sourced from the 2013 'Ofwat August submission tables'[5], as per the methodology used by ADAS (2017).
- Data for 2011-12 to 2016-17 was provided by Ofwat directly via the 'cost assessment submission' which was published alongside Ofwat's consultation on econometric cost modelling in March 2018[6].
- The most recent data submitted to Ofwat are the PR19 data tables, which provide actual data for 2017-18 and forecast data from 2018-19 to 2024-25.

Ofwat provided direction to the supporting documents associated with the PR19 data tables ('Cost Assessment for PR19 – a consultation of econometric cost modelling'), which included spreadsheets sourced through the Stata analysis tool; the 'Ofwat stata master wholesale water' and 'Ofwat stata master wholesale wastewater' spreadsheets. These datasets contained data for spend on resilience (in £million) for water resources, raw water distribution, water treatment, treated water distribution, sewage collection, sewage treatment, total network plus, sludge transport, sludge treatment, sludge disposal and

[3] https://www.ofwat.gov.uk/wp-content/uploads/2017/12/UK-Govt-priorities-FM.pdf
[4] https://www.ofwat.gov.uk/regulated-companies/price-review/2019-price-review/business-plans/
[5] https://www.ofwat.gov.uk/publications/companies-updated-cost-and-performance-august-submission-data/
[6] https://www.ofwat.gov.uk/consultation/cost-assessment-pr19-consultation-econometric-modelling/

sludge total for the years between 2011-12 and 2016-17. These were added together to provide a total spend on resilience for each water company for 2011-12 to 2016-17.

It is noted that in this analysis, the data for 2011-12 to 2014-15 uses the 'cost assessment submission' data, in replacement of the 2013 August submission data used in the previous indicator by ADAS (2017), as this provided a consistent methodology for the most recent years of data. It is recognised that there are some notable differences between the two datasets (cost assessment submission data vs August submission data), with some figures differing (for the same year, but different datasets) by up to £21 million in some instances.

Data for 2017-18 was sourced from the PR19 Business Plan tables[4]. In the individual PR19 Business Plan data tables by each water company, actual data is provided for 2017-18, as well as forecast investment for the period 2018-19 to 2024-25. Investment attributable to resilience is listed as 'A14. Enhancement expenditure by purpose – capital: Resilience'. Within these PR19 business plans, 'enhancement expenditure by purpose – capital: resilience' is defined as '*transition capital expenditure on schemes delivered in the report year to improve resilience. This relates to expenditure to manage the risk of giving consumers an appropriate level of service protection in the face of extreme events caused by hazards that are beyond their control'* and '*to include expenditure to meet new, more onerous requirements stemming from the National Flood Resilience Review*'.

The water and sewerage companies included within these datasets are: Anglian, Dwr Cymru/Welsh water, Northumbrian, Severn Trent, Southern, South West, Thames, United Utilities, Wessex, and Yorkshire. The water only companies included are: Affinity, Bristol, Dee Valley/Hafren Dyfrdwy, Portsmouth, Bournemouth, South East, South Staffordshire, and Sutton and East Surrey.

2.5.3 Trends and implications for climate resilience

The total and forecast annual spend on resilience by all water companies from 2008-09 to 2024-25 is shown in Figure 2.13. Total spend on resilience by all water companies was £132.3 million in 2017-18, a 271% increase since 2008-09 (when total spend on resilience was £35.7 million). The majority of the 2017-18 spend on resilience was by Severn Trent (76%), with the top six water companies accounting for 98.7% of total spend, including Bristol (8.9%), Anglian (5.2%), Affinity (3.8%), United Utilities (2.6%), and Sutton and East Surrey (2.3%).

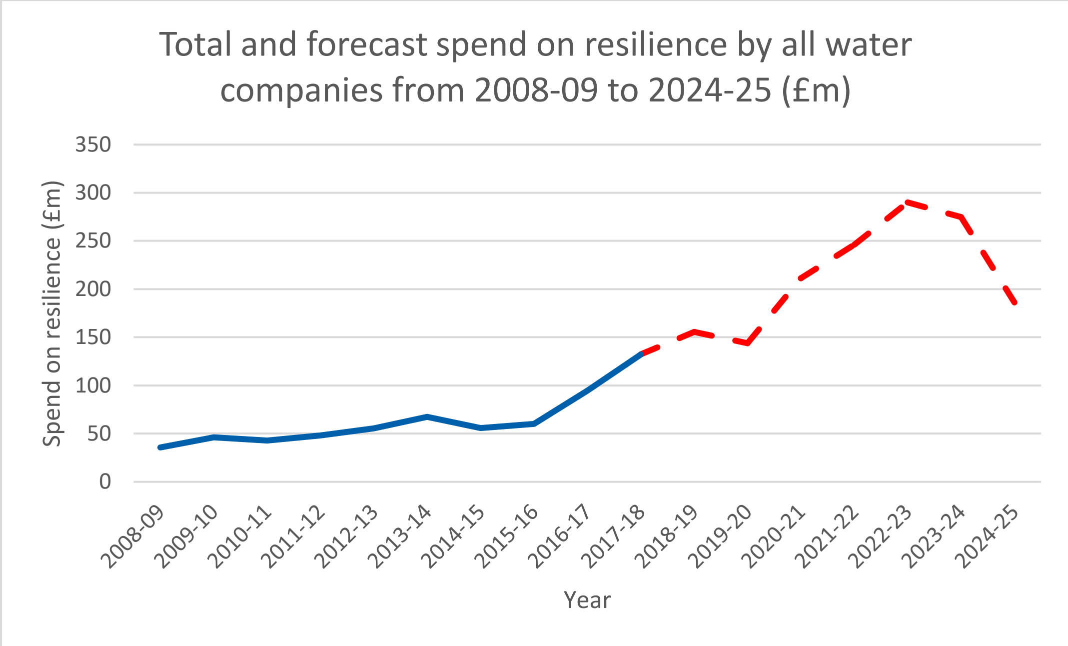

Figure 2.13 – Total (solid blue line) and forecast (red dashed line) spend on resilience by all water companies (both water and sewerage and water only) from 2008-09 to 2024-25, as reported to Ofwat. Data from 2008-09 to 2017-18 is actual data, with forecast spend shown from 2018-19 to 2024-25. Source: ADAS for the CCC.

Figure 2.14 shows that between 2008-09 and 2017-18, 71% of all spend on resilience was by Severn Trent and Anglian Water, who spent £379.1 million and £73.8 million respectively. This is expected, as the size and area covered by these water companies is significantly greater than e.g. Bournemouth Water, so it would be expected that these companies would have a larger spend. A further 25% of spend during the 2008-09 to 2017-18 time period was by Thames (£36.8 million), Bristol (£33.3 million), Yorkshire (£26 million), Wessex (£22.9 million), Affinity (£22.6 million), and Sutton and East Surrey (£16 million). The remaining 10 water companies account for 5% of total spend on resilience between 2008-09 and 2016-17, with a total spend of £28.8 million between them (and individual spend of less than £6 million).

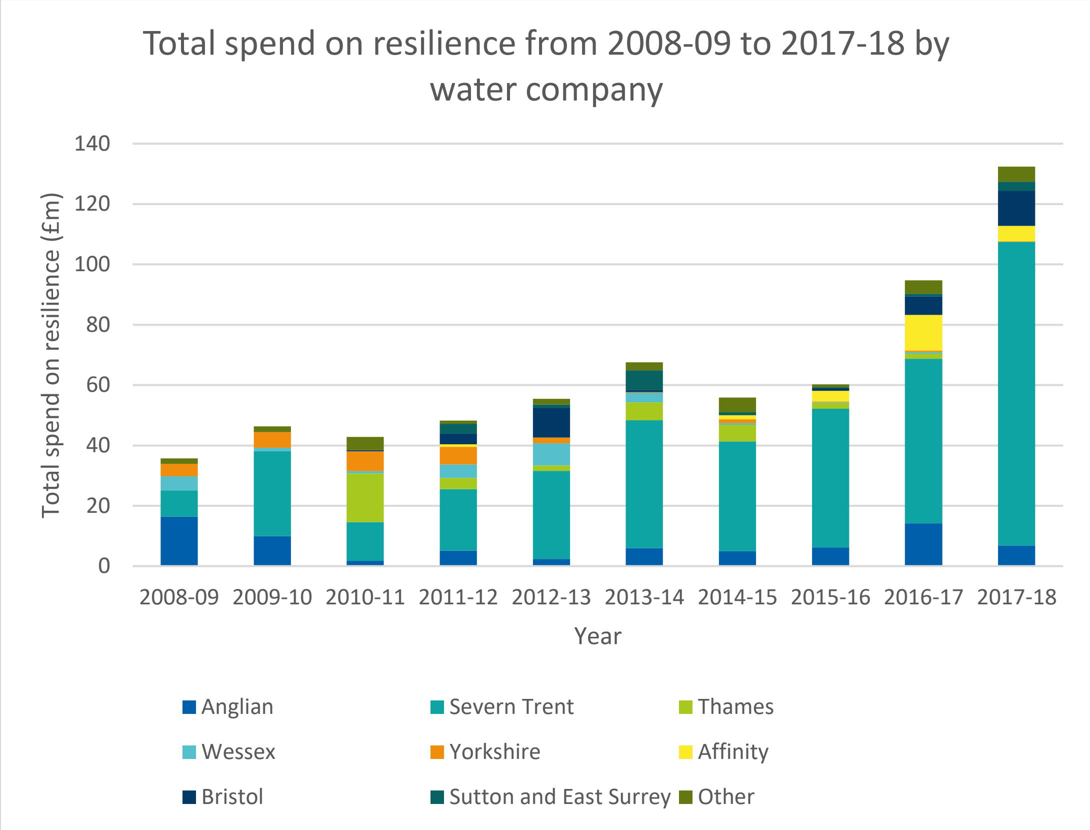

Figure 2.14 – Total spend on resilience from 2008-09 to 2017-18 by individual water company, as reported to Ofwat. Between 2008-09 and 2017-18, 70% of all spend on resilience was by Anglian and Severn Trent. A further 25% of spend was by Thames, Wessex, Yorkshire, Affinity, Bristol and Sutton and East Surrey. The remaining 10 water companies (grouped as 'Other') account for less than 5% of the total spend on resilience across all water companies. Source: ADAS for the CCC.

Looking forwards, total spend on resilience is forecast to increase, peaking at £290 million in 2022-23 before dropping down in 2023-24 and 2024-25, shown in Figure 2.15.

Six companies account for 90% of forecast spend on resilience from 2018-19 to 2024-25. These are Anglian (25.5%; £384 million), Severn Trent (24.4%; £368 million), Thames (14%; £212 million), Northumbrian (10.2%; £153 million), Dwr Cymru (8.3%; £125 million) and United Utilities (8.1%; £123 million). The remaining 11 companies make up the remaining 10% spend on resilience, with Yorkshire Water having no forecast investment from 2018-19 to 2024-25.

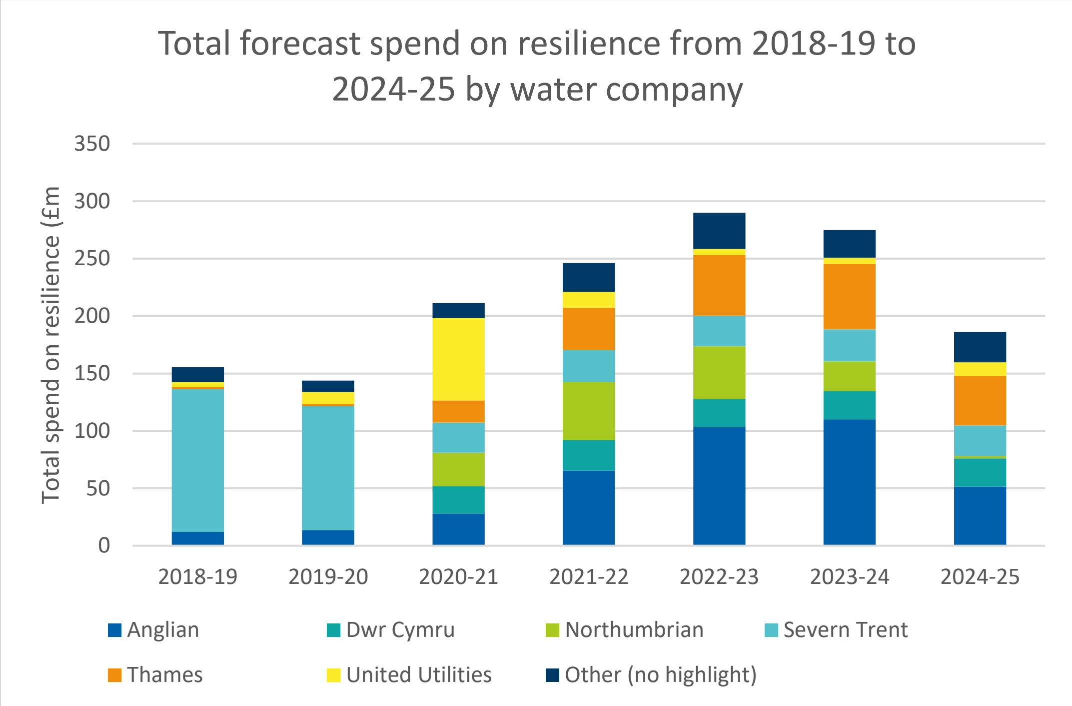

Figure 2.15 – Total forecast spend on resilience from 2018-19 to 2024-25 by individual water company, as reported to Ofwat. Between 2018-19 and 2024-25, 50% of forecast spend on resilience is expected to be by Anglian and Severn Trent. A further 40% of spend is forecast to be by Thames, Northumbrian, United Utilities and Dwr Cymru. The remaining 11 water companies (grouped as 'Other') account for 10% of the total spend on resilience across all water companies. Note that Bournemouth water is not included as this is now part of South West water (bringing the total number of water companies to 17). Source: ADAS for the CCC.

2.5.4 Robustness of indicator

This indicator provides a relatively robust time series of investment and spend on resilience by water companies in England and Wales. Whilst it is recognised that there may be some differences in how companies define resilience in their own organisations, this is anticipated to be minimal due to definitions provided by Ofwat for recording purposes. For comparability purposes between years, there have been some changes to the boundaries of the different water companies in recent years. For example, Bournemouth water became part of South West water in 2016, with the intention to deliver separate South West water and Bournemouth Water 2015-2020 business plans[7]. Dee Valley is now Hafren Dyfrdwy, however with some boundary changes and the addition of Severn Trent's wastewater customers in Wales[8]. Therefore, data before 2017-18 will not be comparable at a company level for Hafren Dyfrdwy or Severn Trent.

The data used in this analysis was freely available from the Ofwat website.

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[7] https://www.southwestwater.co.uk/about-us/latest-news/news-2016/bournemouth-water-merges-with-south-west-water/

[8] https://www.stwater.co.uk/news/news-releases/hafren-dyfrdwy-_-different-name--improved-service-for-customers/

2.6 Water consumption per capita

Description: *Water consumption per capita (metered and unmetered customers)*

Type: *Vulnerability*

2.6.1 Introduction

Water demand is likely to increase in future years due to an increase in population. More frequent erratic weather patterns caused by climate change may change or decrease supply also, however the impact of climate change on demand patterns is not well understood. In order to ensure that there is sufficient water available, it is important for individuals and households to be aware of how much water they are using and take steps to decrease water use where possible.

Data on water consumption per capita helps us to understand whether the volume of water used per person in England is increasing or decreasing over time. This indicator looks at water consumption per capita.

2.6.2 Data source and method

This indicator was updated by the Adaptation Committee in 2017 (ASC, 2017) with data provided directly by the Environment Agency (EA).

In this update, data from 1999-00 to 2004-05 has been sourced from ASC (2017). The EA provided data directly for 2005-06 to 2017-18. The data is presented as a weighted average of per capita consumption for England to more accurately represent the population and associated demands in the water company supply areas, and is measured in litres per household per day (l/h/d).

The EA also provided forecast data for 2020-21 to 2044-45. This forecast data is collated from the 2019 round of draft 'water resources management plans' using a standard scenario[9]. This scenario is the dry year annual average (DYAA) scenario which is intended to represent a dry year with higher than average demand for water, but not in drought. As the actual data for 1999-00 to 2017-18 reflects the actual conditions of the year, which could be a wet, dry, or normal year, this data should not be directly compared against the DYAA scenario planned data.

2.6.3 Trends and implications for climate resilience

Weighted average per capita consumption in England has decreased by 6% from 150 l/h/d in 1999-00 to 141 l/h/d in 2017-18, shown in Figure 2.16. There has been some fluctuation in the data throughout the time series though, with lows of 139 l/h/d in 2012-13, 2014-15 and 2015-16, and a peak high of 155 l/h/d in 2003-04.

From 2020-21 to 2044-45, weighted average per capita consumption for England is forecast to decrease by 7%, from 138 l/h/d, to 129 l/h/d (Figure 2.16).

[9] https://data.gov.uk/dataset/7b9f408a-3980-4699-85ff-1b4e3e0b312a/draft-water-resources-management-plan-2019-supply-demand-data-at-company-level-2020-21-to-2044-45

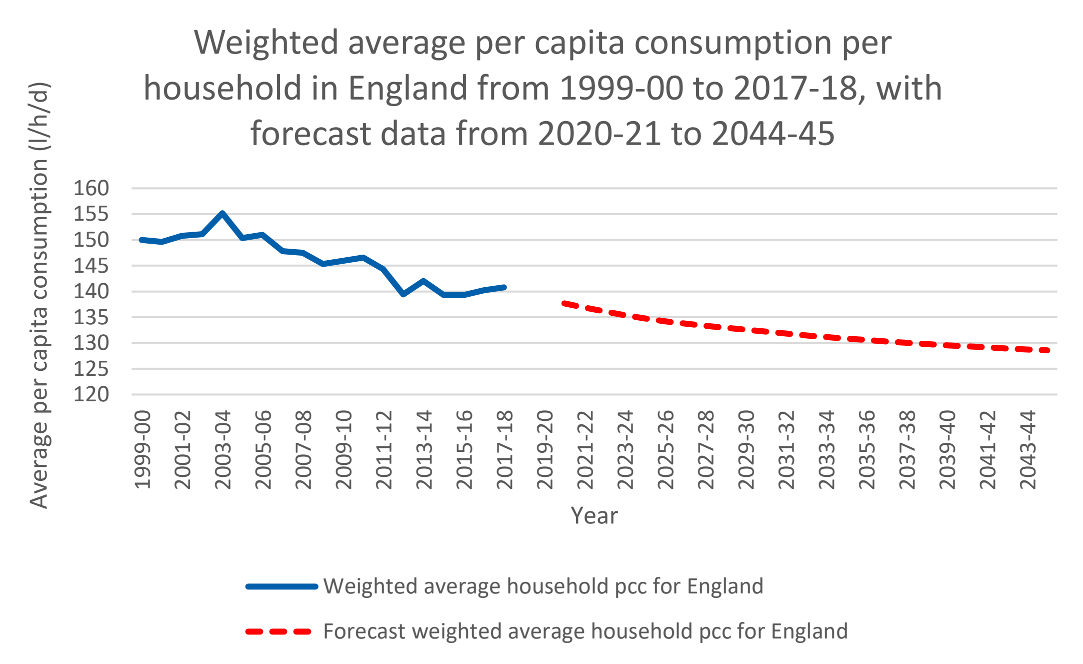

Figure 2.16 – The weighted average per capita water consumption (PCC) in England (litres per household per day) from 1999-00 to 2017-18 (blue line), with forecast data for 2020-21 to 2044-45 (red line), as provided by the Environment Agency. Source: ADAS for the CCC.

2.6.4 Robustness of indicator

The dataset used in ASC (2017) is comparable with that provided by the Environment Agency in January 2019. Hence, the time series from 1999-00 to 2017-18 is considered robust.

It is noted by the EA that the forecast data from 2020-21 to 2044-45 is not finalised, and therefore this may change in the future. It is also acknowledged that the actual and forecast data should not be directly compared. The Draft Water Resources Management Plan data can be freely downloaded at the company level[9]. The EA calculated weighted average PCC based on this published data, which provided the data used in this project.

2.7 Water leakage

Description: *Water leakage (Ml per year)*

Type: *Action*

2.7.1 Introduction

Water shortages are likely to be one of the most serious impacts of climate change in the UK, with even modest temperature rises leading to "severe" water shortages in England. Measures to reduce both leakage and demand are needed in order to adapt to a warmer, drier climate.

Reducing water lost due to leakage is important as it reduces pressure on water resources. In England and Wales, leakage is defined as treated water lost from the distribution system. This includes water lost from the water companies' distribution networks, and supply pipe losses from consumers' pipes[10]. Leakage can be affected by operation strategies (e.g. pressure management), network characteristics (e.g. length of mains), condition (e.g. age) and customer base composition (e.g. whether rural or urban).

Water companies have individual targets based on the sustainable economic level of leakage in their distribution network, and can be held to account by Ofwat if they do not meet these. As part of meeting these targets, Ofwat expect each water company to replace pipes and find and repair any leaks to prevent any unnecessary loss of water.

This indicator looks at the total water leakage across all water companies in England and Wales between 1992-93 and 2017-18.

2.7.2 Data source and method

Data from 1992-93 to 2014-15 was taken from the previous update of this indicator by ADAS (2017). This included data from 1992-93 to 2010-11 that was published by Defra[11] based on data submitted by water companies as part of the 'June return' (an annual data submission to Ofwat); data from 2011-12 to 2013-14, which was taken from Ofwat's web archive; and data for 2014-15, taken from the 'Discover Water' website[12]. All data was recorded in mega litres per day (ML/d).

To update this indicator, data from the Ofwat 2019 Price Review (PR19) has been used. This dataset was used because more recent data on the Discover Water website was only available for 2017-18 (i.e. no data for 2015-16 and 2016-17).

Within the PR19 tables, each company include data for leakage. The PR19 reporting tables provide leakage data for two definitions, a 'new definition' and an 'old definition', which follows the approach that was used in the PR14 reporting. The new definition uses three levels of leakage (an upper limit of sustainable economic level of leakage (SELL), a central point of SELL and a lower limit of SELL) for the years 2016-17 and 2017-18, as well as forecast data for 2018-19 to 2044-45. In order to keep consistent with the previous data set, and benefit from a longer data series, the data under the PR14 reporting definition has been used in this update. This definition is: '*Total leakage measures the sum of distribution losses and supply pipe losses in megalitres per day (Ml/d). It includes any uncontrolled losses between the treatment works and the customer's stop tap. It does not include internal plumbing losses*'.

The PR19 data tables contain data for 2015-16 to 2017-18, and forecast data for 2018-19 to 2024-25. This is found within sheet 'App2' – 'Leakage additional information and old definition reporting'. These tables were used to provide actual data for 2015-16 to 2017-18, and forecast data for 2024-25. The method used to extract this data was done by summing the total leakage for each of the water companies.

The water and sewerage companies included are: Anglian, Dwr Cymru/Welsh water, Northumbrian, Severn Trent, Southern, South West, Thames, United Utilities, Wessex, and Yorkshire. The water only companies included are: Affinity, Bristol, Dee Valley/Hafren Dyfrdwy, Portsmouth, Bournemouth, South East, South Staffordshire, and Sutton and East Surrey.

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[10] https://www.ofwat.gov.uk/households/supply-and-standards/leakage/

[11] Distribution input and supply pipe leakage: 1992/93 to 2010/11

[12] https://discoverwater.co.uk/leaking-pipes

It is noted that the Discover Water website also held data for 2017-18, which was used as a sense check against the PR19 data. With the exception of two water companies (Hafren Dwfrdwy and Severn Trent), the Discover Water data matched the data within the PR19 data tables for 2017-18. The discrepancy between the datasets is likely due to a change in the layout of the water industry, with Severn Trent bringing together all its Welsh customers into a single company. I.e. Hafren Dyfrdwy (previously Dee Valley, with some boundary changes) now also includes Severn Trent's wastewater customers in Wales[8]. This meant that the 35,100 homes and 3,900 businesses in Powys and Monmouthshire who were previously Severn Trent customers, were combined with Dee Valley customers in Wales to be served under the new company Hafren Dyfrdwy[13].

The PR19 data tables have been used in this update in preference over the Discover Water website due to this change in the layout of the water industry, which is better captured in the new tables.

2.7.3 Trends and implications for climate resilience

The overall trend in water leakage in England and Wales over the past 26 years has been downward, shown in Figure 2.17. Leakage has decreased by 38% from a peak of 5,112 ML/d in 1994-95 to 3,171 ML/d in 2017-18. Total leakage has been relatively stable since 2011-12, but is forecast to reduce from 2018-19 onwards.

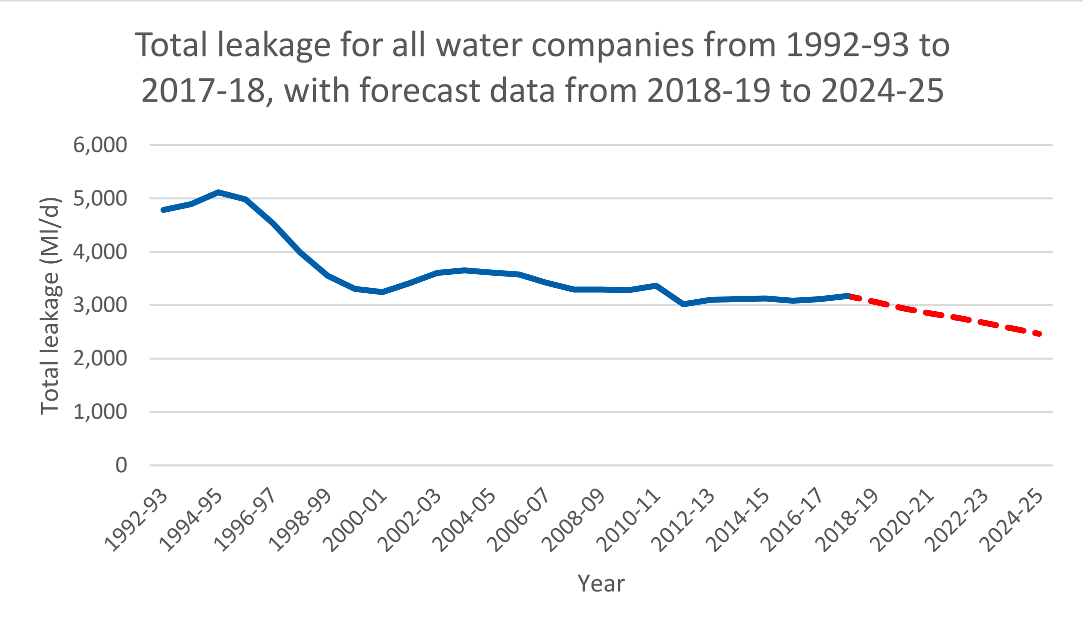

Figure 2.17 – Total leakage for all water companies from 1992-93 to 2017-18 (solid blue line). Forecast data is provided for 2018-19 to 2024-25 (red dashed line), as reported to Ofwat. Source: ADAS for the CCC.

2.7.4 Robustness of indicator

Total water leakage (ML/day) across water companies provides a good insight into the total quantity of water lost to leakage. This indicator provides additional years of data to the

[13] https://www.stwater.co.uk/news/news-releases/hafren-dyfrdwy-_-different-name--improved-service-for-customers/

previous update of this indicator by ADAS (2017). The previous dataset used remains the same with the exception of the data for 2015-16. In ADAS (2017), the Discover Water website was used for 2015-16. However, the data was no longer available for this particular year during this analysis, meaning for this update the PR19 data was used instead. The difference between the Discover Water data used in the previous indicator (ADAS, 2017) and the PR19 data table value, was 0.09% for 2015-16 and 2.6% (82 ML/day) for 2017-18. The two datasets were comparable in 2017-18 for all companies with the exception of Hafren Dyfrdwy and Severn Trent. This is likely attributed to the recent changes in boundaries of these two water companies[8].

2.8 Percentage of properties with water meters

Description: *Number/proportion of properties with water meters (residential/commercial)*

Type: *Action*

2.8.1 Introduction

Water is likely to become scarcer in the future as the population grows, demand for water increases, and the climate changes. Installing water meters provides a way for water companies to understand how much water individual properties are using, and charge customers based on these more accurate recordings, rather than on a fixed rate. Metering also incentivises household water efficiency.

This indicator looks at the total percentage of household properties with water meters installed in England and Wales.

2.8.2 Data source and method

The data used in the previous update of this indicator by ASC (2017) for the period 1999-00 to 2015-16 was sourced from the Environment Agency based on an original dataset from Ofwat. This dataset was for England only, and exhibited a data gap for 2014-15.

To update this indicator, the supporting documents for 'Cost Assessment for PR19 – a consultation on econometric cost modelling'[6] were used. The 'Ofwat stata master wholesale water' supporting document contains information for:

- 000s, Households billed for measured water (external meter)
- 000s, Households billed for measured water (not external meter)
- 000s, Households billed for unmeasured water

This spreadsheet includes data for 2011-12 to 2016-17 for Anglian, Dwr Cymru/Welsh Water, Northumbrian, Severn Trent, Southern, South West, Thames, United Utilities, Wessex, Yorkshire, Affinity, Bristol, Dee Valley (now Hafren Dyfrdwy), Portsmouth, Bournemouth (now part of South West), South East, South Staffordshire, and Sutton and East Surrey.

The three parameters above were totalled to find the total number of households served by each water company, and the water industry as a whole. The total households billed for measured water (both 'external' and 'not external meters') was then divided by the total number of households served to find the percentage of households with water meters.

The updated dataset is for England and Wales and includes water supply (not wastewater) for 'household' properties only. It is not clear if this is the same method taken within the previous update by ASC (2017), but for the years that overlap, the difference between the two values is 1.1% for 2011-12, 1.3% for 2012-13, and 1.2% for 2013-14, suggesting differences are relatively minor

Whilst it may seem possible to estimate the data for England only by removing data for Dwr Cymru and Hafren Dyfrdwy, this may not be accurate due to recent changes in the boundary of Hafren Dyfrdwy, as well as Severn Trent, which operates across both regions[8]. However, the inclusion of these two companies in the dataset make relatively little difference on the results, with the percentage difference between the 'all water companies' (as used in Figure 2.18), and with the removal of Dwr Cymru and Hafren Dyfrdwy is less than 1% for each year between 2011-12 and 2016-17.

Defra (2018) also report the percentage of properties with water meters for England. This data is available for 2014-15 to 2017-18, as well as forecast for 2020-21 and 2044-45. We do not use this data in this analysis as the time series is shorter.

Actual data for 2017-18, and forecast data from 2018-19 to 2029-30 was derived from the individual water companies' PR19 data tables. Sheet WS3 within the PR19 data tables captures: 000s, Households billed for measured water (external meter); 000s, Households billed for measured water (not external meter); and 000s, Households billed for unmeasured water. These three parameters were totalled to find the total number of households served by each water company, and the water industry as a whole. The total households billed for measured water (both external and not external meters) was then divided by the total number of households served to find the actual percentage of households with water meters for 2017-18, and forecast percentage for 2018-19 to 2029-30.

2.8.3 Trends and implications for climate resilience

Figure 2.18 shows the percentage of household properties with water meters. There has been an increase in the percentage of household properties with water meters from 1999-00 to 2017-18. The percentage of properties with water meters has almost trebled from 17% in 1990-00 to 53.6% in 2017-18. The average percentage increase of properties with water meters installed each year was 6.5% between 1999-00 and 2017-18. However, the rate was higher between 1999-00 and 2010-11 (7.5%), compared with an average yearly percentage increase between 2011-12 and 2017-18 of 5.1%.

It is noted that the number of properties serviced by the water companies rose by 2.2% during this period, from 22,408 in 2011-12 to 22,910 in 2017-18. New properties must legally have a water meter fitted upon construction, so increases are expected year on year due to new properties being built. Calculating the percentage of properties of water meters using the 2017-18 number of houses with water meters (12,280) against the 2011-12 property numbers (22,408) shows that 54.8% of properties have water meters. This indicates that the percentage of properties with water meters is increasing at a higher rate than development alone. The average percentage of properties with water meters is expected to increase to 76% by 2029-2030.

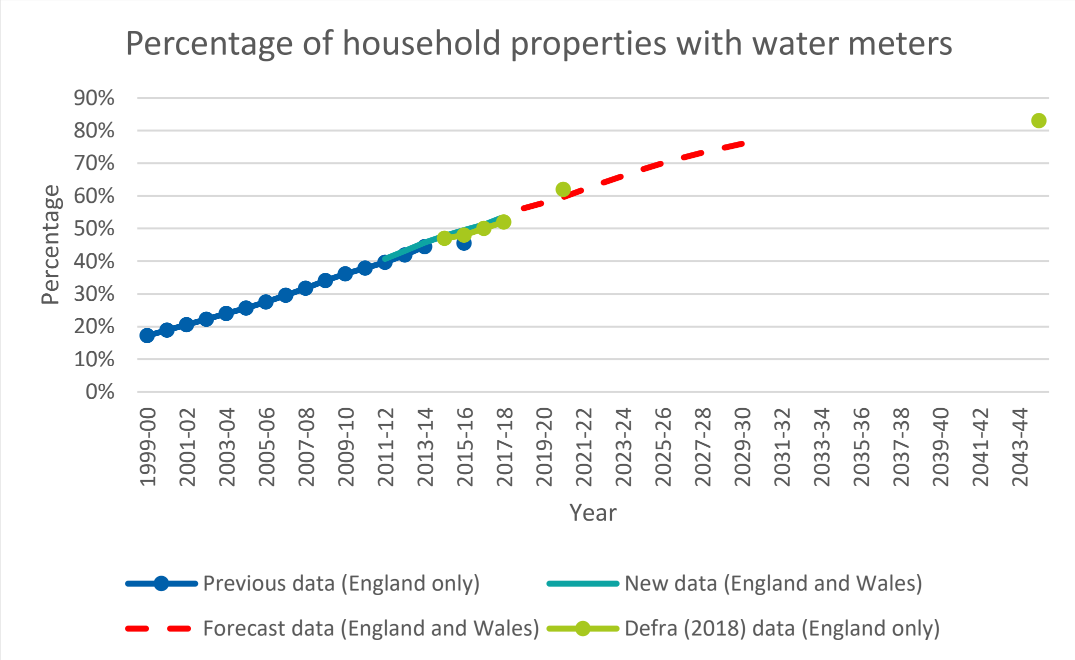

Figure 2.18 – The percentage of household properties with water meters, as reported to Ofwat. Data for 1990-00 to 2015-16, as used in the 2017 update, is for England only, whereas the new data for 2011-12 to 2017-18 (and forecast data) is for England and Wales. Dark blue indicates the data used in the previous ASC (2017) update of this indicator. The turquoise line shows new data for 2011-12 to 2017-18 sourced from the supporting documents to the PR19 data tables and PR19 data tables. The pale green line shows data for England only from Defra (2018). The red dashed line indicates forecast data for 2018-19 to 2029-30 calculated from data within the PR19 data tables. Source: ADAS for the CCC.

2.8.4 Robustness of indicator

The updated data for 2011-12 to 2017-18 is not directly comparable to the previous ASC (2017) dataset, which was for England only. This is due to the new data including Wales also. Whilst it may be possible to remove the Welsh water companies, due to recent changes in the boundaries of the water companies, this would not be directly comparable either. For example, Hafren Dyfrdwy now includes the Dee Valley, with some boundary changes, and the majority of what were previously Severn Trent's Welsh Waste Water customers[8]. The difference in the total figure with the removal of Dwr Cymru and Hafren Dyfrdwy is less than 1% for each year between 2011-12 and 2017-18.

The data is relatively robust, and for the years that there was overlap between the two datasets, the difference between the two values was 1.1% for 2011-12, 1.3% for 2012-13, and 1.2% for 2013-14. There was no data for comparison in 2014-15 and for 2015-16 there was 4% difference. It is not clear why the difference was so great in 2015-16, particularly as there was no data for 2014-15 to see if the trend had been continuing.

The forecast data has been calculated using the same methodology as the updated data for 2011-12 to 2017-18 and, as such, is directly comparable. However, in line with the above, this is not directly comparable to the previous ASC (2017) dataset.

2.9 Total water demand from key sectors

Description: *Total water demand from agriculture, industry, energy, public water supply, other uses*

Type: *Vulnerability*

2.9.1 Introduction

It is expected that there will be an increasing need for the irrigation of certain crops in England, both for high value crops such as potatoes and vegetables, as well as broad acre arable crops such as cereals, where germination and crop development could be affected by extreme temperatures and drought stress. Higher temperatures would also lead to an increase in livestock water consumption.

Production may also be affected by a changing climate, leading to uncertainty in future water demand from both crop irrigation and livestock. The majority of irrigated land is located in water-stressed catchments, which is a cause for concern for protection of our water resources in the future if demand is expected to increase.

This indicator assesses total water demand from agriculture, industry, energy, public water supply and other uses.

2.9.2 Data source and method

2.9.2.1 Agriculture

For water demand in agriculture, the latest available data on livestock numbers and arable areas disaggregated by geographic region is for 2017 and is provided by Defra using the results of the June Survey of Agriculture and Horticulture[14]. Using these figures, estimates of water demand were made for irrigation and for livestock.

The irrigation water needs per crop group (early potatoes; main crop potatoes; cereals; sugar beet; vegetables; soft fruit; grass) and EA region, were provided for the 2010 census year by Cranfield University, reported in Defra project WU0131 (Defra, 2013a). The Defra project used the procedure of Knox et al., (1997) for main-crop potatoes (*Solanum tuberosum*) and the other main crops irrigated.

Data on the irrigated proportion of each crop group by EA region were required to scale the survey statistics to obtain an estimate of irrigated area of each crop group (as not all crops are irrigated, some are rain fed). This was obtained from the Defra 2010 Irrigation Survey[15] and expressed as a proportion of the total crop area per region. Ideally an 'adjustment factor' to represent the difference in agro-climate between 2010 and 2017 would also have been applied, but such a factor was not readily available.

The irrigation water needs for 2010 were divided by the irrigated crop area to obtain a water demand (m^3) per hectare of crop per region. These were then multiplied by the estimates of

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[14] https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

[15]https://webarchive.nationalarchives.gov.uk/20130125180121/http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-farmmanage-fbs-waterusage20110609.pdf

irrigated crop areas for 2017 within each region to obtain updated figures for irrigation water demand for the Defra June Survey year 2017.

Estimates of water demand per head of Defra census livestock category originate from Defra projects WU0101[16] and WU0132[17] and account for the age and size of animals, the composition of their diets, production levels and ambient temperatures. Livestock numbers at the regional level, provided by the 2017 survey were multiplied by estimates of water demand per head of livestock to give a total water demand per region for each livestock type.

2.9.2.2 Public water supply

Water supply data was provided by the Environment Agency for each water company, along with data delineating the water company boundaries. This provided total household consumption in Millions of litres per day (Ml/d) for each water company area. The total household consumption was multiplied by 365 to give an annual total water consumption in Millions of litres (Ml). Cholderton & District Water was excluded from the analysis as they are now a private water supplier with only around 2000 customers.

2.9.3 Trends and implications for climate resilience

2.9.3.1 Agriculture

Irrigation

This analysis assesses the 'theoretical' dry year irrigation demand, based on land use (in 2017) and irrigation practices (in 2010), by crop type, which varies spatially across England. Estimated water demand for irrigated crop groups by region for 2017 is shown in Table 2-11. It is noted that grassland has some fairly high values, particularly in the Eastern and South East regions. This reflects the irrigation demand that would be needed in a theoretical 'dry' year, rather than actual practice – i.e. irrigation of grass is not something that is done in England.

Table 2-11 - Estimated volumetric water demand (x000 m^3) for irrigation, by crop category, by region, based on 2017 land use. Source: ADAS for the CCC.

Region	Potatoes	Cereals	Sugar beet	Vegetables	Small fruit	Grass	Total
North East	513,136	6,674	2,595	12,864	3,877	11,327	550,473
North West and Merseyside	1,342,401	1,988	110	72,767	483	5,533	1,423,282
Yorkshire and The Humber	7,014,509	20,737	222,023	185,620	33,974	15,386	7,492,249
East Midlands	3,721,713	78,839	360,763	375,295	12,905	50,642	4,600,157
West Midlands	3,314,335	41,959	41,186	85,356	69,030	70,506	3,622,372

[16] http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=14402

[17] http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=2&ProjectID=17363

Eastern	41,160,153	995,091	8,246,248	3,164,348	233,899	4,815,971	58,615,710
South East	2,656,823	110,504	265,100	482,035	1,512,709	2,755,642	7,782,813
South West	547,747	572	0	78,490	83,166	345,019	1,054,994

Previous results provide water demand estimates at a different regional breakdown, making it difficult to identify regional trends in water demand. However, national trends in water demand can be observed relatively consistently. Generally, total irrigation between 2010 and 2017 is similar (Table 2-12). The total volumetric water demand for outdoor irrigated crops in England was estimated to be 84.5 million m^3 based on the 2010 cropping pattern, 80.2 million m^3 based on the 2015 cropping pattern, and 85.1 million m^3 based on the 2017 cropping pattern. Note that changes are purely a result of changes in crop areas within the regions – irrigation demand per unit area is assumed to be the same for each crop category and region as previous years. The results do not reflect any changes in climate.

Table 2-12 - Total water demand (x000 m^3) for crop irrigation in England for 2010, 2015 and 2017. Source: ADAS for the CCC.

Crop	2010	2015	2017
Potatoes	57,195,962	55,123,745	60,270,817
Cereals	1,199,613	1,243,982	1,256,364
Sugar beet	10,409,260	7,933,962	9,138,023
Vegetables	5,146,715	5,214,871	4,456,774
Soft fruit	1,473,703	1,625,719	1,950,044
Grass	9,082,023	9,087,931	8,070,026
Total	84,521,396	80,230,211	85,142,050

Livestock

Regional water supply demand for livestock in 2017 is shown in Table 2-13. Trends in water demand can only be observed at the national level.

Table 2-13 - Estimated volumetric water demand (x000 m^3) for livestock, by livestock group, by region, based on 2017 livestock numbers. Source: ADAS for the CCC.

Region	Cattle	Poultry	Pigs	Sheep	Total
North East	2,241	69	249	2,572	5,131
North West and Merseyside	17,074	350	297	4,017	21,738
Yorkshire and The Humber	6,848	507	2,914	2,818	13,087
East Midlands	6,270	904	791	1,649	9,614
West Midlands	10,900	718	420	2,998	15,036
Eastern	1,817	767	2,079	457	5,120
South East	5,087	444	484	1,673	7,688
South West	28,107	617	967	4,306	33,997
England	78,343	4,375	8,202	20,489	111,409

Figures for 2010, 2014 and 2017 are shown in Table 2-14. Water demand from cattle, pigs and sheep appear to stay relatively stable, with small variations between the years, and no consistent pattern. Water demand from poultry has shown a continual decrease.

Table 2-14 - Total water demand (x000 m^3) for livestock in England for 2010, 2015 and 2017. Source: ADAS for the CCC.

Livestock	2010	2014	2017
Cattle	74,238	78,774	78,343
Poultry	11,309	9,731	4,375
Pigs	7,761	7,359	8,202
Sheep	22,911	19,714	20,489
Total	116,219	115,578	111,409

2.9.3.2 Public Water Supply

Water consumption is greatest for the water companies that cover the largest areas (Table 2-15). These include Yorkshire Water, Severn Trent Water and Anglian Water. Thames water and South East water have a high water consumption relative to their area due to the high number of households in these regions. The water company areas with the highest average household consumption are Affinity Water, Cambridge Water and Essex & Suffolk Water.

Table 2-15 - Annual water demand for public water supply by water compary area. Source: ADAS for the CCC.

Water Company	Total household consumption (Ml/d)	Total annual household consumption (Ml)
Affinity Water	566.46	206,758
Anglian Water Services	620.96	226,650
Bournemouth Water	63.21	23,072
Bristol Water	178.79	65,258
Cambridge Water	45.56	1,662
Essex & Suffolk Water*	0.29	106
Northumbrian Water	295.22	107,755
Portsmouth Water Ltd	0.08	29
Severn Trent Water Ltd	365.32	133,342
South East Water	105.05	38,343
South Staffordshire Water Plc	1,024.14	373,811
South West Water Ltd	325.27	118,724
Southern Water	172.74	63,050
Sutton & East Surrey Water	236.80	86,432
Thames Water	319.13	116,482
United Utilities	107.97	39,409
Veolia Water Central	1,434.82	523,709
Veolia Water East	900.87	328,818
Wessex Water**	16.85	6,150
Yorkshire Water	0.37	135
Total	**6,762.76**	**2,468,407**
*** 16/17 figures used** **** 14/15 figures used**		

2.9.3.3 Across sectors

Licenced abstraction by sector is shown in Table 2-16.

Table 2-16 - Licenced abstraction by sector in 2016 (million cubic metres). Source: ADAS for the CCC.

Region	Public water supply	Spray irrigation	Agriculture (excl. spray irrigation)	Electricity supply industry	Other industry	Fish farming, cress growing, amenity ponds	Private water supply	Other	Total
North West	688	2	2	3,241	180	10	0	2	4,125
North East	740	5	2	1,492	90	86	1	1	2,419
Midlands	848	16	2	836	488	17	1	15	2,222
Anglian	745	53	4	810	45	21	2	1	1,683
Thames	1,376	3	3	263	102	42	3	3	1,794
Southern	462	4	10	502	863	280	1	11	2,133
South West	422	1	3	483	73	266	1	6	1,257
England level	5281	84	26	7627	1841	722	9	39	15,633

2.9.4 Robustness of indicator

Irrigation: Previous regional irrigation estimates for each crop were used on current crop areas to estimate water use per region. This was due to a lack of up-to-date data on individual crop demand at the regional level. There was also a difference in the breakdown of region between the regional crop area statistics (Defra regions) and the regional crop water usage (EA regions), however these were matched as best as possible based on geographical extent. A national figure of crop water demand was used on the total crop areas to provide the national water estimates; therefore this figure differs slightly to the totals of the regional estimates. Whilst this method provides a theoretical indication of irrigation demand, it does not reflect actual practice and crop groups such as grass would not typically be irrigated, even in a very dry year (due to both cost, water availability and relative feasibility of such a task).

Livestock: The most recent Defra regional livestock statistics were used with water requirements from Knox et al. (2013) used in previous analyses. The alignment of livestock categories in the water usage data with available livestock categories matched up in most cases. 'Bulls <1 years' were included in the 'Dairy & beef bulls' category, as these were not separated out in the provided statistics. This could lead to a slight overestimation of water usage in these cases.

Public Water Supply: Figures for total household consumption were provided by the EA. Total household consumption is the volume of water in Ml/d that is consumed by both measured and unmeasured households, and excludes customer supply pipe leakage. It therefore accurately represents true water consumption inside households.

2.10 Total water demand against current and future water scarcity

Description: *Total water demand against current and future water scarcity by area*

Type: *Exposure*

2.10.1 Introduction

It is expected that there will be an increasing demand on water across industries as the climate changes. Water-stressed catchments will be particularly vulnerable, which is a cause for concern for protection of our water resources in the future if demand is expected to increase. Competition between agriculture and other industries is expected to increase, with increases in housing also likely to lead to changes in water demand for public water supply.

This indicator assesses total water demand against current and future water scarcity by area.

2.10.2 Data source and method

Water Resource Availability and Reliability data[18] from the Environment Agency (EA), updated 1 April 2018, provides information on water resource availability for each catchment across England. Each catchment has a category of resource availability which describes the percentage of the time additional consumptive resource may be available. This is divided into the following categories; Consumptive abstraction available: less than 30% of the time, at least 30% of the time, at least 50% of the time, at least 70% of the time or at least 95% of the time.

In order to compare the data on water demand with resource availability, the proportion of an area (region or water company boundary) that has a given water availability was calculated. Cholderton & District Water was excluded from the analysis as they are now a private water supplier with only around 2000 customers.

2.10.3 Trends and implications for climate resilience

The proportion of each region with a given water availability is shown in Table 2-17. The regions where there is a large proportion of catchments with low resource availability are the South East (60% of catchments have resource availability less than 30% of the time) and East of England (54% of catchments have resource availability less than 30% of the time). These are also the two regions where there was a high demand for water for irrigation.

Table 2-17 - Percentage of region area covered by catchment resource availability (percentage of the time additional consumptive resource may be available).

Region	less than 30%	at least 30%	at least 50%	at least 70%	at least 95%	Unknown
North East	18	2	11	0	60	8
North West	18	13	9	4	44	11
Yorkshire and The Humber	11	19	28	5	32	4
East Midlands	43	16	6	2	31	2

[18]https://data.gov.uk/dataset/b1f5c467-ed41-4e8f-89d7-f79a76645fd6/water-resource-availability-and-abstraction-reliability-cycle-2

West Midlands	17	29	42	3	7	2
East of England	54	10	10	8	6	12
London	28	28	3	10	9	22
South East	60	8	6	7	8	12
South West	14	5	24	7	38	12
Grand Total	31	13	17	5	26	9

Table 2-18 provides a summary of the Environment Agency Water Resource Availability and Reliability data by water company area. The areas for Cambridge Water (88%), Thames Water (86%) and Affinity Water (79%) all have a very high coverage of catchments which have resource availability less than 30% of the time. These are all catchments with a high household water demand (Table 2-15). While the average household usage within these water company areas is projected to fall, there is likely to be an increase in the number of households, which will lead to an increase in demand.

Table 2-18 - Percentage of water company area covered by resource availability (percentage of the time additional consumptive resource may be available) of a catchment.

Water Company	less than 30%	at least 30%	at least 50%	at least 70%	at least 95%	Unknown
Affinity Water	79	9	1	0	6	5
Anglian Water	52	13	12	7	10	6
Bristol Water	24	9	3	1	58	6
Cambridge Water	88	0	0	12	0	0
Essex & Suffolk Water	19	25	6	2	18	29
Northumbrian Water	18	5	11	0	59	7
Portsmouth Water	37	11	4	15	8	25
Sembcorp Bournemouth Water	0	6	35	30	21	7
Severn Trent Water	24	20	21	2	20	13
South East Water	57	13	2	4	14	9
South Staffordshire Water	21	36	4	2	36	0
South West Water	7	3	21	4	49	17
Southern Water	16	14	12	20	11	27
Sutton & East Surrey Water	77	17	3	3	0	0
Thames Water	86	2	3	3	1	4
United Utilities	19	14	10	5	44	9
Veolia Water Projects	0	5	67	29	0	0
Wessex Water	7	9	39	9	31	5
Yorkshire Water	8	19	30	5	35	3
Grand Total	31	13	15	5	26	9

2.10.4 Robustness of indicator

Metrics for water scarcity could only be derived through the EA Water Resource Availability and Reliability data. This data indicates whether, and for what percentage of time, additional water may be available for consumptive abstraction for each Water Framework Directive Cycle 2 water body. It therefore includes the impacts of current demand on resource. In order to compare this data with demand estimates, percentage of catchment coverage for the different regions or water company areas was the best way to provide a comparison.

2.11 Number of hot days and/or warm days per year

Description: *Number of warm and hot days per year*

Type: *Climate hazard*

2.11.1 Introduction

The latest UK Climate Projections (UKCP18)[19] show that (on average) the UK is likely to experience an increased chance of 'milder, wetter winters' and 'hotter, drier summers' along with an increase in the frequency and intensity of extremes[20]. Consequently, it is expected that the number of days with extreme maximum temperatures will increase over future years.

This indicator assesses the number of warm, very warm and hot days recorded each year in England, between 1878 and 2018, to understand if the frequency of these temperature events has changed during the period of recorded observations.

2.11.2 Data source and method

The Met Office Hadley Centre Central England Temperature (HadCET) dataset is the longest instrumental record of temperature in the world. The mean daily data series begins in 1772 and the mean monthly data in 1659. Mean, maximum and minimum daily and monthly data are also available, beginning in 1878.

This indicator uses the HadCET dataset of 'maximum daily temperature'[21]. Temperatures are "representative of a roughly triangular area of the United Kingdom enclosed by Lancashire, London and Bristol"[22]. Data was extracted from the website for the period 1878 to 2018, with values expressed in tenths of a degree, providing 140 years of temperature records. The data in this analysis was multiplied by 0.1 to provide data in degrees Celsius to one decimal place. E.g. a daily value of 198 (expressed in tenths of a degree) represented 19.8°C.

For each year within the dataset, the number of days that exceeded certain thresholds were calculated, with a particular focus on the number of days per year with a maximum temperature greater than 20°C, 25°C and 30°C. A temperature threshold of 30°C, 25°C and 20°C was used to provide an indication of the number of 'hot', 'very warm' and 'warm' days per year respectively. This provides a consistent methodology with that used previously by ADAS (2017), with the exception that 'warm' now refers to 20°C instead of 25°C, and an additional term 'very warm' has been introduced for 25°C instead. These slight changes allow for a better perspective of how the total number of days above certain thresholds has changed.

2.11.3 Trends and implications for climate resilience

The HadCET record of maximum temperatures shows that there has been an increasing trend in the number of warm, very warm and hot days experienced each year. However, due to annual variability and fluctuations in the trends, the statistical significance over the period

[19] https://www.metoffice.gov.uk/research/collaboration/ukcp

[20] https://www.metoffice.gov.uk/binaries/content/assets/mohippo/pdf/ukcp18/ukcp18-headline-findings.pdf

[21] https://www.metoffice.gov.uk/hadobs/hadcet/data/download.html

[22] https://www.metoffice.gov.uk/hadobs/hadcet/

is relatively weak, e.g. with some years exhibiting no days above the 25°C and 30°C thresholds at all.

Figure 2.19 show that the number of warm days (>20°C) has increased by around ~55% (linear trend) throughout the time series, from an average of 37 days per year in the late 19th century, to almost 58 days per year in the early 21st century. Inter-annual variability is a key feature of the trend, with years ranging from just 7 days above the threshold (i.e. 1979) to more than 95 days (i.e. 1959 and 2018).

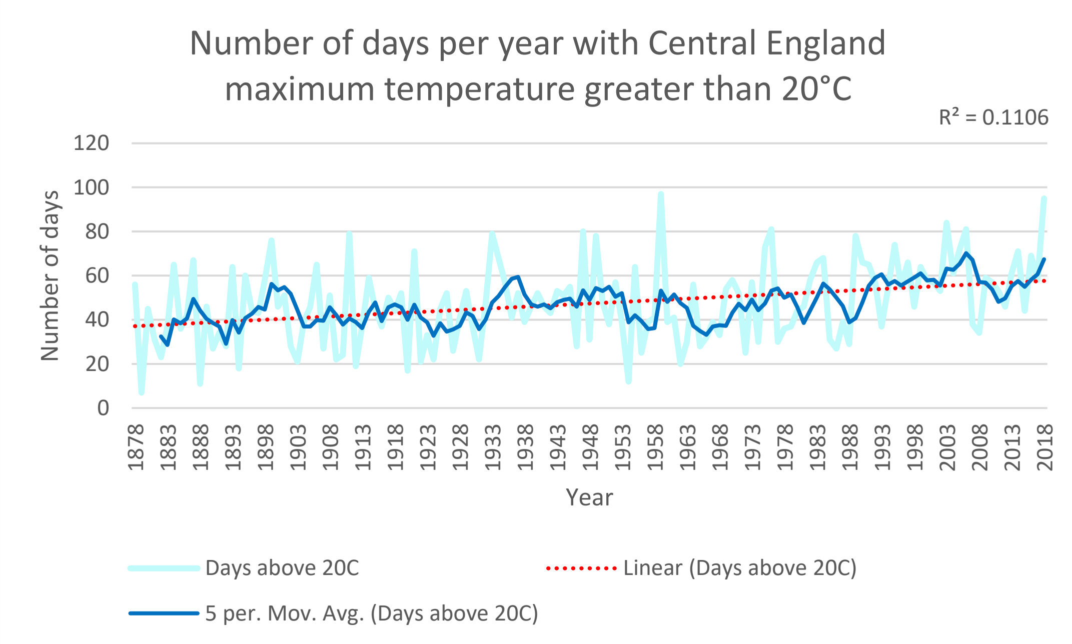

Figure 2.19 – Number of warm days (daily maximum temperature >20 degrees Celsius) in Central England between 1878 and 2018 (light blue line); five year moving average (dark blue line); and linear trend line (dotted red line) to show increase over the period. Data sourced from the Met Office HadCET dataset of mean maximum daily data, which are representative of a roughly triangular area of the UK. Source: ADAS for the CCC.

Figure 2.20 show that the number of very warm days (>25°C) has doubled throughout the time series (linear trend), from an average of 5 days per year in the late 19th century, to almost 10 days per year in the early 21st century. There is however considerable inter-annual variability prevalent in the records, with ten years recording no days above 25°C at all (i.e. 1879, 1882, 1883, 1889, 1890, 1907, 1931, 1956, 1962 and 1993) whilst other years exhibited as much as 25 or more days (i.e. 1911, 1976, 1995, 2006 and 2018).

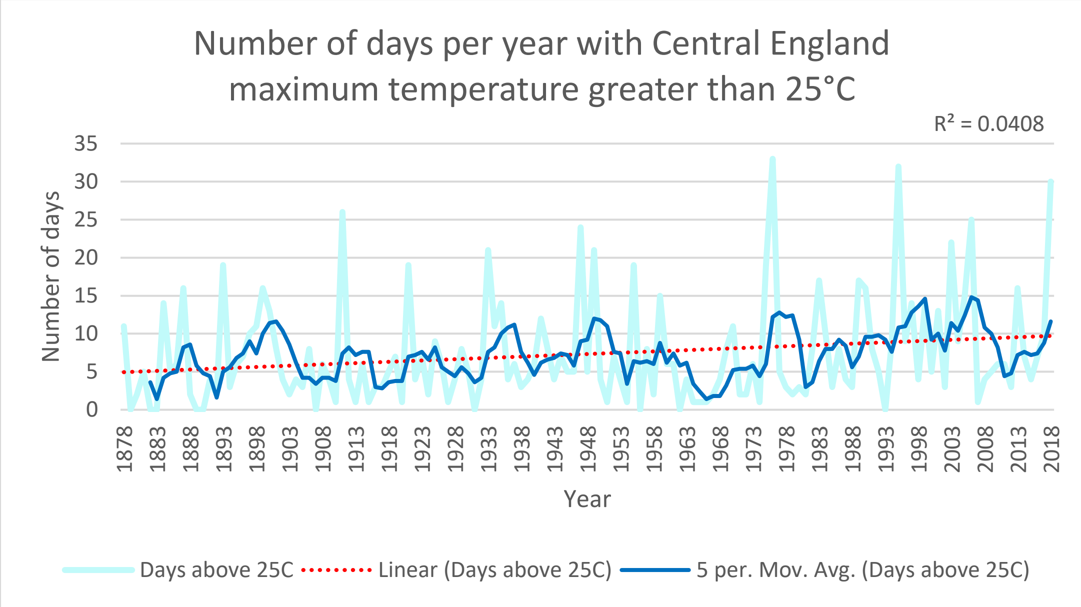

Figure 2.20 – Number of very warm days (daily maximum temperature >25 degrees Celsius) in Central England between 1878 and 2018 (light blue line); five year moving average (dark blue line); and linear trend line (dotted red line) to show increase over the period. Data sourced from the Met Office HadCET dataset of mean maximum daily data, which are representative of a roughly triangular area of the UK. Source: ADAS for the CCC.

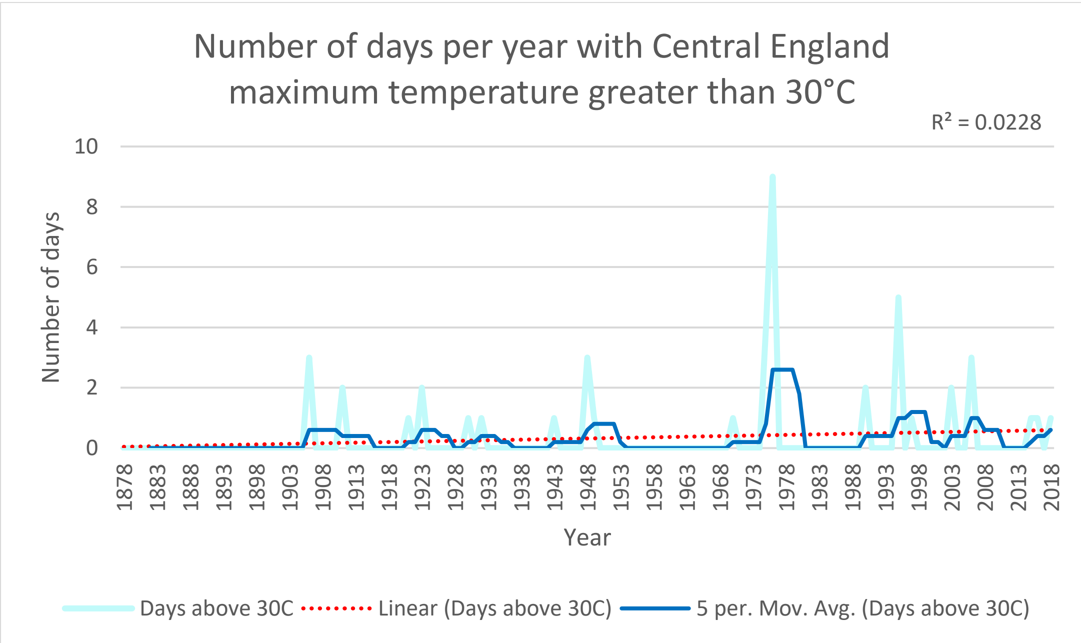

Figure 2.21 – Number of hot days (daily maximum temperature >30 degrees Celsius) in Central England between 1878 and 2018 (light blue line); five year moving average (dark blue line); and linear trend line (dotted red line) to show increase over the period. Data sourced from the Met Office HadCET dataset of mean maximum daily data, which are representative of a roughly triangular area of the UK. Source: ADAS for the CCC.

Figure 2.21 also shows an increasing trend in the number of hot days (>30°C) per year, although this is much less pronounced with an increase on average of just one day every two years. Again, there is considerable inter-annual variability prevalent in the records, with

~85% of years recording no days above the threshold at all. This trend is also heavily skewed by 1976 where 9 days above the 30°C threshold were reached, considerably more than any other year.

The results are in-keeping with UK climate projections, which suggest average daily maximum temperatures have and will continue to increase due to climate change.

2.11.4 Robustness of indicator

The Met Office HadCET dataset is one of the most complete and consistent weather data sets in the world and provides a robust metric to provide an indicator for the number of days where Central England Temperatures exceeded certain thresholds. Manley (1953, 1974) compiled most of the monthly series, covering 1659 to 1973. These data were updated to 1991 by Parker et al. (1992), who also calculated the daily series. Both series are now kept up to date by the Climate Data Monitoring section of the Hadley Centre, Met Office. Since 1974 the data have been adjusted to allow for urban warming: currently a correction of -0.2 °C is applied to mean temperatures (Parker and Horton, 2005).

2.12 Impacts of wildfire

Description: *Area of Forest Estate affected by wildfires per year*

Type: *Realised impact*

2.12.1 Introduction

Wildfires are a prominent risk in many parts of the world (e.g. US, Australia and Southern Europe), with multiple incidents happening each year with often catastrophic consequences on both communities and the environment. In England, incidents of 'severe' wildfires are infrequent. However, UKCP18 projections for hotter, drier summers, alongside increased land-use pressures, will increase the risk of such events occurring, whereby conditions that are favourable for the spread of wildfires occur more often.

This indicator assesses the current evidence base for wildfire impacts in England based on recent case studies and reported incidents and impacts in the media of major wildfires. It is recognised that in e.g. 2018, there were a huge number of smaller wildfires on both managed (arable crops on farm) and unmanaged land (e.g. moorland) as well. We do not attempt to capture or assess the impacts from all of these, rather we concentrate on a few specific case studies.

2.12.2 Data source and method

The Forestry Commission (FC) published a new report in February 2019 - 'Wildfire Statistics for England 2009-10 to 2016-17' (Forestry Commission, 2019). This source was used to extract the key statistics available on wildfires in the natural environment. For this analysis, the FC definition of wildfires was used "*wildfires, including woodland fires, and wildfires on other land cover types, are uncontrolled vegetation fires*". The FC report statistics for two-sub-categories of wildfire, namely; woodland fires, derived from the National Forest Inventory (NFI); and non-woodland fires (i.e. wildfires on other land cover classes), derived from the Centre for Ecology and Hydrology's (CEH) Land Cover Map (LCM)

In this analysis, several of the categories were combined to provide 8 key categories:

Woodland Fires - NFI

- **Broadleaved woodland** (Broadleaved Woodland; and Mixed Woodland - Predominantly Broadleaved)
- **Conifer Woodland** (Conifer Woodland; and Mixed Woodland - Predominantly Conifer)
- **Other Woodland** (Coppice; Young Trees; Low Density; Assumed Woodland; Ground Prepared For Planting; Shrub land; Felled; and Uncertain)

Non-woodland fires – CEH LCM

- **Arable**
- **Improved Grassland**
- **Semi-Natural Grassland**
- **Mountain, Heath & Bog**
- **Other non-woodland** (Woodland - verified in OSMM; Woodland - not verified in OSMM; Other; and No Classification)

The **Built-Up Areas & Gardens** category was not included within this analysis. Whilst it is noted that the natural environment is also within the built environment, such as gardens and parks, the focus of this indicator was wildfires in the non-urban environment. It is acknowledged that this omission may result in some wildfires being omitted, such as wildfires on the rural/urban interface (e.g. the Little Marlow incident on 2nd July 2018 where a blaze in a field spread to nearby industrial units), however the overall impact of omission is deemed to be relatively minor, with the total area burnt in all built-up areas and gardens less than 4% of total area burnt, despite built-up areas and gardens accounting for half of all wildfire incidents reported by the FC.

In addition to the FC report, three case studies are also provided to highlight some of the impacts of wildfire. In the summer of 2018, two major wildfires were experienced in England at Saddleworth Moor (Peak District National Park) and Winter Hill (near Bolton). Since these were relatively well documented in the media, information on the impacts associated with these two wildfires were gathered to give two case studies. Furthermore, detail was gathered on the large Swinley forest fire that occurred in 2011, as a third case study.

2.12.3 Trends and implications for climate resilience

2.12.3.1 *Wildfire incidents and area burnt*

This FC statistical release presents statistics for wildfire incidents attended by the Fire and Rescue Service (FRS) in England for the eight financial years 2009-10 to 2016-17 inclusive. During this period, FRS attended almost 258,867 wildfire incidents in England, with a total of 36,923 hectares of land being burnt. However, half (49.6%, 128,497) of these incidents were classified as “Built-up areas and gardens”, which accounted for <4% of the total area burnt. For this analysis, we have excluded this category. This means that there were effectively 130,370 wildfire incidents in the natural environment, with an area burnt of 35,557, across the time series (2009-10 to 2016-17).

Figure 2.22 shows that the majority of wildfire incidents that occurred in the time series were associated with improved grassland (34%), arable (25%) and broadleaved woodland

(19%). However, in terms of the area burnt (hectares) by land cover class, the largest area lost was associated with mountain heath and bog (50%), improved grassland (18%), arable (11%) and semi-natural grassland (11%), shown in Figure 2.23.

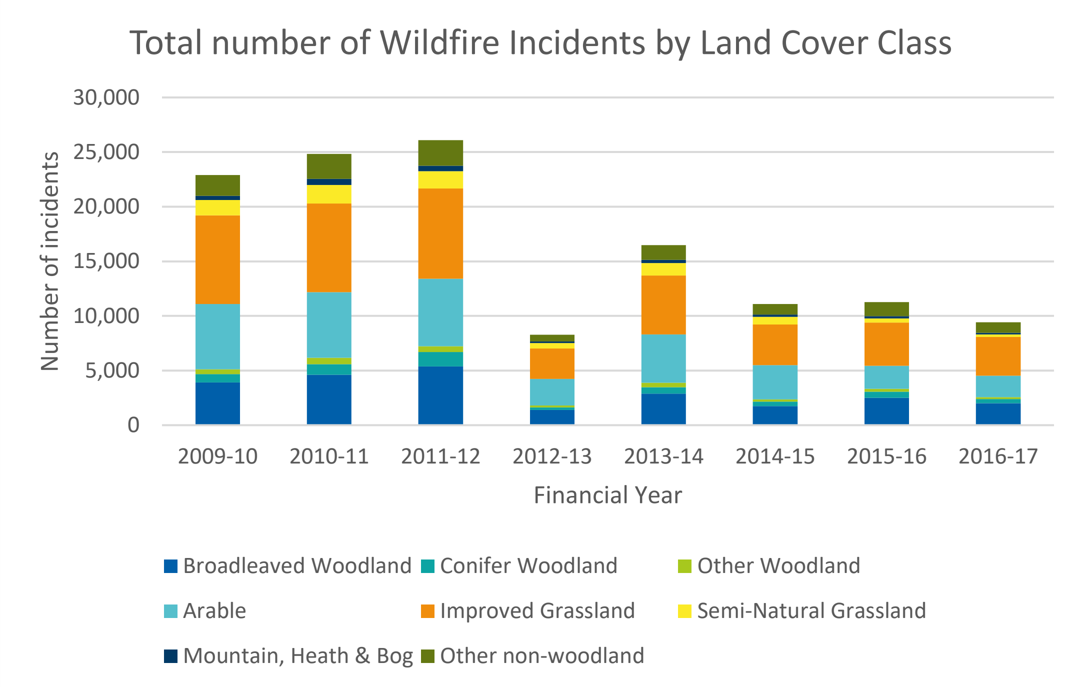

Figure 2.22 – Total number of wildfire incidents recorded each year by the Fire and Rescue Services, split by land cover class. Data sourced from the Forestry Commission (2019) report on wildfire statistics. Source: ADAS for the CCC.

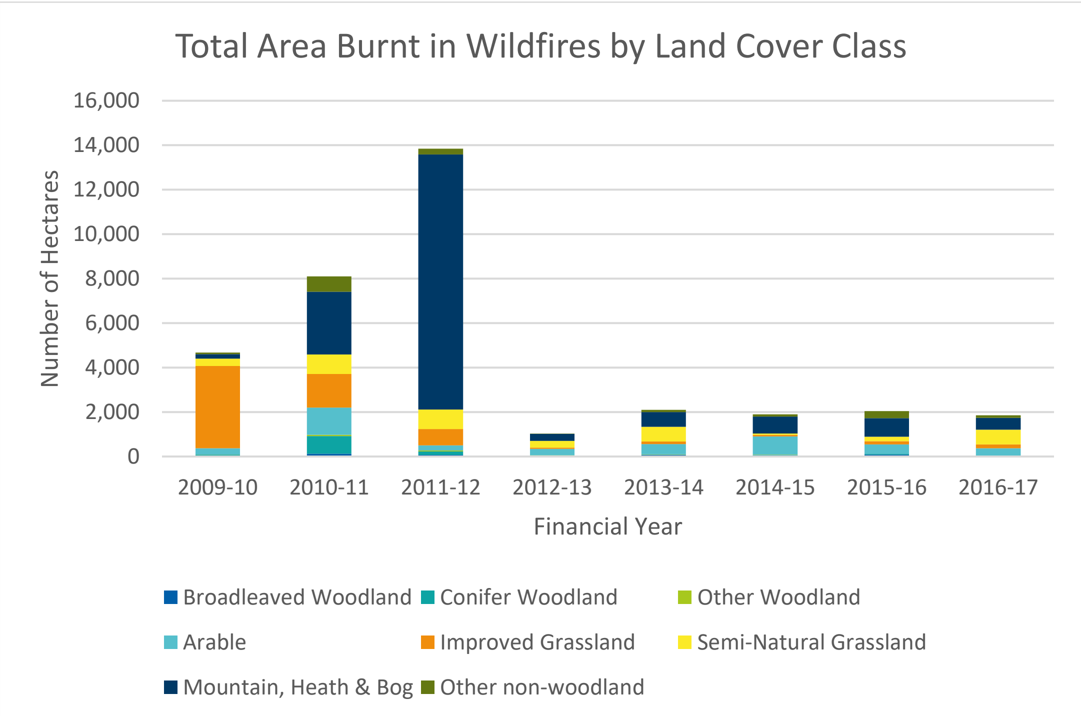

Figure 2.23 – Area burnt in wildfire incidents, recorded each year by the Fire and Rescue Services, split by land cover class. Data sourced from the Forestry Commission (2019) report on wildfire statistics. Source: ADAS for the CCC.

The findings show that both the number of wildfire incidents and the total area burnt have been notably lower in the last five years (2012-13 to 2016-17) than in the three years prior to this (2009-10 to 2011-12). This is most likely attributable to a change in seasonal (drought) conditions, rather than a decrease in wildfire incidents. For example, 2010 to 2012 exhibited drought conditions, which would suggest that conditions would generally be more favourable for the development of wildfires, compared with 2013 onwards, which has seen a return to more 'average' conditions and more frequent episodes of wet weather.

Statistics for 2018-19 are anticipated to be considerably higher than the previous five-year average, following the hot and dry summer of 2018. For example, 3,600 hectares of land were burnt in just the Winter Hill (1800ha) and Saddleworth Moor (1800 ha) fires in 2018. There were also a large number of wildfires within farmland (both pasture and arable land sown with crops such as wheat and barley) whereby fires were triggered during harvesting (e.g. machinery overheating or electrical faults), illustrated in Figure 2.24. Examples wildfires on farmland in 2018 include a 19 ha fire Berkshire[23], a 9 ha fire in Norfolk[24] and a 6 hectare fire in Suffolk[25].

Figure 2.24 - A fire in fields near Blofield, Norfolk in July 2018. Image credited to Mike Page, sourced from an ITV news article[26].

2.12.3.2 Impacts of wildfire through case studies

There are limited case studies published on the recent wildfires in England, however information was gleaned from various research articles (e.g. Finlay et al., 2012; Kitchen, 2012), grey literature (e.g. Lancashire FRS, Wikipedia) and news outlets (e.g. BBC News, Get Reading, Manchester Evening News, Metro, Sky News) to get an 'indication' of the impacts associated with some of England's major wildfires.

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23 https://www.youtube.com/watch?v=PkaPiLObr7o

24 https://www.edp24.co.uk/business/farming/norfolk-farmer-12-000-crop-fire-1-5620077

25 https://www.eadt.co.uk/news/suffolk-firefighters-massive-fire-chelmondiston-pin-milll-1-5609100

26 https://www.itv.com/news/anglia/2018-07-22/farmers-battle-to-stop-crop-fire-spreading/

Table 2-19 outlines some of the key impacts associated with the Swinley Forest, Winter Hill and Saddleworth Moor wildfires. All three major incidents showed similar impacts, with infrastructure disruption, closures of schools, evacuations in two instances and severe negative impacts on the environment (in the short term).

Table 2-19 – Case studies of major wildfire incidents in England. Source: ADAS for the CCC.

Impacts	Swinley Forest	Winter Hill	Saddleworth Moor
Location	Near Bracknell, Berkshire	Near Bolton, Lancashire, North-west England	West Pennines, Greater Manchester
Terrain	Softwood plantation, largely Corsican pine. Some scrub and small open heath.	Plateau of moorland	Plateau of moorland
Land owner	Crown Estate and Forestry Commission	2/3 United Utilities and 1/3 Woodland Trust	Privately owned estate and United Utilities.
Conditions	A high wind speed (>35 km/h) and a changing wind direction combined with very low relative humidity (below 40%) and high temperatures (over 30°C).	Very hot and dry conditions. Winds caused two fires to merge	Very hot and dry conditions
Source of ignition	Suspected Arson	Suspected Arson	Illegal off road bikes were blamed for the initial fire, which was put out, but heatwave conditions allowed the peat to reignite and grow
Fire broke out	2 May 2011	28 June 2018	24 June 2018
Duration	7 days	41 days	21 days
Area burnt (ha)	94 ha burnt	1800 ha / 18 square kilometres	1800 ha / 18 square kilometres
FRS Response	Up to 300 firefighters from 7 brigades	Hundreds of firefighters tackled the blaze	More than 100 firefighters on 29 fire engines
Relative reported size	Deemed the biggest in the South East since the end of WW2	Greater scale than previous wildfires in the region	The largest English wildfire in living memory
Proximity to people	Close to a built-up area and to Broadmoor high security hospital	Relatively remote on a hill	Near to village
Evacuations	13 homes evacuated, and businesses	Homes protected without evacuations. 'four-mile no-go zone'	34 homes
Infrastructure	Several roads and footpath closures	Several roads and footpath closures	Several roads and footpath closures
Air Quality	Non-toxic but risk of smoke induced illnesses. People in the area advised to stay indoors and close windows	Alongside the Saddleworth Moor fire, the region was covered in smoke and ash and air quality was, at times poor	Smokey haze over Manchester with high levels of particulate matter. Asthmatics and pets advised to stay indoors
Health	Risk of smoke induced illnesses was advised	People in nearby areas were asked to keep doors and windows closed.	Reported respiratory illnesses relating to the fire included nosebleeds, coughs and eye problems
Wildlife	Swinley Forest is part of a Special Protection Area (SPA) for three rare birds: Dartford Warblers, Woodlarks and Nightjars.	Birds had their homes destroyed, while reptiles like frogs, toads and lizards have perished	Deer described as 'running from the flames on fire' and further fears for birds and at least 60 sheep died
Education	Three school closures	One school closure	Four school closures

2.12.4 Robustness of indicator

The data used within the FC report was sourced from the Home Office's online Incident Recording System (IRS). Fire and Rescue Services (FRS) provide records about wildfires (and other) incidents on the IRS. This includes a wildfire element of the IRS that provides a record of the nature of incidents requiring a response by the Fire and Rescue Services, in line with the UK Vegetation Fire Standard (UKVFS). The UKVFS is a series of data fields across all vegetation types, which provides a standardised approach to the reporting of the context, management and consequences of wildfires and controlled burning (Gazzard, 2009). The FC report is deemed to be robust with a consistent methodology applied to calculate the number of wildfire incidents, and area burned, each financial year. It is not known when the FC will publish its next report on wildfires.

The information contained within Table 2-19 is intended to be indicative only as the detail is gleaned from a range of grey literature sources that provide ad-hoc information, which may not have been fully verified or representative of the actual events.

2.13 Incidents of harmful algal blooms

Description: *Number of incidents of Harmful Algal Blooms*

Type: *Exposure*

2.13.1 Introduction

Algae are photosynthetic organisms that occur naturally in inland waters such as rivers, streams and lakes. When conditions are ideal for growth, an algal bloom can occur, whereby the water becomes less clear and may look green, blue-green or greenish-brown. The most important parameters regulating algal growth are nutrient quantity and quality, light, pH, turbulence, salinity and temperature[27]. The phenomenon is seasonal because growth of algae is controlled by hours of sunlight and water temperature[28]. Human activity has been linked to an increased frequency of algal blooms, with increases of nitrate or phosphate in the water from agriculture, and some industrial processes, which encourages the growth of algae. A warmer climate and subsequent warmer water temperatures may also increase the conditions that are favourable for algal blooms. However, it is noted that this link is weak and that the climate driver is less significant to algal developments compared with some of the other factors also required for algal bloom development (nutrient quantity and quality, light, pH, turbulence etc.).

Algal blooms block sunlight from reaching other plants in the water and use up oxygen in the water at night, which can suffocate fish and other creatures. Cyanobacteria or 'blue-green algae' are a particularly harmful type of algae that can produce toxic blooms, commonly referred to as Harmful Algal Blooms (HAB). HABs typically occur during the summer or when water temperatures are warmer than usual. The toxins produced by HABs can harm people, producing rashes after skin contact and illnesses if swallowed, as well as kill wild animals, livestock and pets[29].

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[27] http://www.fao.org/docrep/003/W3732E/w3732e06.htm

[28] http://dwi.defra.gov.uk/consumers/advice-leaflets/algal.pdf

[29] https://www.gov.uk/government/publications/algal-blooms-advice-for-the-public-and-landowners/algal-blooms-advice-for-the-public-and-landowners#report

In England, incidents of water pollution (including algal blooms) are reported to the Environment Agency (EA) who respond to reported events and advise on the prevention, control and long-term management of water bodies.

This indicator assesses the number of substantiated algal bloom incidents that have been dealt with by the EA since 2011, it updated work done by ADAS (2017) to provide more recent data.

2.13.2 Data source and method

The Environment Agency provided an annual time series of substantiated algal bloom incidents that have been dealt with by the EA in England between 2011 and 2018. The dataset provides a summary of all closed incidents in England where the pollutant was specifically recorded as algae. This data originates from a live incident reporting system and shows the number of blooms each year which were reported as pollution incidents within various categories.

The EA classify incidents using the Common Incident Classification Scheme (CICS) (Environment Agency, 2011). The CICS environmental impact categorisation is split into four categories: Category 1 (major, serious, persistent and/or extensive impact or effect on the environment, people and/or property), Category 2 (significant impact or effect on the environment, people and/or property), Category 3 (minor or minimal impact or effect on the environment, people and/or property) and Category 4 (substantiated incident with no impact).

The dataset provide an indication of incident occurrence. It should be noted that there may have been other incidents reported that were not substantiated, or there may have been instances where algal blooms were found and dealt with during routine work by the EA, and which were not recorded on the live incident reporting system. In addition, data for 2018 is still subject to change following completion and EA quality assurance of the incident record, which will happen in spring 2019.

Detail is not available on whether the incidents recorded in the system is related to toxic or non-toxic algal blooms. Consequently, this indicator provides an indication of the trends in the number of substantiated algal blooms reported to the EA, and does not provide an indication of the number of, or trends in those that are deemed to be toxic or harmful.

2.13.3 Trends and implications for climate resilience

A total of 554 substantiated algal bloom incidents have been dealt with by the EA since 2011. The majority of these incidents, 507 or 91.5%, were classified as category 3 or 4 pollution incidents, where the algal blooms exhibited either minor or minimal impact or effect on the environment, people and/or property, or no impact.

There were 41 category 2 pollution incidents that occurred between 2011 & 2018, with 5-6 typically reported each year on average where the algal bloom was classified as having a significant impact or effect on the environment, people and/or property.

Category 1 pollution incidents are much more infrequent, with just 0.9% of all incidents falling in this category. Since, 2011, only five incidents met the criteria for category 1 (major, serious, persistent and/or extensive impact or effect on the environment, people and/or property), occurring once in each of the years 2011, 2012, 2015, 2016 and 2018.

Figure 2.25 show that the number of incidents in 2018 was considerably higher than previous years, with 125 incidents. This is more than double the 2011 to 2017 average of 61 incidents and almost a third higher than the year with the second greatest number of incidents, 2003.

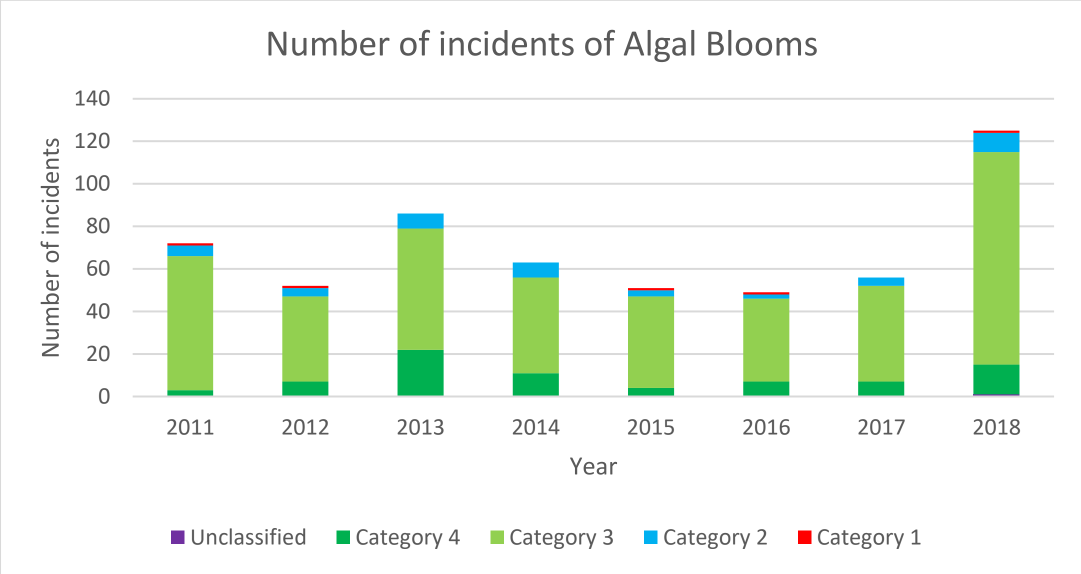

Figure 2.25 - Number of substantiated incidents of algal blooms recorded by the EA in England between 2011 and 2018. Incidents are recorded in four categories - Category 1 (major, serious, persistent and/or extensive impact or effect on the environment, people and/or property), Category 2 (significant impact or effect on the environment, people and/or property), Category 3 (minor or minimal impact or effect on the environment, people and/or property) and Category 4 (substantiated incident with no impact). Data sourced from the Environment Agency. Data for 2018 is subject to change as some unclosed incidents may not yet be recorded. Source: ADAS for the CCC.

This provides interesting results, given that 2018 was the hottest summer on record for England, and joint hottest summer for the UK as a whole. The literature suggest that the optimum temperature for photosynthesis of blue-green algae to be 20–30°C during summer (Singh and Singh, 2015) with water temperatures above 25°C optimal for the growth of Cyanobacteria. At these temperatures, blue–green algae have a competitive advantage over other types of algae whose optimal growth temperature is lower (12-15°C)[30]. Section 2.11 show that there were 30 days where Central England air temperatures were greater than 25°C, the third highest number in the records going back to 1878.

The annual time series shown in Figure 2.25 is too short to determine any long-term trends in the number of incidents of substantiated algal blooms, nor to attribute either the frequency or intensity of these incidents with climate change or climatic factors. However, it is possible that the hot summer of 2018 provided more favourable conditions for the development of algal blooms. Unfortunately, it was not possible to assess the number of HABs as this detail was not available in order to split toxic and non-toxic blooms out from the total figures provided.

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[30] http://www.cees.iupui.edu/research/algal-toxicology/bloomfactors

2.13.4 Robustness of indicator

Overall, the dataset provides a relatively robust and consistent annual series of algal blooms recorded in England since 2011. However, it should be recognised that the data provided by the EA for 2018 is subject to change following incident reviews and quality assurance. In addition, it is noted that not all incidents from 2018 are currently closed, therefore there may be additional incidents from 2018 that do not appear in the data.

Whilst it is expected that the EA will continue to record the number of substantiated incidents of algal blooms, enabling this indicator to be further updated, it is not possible to assess the number of HABs, unless the EA split these out in future records. This indicator only records the number of algal blooms that are reported, it is unknown how many algal blooms go unreported.

2.14 Change in habitats in favourable condition

Description: *Change in habitats in favourable condition (terrestrial, freshwater, marine, peatlands)*

Type: *Action*

2.14.1 Introduction

Priority habitats are a focus for conservation action in England. They cover a wide range of semi-natural habitat types, and are those that were identified as being the most threatened and requiring conservation action under the UK Biodiversity Action Plan (BAP). Their condition is assessed and reported by Natural England.

Favourable Condition is used as a proxy for resilience, in that it is assumed that a site in favourable condition means that the habitat is in optimum condition and non-climatic adverse drivers have been addressed. However climate change could increasingly mean that it is not possible to achieve favourable condition due to changes in species/communities. Therefore the definition of favourable condition at some sites may be different in future years compared to past years, changes in climate or other adverse impacts prevent favourable conditions (as defined now) from being achievable.

This indicator assesses the change in habitats (terrestrial, freshwater, marine, peatlands) that are in favourable condition between 2016 and 2018.

2.14.2 Data source and method

The most up to date data on the condition of priority habitats was provided by Natural England for 2016 and 2018. These dataset provided figures on areas of priority habitat in different conditions linked with Sites of Special Scientific Interest (SSSI) and Higher Level Stewardship (HLS). The five priority habitat types assessed in this analysis were: SSSI Favourable; SSSI Recovering; Outside SSSI in HLS; SSSI Unfavourable; and Outside SSSI not in HLS.

A comparison between the 2016 and 2018 figures was carried out to examine the change in areas of habitat and their condition. In order to do this, the priority habitats were grouped into four major habitat categories: 'Terrestrial', 'Marine and Coastal', 'Peatland' and 'Freshwater', shown in Table 2-20. These categories were produced from the different priority habitat types, which differ from previous assessments of habitat condition; whereby previously the habitat types were based on Natural England's BAP habitat inventories. This is due to the 2018 dataset being a new inventory, which replaced Natural England's previous separate BAP habitat inventories. Therefore the habitat categories will differ slightly between 2016 and 2018 and from previous assessments, meaning they are not completely comparable.

Table 2-20 – Grouping of priority habitats into four habitat categories ('Terrestrial', 'Marine and Coastal', 'Peatland' and 'Freshwater').

Priority Habitat	Habitat Category
Calaminarian grassland	Terrestrial
Deciduous woodland	Terrestrial
Limestone pavement	Terrestrial
Lowland calcareous grassland	Terrestrial
Lowland dry acid grassland	Terrestrial
Lowland heathland	Terrestrial
Lowland meadows	Terrestrial
Mountain heaths and willow scrub	Terrestrial
Purple moor grass and rush pastures	Terrestrial
Traditional orchard	Terrestrial
Upland calcareous grassland	Terrestrial
Upland hay meadow	Terrestrial
Upland heathland	Terrestrial
Coastal and floodplain grazing marsh	Marine and Coastal
Coastal saltmarsh	Marine and Coastal
Coastal sand dunes	Marine and Coastal
Coastal vegetated shingle	Marine and Coastal
Maritime cliff and slope	Marine and Coastal
Mudflats	Marine and Coastal
Saline lagoons	Marine and Coastal
Blanket bog	Peatland
Lowland raised bog	Peatland
Lowland fens	Freshwater
Reedbeds	Freshwater
Upland flushes, fens and swamps	Freshwater

2.14.3 Trends and implications for climate resilience

There has been an increase in total habitat area for all habitat categories between 2016 and 2018, apart from Marine and Coastal habitats, which shows a slight decrease in area, shown in Table 2-21.

Table 2-21 - Change in area (ha) of priority habitat and condition between 2016 and 2018. Data sourced from Natural England. Source: ADAS for the CCC.

	2016 (no. of hectares)				2018 (no. of hectares)			
	Terrestrial	Marine and Coastal	Peatland	Freshwater	Terrestrial	Marine and Coastal	Peatland	Freshwater
SSSI Favourable	104,916	72,105	30,737	9,005	117,129	79,838	25,815	9,981
SSSI Recovering	231,269	45,977	128,336	11,416	240,113	50,847	162,333	11,350
Outside SSSI in HLS	158,647	57,190	47,502	5,923	403,447	59,743	69,839	8,964
SSSI Unfavourable	33,596	32,660	7,477	4,522	17,703	15,069	11,147	1,954
Outside SSSI not in HLS	616,264	142,796	25,153	6,723	416,451	142,712	20,572	7,814
Total priority habitat area	1,144,692	350,727	239,204	37,590	1,194,844	348,209	289,706	40,046

It is noted that the peatland category shows a significant increase in area between 2016 and 2018. This notable increase is due to an increase in the area of Blanket Bog. The increase in blanket bog is primarily due to changes in the way that the land parcels are attributed. For example, for the blanket bog category, a change in the definition included that "Blanket bog candidates below the moorland line are no longer rejected", meaning an increase in Blanket Bog area as a greater area is included within the definition (Natural England, 2015).

A breakdown of habitat condition by percentage area is shown in Figure 2.26. The greatest change can be seen within terrestrial habitats, whereby there is a large increase in the area (and percentage) of terrestrial habitats 'outside SSSI in HLS', whilst a large decease in the area 'Outside SSSI not in HLS' is also seen, indicating that a much greater area of SSSI is now part of HLS than in 2016. The peatland habitat category is the only one that sees a slight fall in the in the percentage area of 'SSSI favourable' condition, however there is also a fall in the area of 'Outside SSSI not in HLS' in this category as well, with an increase in 'outside SSSI in HLS' seen.

Marine and coastal, and freshwater habitats both see a moderate decrease in the percentage area in 'SSSI unfavourable condition'.

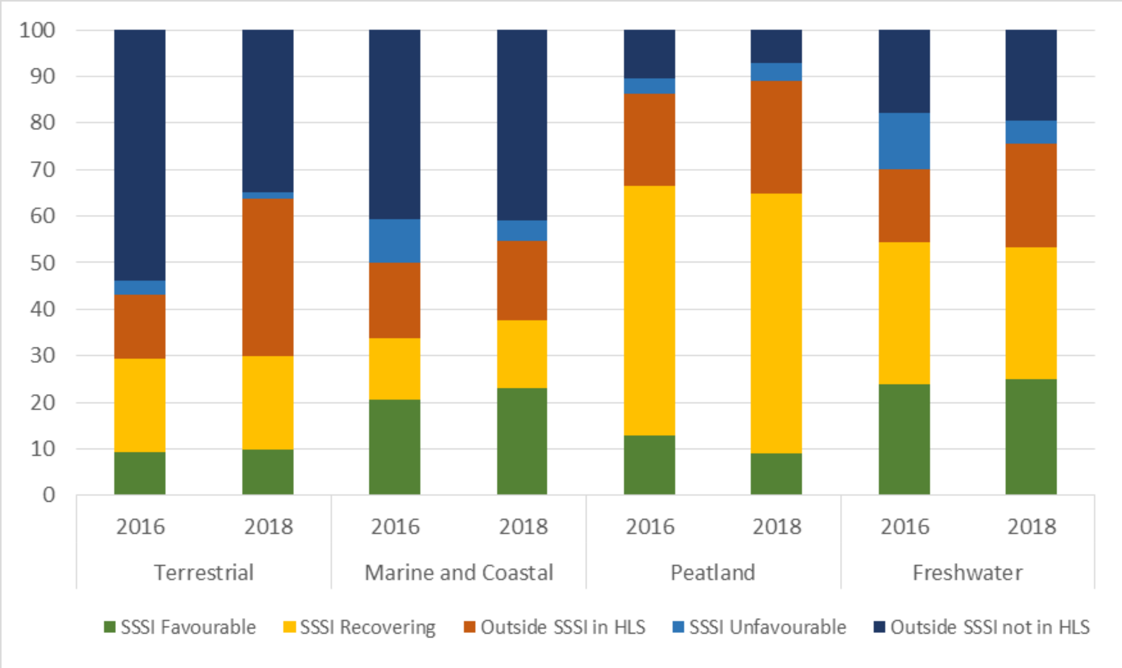

Figure 2.26 - Percentage of habitat condition by habitat category, 2016 to 2018. Data provided by Natural England. Source: ADAS for the CCC.

2.14.4 Robustness of indicator

The dataset describes the condition of Natural Environment and Rural Communities Act (2006) Section 41 habitats of principal importance. This inventory replaces Natural England's previous separate BAP habitat inventories. It therefore does not include habitats that were previously used in the previous indicators.

2.15 Agricultural land / forest converted to development

Description: *Area of agricultural land / forest converted to development, by grade*

Type: *Vulnerability*

2.15.1 Introduction

Conversion of land from woodland or agricultural land to development can have a number of consequences, including changes to mitigation and adaptation potential, flood risk, food security, biodiversity and air quality, among many others.

This indicator assesses the area of agricultural land and forest converted to urban developments.

2.15.2 Data source and method

The Centre for Ecology and Hydrology's Land Cover Map (LCM)[31] provides information on land cover from satellite data at 25m resolution. Land cover is based on UK Biodiversity Action Plan Broad Habitats classes[32]. Data for 2007 and 2015 were available for comparison.

Using the LCM 2015 dataset, 'developed' areas were identified by selecting the 'Urban' and 'Suburban' classes. This layer of developed land for 2015 was used as a mask to extract 2007 land cover to identify the land cover type in 2007 (for these developed areas). Areas that had previously been classed as 'Broadleaved, mixed and yew woodland' or 'Coniferous woodland' were identified as developed woodland, and those areas identified as 'Arable and horticulture' or 'Improved grassland' identified as developed agricultural land.

2.15.3 Trends and implications for climate resilience

Areas and percentages of woodland and agricultural land that have been developed (where land use has changed to urban or suburban class) are shown in Table 2-22. The percentages are calculated as a proportion of the total woodland and agricultural land in 2007.

Table 2-22. Areas of Woodland and Agricultural land developed between 2007 and 2015. Source: ADAS for the CCC.

Region	Area (ha) of woodland converted	Area (ha) of agriculture land converted	Proportion (%) of 2007 woodland developed	Proportion (%) of 2007 agricultural land developed
East Midlands	2,152	36,087	2.4	2.9
London	1,375	5,431	13.5	14.3
North West	3,506	27,436	2.8	4.0
West Midlands	2,372	30,832	2.3	3.1
Yorkshire and the Humber	3,302	32,372	3.1	3.3
South East	11,884	53,841	4.0	4.2
North East	1,460	13,159	1.4	3.1
Eastern	7,101	45,388	4.9	3.0
South West	8,466	38,632	3.3	2.2

The extent of regional development is shown geographically in Figure 2.27. This shows that large proportions of woodland and agricultural land are being developed in the South-East region.

[31] https://www.ceh.ac.uk/services/land-cover-map-2015

[32] http://jncc.defra.gov.uk/page-5711

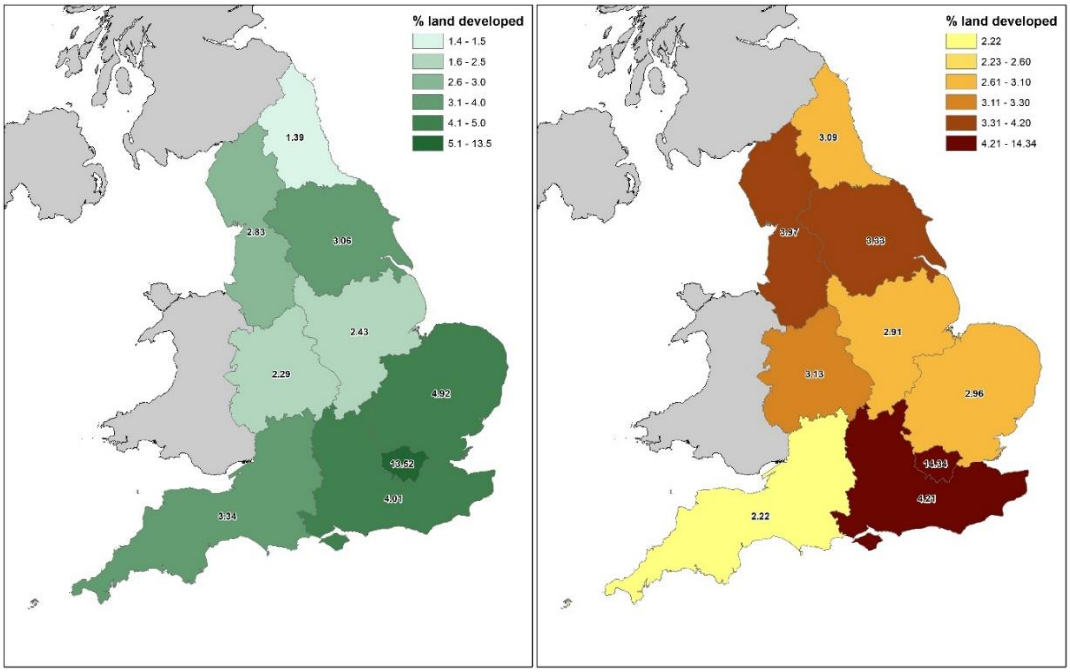

Figure 2.27 - Percentage of woodland (left) and agricultural land (right) developed by region, using the LCM 2015 dataset. Source: ADAS for the CCC.

The results in this study indicate a greater proportion of forest converted to development than other sources, such as the Forestry Commission (FC). The FC indicate that an average of 356 ha of woodland removal per annum is attributable to development (Forestry Commission, 2018a).

The reason for these differences is due to the differences in definition of woodland between the National Forest Inventory (NFI), and the LCM. The NFI definition of woodland is a minimum area of 0.5 hectares under stands of trees with, or with the potential to achieve, tree crown cover of more than 20% of the ground. The LCM definition is stands and plantations, with cover >20%. Therefore the LCM is likely to identify smaller areas of woodlands and therefore identify a greater proportion of woodland loss attributed to development.

2.15.4 Robustness of indicator

LCM data provides land cover at a 25 x 25 m grid. A single land cover can only be provided for this area, and small areas of land cover will not be represented in these areas. While each cell is not fully representative of the land cover in the area, the dataset is able to provide a reasonable overview of land cover and land cover changes across England. The data also gives a good breakdown if land cover types and so is a suitable dataset for identifying developed agricultural land and woodland. LCM provides an overall accuracy of 83% for the LCM2007 classes (Morton et al., 2011).

2.16 Change in agricultural area projected to become climatically unsuitable

Description: *Change in agricultural area for key crops that are projected to become climatically unsuitable in future*

Type: *Vulnerability*

2.16.1 Introduction

Climate change is expected to impact on the growing conditions in key agricultural areas, making some crops climatically unsuitable or unfavourable for production in areas that were previously deemed favourable.

Through quantifying the area of each of the indicator crops under different Agricultural Land Classification (ALC) grades and future predictions of ALC grades under climate change scenarios, threats to the future productivity of these crops can be estimated.

This indicator examines the current and future distribution of crops within the ALC grades.

2.16.2 Data source and method

The Crop Map of England (Crome)[33] database is an annually updated polygon dataset containing approximately 32 million hexagonal cells covering England. The cells are classified into a large number of main crop types, grassland, and other land covers (water, woodland, fallow land, etc.). The Crome 2015 data was used together with land-parcel identification system (LPIS) parcels to estimate cropping within these parcels and align the resulting dataset with June Agricultural Survey (JAS) statistics. The analysis made use of a set of amalgamated crop categories which were common to both JAS and Crome.

This method provided high resolution crop data that could be aligned with ALC data. The area of crops within the grades of the ALC scheme was calculated from the 2016 Crome-derived LPIS data. Agricultural land within the ALC scheme is allocated to one of five grades:

- Grade 1 is 'excellent quality land'
- Grade 2 is 'very good quality land'
- Grade 3 is 'good and moderate quality land'
- Grade 4 is 'poor quality land'
- Grade 5 is 'very poor quality land'

For future ALC scenarios, a study for Defra (Keay et al., 2014) assessed how future changes in climate may affect agriculture in England and Wales using the ALC system. ALC grade was calculated using 5 km grid maps for 10 criteria, with the final ALC grade being determined by the most limiting criterion. Projected ALC grades for high and low scenarios for 2050 were used to calculate crop areas within these ALC grades using the 2016 Crome derived LPIS data. The analysis does not consider whether the limitations of particular grades could be overcome by added measures (e.g. use of irrigation to improve the quality of land).

33 https://data.gov.uk/dataset/21c91d36-1770-475e-99ce-5c54ea4b3eae/crop-map-of-england-crome-2016-midlands

2.16.3 Trends and implications for climate resilience

The distribution of crops between ALC grades for baseline, 2050 low and 2050 high scenarios are shown in Figure 2.28. Under baseline conditions, a high proportion of potatoes (57%) and other vegetables (41%) are grown on Grade 1 or Grade 2 land. Under the 2050 low scenario these figures fall to 13% and 11% respectively, and 11.6% and 10% under the 2050 high scenario. For the cereal crops, the majority are grown under Grade 3 land under baseline conditions, however the majority of cereal crops will be grown in Grade 4 land under the 2050 high scenario (if they were to be grown in the same locations as currently).

The 'other' class are areas of land that have classified as non-agricultural or urban. Due to the variation in scales that the baseline and two scenarios attribute the land at, there are large changes in the proportion of crops within the 'other' category.

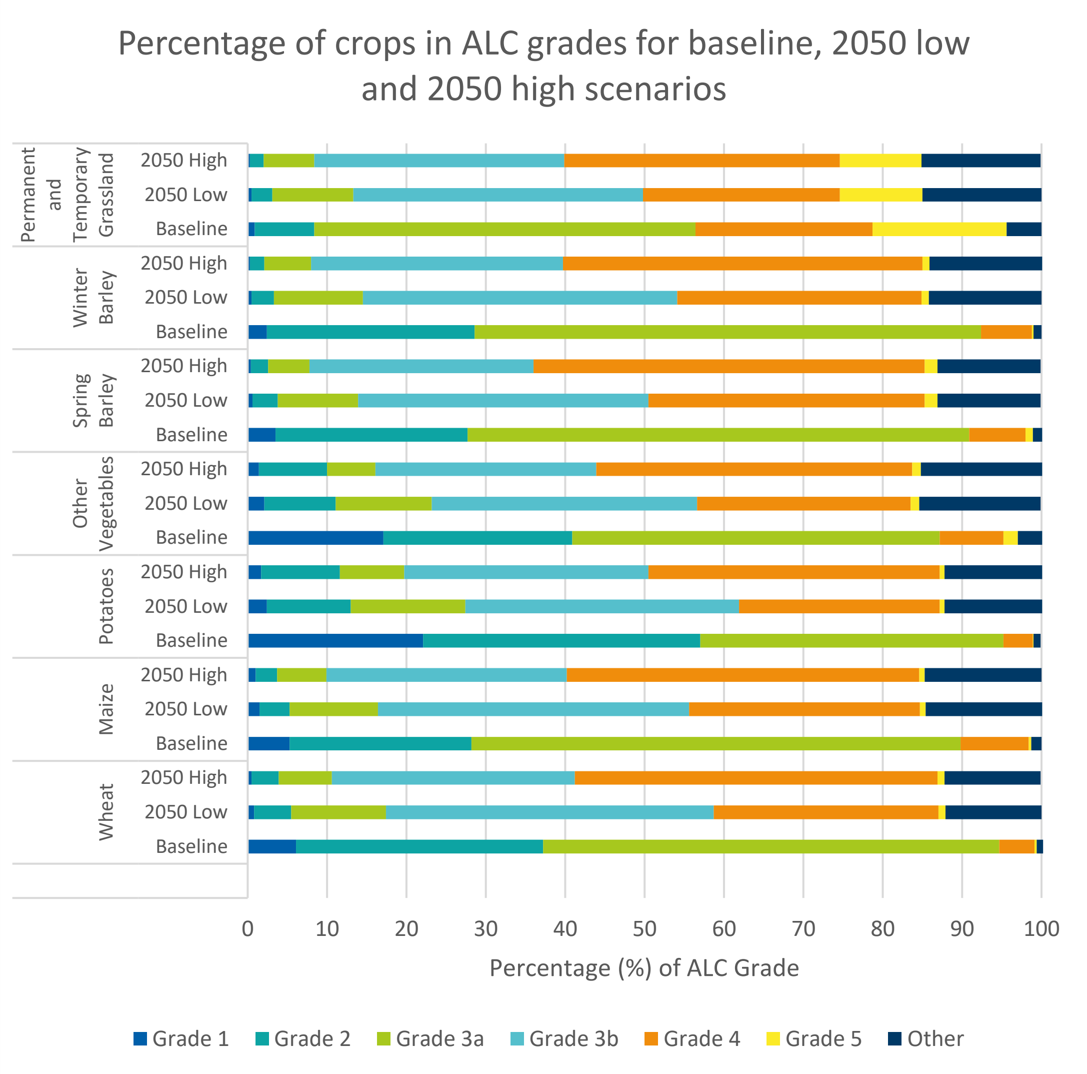

Figure 2.28 - Percentage of crops (wheat, maize, potatoes, other vegetables, spring barley, winter barley and permanent and temporary grassland) in ALC grades (1-5 and other) for the baseline period, a 2050s low emissions scenario and a 2050s high emissions scenario. Data sourced from Crome (Crop Map of England) database. Source: ADAS for the CCC.

2.16.4 Robustness of indicator

Attributing Crome data to the LPIS parcels provides crop data that is more spatially accurate than JAS data provided by Defra, but still a good match with national JAS totals. This finer-scale resolution is required to perform an overlay analysis with the ALC data. The baseline ALC map is provided as a polygon dataset. The projected ALC grades for 2050 low and 2050 high are mapped in a 5 x 5 km grid.

2.17 Number of flood warnings issued

Description: *Number and coverage of flood warnings issued by type*

Type: *Action*

2.17.1 Introduction

In addition to hard-infrastructure improvements to prevent flooding, enhancements in forecasting and warning systems for businesses and residents is increasingly important to raise awareness of potential flood events before they happen.

Flood warnings for England are provided on the gov.uk website[34] and broken down into three core warning types:

- **Severe Flood Warning** (severe flooding – danger to life)
- **Flood Warning** (flooding is expected – immediate action required)
- **Flood Alert** (flooding is possible – be prepared)

Flood warnings are issued by the Environment Agency (EA) through Floodline Warnings Direct (FWD), a free service run that provides flood warnings by phone, text or email to home owners and businesses. These warnings form the basis of the gov.uk website, which displays the warnings on a map so that users can zoom in on a particular area to understand risks nearby to the location of interest, shown in Figure 2.29.

[34] https://flood-warning-information.service.gov.uk/warnings

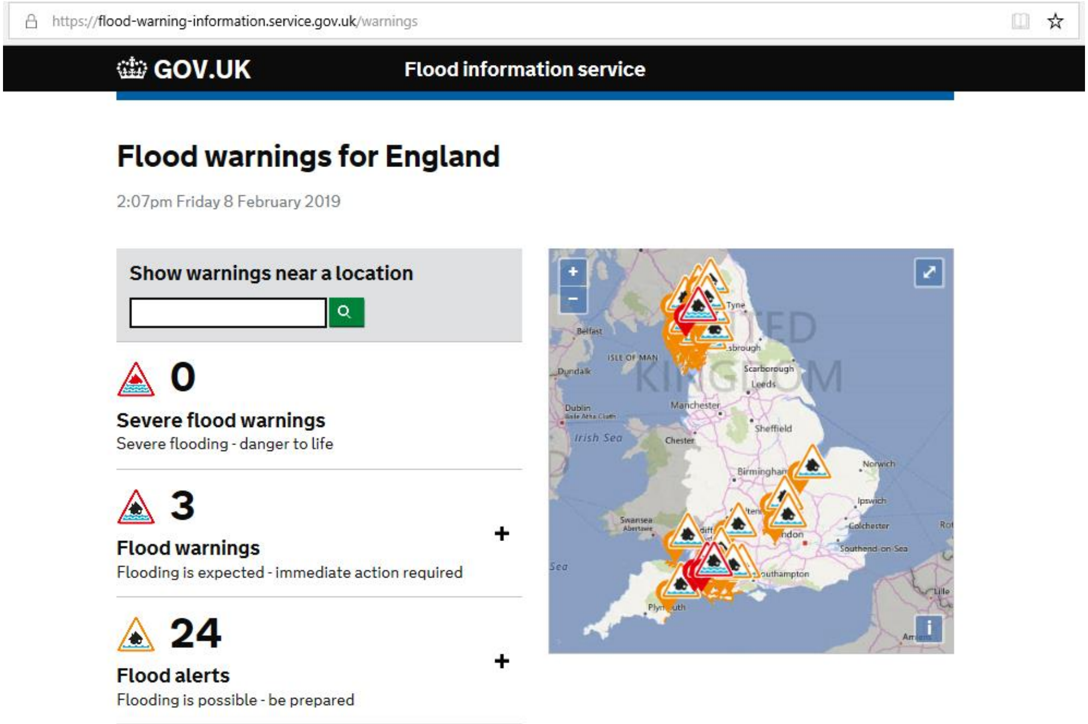

Figure 2.29 – Flood warnings for England that were issued on 8 February 2019. The warnings on this day were largely congregated in the South West and North West regions. Source: gov.uk website[35]

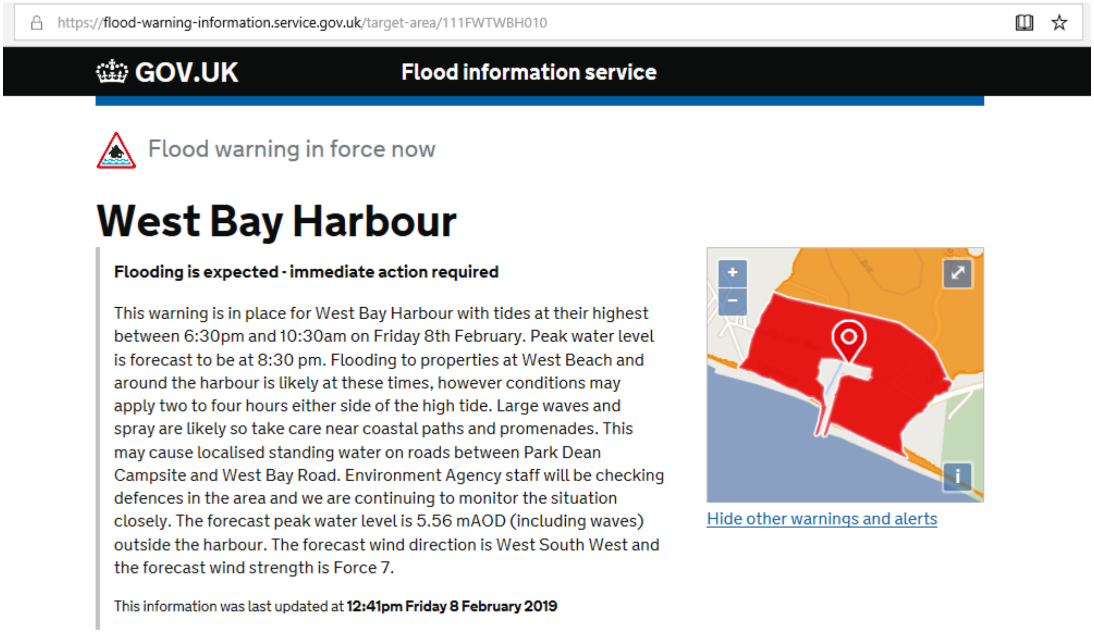

Figure 2.30 – Targeted advice from the EA for West Bay Harbour in Dorset on 8 February 2019 following a 'flood warning' being issued. Source: gov.uk website[36]

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[35] https://flood-warning-information.service.gov.uk/warnings. Accessed on 8 February 2019

[36] https://flood-warning-information.service.gov.uk/target-area/111FWTWBH010. Accessed on 8 February 2019

To help residents and businesses take action, the EA provides targeted advice, outlining as much detail about the event and potential risk as possible. Using the example of 8 February 2019, Figure 2.30 shows the targeted advice provided by the EA for West Bay Harbour in Dorset, which had a 'flood warning' in place as flooding was 'expected'.

This indicator assesses the total number of flood warnings issued on FWD in England for the period 2006 to 2018.

2.17.2 Data source and method

The FWD dataset is held by the EA and provides a listing of all Severe Flood Warnings, Flood Warnings and Flood Alerts issued since the FWD service went live in January 2006.

The dataset used in this analysis was sourced from the Environment Agency in two spreadsheets. For the years 2006 to 2015, data was sourced from the previous update of this indicator (ADAS, 2017). For the years 2016 to 2018, data was provided directly from the EA.

The datasets include flood warnings (including flood alert, flood warnings and severe flood warnings) issued for flooding from rivers and the sea and, for a limited number of locations, for groundwater flooding. For this analysis, we do not include groundwater flood warnings.

Analysis was conducted for the time series by warning type to assess if the total number of flood warnings has changed over time.

2.17.3 Trends and implications for climate resilience

In total, 40,858 flood warnings were issued on FWD between 31 January 2006 and 31 December 2018. Of these, 75% (30,603) refer to Flood Alert warnings being issued, 24% (9,832) refer to Flood Warnings being issued, and 1% (423) refer to Severe Flood Warnings being issued.

There is considerable variability in the number of warnings issued each year, shown in Figure 2.31. The highest number of flood warnings were issued in 2012 with 5548 warnings, followed by 2014, which had 5053 warnings. The lowest number of flood warnings were issued in 2011, with 1251 warnings, followed by 2018 which had 1264 warnings

The differences observed in the number of warnings issued by year is not easily attributable to an increase in the number of flood events in a particular region or year, hindered by changes in the number of flood warning areas, which have increased from approximately 2000 flood warning areas in 2006 to almost 3000 areas in 2016.

Subsequently during the time series, the number of flood warning areas have increased, meaning that a greater number of flood warning areas are available which could be issued at any given time. The reason for this is twofold. Firstly, new areas have been added so that all properties within a flood zone 2 area are covered. Secondly, it is due to the EA providing more targeted warnings, such that a warning area that covered a risk area in 2006, may now be split into 4 warning areas, for example.

However, the number of additions/splits like these have been limited since 2015, so the last four years provide a more stable indication into year-to-year variability.

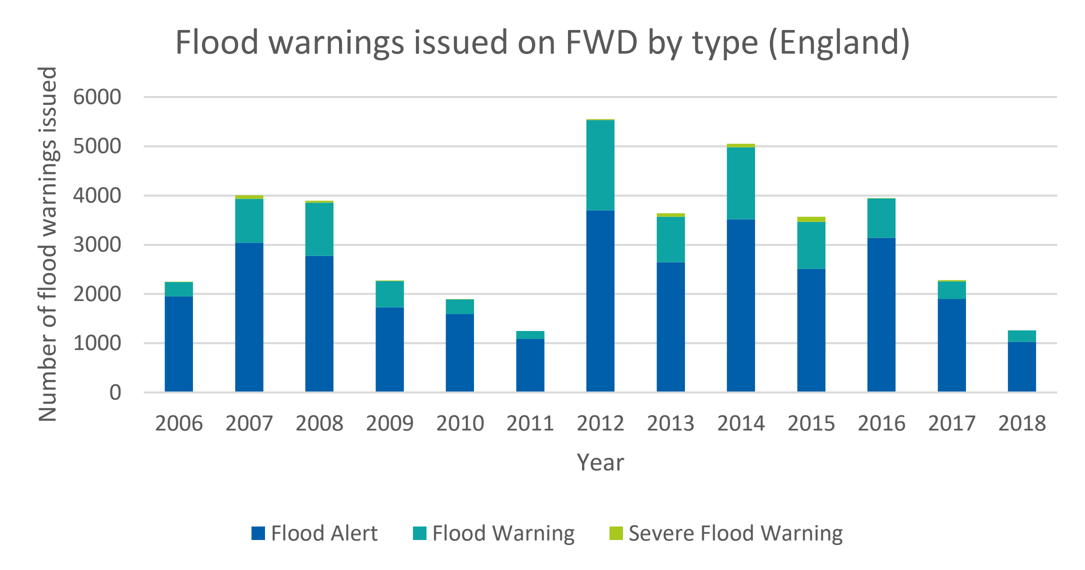

Figure 2.31 – Shows the number of flood warnings issued by type (Alert, Warning, Severe) for surface level flood warnings issued in England. The 2006 data is a partial year from 26/01/06 to 31/12/06, whilst the other 11 years show full data. Source: ADAS for the CCC.

2.17.4 Robustness of indicator

This indicator provides an indication into the number of warnings issued on FWD, however, the data is not robust enough to interpret trends over the long-term due to changes in the flood warning areas. Since 2006, the number of flood warning areas has increased from around 2000 flood warning areas to around 3000 flood warning areas as of 2016. This is due to FWD services being expanded into appropriate areas and because Flood Warnings have got more targeted (i.e. flood warning areas have got smaller and more precise).

The EA noted that the number of flood warning areas has increased, but detail was not available on the exact number of flood warning areas within each year, or which areas have become more targeted. This limits the potential to assess trends in the number and severity of flood warnings that have been issued in the time series. Furthermore, warnings may not be triggered by exactly same threshold etc., meaning consistency over the long-term is less reliable.

2.18 People with chronic respiratory conditions

Description: *Number of people living with chronic respiratory conditions (asthma and COPD)*

Type: *Vulnerability*

2.18.1 Introduction

Chronic respiratory diseases are chronic diseases of the airways and other structures of the lung. Some of the most common are: asthma, chronic obstructive pulmonary disease (COPD), occupational lung diseases and pulmonary hypertension. It is estimated that 5.4 million people in the UK have asthma[37]. For England, this is 4.5 million people, which equates to approximately 8.8% of the population[37].

This indicator looks at the number of people living with asthma and COPD, as well the number of deaths associated with both of these respiratory conditions.

2.18.2 Data source and method

The Office for National Statistics (ONS, 2018c) provided data on deaths from asthma and COPD from 2001 to 2017.

There is also NHS data available within the Quality and Outcomes Frameworks[38] which provides the number and percentage prevalence of patients receiving treatment for asthma and COPD in England. These reports are available for consecutive years from 2010-11 to 2017-18. Regional data was also found within the NHS Quality and Outcomes framework for 2011-12 to 2017-18.

2.18.3 Trends and implications for climate resilience

2.18.3.1 Deaths associated with Asthma and COPD

The total number of deaths in England where the underlying cause was COPD increased by 19% from 22,818 in 2001 to 27,230 in 2017. This increase is reflected in the trend line shown in Figure 2.32, however, there have been fluctuations throughout this time period. Conversely, the total number of deaths in England where the underlying cause was Asthma has decreased by 1.7% from 1,176 in 2001 to 1,156 in 2017.

Over 20% of deaths in each year where the underlying cause was asthma were in the 85+ age group (Figure 2.33). The number of deaths of those aged 85 and over, where the underlying cause was asthma, increased by 109% from 300 in 2001 to 626 in 2017. All other age groups saw a decrease in the number of deaths where the underlying cause was asthma between 2001 and 2017. The highest percentage decrease was for the 35-44 age group, where deaths fell from 64 in 2011 to 16 in 2017. However, great fluctuations are seen between years, as shown in Figure 2.33.

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[37] https://www.asthma.org.uk/get-involved/campaigns/data-visualisations/

[38] https://digital.nhs.uk/data-and-information/publications/statistical/quality-and-outcomes-framework-achievement-prevalence-and-exceptions-data

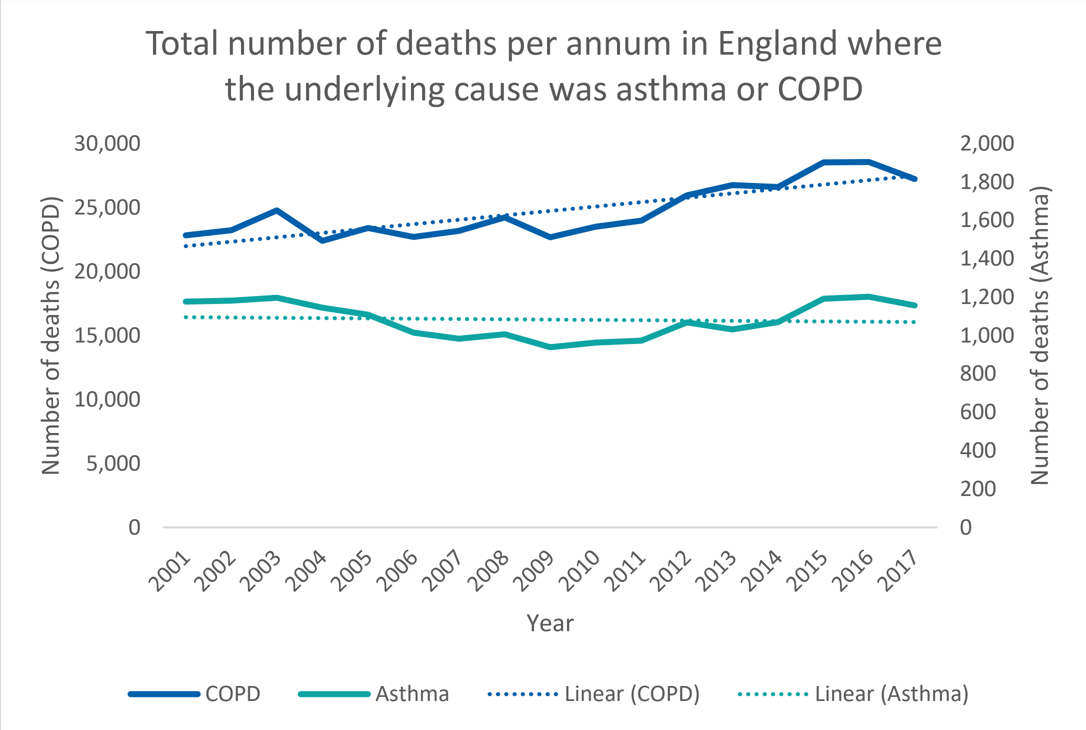

Figure 2.32 – The total number of deaths per annum in England where the underlying cause was asthma or COPD, using data from the Office for National Statistics (2018c). Source: ADAS for the CCC.

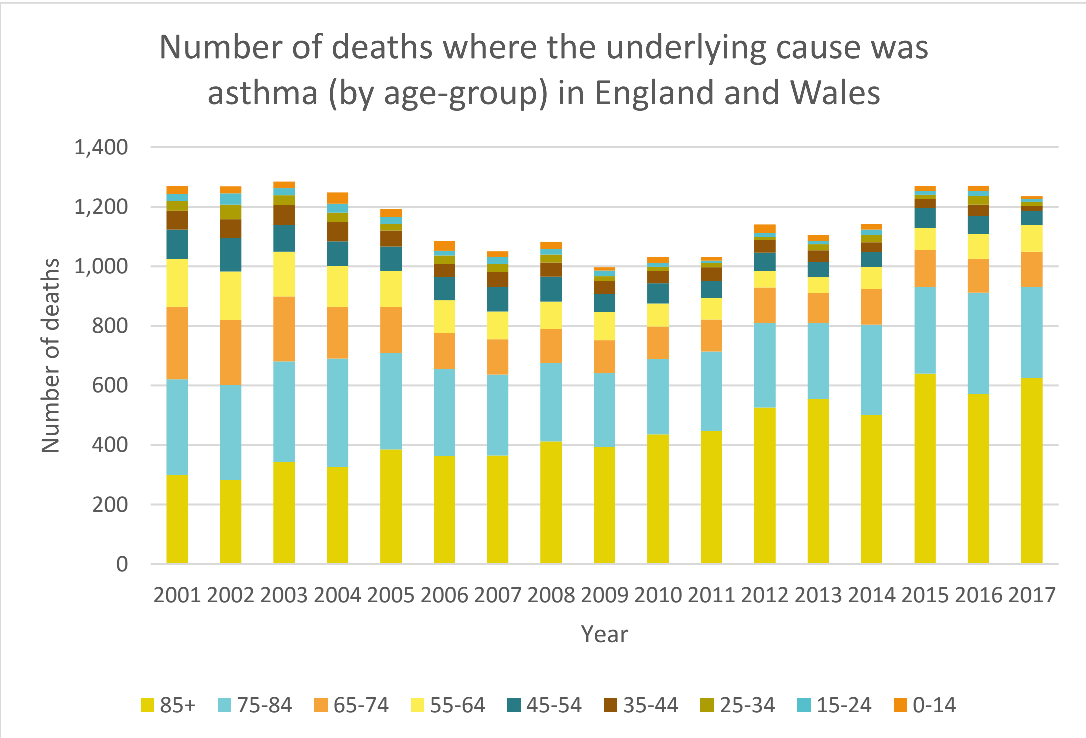

Figure 2.33 – The total number of deaths per annum in England and Wales where the underlying cause was asthma by age group, using data from the Office for National Statistics (2018c). Source: ADAS for the CCC.

2.18.3.2 Prevalence of Asthma and COPD

There has been a 6% increase in the number of patients receiving treatment for asthma in England from 3.3 million patients in 2010-11 to 3.5 million patients in 2017-18 (Figure 2.34). However, this increase could in part be attributed to population growth as the percentage prevalence of patients receiving treatment for asthma has remained at a similar level; fluctuating between 5.9% and 6% between 2010-11 and 2017-18, shown in Figure 2.34.

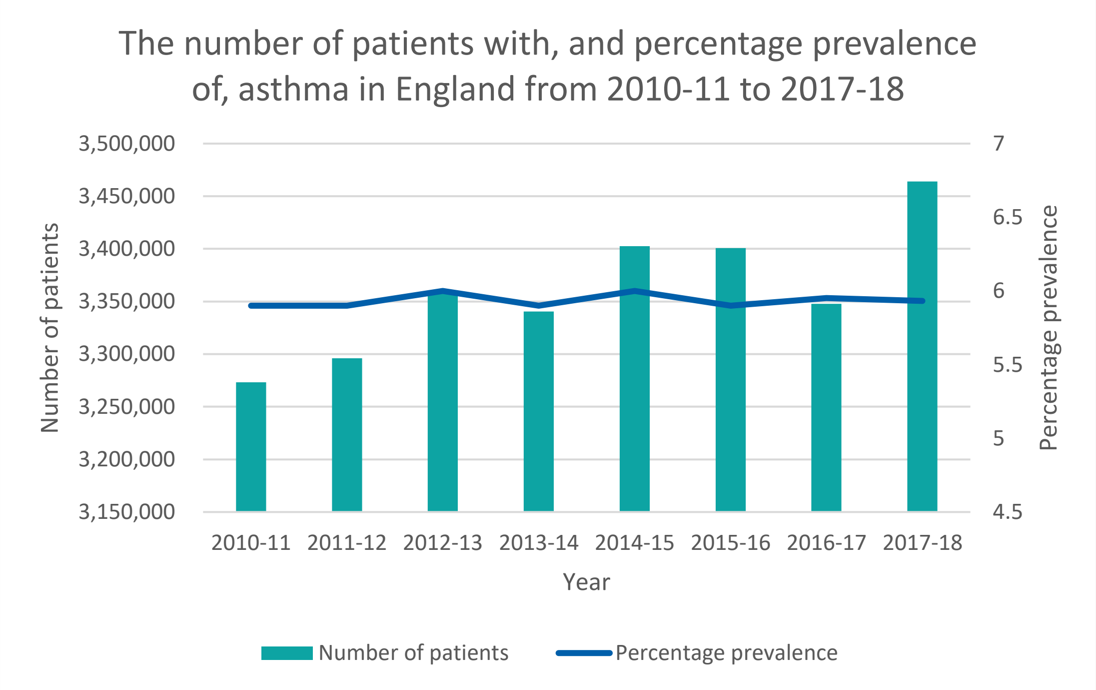

Figure 2.34 – The number of patients receiving treatment for asthma plotted against the percentage prevalence of patients with asthma in England from 2010-11 to 2017-18, as reported in the NHS Quality and Outcomes Frameworks[38]. Source: ADAS for the CCC.

The number of patients receiving treatment for COPD increased by 24% in England from 898,989 patients in 2010-11 to 1,113,417 patients in 2017-18 (Figure 2.35). The percentage prevalence of patients with chronic obstructive pulmonary disease has also been steadily increasing; from 1.6% in 2010-11 to 1.9% in 2017-18 (Figure 2.35).

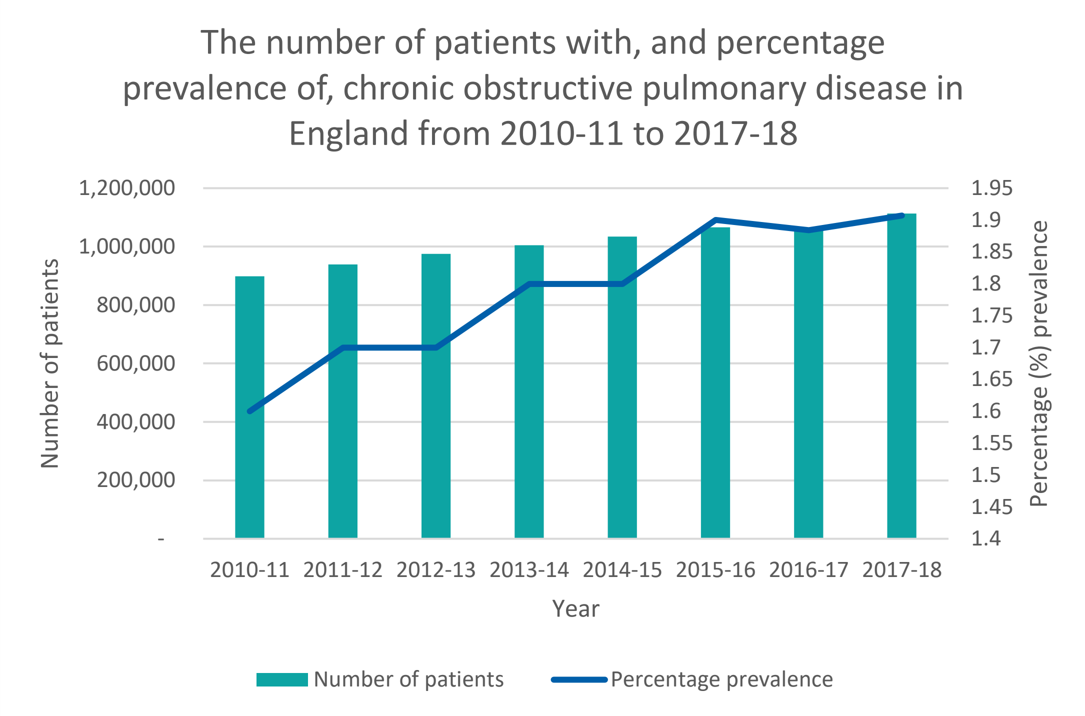

Figure 2.35 – The number of patients receiving treatment for COPD plotted against the percentage prevalence of patients with COPD in England from 2010-11 to 2017-18, as reported in the NHS Quality and Outcomes Frameworks[38]. Source: ADAS for the CCC.

Figure 2.36 and Figure 2.37 show the percentage prevalence of patents being treated for COPD and asthma by region. London has the lowest percentage prevalence of patients being treated for either COPD or asthma, with the North of England having the highest percentage.

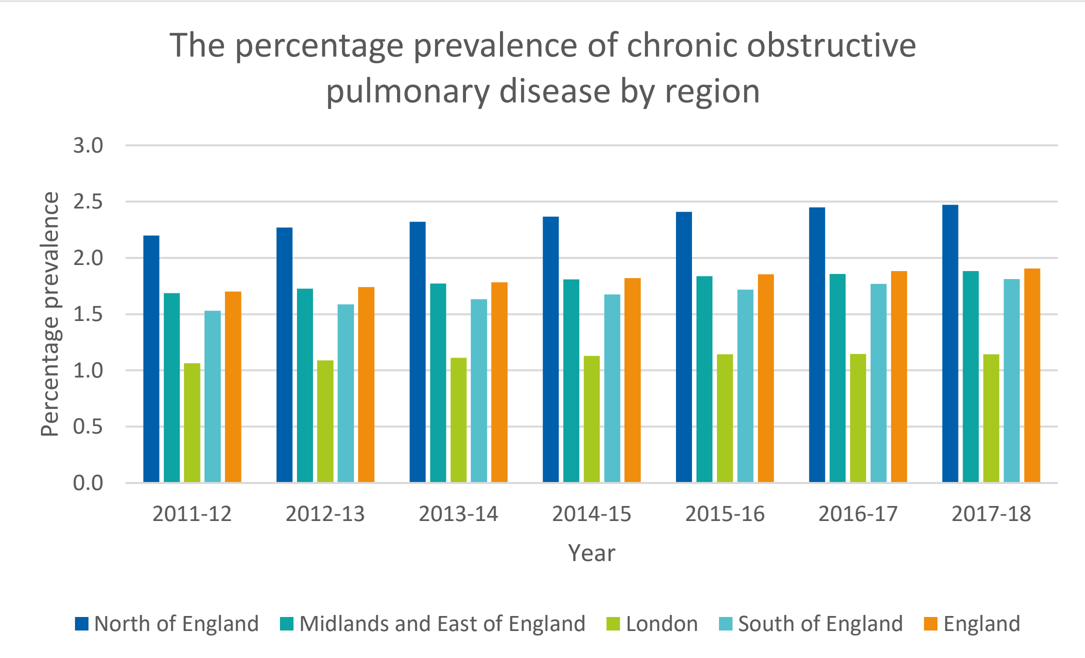

Figure 2.36 – The percentage prevalence of patients being treated for COPD in England by region, as reported in the NHS Quality and Outcomes Frameworks[38]. Source: ADAS for the CCC

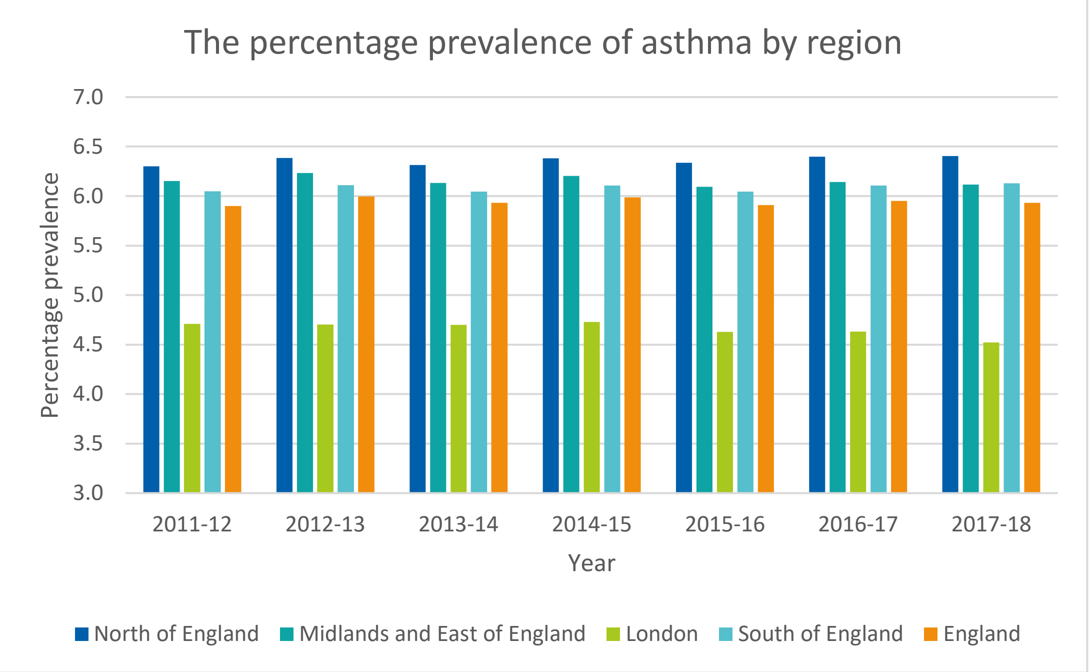

Figure 2.37 – The percentage prevalence of patients being treated for asthma in England by region, as reported in the NHS Quality and Outcomes Frameworks[38]. Source: ADAS for the CCC.

2.18.4 Robustness of indicator

The ONS dataset if a fairly robust and consistent time series of data, which provide a record of the number of deaths per year where asthma or COPD were registered as the cause of death.

Statistics for asthma and COPD prevalence and diagnosis are not well covered. The Quality and Outcomes Framework data for asthma and COPD is based on the number of people currently receiving treatment from their GP for asthma each year, with data going back over 10 years. However, there are some issues with the way this data is collected that prevent it from being the definitive prevalence figure within the industry. Nevertheless, in the absence of a more robust dataset, it provides the best indication of the number of people that are living with asthma and COPD.

2.19 Weather-related insurance claims

Description: *Weather-related insurance claims by households, businesses, farmers*

Type: *Realised Impact*

2.19.1 Introduction

According to the Association for British Insurers (ABI), the UK insurance and long-term savings industry is the largest in Europe and the fourth largest in the world.[39] Of the 27.2 million households in the UK in 2015-16, 19.7 million had contents insurance and 16.6 million had buildings insurance. The average amount paid (including insurance premium tax) for a combined buildings and contents policy in 2017 was around £300. Insurers paid out £12.9m per day in 2016 in property claims, of which £7.4m was for domestic claims and £5.5m related to commercial claims (ABI, 2017). Approximately 16% of the total domestic value of gross claims were associated with the weather, shown in Figure 2.38.

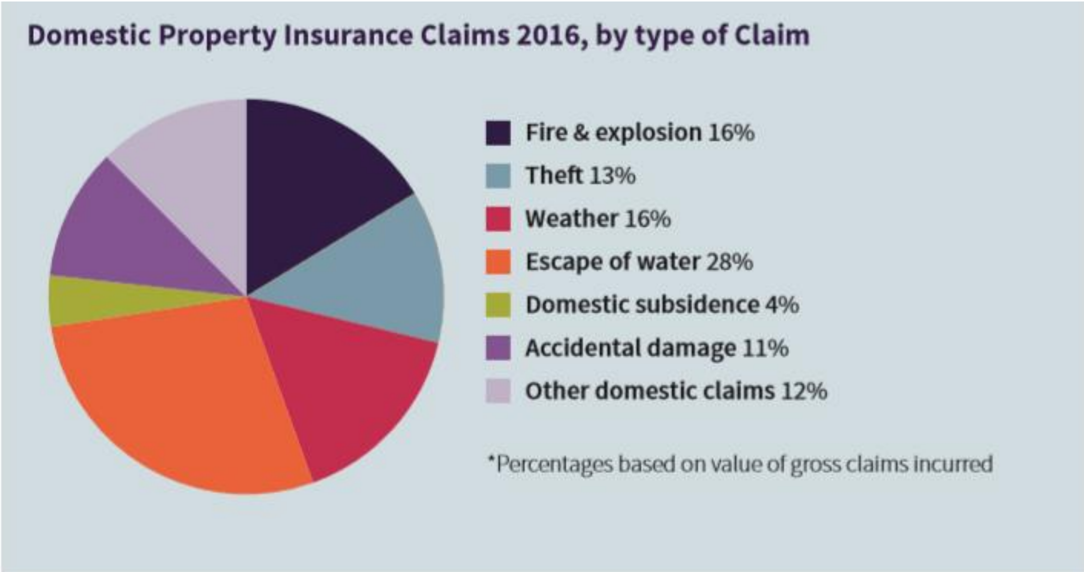

Figure 2.38 – Domestic Property Insurance Claims in 2016, split by type of claim. Source: ABI (2017)

This indicator assesses weather-related insurance claims by domestic (households) property and industrial and commercial property in the UK, between 1989 and 2017, to understand if the frequency and or magnitude of weather-related insurance claims has changed.

2.19.2 Data source and method

The ABI collects extensive data from insurers and long term savings providers (covering everything from motor and property insurance to life assurance and pensions) and industry data is available on the website for a subscription fee. The data used in this analysis was provided directly by the ABI data team.

[39] https://www.abi.org.uk/data-and-resources/industry-data/uk-insurance-and-long-term-savings-key-facts/

Data was provided in Excel format, with summary claims outlined for each year, as well as by quarter (Q1 was Jan-Mar; Q2 was Apr-Jun; Q3 was Jul-Sep; and Q4 was Oct-Dec). A number of terms are used within this analysis, outlined here:

- Gross claims incurred refers to the value of total claims received within the quarter, based on the insurance companies' interpretation of the damage value.
- The number of claims notified refers to the total number of claims received within a quarter, including zero-cost claims.
- Domestic (Household) claims refers to damage to household property, including both buildings and contents.
- Weather-related insurance claims include (and are broken down within the domestic insurance claims) those claims related to pipes, storm wind and flooding:
  - Pipes refer to any claims arising from damage caused by escape of water from any tank, apparatus or pipe related to weather (e.g. frozen and burst pipes in winter).
  - Storm wind refers to any claims arising from wind-blown and debris damage to property, including fallen trees, lightning etc.
  - Flooding refers to any claims associated with surface, river or coastal flooding to property.

2.19.3 Trends and implications for climate resilience

Over the last 29 years (1989-2017), weather-related gross claims incurred to UK property is estimated to total around £24 billion, of which around 68% is related to domestic property and 32% commercial property. This indicates that on average, £833 million of weather-related gross claims are incurred each year. There is however considerable inter-annual variability in the time series, with gross claims incurred ranging from £320 million in 2017 to almost £2.5 billion in 2007, shown in Figure 2.39.

There are two standout years in Figure 2.39, 1990 and 2007, where gross claims incurred where considerably greater than average, suggesting major weather-related events caused significant damage to property. It is noted that attribution to specific weather events may not be completely clear-cut, however, it is likely that these two spikes were (at least partially) attributed with the Burns Day Storm in 1990 and the summer 2007 flooding event.

Burns Day Storm

The Burns' Day Storm (also known as Cyclone Daria) was an extremely violent windstorm that took place on 25–26 January 1990 over north-western Europe. An intense depression tracked across southern Scotland bringing severe gales and storm force winds to much of England and Wales. The strong winds affected a much larger area than in October 1987 and they struck during the day so consequently there were more deaths and injuries, with 47 lives lost. There were disruptions to power supplies and to transport, particularly to road transport because of fallen trees and overturned vehicles. There was also considerable damage to buildings, particularly to housing and to the south of a line from west Wales to Suffolk.[40]

Flooding – summer 2007

[40] https://www.metoffice.gov.uk/climate/uk/interesting/jan1990

Torrential downpours in May, June and July 2007 left large swathes of the country under water. The floods threatened lives and caused substantial damage to property. Part of the reason for the heavy rain was a stronger than normal jet stream, which caused depressions near the UK to be more intense. Some of these depressions pulled in the very warm and moist air to the south of the UK, generating exceptionally heavy and intense rainfall. Tragically five people died and thousands more had to spend nights in temporary accommodation or were left without power. Key impacts included: surface water flooding in Hull with widespread disruption and damage to more than 7,000 houses and 1,300 businesses; the River Don burst its banks, flooding Sheffield and Doncaster; and flooding was experienced in Derbyshire, Lincolnshire and Worcestershire.[41]

There are no clear trends shown in Figure 2.39, with too much noise in the inter-annual variability to determine clear changes over time, both with regards to the gross claims incurred and the number of claims notified.

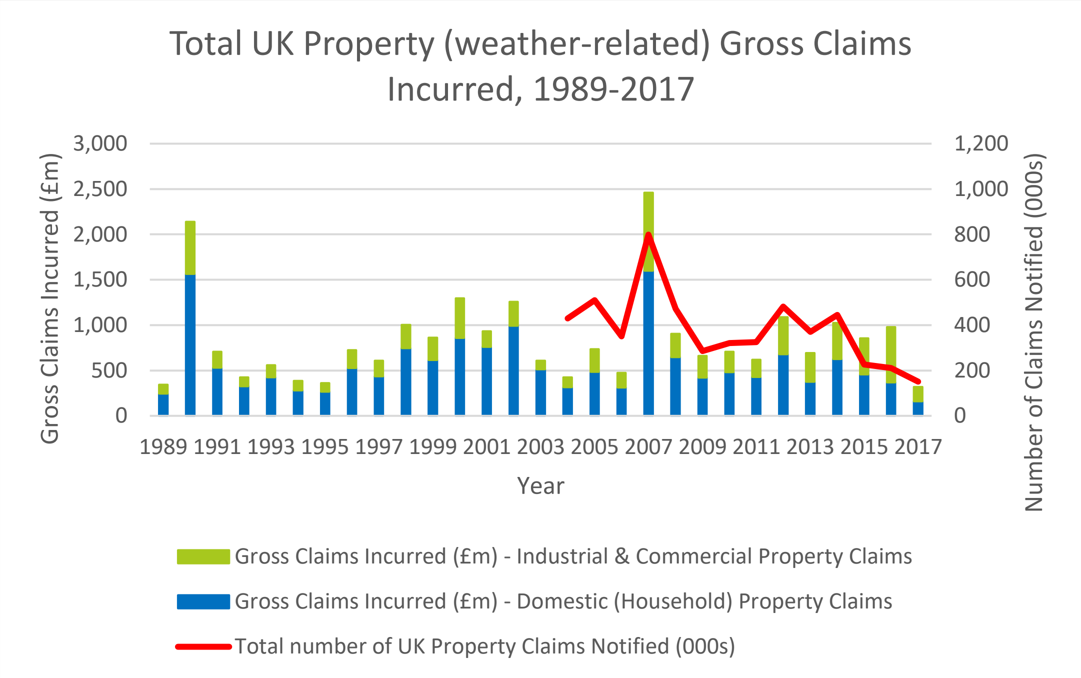

Figure 2.39 – Stacked column chart showing the total UK property weather-related gross claims incurred between 1989 and 2017, split by domestic/household (blue stacks) and commercial (green stacks). The total number of property claims notified within each year is also provided from 2004 onwards (red line). The underlying data was sourced from the ABI. Source: ADAS for the CCC.

For domestic weather-related claims, the ABI have data broken down by weather-related insurance type. This enables a better insight into the types of events that triggered spikes in insurance claims in these periods. For example, it is possible to correlate known weather events with spikes in gross claims incurred to provide an indication of the event that might have caused or contributed to the spike. Figure 2.40 show gross claims incurred by quarter from 1998 to 2018.

[41] https://www.metoffice.gov.uk/about-us/who/how/case-studies/summer-2007

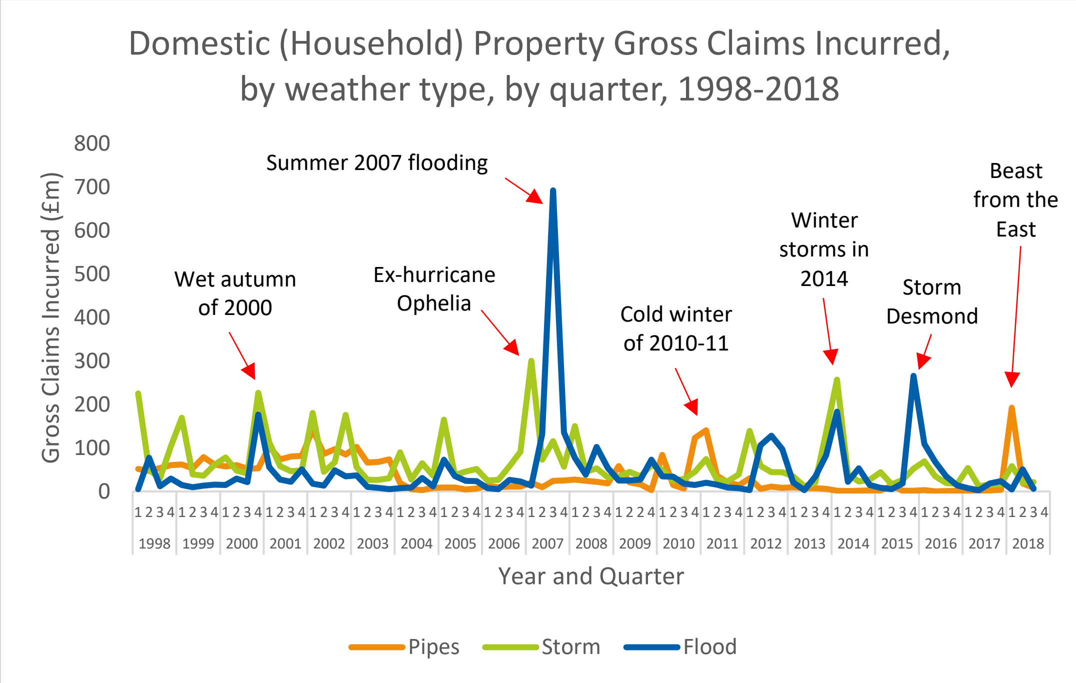

Figure 2.40 – Line chart showing total domestic (household) property gross claims incurred on a quarterly basis between 1998 and 2018, by weather type: pipes (orange line), storms (green line) and floods (blue line). The underlying data was sourced from the ABI quarterly dataset of domestic gross claims incurred. Source: ADAS for the CCC.

Figure 2.40 shows little in the way of trends, again due to the considerable variability year to year. However, some high level observations indicate that a) gross claims incurred from pipes has reduced in the latter half of the dataset, with just periodic spikes, as opposed to a fairly consistent run between 1998 and 2003 – perhaps due to warmer winters or better insulation and protection of pipes; and b) the impact from storms also seems to be less severe in the latter half of the dataset, with spikes in storm-related gross claims being much more pronounced in the first half of the data.

There are several notable spikes in the data, which coincide with well-documented weather events, outlined in Table 2-23. It is likely that these weather events contributed and/or exacerbated the gross claims incurred by the insurance industry during and shortly following these periods.

Overall, the ABI data show that weather-related insurance claims continue to occur year-on-year, with significant weather events attributed to higher gross claims incurred. To date, there are no clear trends of whether an increase or decrease in the total value of gross claims incurred on average, however it might be expected that more extreme weather in the future will create greater spikes in the dataset, if adaptation to e.g. flooding is not implemented to the required standards to mitigate or reduce the risk of damage to property.

Table 2-23 – Indicative weather events related to spikes in gross claims incurred. Source: ADAS for the CCC.

Year	Key weather type	Indicative Event
2000	Storm and flood	Wet autumn of 2000[42]
2006	Storm	Ex-Hurricane Ophelia[43]
2007	Flood	Summer 2007 flooding event[44]
2010-11	Pipes	Exceptionally cold winter of 2010/11[45]
2013-14	Storm and flood	Winter storms in January to February 2014[46]
2015	Flood	Storm Desmond and associated flooding in Cumbria[47]
2018	Pipes	'Beast from the East' associated with snow / low temperatures[48]

2.19.4 Robustness of indicator

The ABI data provided is based on that of the ABI's members, but grossed up to approximate the whole of the industry. This is done by the ABI because the ABI members across each line of insurance (domestic and commercial) in this collection represent the majority of the industry, so grossing up by ABI doesn't involve excessive extrapolation. The data is provided voluntarily by ABI members through quarterly data collections (which are consistent and strictly quantitative, and so comparable), and each set of submitted data is quality assured by the ABI data team to ensure that mistakes aren't allowed through to publication.

Having said this, and despite the ABI's best efforts, ABI do not have perfect knowledge of the data that their members collect, therefore there may occasionally be mistakes that filter through to the published results. Furthermore, there is not absolute certainty regarding the quality assuring practices of the previous ABI data and analytics team members in the early years of the dataset, compared with the current team. The ABI note that as the data collections have aged, the ability for the ABI to quality assure and streamline data has also improved, so the earlier years of data collection may be slightly less reliable.

Overall, the ABI data and this indicator provide a strong insight into weather-related insurance claims for property. There appears to be a relatively strong correlation between spikes in domestic claims and severe weather events by type. It is therefore expected that major weather events in the future, which impact domestic property, will coincide with an increased number of, and gross claims incurred. The ABI update the dataset on a quarterly basis.

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[42] https://www.metoffice.gov.uk/climate/uk/interesting/autumn2000.html

[43] https://www.metoffice.gov.uk/climate/uk/interesting/2017-ophelia

[44] https://www.metoffice.gov.uk/about-us/who/how/case-studies/summer-2007

[45] https://www.metoffice.gov.uk/climate/uk/summaries/2011/winter

[46] https://www.metoffice.gov.uk/climate/uk/interesting/2014-janwind

[47] https://www.metoffice.gov.uk/climate/uk/interesting/december2015

[48] https://www.metoffice.gov.uk/climate/uk/interesting/february2018-snow

2.20 Number of wine producing vineyards

Description: *Number of wine producing vineyards and area under vine*

Type: *Realising Opportunity*

2.20.1 Introduction

According to the International Organisation of Vine and Wine (OIV) Statistical Report on World Vitiviniculture, the global area under vines, was estimated at 7.5 million hectares in 2017, with 37% of total world grapes being produced in Europe, 34% in Asia and 19% in America (OIV, 2018).

Shifts in global and regional climate are expected to make some key wine producing areas less suitable for grape production, whilst creating more favourable conditions in other areas that were not previously deemed as favourable, such as England. This presents an opportunity for some farm businesses in England, particularly in the south, to diversify or change cropping to vineyards.

Wine Great Britain (WineGB) note that grape growing and winemaking in the UK has changed dramatically during the last 50 years. The area under vine in Great Britain has increased by 160% in the past 10 years to reach 7,000 acres (2,888 ha). In 2018, 1.6 million vines were planted with a further 2 million expected in 2019[49].

England and Wales now have approximately 700 vineyards (of which about 75-80% are commercial), and over 160 wineries producing world-class internationally award winning sparkling, white, rose and red wines[50].

This indicator assesses how the area of vineyards planted and hectolitres of wine produced has changed in England and Wales from 1989 to 2018.

2.20.2 Data source and method

This indicator was developed by ADAS (2017) and covered the period 1994 to 2015 for the total area planted. Additional data was sourced in this analysis to extend the time series for the total area planted to 30 years (1989 to 2018). Data was not obtained on the number of vineyards in this analysis as robust data was not available. However, a new dataset was sourced that provided data on the amount of wine produced each year. This data also covers three decades, from 1989 to 2018.

For the total area planted, data is from the Food Standards Agency (FSA) for the period 1989 to 2017, sourced through the FSA directly and through WineGB. Indicative data for 2018 was sourced from the vine variety database, although it is noted that this data might not tally with the wine production figures when they are published.

For the total amount of wine produced, data is from the FSA for the period 1989 to 2015, sourced through the English Wine Producers[51] UK Vineyards Stats (May 2016) summary table

[49] https://www.thedrinksbusiness.com/2019/02/record-15-6m-bottles-of-wine-produced-in-england-and-wales-last-year/

[50] https://www.winegb.co.uk/industry/membership/uk-wine-production-industry/

[51] http://www.englishwineproducers.co.uk/files/4114/7508/1393/UK_vineyard_stats_May_2016.pdf

(ADAS, 2017), and the FSA vineyard register[52]. Data for 2016 to 2018 was sought directly from the FSA, however this was not provided in time for this analysis. In substitute, indicative figures were sourced from English Wine[53] / WineGB[54] for the years 2016-2018. However, as these figures were not confirmed by the FSA, there is some uncertainty around the accuracy of this data, although it is anticipated to have a good degree of accuracy.

The data provided by both sources was originally sourced through annual harvest and production declarations provided to the Food Standards Agency from commercial vineyards.

2.20.3 Trends and implications for climate resilience

The total area planted with vines in England and Wales has trebled since 2004 from 761 hectares, to an estimated 2,289 hectares in 2018, shown in Figure 2.41. These figures are for commercial vineyards and exclude 'hobby vineyards' or 'abandoned vineyards'.

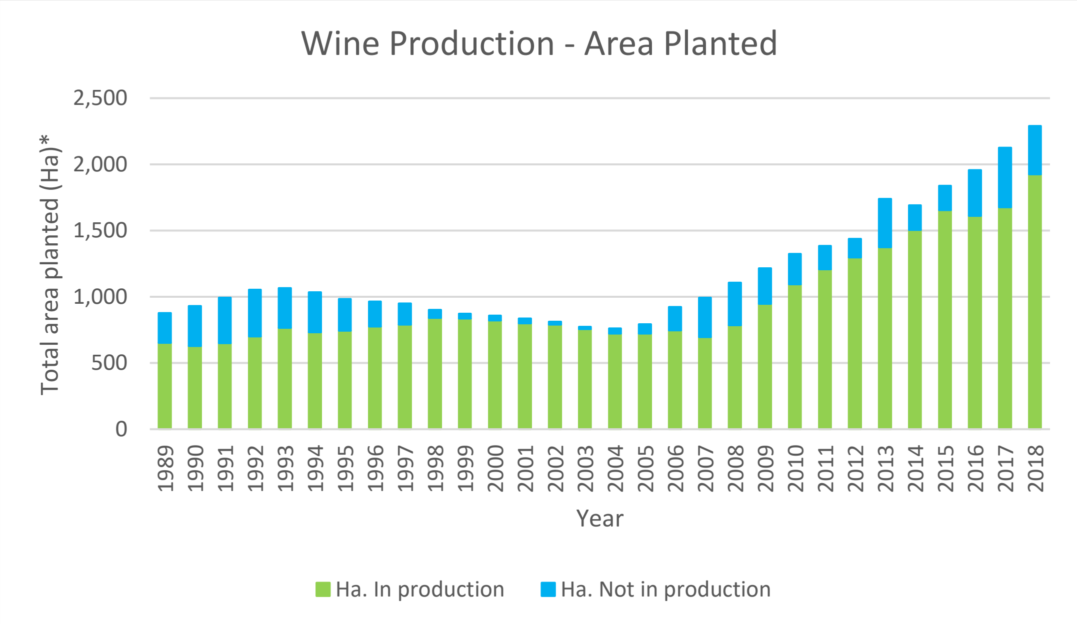

Figure 2.41 – Total planted area (hectares) of vines each year, excluding 'hobby vineyards' or 'abandoned vineyards', split between area in production, and not in production, for England and Wales from 1989 to 2018. Data sourced through FSA survey. Source: ADAS for the CCC.

Approximately 84% (2,289 hectares) of the total planted area in 2018 was in production. The 16% of the planted area not in production is likely due to newly planted crops that have not yet been fully established, and thus not growing high quality fruit in the quantities required.

There is no indication in the datasets as to whether this increase in area is being driven by improving climatic conditions for the vines, or whether there are other economic reasons for the increase in area. However, it anticipated that the climate is becoming more suitable

[52] https://www.food.gov.uk/business-guidance/uk-vineyard-register. Accessed on 17/12/2018.

[53] http://www.englishwine.com/harvestreport2017.htm

[54] https://www.thedrinksbusiness.com/2019/02/record-15-6m-bottles-of-wine-produced-in-england-and-wales-last-year/

for vine production and thus allowing the opportunity to be capitalised upon by growers interested in wine production.

In terms of the total amount of wine produced each year (i.e. number of bottles produced), this is highly variable depending on the weather. Figure 2.42 shows how wine production has changed year on year.

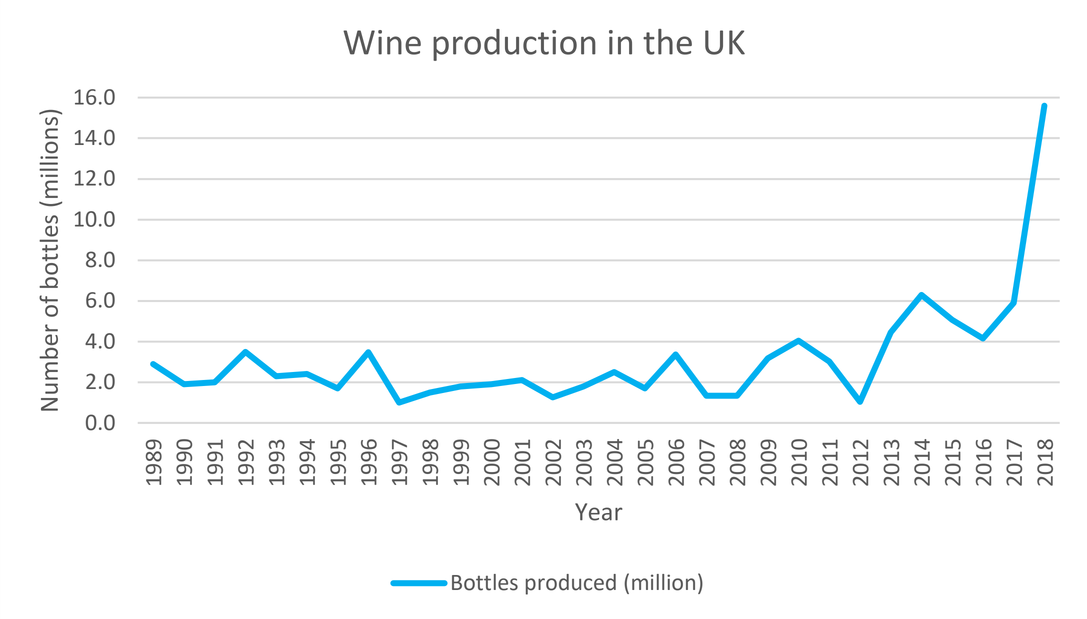

Figure 2.42 – Wine production (millions of bottles produced) in the UK from 1989 to 2018. Data sourced from FSA (1989-2015) and English Wine / WineGB (2016-2018). Source: ADAS for the CCC.

Some key years to note include:

- 2012 - Production was considerably down compared to previous years. This was associated with a disastrous growing season, which included the wettest June and the coldest summer since 1988, and the dullest summer since 1987 with just 403 hours of sunshine across the UK (80% of the 1981-2000 average)[55]. This was not just a UK problem however, with BBC News reporting that a poor grape harvest in 2012 was experienced across the world, causing global wine production to fall to its lowest level since records began in 1975[56].
- 2016 - English Wine report that the UK officially produced 4.15 million bottles of wine in 2016[57]. This was lower than the average production in the previous 3 years (2013 to 2015), due to a combination of cool conditions during the summer and a lack of moisture in the later part of the growing season.
- 2018 – Reports show the 2018 was an exceptional growing season. The Drinks Business (a monthly international business-to-business magazine and website published by Union Press) reports that WineGB figures show 15.6 million bottles of wine were produced in 2018, beating the previous record (6.3 million bottles in

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[55] https://www.metoffice.gov.uk/climate/uk/summaries/2012/summer

[56] https://www.bbc.co.uk/news/world-europe-20152231

[57] http://www.englishwine.com/harvestreport2017.htm

2014) by 9.3 million bottles[58]! The growing season had been unprecedented in terms of quality and the prolonged spell of hot weather was followed by a period with very little rain, enabling the grapes to fully ripen on the vine without the need to rush the harvest[59].

2.20.4 Robustness of indicator

The data provided by the Food Standards Agency, albeit obtained through several different sources, is fairly robust and provides a good indicator for the total area planted each year (both in and out of production), and the number of bottles produced (dependent on the success of that years growing season – largely attributable to the weather). There is some uncertainty around the 2016-2018 figures for wine production as these were not confirmed by the FSA, but sourced from industry news articles and web pages.

The original source of the FSA data comes from annual declarations on a survey, completed by commercial vineyard growers. Consequently, there is the potential that some data could be falsified, but this is anticipated to be a minor issue. It is anticipated that the FSA will continue to collect this data year on year, allowing for future updates of the data set. In addition, the new national body for the English and Welsh wine industry (Wines of Great Britain or WineGB for short) may also provide greater insight also.

58 https://www.thedrinksbusiness.com/2019/02/record-15-6m-bottles-of-wine-produced-in-england-and-wales-last-year/

59 https://www.thedrinksbusiness.com/2018/10/record-year-english-and-welsh-wine-producers-comment-on-2018-vintage/

3 Updated Evidence Bases

3.1 Number of care facilities that experience overheating

Description: *Number of hospitals / care homes / surgeries that experience overheating or are implementing heatwave plans*

Type: *Realised Impact / Action*

3.1.1 Introduction

During hot summer days, many buildings can experience overheating, including hospitals, care homes and surgeries. For many buildings, this may be an infrequent issue on a few days a year where temperatures are 'extreme', whilst for other buildings, particularly those with poor design or inadequate cooling mechanisms, this may be much more common.

Heatwaves are projected to become more frequent and more severe in the coming decades due to a warming climate. The Public Health England (PHE) Heatwave Plan for England aims to increase year-round planning and awareness of the threat of heatwaves amongst health and social care services as well as the general public (PHE, 2018a). By improving preparedness, the aim is that adverse health impacts of heatwaves will be reduced, such as heat stress or excess mortality.

The UK Climate Change Risk Assessment Evidence Report highlighted the future risks of overheating in hospitals, care homes, schools and offices, and commented that there are no current policies to adapt homes or other buildings to higher temperatures (Kovats and Osborne, 2016). Furthermore, research by ADAS (2017) also found that to date, there has been limited data and evidence available on the number of medical/care buildings that experience overheating and/or that have implemented heatwave plans.

Here we provide an update to the evidence base, reflecting on new research, for the number of hospitals/care homes/surgeries that experience overheating.

3.1.2 Data source and method

3.1.2.1 Hospitals

A new dataset has become available on the number of hospitals that experience overheating. The Estates Return Information Collection (ERIC) is a mandatory collection for all NHS Trusts including Ambulance Trusts. It comprises information relating to the costs of providing and maintaining the NHS Estate including buildings, maintaining and equipping hospitals, the provision of services (e.g. laundry and food), and the costs and consumption of utilities. The survey is conducted 31st March each year and available through the NHS Hospital Estates and Facilities Statistics. For the 2016/17 ERIC, a new item was added to the survey "overheating occurrences triggering a risk assessment", which records where wards, for each of the 236 NHS trusts, exceeded a daily maximum temperature of 26°C. The count provided in the survey include each occupied ward or clinical area having a daily maximum of over 26˚C as one incident. For example, if two wards within the same hospital exceeded the daily maximum temperature for two days and one clinical area exceeded the threshold for one day, then the response would be five.

The supporting guidance to the survey question 'number of occasions in each occupied ward or clinical area where the daily maximum temperature exceeded 26˚C', states that "for each clinical area, decisions about setting environmental conditions should only be made after careful judgements as to the vulnerability and duration of stay of the intended patients. In all clinical areas, year round internal temperature monitoring is recommended. At any time of the year where temperatures are found to exceed 26˚C, a risk assessment should be carried out and appropriate action taken to ensure the safety of vulnerable patients."[60]

For this analysis, ERIC data was sourced online for two financial years (running from April to March) for 2016-17 and 2017-18, from the NHS Digital Archives.

3.1.2.2 *Care Homes*

Similarly to research by ADAS (2017), no known datasets are available to provide an indication into the number of care homes that experience overheating, or which implement heatwave plans. Here we review some of the recent work and research that has been conducted to update the evidence base.

3.1.2.3 *Surgeries*

No data was identified to provide specific insight into overheating in surgeries.

3.1.3 Trends and implications for climate resilience

3.1.3.1 *Hospitals*

The limited data available for the first two years of this specific question being asked on the ERIC survey shows that a total of 5442 overheating occurrences were recorded across all NHS Trusts, of which 2980 overheating occurrences were in 2016-17 and 2462 in 2017-18. This data should be interpreted with caution however.

The data indicates that a greater number of Trusts recorded one or more occurrences of overheating in 2017-18, despite a lower number of overheating occurrences being exhibited overall, shown in Figure 3.1. Across the two years of data, one trust accounted for 28% (1519) of total occurrences, whilst four Trusts (out of the 236 Trusts) accounted for over half (54%) of the total number of overheating occurrences.

[60] https://www.gov.uk/government/publications/making-energy-work-in-healthcare-htm-07-02

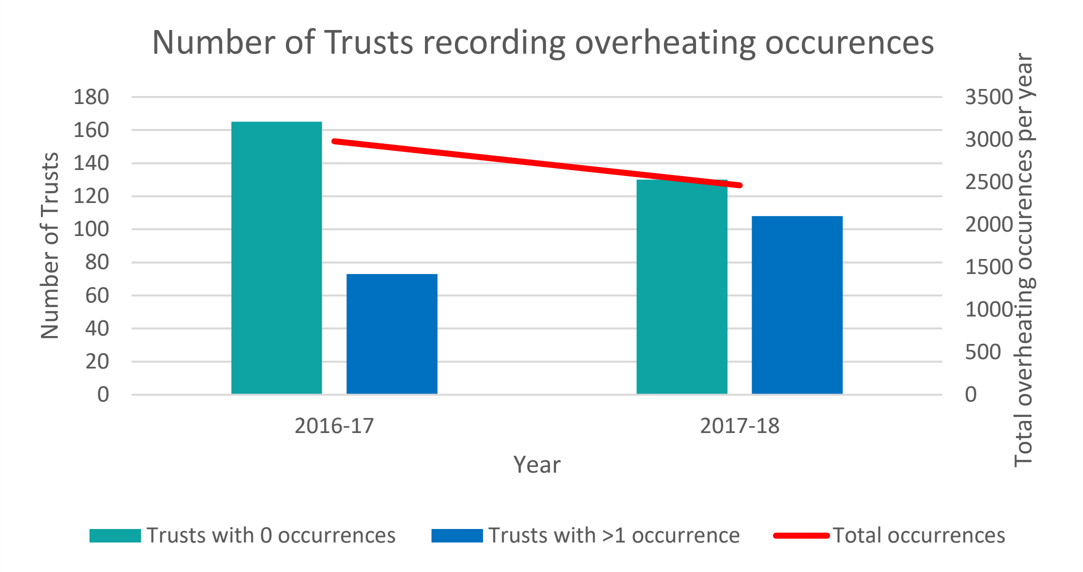

Figure 3.1 – Number of NHS Trusts (236 total) recording none (light blue) or one or more (dark blue) overheating occurrences in 2016-17 and 2017-18. The total overheating occurrences for each year is also provided (red line). The count provided include each occupied ward or clinical area having a daily maximum of over 26˚C as one incident. For example, if two wards within the same hospital exceeded the daily maximum temperature for two days and one clinical area exceeded the threshold for one day, then the response would be five. Baseline data sourced from ERIC survey from NHS Digital Archive. Source: ADAS for the CCC.

The available data suggests a particular issue with overheating in a select few Trust buildings, rather than a widespread issue. For those few Trusts where a high number of overheating occurrences is exhibited, this may indicate an overheating issue with the particular Trust affected, which could have implications for the management of at risk patients.

Alternatively, these insights could just simply be a product of inconsistencies in data recording, both within and between Trusts. The dataset is not deemed robust and there are a number of areas of concern where misrepresentation of data might have occurred:

- Whilst guidance is provided with the survey to help in the provision of data, there is no guarantee that this is being followed.
- It is also likely that interpretation of the guidance varies between different Trusts. For example, there were concerns that some Trusts might be over reporting, e.g. reporting multiple times within a 24 hour period when temperature exceeded 26°C, rather than reporting that the 26°C threshold had been exceeded within a 24 hour period (e.g. if 1pm = 27 degrees, 2pm = 24 degrees and 3pm = 28 degrees; some Trusts may have counted this as two exceedances, rather than one).
- The technology used to record temperature is likely to be variable between Trusts, with some having modern systems that digitally record and monitor temperature, whilst others may simply have a thermostat on the wall that is manually read.
- Where a Trust has recorded zero overheating occurrences in the survey, it is unclear if the Trust actually had no overheating incidents, or the data was simply not provided.

Data for the year 2018-19 is not expected to be published until autumn 2019. However the results, once published, should provide an indication into the number of NHS Trusts and buildings that experience overheating, following the extremely hot summer of 2018, which has been recognised as the joint hottest on record for the UK as a whole[61]. For example, a news report from Huffington Post[62] suggested that a fire alarm at a hospital in Hampshire went off after a glass stairwell reached temperatures of 50°C; whilst reports from nurses indicated that some hospitals were getting so hot that patients and relatives were passing out and vomiting (according to the Royal College of Nursing); as well as reports of wards with no air conditioning experiencing temperatures in excess of 30°C, despite the hospital being built in the 21st century.

These findings are broadly in line with what might be expected, with summer 2016 being warmer than 2017; and summer 2018 being considerably hotter than both 2016 and 2017. The Met Office assessment of the weather experienced across the UK during each of these summers (June, July and August), compared with the 1981 to 2010 average, confirm:

- 2016 summer (FY 2016-17) was the second warmest summer since 2006, with a mean UK temperature of 14.9°C (0.6°C above average) and 475 hours of sunshine (94% of average), but the positive anomaly was larger by night than by day. There was a short but marked heat-wave in the third week of July[63].
- 2017 summer (FY 2017-18) was slightly warmer than average (largely due to a warm June) and was rather wet, with rainfall above average for the UK in each individual month. The mean UK temperature was 14.7°C (0.4°C above average) with 480 hours of sunshine (95% of average)[64]
- 2018 summer (FY 2018-19) was the equal warmest on record for the UK with most of the summer dominated by warm and largely sunny weather with temperatures well above average for much of the time with numerous days bringing readings above 30°C somewhere in the UK. The mean UK temperature was 15.8°C (1.4°C above average) with 625 hours of sunshine (124% of average)[65].

3.1.3.2 Care Homes

There has been relatively little in the way of data collected on the occurrences and impacts of overheating in care homes. Whilst there is anecdotal evidence of overheating being an issue in some NHS facilities and in care homes, the extent of this problem is not currently well understood[66]. ADAS (2017) outlined some of the most recent research, whereby one study had assessed overheating in care homes through four case studies in England (Gupta and Gregg, 2017; Gupta et al., 2017).

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[61] https://www.metoffice.gov.uk/news/releases/2018/end-of-summer-stats

[62] https://www.huffingtonpost.co.uk/entry/patients-and-nurses-are-being-put-at-risk-as-hospitals-overheat-on-hottest-day-of-the-year_uk_5b55cf99e4b0de86f48edad5?guccounter=1&guce_referrer_us=aHR0cHM6Ly93d3cuYmluZy5jb20vc2VhcmNoP3E9b3ZlcmhlYXRpbmcraW4raG9zcGl0YWxzJnFzPW4mZm9ybT1RQlJFJnNwPS0xJnBxPW92ZXJoZWF0aW5nK2luK2hvc3BpdGFscyZzYz0xLTI0JnNrPSZjdmlkPTgyQjg5ODZBNEZFMTRFMkRCREFBQkQyNDI3ODE1OTBB&guce_referrer_cs=iuYPuMnbwGNtFRDxTR20Qw

[63] https://www.metoffice.gov.uk/climate/uk/summaries/2016/summer

[64] https://www.metoffice.gov.uk/climate/uk/summaries/2017/summer

[65] https://www.metoffice.gov.uk/climate/uk/summaries/2018/summer

[66] https://www.climatexchange.org.uk/research/projects/the-risk-of-overheating-in-healthcare-buildings/

Other more recent research has looked at overheating in hospital care facilities in Scotland. The study by the Building Research Establishment (BRE), commissioned by ClimateXChange, assessed how extensive existing internal temperature data could be used to inform possible future research on the potential impacts of overheating in buildings housing vulnerable people in Scotland (BRE, 2018). The study considered five sample hospitals with in-patient facilities to assess internal temperatures in care facilities. This was conducted through questionnaires, on-site surveys and investigation and analysis of suitable data at the sites. Whilst anecdotal evidence of overheating was identified in the research, the study found a significant lack of data that would enable a robust assessment of overheating in in-patient areas; noting that it may not be appropriate to link common overheating 'issues' to common hospital archetypes, due to the complex, and in many cases, site specific nature of thermal comfort and overheating issues in hospital buildings[67].

There is little in the way of robust, evidence-based data, overheating in care facilities is recognised as a potential problem, particularly as the climate warms. Public Health England published some new awareness guidance in 2017, "Beat the Heat", which aims at keeping residents safe and well in hot weather (PHE, 2017). The guidance provides a questionnaire that care home managers can complete to assess the risk for their residents. Where a risk is identified, the guidance signposts the manger to the Heatwave Plan for England and associated guidance.

*3.1.3.3 **Summary***

For hospitals, the ERIC survey provides the best data currently available to form the basis of an indicator. The ERIC dataset is generally considered the primary source of data on NHS Trust Estates, however, new questions (such as the overheating occurrences) should be considered 'experimental data'. This is due to the considerable uncertainty with this data, methodology and representativeness, as discussed above. Therefore the dataset is not considered robust to draw any firm conclusions, particularly as there are only a couple of years of data and NHS Trust Estates experience of providing the data is new, and therefore subject to mistakes and misinterpretation. It is expected that this data will be made available annually (whilst the questions are included within the ERIC survey) and will become more robust and representative as the Trusts get familiar with the guidance and method to provide the data. Further down the line, it is anticipated that the dataset may provide relatively good insight and trends into the number of overheating occurrences experienced within NHS Trusts each year in England, once the requirement becomes more familiar to Trusts and methods or recording the data are improved. However, due to the discussed issues in terms of interpretation of the guidance, technology used to monitor temperature etc. it may be that trends within individual Trusts (across years) is more meaningful than comparisons between Trusts, or considering all Trusts together.

For care homes and surgeries, no known datasets are available and the current evidence base is reliant on ad-hoc research. Insight into the number of care homes and surgeries that experience overheating is subsequently poor, and whilst research demonstrates it is a problem in small studies, the relevance and extrapolation for all of these buildings across England is not possible.

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[67] https://www.climatexchange.org.uk/research/projects/the-risk-of-overheating-in-healthcare-buildings/

3.2 Number of homes with property-level flood protection

Description: *Number of households in flood risk areas retrofitting property-level flood protection measures*

Type: *Action*

3.2.1 Introduction

Heavy rainfall can lead to flooding, which can cause damage to homes and businesses. Property level protection (PLP) and property level resilience (PLR) measures can help reduce the risk of water getting into homes and businesses, and reduce the impact of the flood water if it does get in[68].

Protection measures can include flood boards and doors, air brick covers, non-return valves, pumps, and toilet bungs. These are all measures which will reduce the risk of water getting into a property. Additional considerations include ensuring that pointing is well maintained below ground and that cable entries are sealed.

Resilience measures can include using porous plaster, fitting solid floors or tiled floor coverings, and raising electrics above likely water levels (e.g. in areas prone to flooding). These actions aim to minimise the amount of damage caused during a flood event.

This indicator assesses the evidence base to understand the number of homes with property-level flood protection.

3.2.2 Data and information availability

There is little publically available data on the number of homes with PLP, with no known datasets that provide annual time series on the number of properties that have PLP. However, the Environment Agency (EA) provide some estimations.

The data used in this analysis was provided by the EA for three time periods, including measured data for financial years 2015-16 to 2017-18, and forecast data for 2018-19 to 2020-21, and April 2021 onwards. The data for 2015-16 to 2017-18 is sourced from the EA's extensive programme of PLP schemes, whereby the figures relate to homes on the scheme with a PLP project code, plus instances of where homes have benefitted from PLP within schemes that have a non-PLP project code. These have been quality assured by EA area teams. The figures for 2018-19 onwards are based on forecasts in the Environment Agency's FCRM1 programme, for schemes with PLP project codes. For these forecasts, data is not included on PLP benefits within other schemes. For figures relating to April 2021 onwards, the EA note that there is no fixed end date to this time period. The EA programme profiles out schemes indefinitely to the future, although the level of detail for data in the far future years are liable to change and develop as time goes on.

The data therefore provides an indication into the number of properties that implemented PLP through the relevant schemes, rather than a representative example of the total number of properties that benefited from PLP in England, due to the limitations of the dataset. For example, the data does not capture PLP within recovery grants, whereby households may have installed PLP after a flooding event. Furthermore, households that implemented their own PLP or PLR measures are not captured within this dataset.

[68] https://nationalfloodforum.org.uk/about-flooding/reducing-your-risk/protecting-your-property/

Additional insight on PLP and PLR was obtained through consultation with a representative at the National Flood Forum.

3.2.3 Evidence base and implications for climate resilience

The data from the EA PLP schemes and other Risk Management Authorities (RMAs) indicate that 1,245 additional properties have benefitted from property level protection in the period 2015-16 to 2017-18 (Table 3-1). In the following period (2018-19 to 2020-21), it is estimated that 650 properties will take out schemes to improve PLP. The reason for fewer schemes taking out funding to deliver PLP in this second period is because most of the PLP schemes have been front loaded on the six year capital programme. From April 2021, an additional 6,951 properties are envisaged to implement PLP within the various schemes, although this is liable to change as there is much less confidence in the figures for beyond 2021.

Table 3-1 – The number of homes benefiting from property level flood protection for EA schemes and other Risk Management Authorities schemes. Source: Environment Agency.

Authority	2015-18	2018-21	2021-beyond
EA	532	378	3,549
Other RMAs	713	272	3,402
Total	**1,245**	**650**	**6,951**

The National Flood Forum (2018) highlight that PLP can be important for health and wellbeing, as having property level resilience can help people psychologically as it gives them a sense of security. However, these benefits can often be misplaced if the resilience measures fail further down the line, e.g. the PLP's design / operating parameters are exceeded due to a larger flood event occurring than the PLP was designed to protect against. There can also be challenges around the cost of property level resilience products; with many products being ineffective unless the full package is installed (for example just installing a flood door is unlikely to have much impact, but installing air brick covers, non-return valves and pumps together will have greater effect).

Funding is often a barrier to households taking up PLP, with investments largely being required of the property owners themselves. However, there is some evidence of government grants being made available for resilience measures[69]. One example was following Storm Desmond and Storm Eva in December 2015, where grants of up to £5,000 per property where made available for those householders and businesses impacted. The fund was available for measures which would *'improve a property's resilience or resistance to damage from flooding, over and above repairs that would normally be covered by insurance… The resilience grant provides an opportunity for those who have been flooded to better prepare their homes for future floods, both to prevent flood water from entering the property and to speed up the recovery if it does so'*[70].

[69] http://www.smf.co.uk/wp-content/uploads/2018/03/SMF-Incentivising-household-action-on-flooding_web-14-03-2018.pdf

[70] https://www.bitc.org.uk/sites/default/files/berg_-_property_level_flood_resilience_local_authority_guidance.pdf

3.3 Particulate or other pollution episodes linked to severe weather

Description: *Particulate or other pollution episodes linked to severe weather (e.g. wildfires, hot and dry conditions)*

Type: *Exposure*

3.3.1 Introduction

Particulate matter (PM) can originate from both man-made and natural sources and contains a range of chemical compounds made up of many solid and liquid materials of variable size. PM is classified according to its size, with the most commonly used measurements being PM_{10} and $PM_{2.5}$. PM_{10} is the concentration of particles that are less than or equal to 10 µm in diameter, with $PM_{2.5}$ describing the concentration of particles that are less than or equal to 2.5 µm in diameter[71].

$PM_{2.5}$ can be harmful to human health, with both short and long term exposure being linked to respiratory and cardiovascular illness and, in severe cases, death[71]. The Air Quality Expert Group (AQEG, 2005) indicates that the available evidence suggests that it is the fine components of PM_{10}, which have a diameter of 2.5 µm or less and are formed by combustion, that are the main cause of the harmful effects of particulate matter. These fine particles consist of carbon, trace metals (such as copper and zinc) and organic compounds.

Whilst PM is often associated with pollution in cities from e.g. vehicle emissions, severe weather can also cause and/or exacerbate PM events. For example, hot and dry conditions can increase the risk of wildfires, which can be a source of particulate matter. Increased hot and dry weather due to climate change is expected to lead to more frequent moorland fires in the UK[72], and increase the risk of grassland and forest fires. Wildfires can create extensive and long-lasting air pollution events which have large impacts on public health, industrial productivity and transport systems[72].

This indicator looks at particulate pollution linked to severe weather and in particular from wildfires.

3.3.2 Data and information availability

The Defra UK Air database[73] contains substantial amounts of data for different pollutants at numerous monitoring sites across the UK. Daily mean $PM_{2.5}$ concentration was collected for Automatic Urban and Rural Network (AURN) sites in the North West of England from May to October 2018 using the Data Selector page of the Defra UK Air site[74]. The locations of these monitoring sites were around Liverpool, Blackpool, Preston, Wigan, Warrington and Manchester. The data from these monitoring sites was compared against dates of major wildfires in the North West of England in 2018 to determine the impact of wildfires on particulate pollution.

Following initial screening, just the three closest Defra UK Air monitoring sites (Wigan Centre, Salford Eccles, and Manchester Piccadilly) to the Winter Hill and Saddleworth Moor

[71] https://uk-air.defra.gov.uk/assets/documents/reports/aqeg/pm-summary.pdf
[72] https://www.ncas.ac.uk/en/18-news/2926-scientists-take-to-the-skies-to-measure-emissions-from-yorkshire-moors-fires
[73] https://uk-air.defra.gov.uk/
[74] https://uk-air.defra.gov.uk/data/data_selector

wildfires were subsequently assessed, as the other monitoring stations showed no notable spikes in the data records, likely attributable to distance from the fire sources.

Information on the distribution and extent of the wildfires was sourced from news articles and web pages.

3.3.3 Evidence base and implications for climate resilience

The summer of 2018 was a particularly hot and dry summer. This likely contributed to more favourable conditions for the outbreaks and severity of wildfires, including two major wildfires in the summer of 2018 that were declared as major incidents in the North West of England, as well as several smaller wildfires in various parts of England. In this analysis, we concentrate on these two major incidents:

Saddleworth Moor[75]

'The fire first broke out on Saddleworth Moor, between Sheffield and Manchester, on 24 June 2018, but that fire was extinguished later that same day. The next day, pockets of the fire re-ignited, perhaps from burning of peat which had dried out deep; this began to burn out of control from 26 June, and a major incident was declared that day. By 27 June, the moorland fire had grown to cover over 2,000 acres (810 ha) and remained uncontained.

Satellite imagery showed smoke drifting towards Sheffield and Leeds on 25 June, before the wind direction changed and the smoke cloud was redirected over Manchester and towards Liverpool on 26–27 June. As a result, air quality levels across Greater Manchester dropped due to smoke and ash drifting across the city from the fire, forming a widespread haze at ground level. After three weeks, on 18 July, it was declared the fire was extinguished.

The Saddleworth Moor fire has been described as the largest English wildfire in living memory'.

Winter Hill[76]

'A large wildfire broke out on Winter Hill, north of Bolton in Lancashire, at around 3:20 pm on Thursday 28 June 2018. Elsewhere, on the 29 June at 2 am other wildfires started near Horrocks Moor Farm, on Scout Road in Bolton. On 30 June it was reported this fire had merged with the fire on Winter Hill, and as result the two official fire incidents became one and a major incident was declared.

The fire was brought under control on 16 July, in total it had spread over 7 square miles (18 km^2). The fire service said there was "still significant work to do" as peat was still burning underground and despite some rainfall even by 23 July the fire was not fully out'.

Figure 3.2 shows the locations of the Saddleworth Moor and Winter Hill fires. The three closest monitoring sites to the two fires are Manchester Piccadilly, Salford Eccles, and Wigan Centre, which are all located to the West of Saddleworth Moor.

[75] https://en.wikipedia.org/wiki/2018_United_Kingdom_wildfires#Saddleworth_Moor
[76] https://en.wikipedia.org/wiki/2018_United_Kingdom_wildfires#Winter_Hill

Figure 3.2 – Map showing the locations of the Saddleworth Moor and Winter Hill fires (Saddleworth Moor = red circle to the right of the map, and Winter Hill = red oval to the left of the map), and the locations of three Defra UK Air monitoring sites (blue circles from left to right: Wigan Centre, Salford Eccles and Manchester Piccadilly). Source: Google Maps imagery.

Particulate matter recorded at each of these monitoring sites is shown in Figure 3.3. The peak PM level, of 62 µg/m^3, shown in Figure 3.3 occurs on the 27th June 2018, suggesting the Saddleworth Moor fire directed smoke over Manchester on the 26-27th June, reportedly forming a widespread haze at ground level[75]. This correlates with a Guardian article[77] which reports that the 27th June was a particularly bad day for air pollution, with smoke from the Saddleworth Moor fire covering much of Greater Manchester. This supplementary information suggests that the increase in $PM_{2.5}$ seen on the 27th June 2018 within Figure 3.3 is likely associated with the Saddleworth Moor fire. The peak PM level of 62 µg/m^3 recorded at Salford Eccles is more than twice that of the UK air quality objective annual mean target of 25 µg/m^3.[78]

The effect of the Winter Hill fire does not appear to be captured within Figure 3.3. This may be because there are no Defra UK Air monitoring sites directly to the East or West of this fire, and thus prevailing wind directions may not have been in the direction required to be picked up in the monitoring stations analysed in this study.

[77] https://www.theguardian.com/environment/2018/jul/05/pollutionwatch-smoke-from-wildfires-causes-pollution-over-large-distances

[78] https://uk-air.defra.gov.uk/assets/documents/Air_Quality_Objectives_Update.pdf

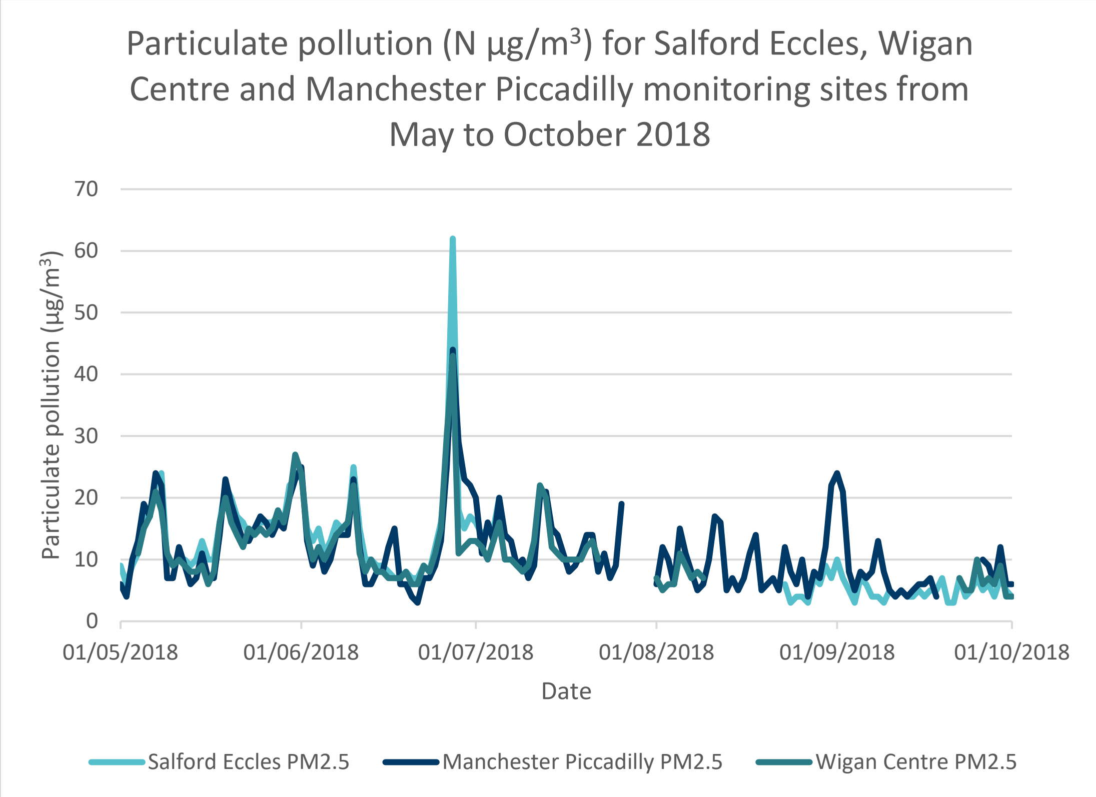

Figure 3.3 – Particulate pollution ($PM_{2.5}$) for Salford Eccles, Wigan Centre, and Manchester Piccadilly AURN monitoring sites from May to October 2018, as reported by Defra UK Air. Source: ADAS for the CCC.

The Defra UK Air dataset is deemed to be robust. However, the location of monitoring stations and the applicability of correlating these with severe weather-driven events, such as wildfires, is problematic and attribution above the noise of other pollution is uncertain.

3.4 Climate-sensitive pathogens and vectors

Description: *Distribution and spread of climate-sensitive pathogens or vectors across England or Europe*

Type: *Exposure*

3.4.1 Introduction

There are several vector-borne diseases which have been emerging into Europe in recent years. These include: vivax malaria; West Nile fever; dengue fever; Chikungunya fever; leishmaniasis; Lyme disease; and tick-borne encephalitis (Baylis, 2017). The vectors of these diseases are mosquitoes, sand flies, and ticks. Warmer temperatures would increase the suitability of the UK's climate for these species; hence increasing the risk that they may spread disease (Baylis, 2017).

This indicator looks at the distribution of ticks, mosquitos and sand flies across the UK and Europe.

3.4.2 Data and information availability

Ticks are widely monitored in the UK, with tick maps by Public Health England[79], and from the 'Big Tick Project' survey[80] available. Cull *et al.,* (2018) have published a paper on the surveillance of British ticks, and within this have used data from the Biological Records Centre (BRC) and Tick Surveillance Scheme (TSS) to provide an updated map including data from 1878 to 2016. This is included within section 3.4.3. Laboratory confirmed cases of Lyme disease are also recorded for England and Wales from 2001 to 2017[81]. It should be noted that these laboratory confirmed cases do not include cases which are diagnosed on the basis on clinical features without laboratory testing; for example where cases are diagnosed and treated following the early rash of Lyme disease. Public Health England therefore estimate that there are likely to be a further 1,000 to 2,000 cases of Lyme disease each year in addition to those which are laboratory diagnosed[81].

The European Centre for Disease Prevention and Control (ECDC) and European Food Safety Authority (EFSA) publish regular maps[82] which show the distribution of mosquitos and other vector, including ticks and sand flies across Europe. These show areas where species are established, introduced, absent, where information is unknown or there is no data based on the ECDC's knowledge of the distribution at given time points.

In this analysis we assess the evidence across these data sources to provide an update of climate-sensitive pathogens or vectors across the UK and Europe.

3.4.3 Evidence base and implications for climate resilience

3.4.3.1 *Ticks*

The total laboratory confirmed cases of Lyme disease in England and Wales has increased by 490% from 268 in 2001 to 1,579 in 2017, shown in Figure 3.4. This is slightly higher than the percentage increase in the mean annual rate per 100,000 population, which increased by 440% from 0.5 in 2001 to 2.7 in 2017. There was a slight decrease in instances of Lyme disease (*Ixodes ricinus)* during 2014 before a 40% increase (the steepest increase seen across all years) in the number of instances of Lyme disease between 2016 and 2017. It is not clear if this increase is associated with an increase in the actual number of cases of Lyme disease instances, or an increase in the number of those being tested through heightened media awareness of Lyme disease and the symptoms (e.g. celebrities sharing their stories). There are estimated to be a further 1,000 to 2,000 cases of Lyme disease each year in addition to the laboratory confirmed cases[81].

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[79] https://www.gov.uk/government/publications/ticks-distribution-of-ixodes-ricinus-in-england-scotland-and-wales

[80] http://www.bigtickproject.co.uk/ticks-in-the-uk/uk-tick-threat-map/

[81] https://www.gov.uk/government/publications/lyme-borreliosis-epidemiology/lyme-borreliosis-epidemiology-and-surveillance

[82] https://ecdc.europa.eu/en/disease-vectors/surveillance-and-disease-data

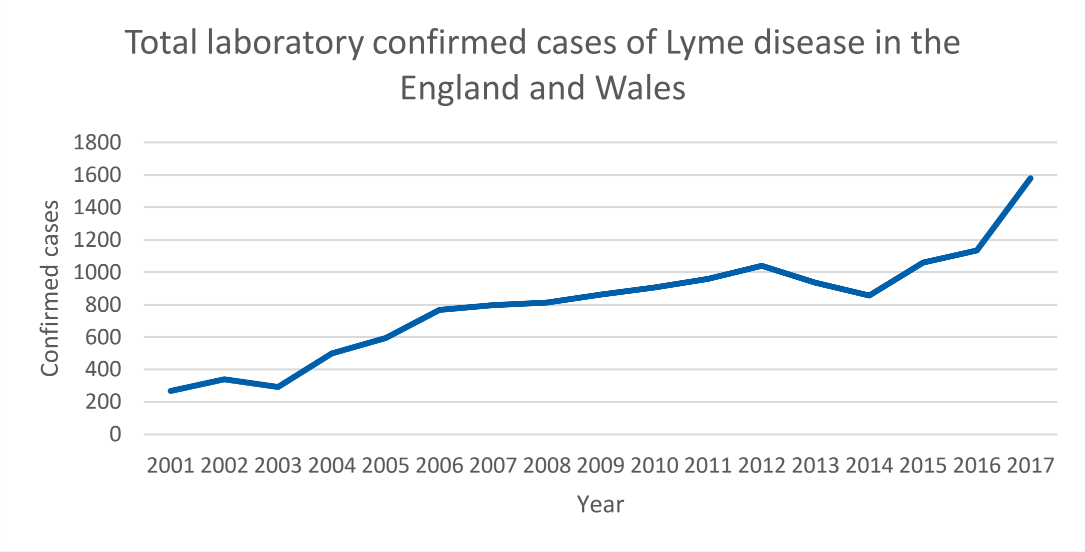

Figure 3.4 – The total number of laboratory confirmed cases of Lyme disease in England and Wales for 2001 to 2017, as reported by Public Health England[81]. Source: ADAS for the CCC.

Baylis (2017) notes that Lyme disease is increasing in incidence in Europe which could be due to the influence of climate on ticks. This is supported by recent changes in Sweden, where an increase in tick density and spread to higher latitudes has been linked to milder winters as a result of climate change. However, Baylis (2017) also recognises that non-climate drivers such as agriculture, land use, tourism and wild animal populations may have a more dominant influence on the incidence and distribution of Lyme disease than climate related factors.

Other tick species, such as *Hyalomma*, which are currently limited in the UK due to cooler climate and precipitation volumes preventing establishment, may be able to survive in the future if there is a warmer or drier climate in the UK as a result of climate change[83]. This tick species transmits haemorrhagic fever and is imported to the UK via migrating birds from sub-Saharan Africa.

A study by Cull *et al.,* (2018) looked at how the distribution of ticks has changed over the period from 1878 to 2016. As shown in Figure 3.5 and Figure 3.6, the distribution and density of ticks has increased from pre 2005, to 2016, which may have contributed to an increase in the number of confirmed cases of Lyme disease, shown in Figure 3.4, along with increased media coverage etc.

In 2016, the cumulative percentage of 10 km grid squares with ticks present was highest for Greater London (80% of 10 km grid squares), the South East (67% of 10 km grid squares) and the South West (65% of 10 km grid squares).

[83]http://researchbriefings.files.parliament.uk/documents/POST-PN-0545/POSTbf16_Climate_Change_and_Infectious_Disease_in_Humans_in_the_UK.pdf

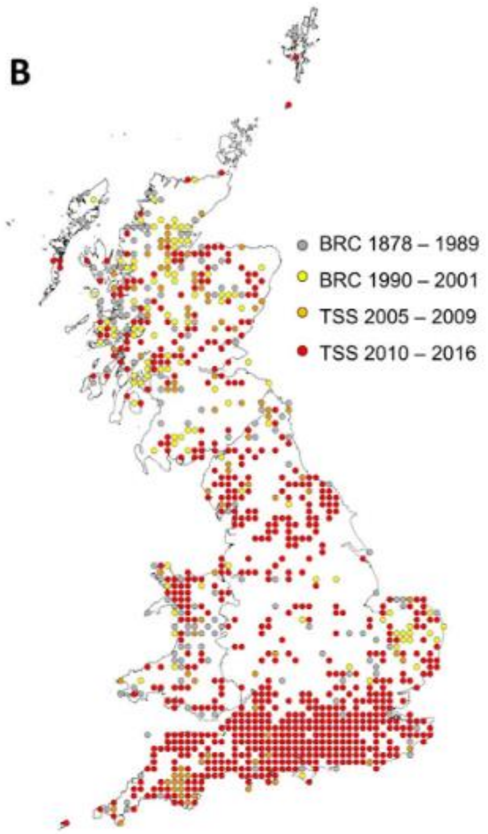

Figure 3.5 – The distribution of ticks in the UK including Biological Records Centre (BRC) data for 1878-1989 and 1990-2001, and Tick Surveillance Scheme (TSS) data for 2005-2009 and 2010-2016. More recent records are overlaid on top of older records. Source: Cull *et al.,* (2018).

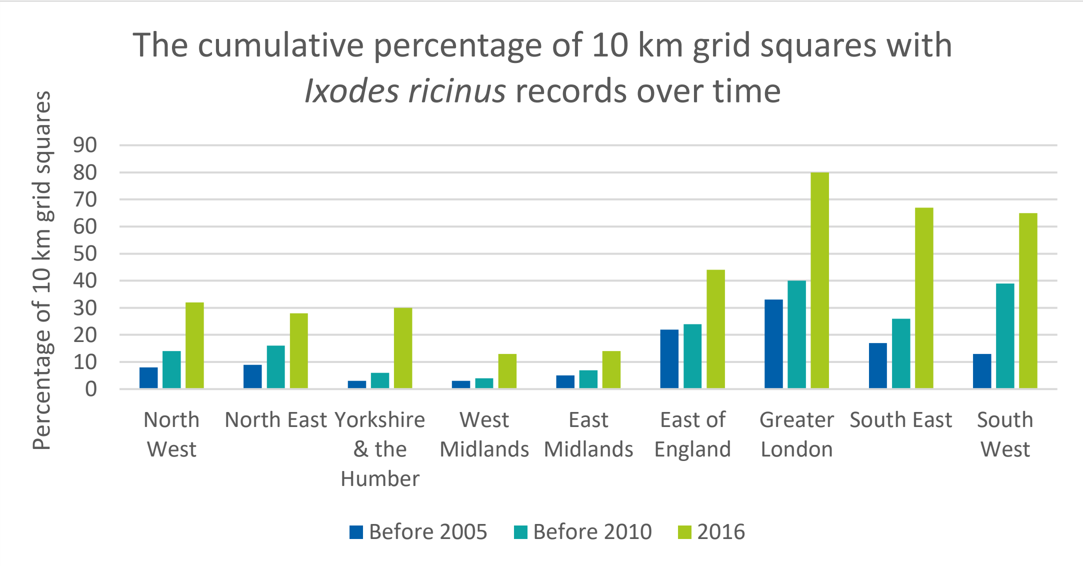

Figure 3.6 – The regional distribution of ticks, showing cumulative percentage of 10 km grid squares with *Ixodes ricinus* records over time. Before 2005 is derived from BRC data (1878-2001); before 2010 is derived from BRC and TSS data (2005-2009), and 2016 is derived from BRC and TSS data (2005-2016). Percentage figures are as reported in Cull *et al.,* (2018). Source: ADAS for the CCC.

This data will have been impacted by the number and location of those who participated in the tick surveillance survey. For example, if low numbers participated from a particular region, the figures for this region may not be fully represented. Therefore this data is only considered to be moderately robust as increases could be attributed to increased participation in the survey rather than occurrence of the ticks.

3.4.3.2 Mosquitoes

Maps of *Aedes japonicus* (August 2018), *Aedes albopictus* (June 2018), *Aedes koreicus* (June 2018), *Aedes aegypti (*June 2018), and *Aedes atropalpus* (June 2018) were downloaded from the ECDC website[82].

The map for *Aedes albopictus*, the Asian tiger mosquito, Figure 3.7, shows that this mosquito is introduced (without confirmed establishment) in a small area in the far South East of England. This was detected in September 2016 in Kent, close to the Eurotunnel. This mosquito is an invasive species which can transmit dengue, chikungunya and zika virus. As the map indicates, this species is widely established in Europe.

The maps for the other mosquitos listed above show green (absent) for the UK.

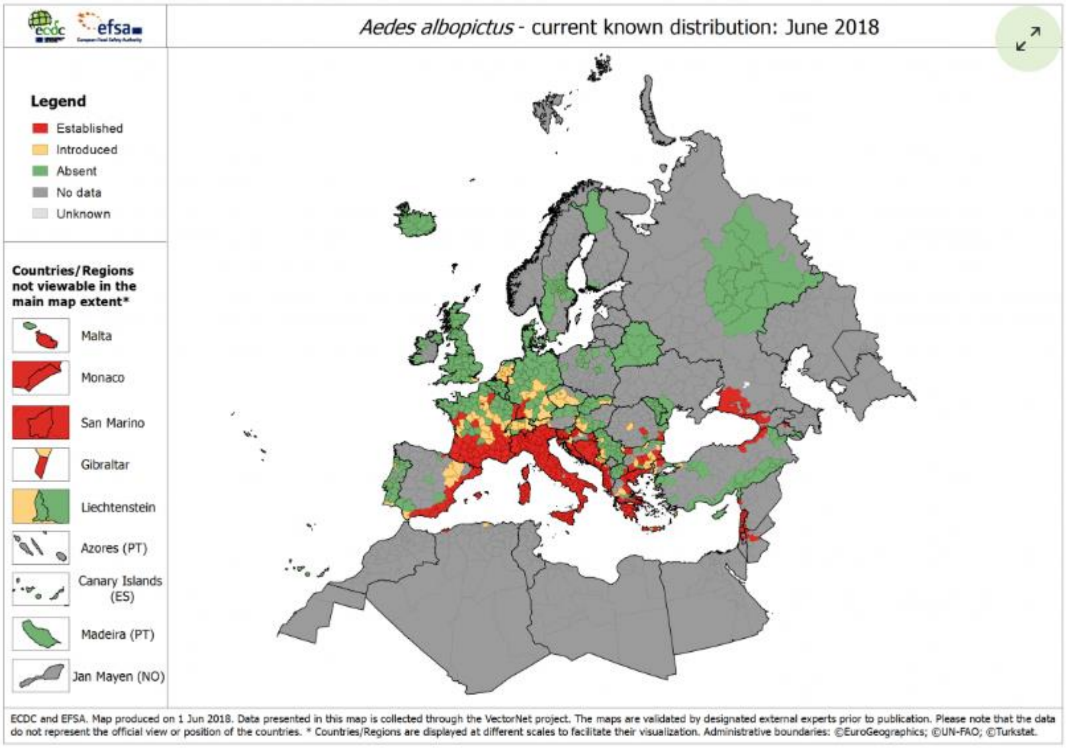

Figure 3.7 – Distribution map of Aedes albopictus, the Asian tiger mosquito, in June 2018. Source: ECDC (2018)[84].

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[84] https://ecdc.europa.eu/en/publications-data/aedes-albopictus-current-known-distribution-june-2018

3.4.3.3 *Sand flies*

The ECDC publish maps for the distribution of *Phlebotomus* sandfly species[85] in Europe. Maps are published for the distribution of each of the following species: *Phlebotomus ariasi*, *Phlebotomus neglectus*, *Phlebotomus papatasi*, *Phlebotomus perfiliewi*, *Phlebotomus perniciosus*, *Phlebotomus sergenti*, *Phlebotomus similis*, and *Phlebotomus tobbi*. These maps were last updated in May 2018 and on visual inspection show as green (absent) for the UK.

Whilst not present in the UK at the moment, with milder temperatures and increased precipitation, the range of sand flies may increase in Europe; resulting in them being able to survive in areas where they cannot at present[86].

3.5 Exotic fruit crops grown

Description: *Number of farms and area of exotic fruit crops grown*

Type: *Realising Opportunity*

3.5.1 Introduction

Climate change in the UK is expected to present opportunities, as well as risks. The CCC (2017) note that UK agriculture and forestry may be able to increase production with warmer weather and longer growing seasons, and whilst uncertain, some crops and tree species may also benefit from increased CO_2 availability. Increased temperatures and reduced frost day's presents an opportunity for some farms to grow new and exotic crops, which were previously not deemed climatically suitable for UK agriculture. One example is grape vines and wineries, which have been growing rapidly in popularity in recent years.

The evidence base and realised opportunities from growing exotic fruit (e.g. avocados, banana, dates and gigs, melons, pineapples, apricots, kiwi etc.) and citrus fruit (lemons, limes, oranges etc.) is not well-documented in the UK. Whilst some exotic and citrus fruit is currently (and may well continue to be) unsuitable (both climatically and financially) for production in the UK, some fruit (e.g. apricots) have potential for increased growth. Here we briefly assess the current known evidence base.

3.5.2 Data and information availability

There are currently no known datasets that provide detailed, annual information on the production of exotic and citrus fruit crops in England. The most comprehensive dataset on horticultural crops is Horticulture statistics[87], an annual statistical publication by Defra on the area, yield, production, trade and valuation of fruit and vegetable crops grown in the UK. Data is not currently collected on citrus and exotic crops, as they are not grown in quantities to merit their collection. If these crops were to become more significant in the future, data 'could' be collected through the June Survey of Agriculture[88]. However, there are no plans for this in the foreseeable future.

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[85] https://ecdc.europa.eu/en/disease-vectors/surveillance-and-disease-data/phlebotomine-maps

[86] https://ecdc.europa.eu/en/disease-vectors/facts/phlebotomine-sand-flies

[87] https://www.gov.uk/government/statistics/latest-horticulture-statistics

[88] https://www.gov.uk/agricultural-survey

For this indicator, we provide some ad-hoc insight into exotic and citrus crops grown in the UK, as reported in news article publications, to provide understanding of the current evidence base.

3.5.3 Evidence base and implications for climate resilience

There is very limited data and information on exotic and citrus crops grown in the UK. However, insight can be gleaned through case study examples.

A news article 'Global warming means exotic fruits now being grown in Britain' in the Independent in 2016 noted that an agricultural revolution had been gaining momentum in the fields of southern England with climate change meaning apricots, peaches and all manner of exotic crops are springing up in a way unimaginable just a generation ago. The article reported that Britain's first ever crop of sweet, seedless "table" grapes were due to hit supermarket (ASDA) shelves in the autumn of 2016. Other crops reportedly being grown in Britain included tea, sunflowers, sweet potatoes, water melons and walnuts[89].

Other supermarkets have also reported sourcing exotic crops from British soils. Tesco were the first UK retailer to start selling English grown apricots[90] and started working on a production partnership with one of the UK's largest stone fruit producers from Kent back in 2010. Apricots typically flourish in continental climates with cold winters, but without spring frosts (e.g. Spain, France, Morocco, Turkey and Iran). However, the arrival on the market of apricot cultivars or tree hybrids bred especially for climates like the UK's (i.e. that would flower later in the spring), have made English apricot production possible in some southern regions. Combined with climate projections for warmer summers and reduced frost days, the prospect of growth in these crops is expected to increase.

It is anticipated that a wider range of exotic crops, grown in the UK, will increase over the coming decades, with more retailers looking to source locally grown produce. However, the scale of this increase will be difficult to monitor unless key statistics are collected and reported within the industry.

3.6 Agricultural or timber losses from climate-sensitive pests or pathogens

Description: *Agricultural or timber losses from climate-sensitive pests or pathogens*

Type: *Realised Impact*

3.6.1 Introduction

3.6.1.1 Timber

In the UK Climate Change Risk Assessment Evidence Report, Brown *et al.,* (2016) highlight several pests and pathogens that may be influenced by climate change. Within this, there are three main pathogens which present a risk to UK timber production and/or woodland:

- *Chalara fraxinea,* also known as ash dieback, was first reported in the UK in 2012, and since 2016, has been present in all English counties at a level of 39% of 10 km

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89 https://www.independent.co.uk/environment/global-warming-means-exotic-fruits-now-being-grown-in-britain-a6842676.html

90 https://www.tescoplc.com/news/news-releases/2017/british-apricots/

squares in England (Brown *et al.,* 2016). The disease causes leaf loss, bark lesions and crown dieback; and once a tree is infected, the disease is usually fatal[91].

- *Dothistroma septosporum* causes needle blight on pine. The disease was found on 70% of Corsican pine stands inspected in 2006 in Great Britain, and is spread by moist winds and mists[92]. It is estimated that 44% of infected stands have crown infection levels greater than 30%[92].
- *Phytophthora ramorum* was first found to be infecting larch in south-west England in 2009. By October 2013, approximately 16,000 hectares of larch trees had been felled or were under notice to be felled because of infection[93]. Larch is the most commonly affected tree species, however, species of beech, oak, and sweet chestnut can also be hosts for this disease[94].

Also of relevance is *Ips typographus* (larger eight-toothed European spruce bark beetle). Jonsson et al (2007) suggest that climate change will affect the population dynamics of this pest directly as the swarming activity and development rate are mainly controlled by temperature, and indirectly via changes in availability of brood trees. The Forestry Commission (FC) recognise that the beetle is the most serious and destructive pest of spruce species in its Eurasian range. It is a significant quarantine pest risk in areas where spruce is native or planted (such as the UK) and whilst it is officially absent from the UK, occasional interceptions of the pest have occurred at UK ports and timber-processing yards. An outbreak of the pest in the UK could result in extensive tree mortality[95].

The FC provide an indicator on the number of high priority forest pests in the UK Plant Health Risk Register (UKPHRR). At the end of March 2018, there were 14 high priority forest pests in the UKPHRR, that require actions – in addition to mitigations already implemented – to prevent them having a potentially substantial negative impact on England's woodland. The FC report that there has been no change in the number of high priority forest pests since December 2017, shown in Figure 3.8.

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[91] https://www.forestry.gov.uk/ashdieback
[92] https://www.forestry.gov.uk/forestry/INFD-74JJFK
[93] https://www.forestry.gov.uk/forestry/infd-9jvavq
[94] https://www.forestry.gov.uk/forestry/INFD-8XLE56

[95]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/761958/Ips-typographus_contingency-plan.pdf

Number of high priority forest pests in the UK Plant Health Risk Register

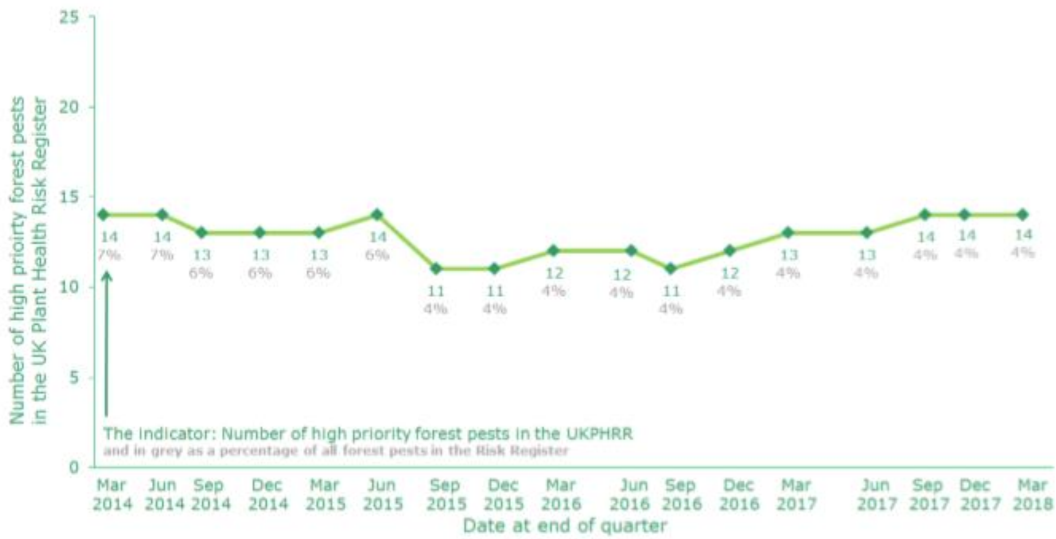

Figure 3.8 - Number of high priority forest pests in the UK Plant Health Risk Register (UKPHRR). Data originally sourced from UKPHRR data[96]. Source: Forestry Commission, 2018a.

3.6.1.2 *Agriculture*

Pests and diseases can have a significant impact on agricultural productivity, through reducing yields or causing crop failure; both of which can result in large economic impacts on farm. Climate change will have an influence on both the activity and distribution of pests and diseases affecting agriculture. However, there can be considerable difficulties in determining the impact on yield from pests and disease, given there are multiple factors which influence yields in any one year, including the weather, availability of pesticides (insecticides and fungicides), and the effectiveness of these chemicals (i.e. resistance is being found from some pests to key chemicals, making them ineffective).

Diseases which impact livestock, such as bluetongue, can also result in agricultural losses. Bluetongue is a recently emerged disease that affects sheep, other ruminants such as cattle and goats, and camelids such as llamas[97]. The first outbreak of bluetongue in Northern Europe occurred in 2006, with the disease entering the UK in 2007 (Turner *et al.,* 2012). Cattle are widely considered to be the host of the disease, with sheep often severely affected.

The agricultural indicator aims to link changes in pest and disease incidence to agricultural losses of wheat, as well as the impact of bluetongue and agricultural losses due to the disease.

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[96] https://secure.fera.defra.gov.uk/phiw/riskRegister/

[97] https://www.gov.uk/guidance/bluetongue

3.6.2 Data and information availability

3.6.2.1 Timber

There is little data available on the amount of timber that is lost as a result of pests and pathogens. Some data is available from the Forestry Commission (FC) on the prevalence of ash dieback, needle blight on pine, and *P. ramorum*.

Other pests identified as important by stakeholders, but which data was not obtained, include *Dondroctonus micans* (great spruce bark beetle) and *Ips typographus* (larger eight-toothed European spruce bark beetle).

Other climate-sensitive pests include *Elatobium abietinum* (green spruce aphid). While there have been very significant inter-annual fluctuations in its impact, no survey data are available.

3.6.2.2 Agriculture

ADAS (2017) reported on pests and diseases which may impact on losses of agricultural crops, focussing on wheat and oilseed rape. In ADAS (2017), the yield responses in the Agriculture and Horticulture Development Board (AHDB) recommended list trials for wheat were plotted against the UK average wheat yield (from data.gov.uk and Defra Farming Statistics) to show where high disease pressure corresponded to poorer yields. The yield response was calculated by finding the difference between the averages for treated and untreated yields. The yield response figures only include sites where both treated and untreated yield data was available.

This method has been repeated for winter wheat with data for 2016, 2017 and 2018 added from the AHDB Harvest Data (yield results)[98]. The percentage infection of yellow rust and septoria was also updated for 2016 to 2018 using the AHDB Harvest Data (harvest results)[98]. The data series for average UK wheat yields has been extended by using Defra Farming Statistics[99]. Oilseed rape has not been included in this analysis as yield response data was unavailable for the years 2011 to 2017.

Both UK Government and the European Commission monitor the distribution and risk of bluetongue, however, there is minimal information on confirmed livestock losses. In this analysis, we provide an evidence base based on available information.

3.6.3 Evidence base and implications for climate resilience

3.6.3.1 Timber

<u>Ash dieback (*Chalara fraxinea*)</u>

Data from the Forestry Commission[91] shows that the number of 10 km grid squares in England with one or more *Chalara* (dieback of ash) infections confirmed in the wider environment per year, increased consistently from 60 in 2013, to 310 in 2016; a 417% increase (Figure 3.9). The number of infections confirmed per year then decreased by 72% from 2016 to 2017 and continued to decrease by a further 12% from 2017 to 2018. The

[98] https://cereals.ahdb.org.uk/varieties/current-trials-and-harvest-results.aspx

[99]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766487/structure-jun2018final-uk-20dec18.pdf

number of infections confirmed in England between 2012 and 2018 totalled 1000 10 km grid squares; representing 68% of all 10 km grid squares in the country. Note that the increases indicate when infection sites were found, rather than when the fungus first arrived at the site, therefore this data should not be interpreted as an indication of the rate of spread of the disease[91].

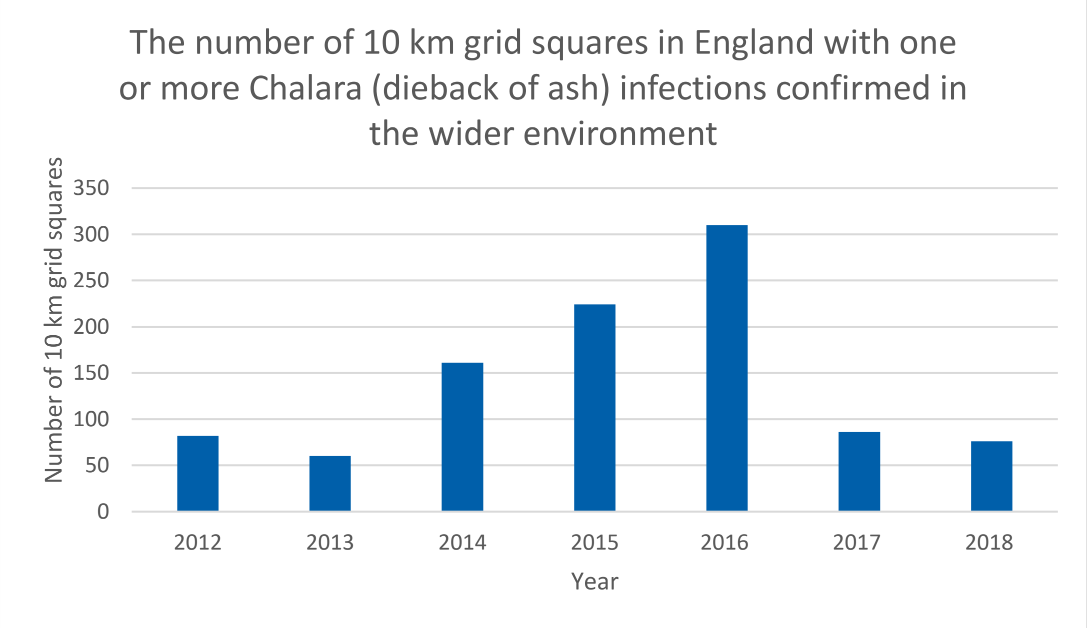

Figure 3.9 – The number of 10 km grid squares in England with one or more Chalara dieback of ash infections confirmed in the wider environment within each year from 2012 to 2018, as recorded by the Forestry Commission[91]. Note that these figures are cumulative, with 1000 10 km grid squares accounted for between 2012 and 2018. Source: ADAS for the CCC.

Figure 3.10 shows the distribution of the sites where infections of Chalara have been confirmed in England, and in which year this occurred.

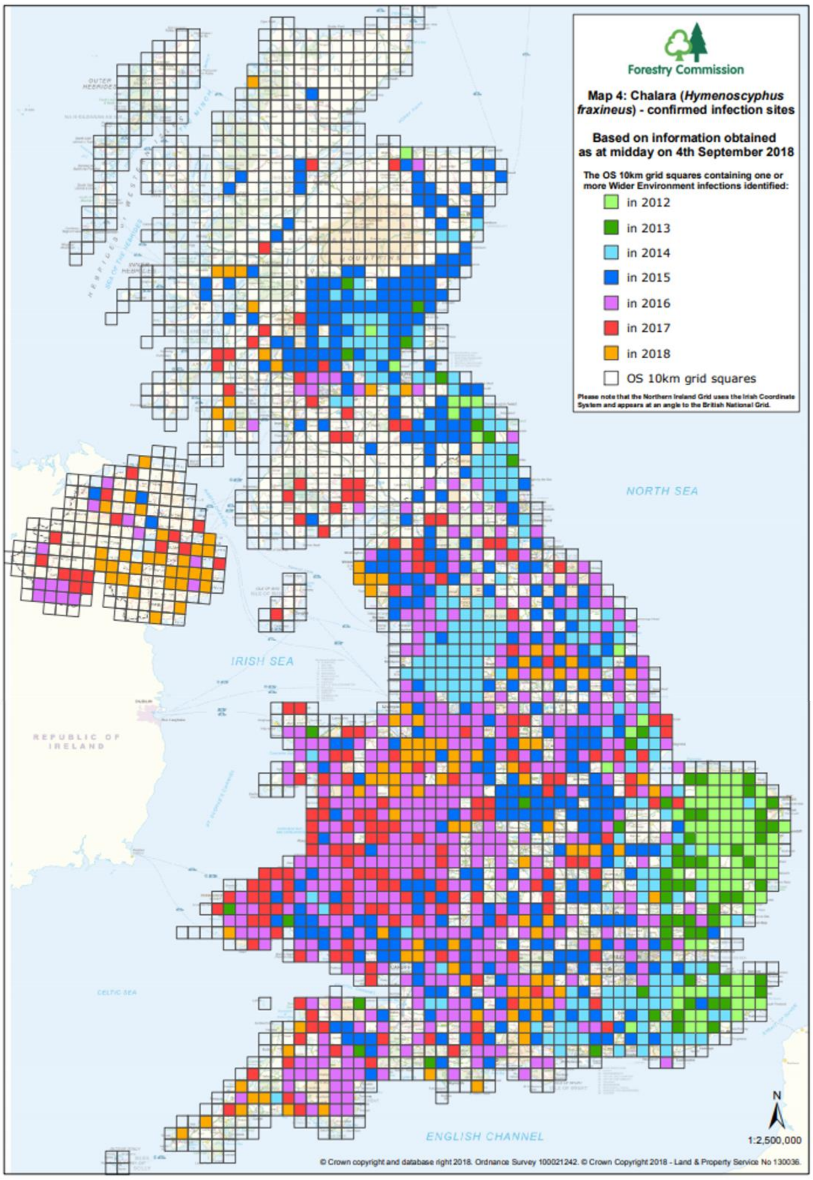

Figure 3.10 – The distribution of sites confirmed to be infected with Chalara dieback of ash, as recorded by the Forestry Commission. Source: Forestry Commission[100].

Dothistroma needle blight (*dothistroma septosporum*)

Dothistroma Needle Blight (DNB), also known as Red Band Needle Blight because of the colourful symptoms it shows on pine, is an economically important disease affecting a number of coniferous trees, in particular pines. In Britain, DNB is caused by the fungus *dothistroma septosporum* and causes premature needle defoliation that results in the loss of timber yield and, in severe cases, tree mortality (Forestry Commission, 2008).

Incidence of the disease has increased dramatically in Britain since the 1990s, particularly on Corsican Pine. Figure 3.11 shows reports of disease outbreaks of DNB up to 2007. The maps show that outbreaks in Corsican pine grew substantially from 2002 to 2007. There were also

[100]https://www.forestry.gov.uk/pdf/UK_outbreak_Map4_Web_Version.pdf/$FILE/UK_outbreak_Map4_Web_Version.pdf

outbreaks of red band needle blight on lodgepole pine in Scotland, Wales and parts of England, with localised outbreaks on other minor pine species. Note that this does not give an indication of the number of trees lost in each region, nor provide a complete record or accurate representation and/or spatial distribution of the disease.

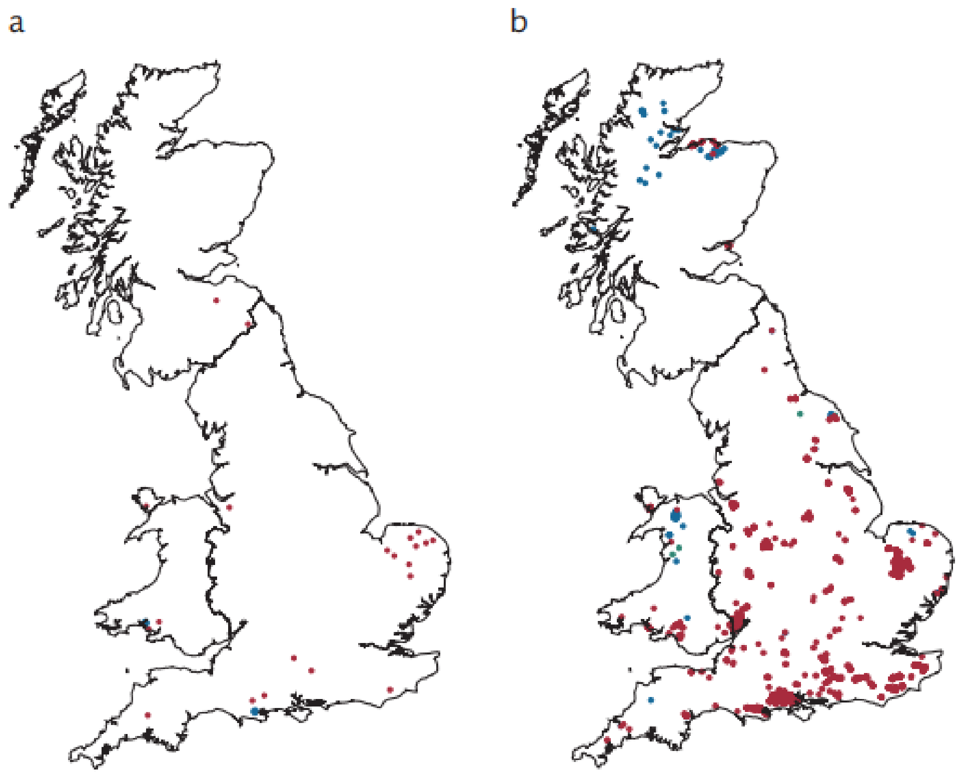

Figure 3.11 – Map showing locations of reported DNB outbreaks. Map 'a' on the left shows data from 1955 to 2002: blue indicates cases from 1955 to 1966, with red indicating cases from to 1989 to 2002. Map 'b' on the right shows data from the 2006 and 2007 surveys with records of occurrence in Corsican pine (red dots), lodgepole pine (blue dots) and minor pine species (green dots). Source: Forestry Commission (2008).

Figure 3.12 shows a more recent (2016) map for the detection of DNB in Scotland. Spread of DNB is widespread in Scotland, with eradication not considered a practicable option (Forestry Commission Scotland, 2017).

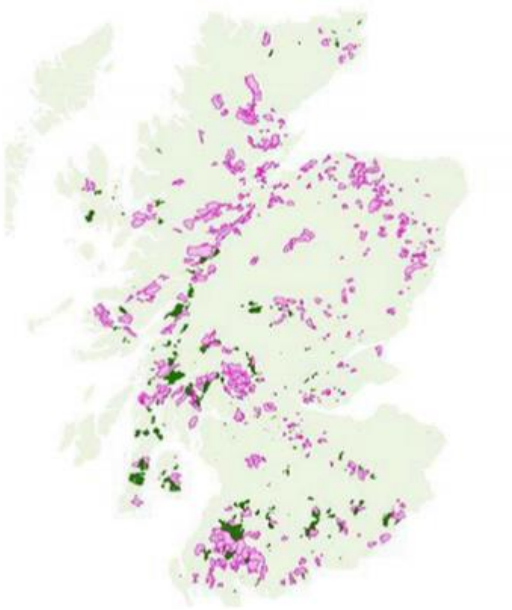

Figure 3.12 – Map showing the distribution of DNB on the Scottish national forest estate in 2016. Purple shows a presence of needle blight, with green areas representing areas where needle blight is absent. Source: Forestry Commission Scotland (2017).

In England, an extensive survey of DNB was conducted in 2014 by Plant Health England / Forestry Commission. In total, 575 sites were surveyed across five main regions in England: EEM (East and East Midlands), NWWM (North West and West Midlands), SE (South East), SW (South West) and YNE (Yorkshire and North East). Figure 3.13 show the number of sites where DNB was found to be present in the survey. The results show that 452 (78.6%) of sites surveyed tested positive for DNB, with all regions exhibiting a very high (>70%) number of sites with incidence of DNB, apart from the SE region where 31% of sites recorded positive for DNB.

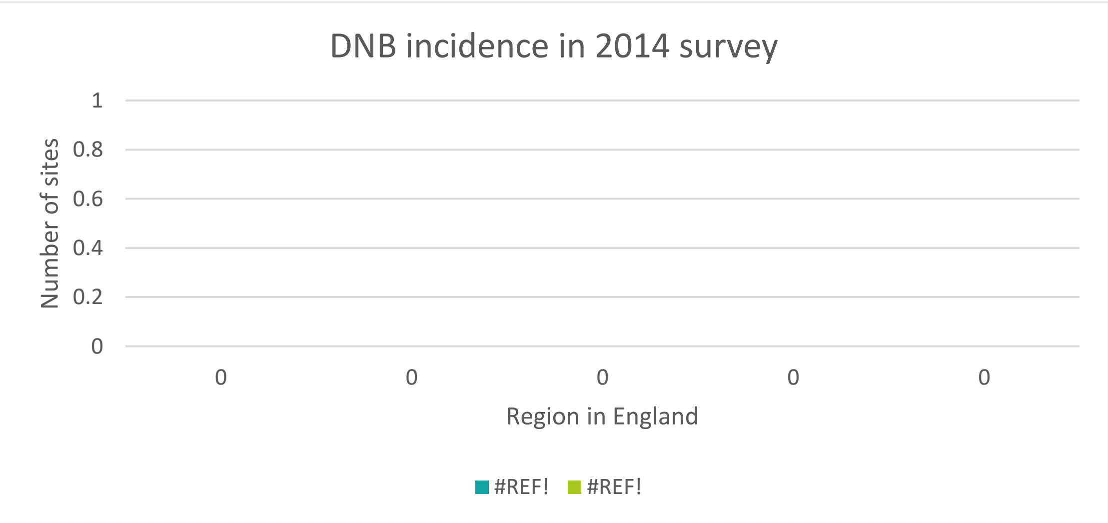

Figure 3.13 – Incidence of DNB in the extensive DNB survey conducted in 2014. The graph shows the number of sites where DNB was present (blue) and absent (green) across England: EEM (East and East Midlands), NWWM (North West and West Midlands), SE (South East), SW (South West) and YNE (Yorkshire and North East). Data provided by the Forestry Commission. Source: ADAS for the CCC.

In 2015, a further survey was conducted to evaluate known infected sites (over 1 Ha in size) to assess mortality and live needle retention in Scots Pine aged between 10 and 30 year. A total of 255 sites (of the 452 sites that showed positive for DNB in the 2014 survey) were surveyed. At each identified site an assessment of DNB mortality and needle retention on Scots Pine was conducted. Results showed an average mortality of 0.83% and average needle retention of 1.45 years. These findings form a baseline for future surveys, including a repeat of this survey conducted in early 2019 (results were not available at time of publication). It is not known if future (comparable) surveys will be conducted.

<u>Phytophthora ramorum</u>

There has been an increase in *P. ramorum* disease on trees in recent years. The red circles on Figure 3.14 show the statutory plant notices in 2017-18. These notices help prevent the spread of disease as they normally require owners to fell infected trees prior to them producing new spores in the autumn and spring. Therefore a statutory plant notice indicates a diseased tree. It is likely that this is an underestimate as the map only shows instances of disease where a statutory plant notice has been issued. Comparing this map with that used in the previous update of this indicator in ADAS (2017), there has been an increased number of statutory plant notices in 2017-18.

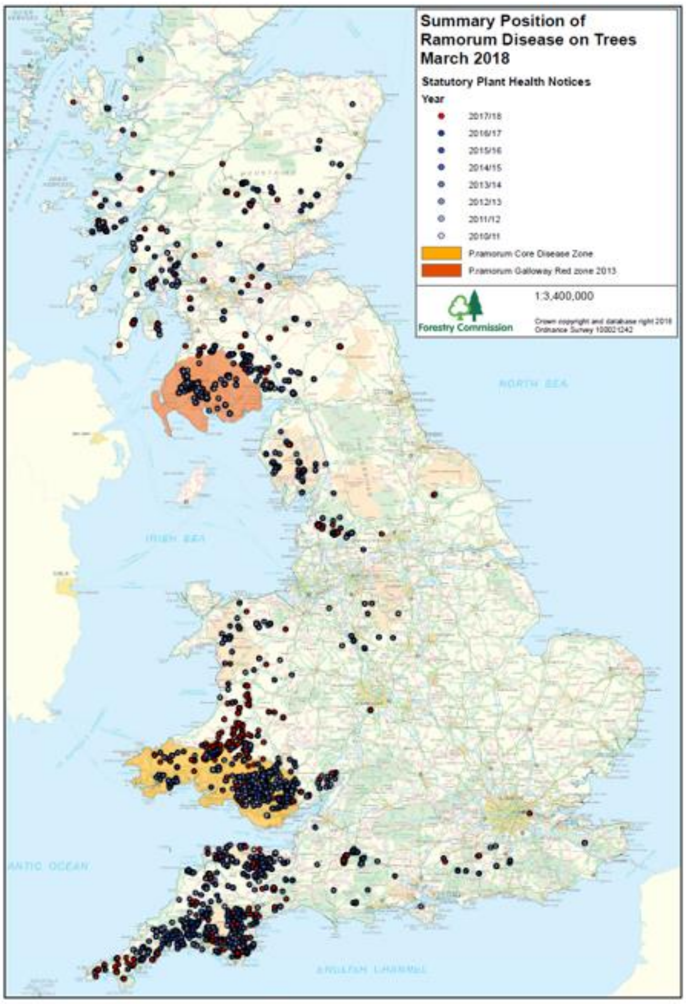

Figure 3.14 – The distribution of *P. ramorum* disease on trees (March 2018). The red dots show data from 2017-18, with the darkest blue colour showing data for 2016-17, taken from the Forestry Commission (2018b).

European spruce bark beetle (*Ips typographus*)

The FC report[101] that the larger eight-toothed European spruce bark beetle (*Ips typographus*) is considered a serious pest on spruce in Europe and has recently been found in the wider environment in England as part of routine plant health surveillance activity. The beetle is deemed to be mainly a secondary pest, preferring stressed or weakened trees, although beetle numbers can increase enough in some instances to result in attacks on living trees - under the right environmental conditions. If left uncontrolled, the beetle, in association with pathogenic fungi (particularly the blue stain fungus *Endoconidiophora polonica*), has the potential to cause significant damage to Britain's spruce-based forestry and timber industries.

To protect the country against this pest, the 'Plant Health (*Ips typographus*) (England) Order 2019' came into force on 16 January 2019. The Order allows the FC to demarcate areas around confirmed outbreak sites, and imposes movement restrictions on conifer material capable of spreading the pest using a Notice.

3.6.3.2 Agriculture

Yield response in wheat

It is almost impossible to attribute yield losses to pests, however, insight can be gleaned from diseases. To assess the impact of disease on wheat crops, average yield data was plotted against yield response to fungicide treated wheat crops, shown in Figure 3.15.

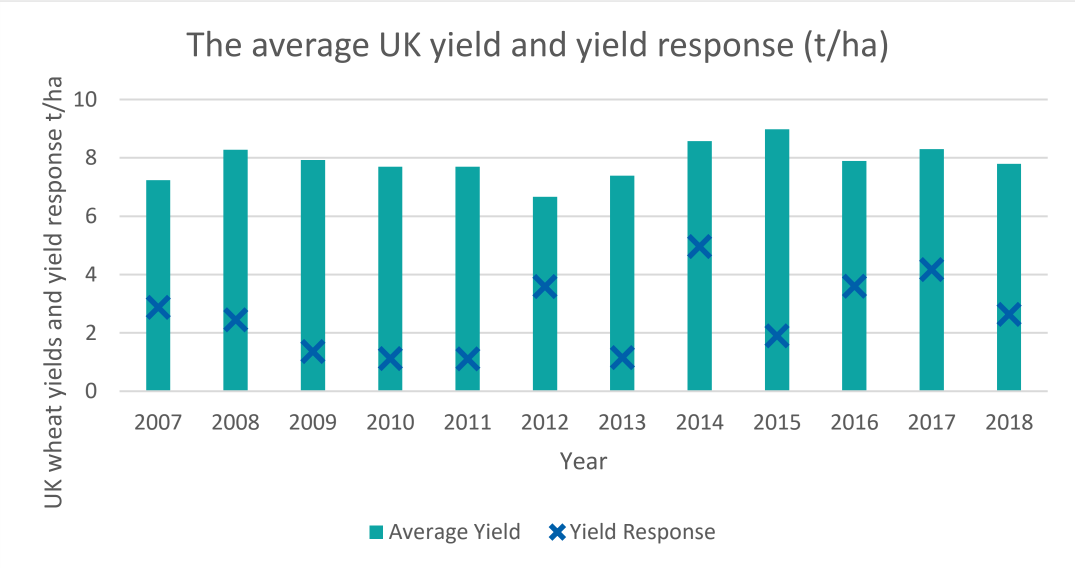

Figure 3.15 - The average UK yield, taken from gov.uk (2007 to 2013)[102] and Defra Farming Statistics (2014 to 2018)[103], plotted against yield response, as determined from AHDB Harvest Data[98]. Source: ADAS for the CCC.

[101] https://www.gov.uk/guidance/eight-toothed-european-spruce-bark-beetle-ips-typographus#reporting-sightings

[102] https://data.gov.uk/dataset/76ca636f-a449-44ba-ac2f-f8febecec2a2/cereals-and-oilseeds-production-harvest/datafile/b1629e8a-f2e7-4e70-876a-64d54ccb71aa/preview

[103] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766487/structure-jun2018final-uk-20dec18.pdf

It should be noted that the yield response was calculated in field experiments with treated and untreated crops grown under the same conditions. The response does not relate directly to the national yield, but gives an indication of the impact fungicides were having each year.

Yield responses were highest in 2012, 2014, 2016 and 2017. As noted in ADAS (2017), average yields across England in 2012 of 6.7 t/ha were well below the average for the period 2007 to 2018 of 7.9 t/ha, with the yield response from treated crops accounting for over half of the total average yield at 3.59 t/ha; indicating disease may have been a contributing factor to poor yields. However, weather conditions tend to be the dominant driver, with weather during grainfill having a significant influence on ultimate yield.

Yellow rust and septoria in wheat

Figure 3.16 demonstrates the percentage of infection found on winter wheat crops from yellow rust and septoria. Infection of septoria was highest in 2012, 2016 and 2017, with infection of yellow rust highest in 2014 and 2016. During these four years, the untreated yield was much lower than the treated yield (with a yield gap in the range of 3.6 t/ha to 5 t/ha). This difference in treated and untreated yields provides an indication of disease pressure; which could be contributed to by the increased incidence of septoria and yellow rust seen within these years. Levels of both septoria and yellow rust infection have decreased from 2016 to 2018.

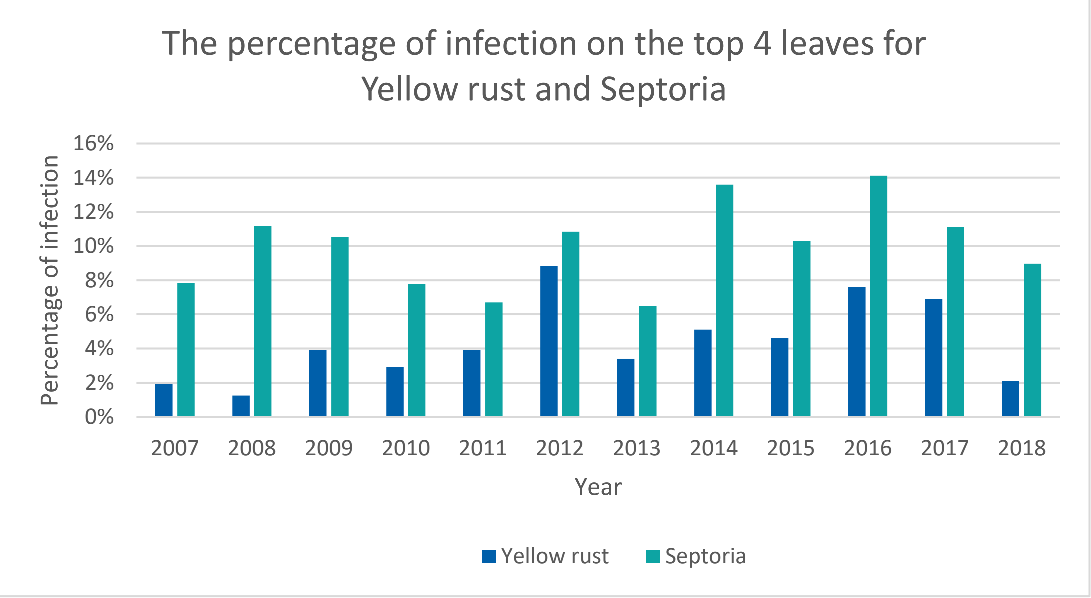

Figure 3.16 - The percentage of infection of Yellow rust and Septoria on the top four leaves of winter wheat crops, as reported in AHDB Harvest Data Results[98]. Source: ADAS for the CCC.

Bluetongue in livestock

Government guidelines state that land owners or farmers that keep livestock in the UK are expected to keep a close watch for, and report, any signs of bluetongue disease in their animals. There is an equal risk of two separate types of bluetongue (BTV-4 and BTV-8) spreading into the UK if infected midges are carried by the wind to the south and south-east of England. The exact level of risk of blue tongue prevalence in the UK continues to depend on the level of disease in nearby areas of Europe, as well as on the weather[104].

Figure 3.17 shows the distribution of confirmed cases of bluetongue in the UK in 2007 and 2008. October 2007 exhibited 61 confirmed cases of bluetongue; rising to 151 cases by December 2008 (Turner *et al.,* 2012). The study by Turner *et al.,* (2012) looked at the way that bluetongue is spread, and determined that although movement restriction can limit the spread of the disease to some extent, the main contributor to the spread of bluetongue is due to vector transmission.

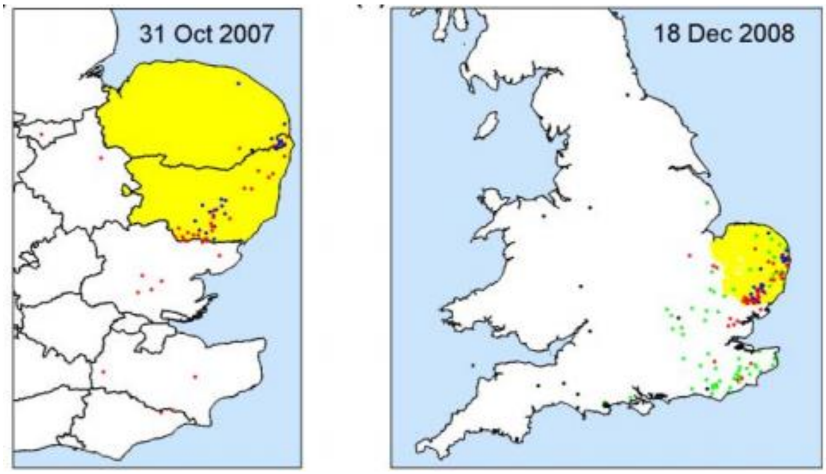

Figure 3.17 – The distribution of confirmed cases of bluetongue in the UK in 2007 and 2008. Red = reported case, blue = identified through surveillance, surveillance plus pre-movement testing or overwintering survey, green = identified through pre-movement testing, private testing or tracing, black = post import test notification. Source: Turner *et al.,* (2012).

Defra carry out regular risk assessments of the entry of bluetongue into the UK as well as report on the outbreak assessments in countries such as France and Germany[105]. In addition to this, the European Commission presents maps which show the restricted zones per bluetongue serotype; an example of which is provided in Figure 3.18.

[104] https://www.gov.uk/guidance/bluetongue

[105] https://www.gov.uk/government/publications/bluetongue-virus-in-europe

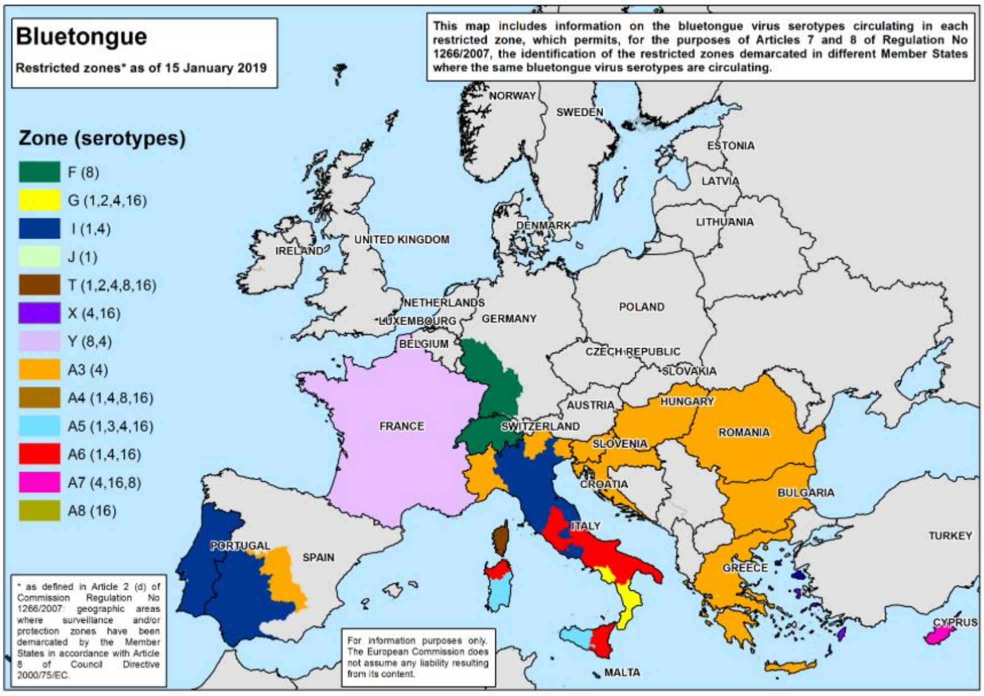

Figure 3.18 – A map showing restricted zones per bluetongue serotype in Europe, as of 15th January 2019. Source: European Commission[106]

3.7 Changes in soil health

Description: *Changes in soil health*

Type: *Realised impact*

3.7.1 Introduction

Soil physics, chemistry and biology all contribute to soil quality and maintaining soil health. As defined by the FAO (2008):

'Soil health is the capacity of soil to function as a living system, within ecosystem and land use boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promote plant and animal health. Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots; recycle essential plant nutrients; improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production'.

Improving soil health features within the 25 Year Environment Plan[107] published by Government (HM Government, 2018). Specific areas of focus are developing better information on soil health, restoring vulnerable peatlands, and ending peat use in horticultural products by 2030. With regards to soil health, Defra will invest at least £200,000 to help develop *'meaningful metrics that will allow us to assess soil improvements and to develop cost-effective and innovative ways to monitor soil at the farm and national level'*.

[106] https://ec.europa.eu/food/sites/food/files/animals/docs/ad_control-measures_bt_restrictedzones-map.jpg

[107] https://www.gov.uk/government/publications/25-year-environment-plan

This will build on existing knowledge and programmes such as the Countryside Survey (CS). The Government will also work with the industry to update the 2001 guidance on crop establishment and optimal tillage choice.

3.7.2 Data and information availability

There is currently little data available on soil health.

There are various organisations which undertake work on soil. The UK Soil Observatory, UKSO, collates information about research conducted on soil and provides links to data that is currently available[108]. One of the databases highlighted by the UKSO is the National Soils Inventory (NIS). The NIS includes a topsoil database with 6,127 points located in a 5km grid across England and Wales[109]. This database is found within Cranfield University's Land Information System, LandIS, alongside other National Soil Maps (NATMAPs)[110].

The CS, a unique study or 'audit' of the natural resources of the UK's countryside carried out at discrete intervals (1978, 1998 and 2007). records data on a range of soil metrics including soil physico-chemical properties, soil metal concentrations, soil invertebrates and topsoil mineralisable nitrogen[111]. Data for the first of these three parameters was captured in both 1998 and 2007 and trends assessed in this study. As topsoil mineralisable nitrogen is only available for 2007, this was not compared.

3.7.3 Evidence base and implications for climate resilience

There is limited national data on soil health, however some changes in soil parameters can be inferred from data recorded in 1998 and 2007 as part of the CS. The survey results present average data for England, and do not account for any differences in region or soil type.

3.7.3.1 Soil invertebrates

Soil invertebrates are critical for many soil functions, including biomass production, nutrient and water cycling, and filtering of contaminants; therefore making them a good potential indicator of soil health (Emmett *et al.,* 2010). Findings from the CS Report (Emmett *et al.,* 2010) show key changes in soil invertebrates in Great Britain between 1998 and 2007.

The mean number of invertebrates collected from cores was 52.3 in 1998 and 77 in 2007, representing an overall increase of 47% in total catch. The mean number of invertebrate taxa represented by at least one individual in soil cores was 4.34 in 1998 and 3.85 in 2007, representing an overall decrease of 11% in average taxa representation. This reduction is highly statistically significant ($p<0.001$) and demonstrates a reduction in community richness.

Mean Shannon diversity (which measures abundance and evenness of the species present) was 1.02 in 1998, and in 2007 this value had reduced to 0.72, representing an overall reduction of 0.3 units.

[108] http://www.ukso.org/maps.html

[109] http://www.landis.org.uk/data/nsitopsoil.cfm#nsitopsoil95

[110] http://www.landis.org.uk/data/natmap.cfm

[111] https://countrysidesurvey.org.uk/content/survey-data

3.7.3.2 *Soil metals*

High concentrations of metals in soils can reduce the diversity and abundance of communities of soil taxa such as earthworms, springtails, nitrifying bacteria, and others (Emmett *et al.,* 2010). Metals in soil are not broken down over time, and therefore are removed slowly, through the process of leaching and cropping (Emmett *et al.,* 2010). The CS does not provide comparable data for England between the two surveys.

A comparison of back corrected CS soils (0-15cm) analyses for 1998 and 2007 samples indicated that only relative small changes in soil trace metal concentrations occurred between surveys despite reported declines in atmospheric deposition due to the long residence time of metals in soils.

- Cadmium (Cd) – soil (0-15cm) Cd showed only relatively small changes between surveys with an overall decline of 0.013 mg/kg (3%) in 2007 soils.
- Chromium (Cr) – soil (0-15cm) Cr showed a decrease of 0.9 mg/kg (4.6%) between 1998 and 2007.
- Copper (Cu) – soil (0-15cm) Cu was the only metal that showed a significant change at the Great Britain (GB) scale, increasing by a mean value of 2 mg/kg across the full dataset.
- Nickel (Ni) – soil (0-15cm) Ni increased across all soils by 1.6 mg/kg between survey years.
- Lead (Pb) – soil (0-15cm) Pb concentrations showed a small non-significant decrease between surveys.
- Zinc (Zn) – soil (0-15cm) Zn showed a small non-significant decrease between surveys and Zn concentrations were significantly reduced in two habitats, Arable and Horticulture and Neutral Grassland.

Of the metals for which repeat measurement were made during the 2007 survey, only Cu showed a statistically significant difference in soil concentrations at the GB level.

3.7.3.3 *Soil physico-chemistry properties*

Soil pH gives an indication of soil acidity and can impact on the presence and abundance of biodiversity; with acidic deposition potentially damaging soils (Emmett *et al.,* 2010). Soil pH is a measure of the acidity and alkalinity in soils, with pH levels ranging from 0 to 14, with 7 being neutral, below 7 acidic and above 7 alkaline. The CS shows that mean pH for 'broad habitats' in England has increased between the two surveys, from 6.19 in 1998 to 6.51 in 2007, indicating a slight decrease in the average acidity of soil.

Soil carbon is a key indicator of soil quality as carbon is the primary energy source in soils, and provides a fundamental role in maintaining soil structure, water retention, and resilience (Emmett *et al.,* 2010). The CS shows that both soil carbon concentration and soil carbon density (0-15cm), for 'broad habitats' in England, has decreased slightly between the two surveys. Soil carbon concentration has decreased from 79.7 in 1998 to 75.6 in 2007; whilst soil carbon density has decreased from 71.5 to 70.2. However, these trends do not denote a significant change ($p<0.05$ level).

The CS shows that nitrogen concentration (% dry wt. soil) of soils (0-15cm), for 'broad habitats' in England, decreased 11.5% between 1998 and 2007. This could be due to a number of factors including changing practices, such as increased efforts to nutrient plan; and only apply the N required by the crop (i.e. not over fertilise). Other factors could be leaching or increased removal of N from the soil by vegetation; or linked to the increased storage of carbon in the soil due to increases in plant productivity, which could 'dilute' the levels of N (Emmett *et al.,* 2010). Average phosphorous (PO_4) availability also decreased from 1998 to 2007; this is thought to be likely linked to a reduction in the use of phosphorous fertiliser over the same time period (Emmett *et al.,* 2010).

3.7.3.4 Future work

Soil Biology and Soil Health Partnership

Going forwards, the 'Soil Biology and Soil Health Partnership' running from 2017 to 2021 and funded by AHDB and BBRO aims to '*help farmers and growers maintain and improve the productivity of UK agricultural and horticultural systems, through better understanding of soil biology and soil health'*[112]. This partnership will work on selecting methods to measure soil health and soil biology and will use these in the development of a soil health scorecard, with a determined target level for each indicator. An example scorecard is shown in Figure 3.19. It may be that this work will provide additional data from which to track changes in soil health in the future.

Analysis	Result	Units	Management Indication
pH	5.9	----	
Extractable P	60	mg litre^{-1}	
Extractable K	140	mg litre^{-1}	
Extractable Mg	100	mg litre^{-1}	
Loss on Ignition	5.5	%	
Bulk Density	1.25	g cm^{-3}	
VESS	4	score	
Penetrometer resistance	3.0	MPa	
Microbial Biomass Carbon	400	mg kg^{-1}	
Earthworms	19/2	no. 20cm^2/no. types	

Figure 3.19 – An example soil health scorecard as presented within Griffiths *et al.,* (2018).

Innovative approaches to monitoring soil health

In August 2018, Defra put out a research opportunity looking at innovative approaches to monitoring soil health in England and Wales[113]. This research will aim to develop an innovative and cost effective monitoring solution to improve the understanding of soil health status across England and Wales. This will involve developing a robust soil monitoring methodology or framework which can both collate and integrate multiple data sources and also allow further data inputs to meet future needs. This project will provide evidence to inform the soil metrics mentioned within the HM Government (2018) 25 year environment plan.

UK-SCaPE soil programme

[112] https://cereals.ahdb.org.uk/publications/2017/august/14/soil-biology-and-soil-health-partnership.aspx

[113] https://www.soilsecurity.org/defra-soil-health-research-and-innovation-opportunity/

A new survey is due to start in 2019, the UK-SCaPE soil programme. This survey, supported by the Natural Environment Research Council (NERC), will be comparable with the CS (previously funded by a consortium of partners led by MAFF/Defra) to allow long term trends to be assessed. The UK-SCaPE soil programme survey will involve revisiting permanent plots set up on former CS 1km squares in England, Scotland and Wales. All the original 1978 CS squares will be resurveyed, along with a selection of additional squares from the 1998 and 2007 surveys.

In total, 100 squares will be revisited each year for 5 years through a rolling programme beginning 2019. This contrasts to the CS where only a single year was done each time. As such, both long term trends (1978, 1998, 2007 and 2019-24) and short terms trends (2019 to 2014) can be assessed. The method will include five (15cm long x 5cm diameter) soil cores to be collected and associate vegetation recorded at each of five permanent plots within each 1km square. Soil cores will be analysed (for pH, LOI, C & N, Olsen P, Total P and Bulk density) or be stored in a long term archive for potential future analysis. One core from each location will be frozen in long term storage for potential DNA analysis in future. Plant species richness and abundance will also be recorded at each permanent plot. This research programme forms the NERC soil and vegetation research platform supported by the NERC award number NE/R016429/1 as part of the UK-SCaPE programme delivering National Capability.

In summary, whilst there is limited and ad-hoc soil health data available, it is expected that new datasets will become available, enabling a full indicator to be developed at some point in the future.

3.8 Number of farms implementing water efficiency measures

Description: *Number of farms implementing water efficiency measures (e.g. drip irrigation, on-farm reservoirs)*

Type: *Action*

3.8.1 Introduction

Water is essential on farms for crop growth and for watering stock. In addition, in certain types of farming enterprises it is used for washing down equipment and buildings. Many English farms rely on rainwater for the majority of their water needs, however there are particular groups of farms that have higher water needs or water needs at periods of low rainfall that therefore require supplementary water either from the mains, or abstraction sources.

Higher users of water in the agriculture sector include horticulture and potato production where supplementary irrigation is often required to achieve yield and quality; and the dairy sector where water is used both for watering the cattle and for maintaining hygiene levels of dairy and associated buildings. Other livestock sectors use water for watering their stock, with pigs and poultry also having a requirement for cleaning housing. The level of water demand will vary with the season, location and production system.

In order to adapt to climate change and other pressures such as changing land use, water needs to be used efficiently and sustainably on farm (Defra, 2017). Using water efficiently can help ensure that farmers are able to maintain access to necessary volumes of water for their business to continue without experiencing disruption.

Water efficiency measures such as drip irrigation can help preserve water sources, whilst use of on-farm reservoirs can help with storing surplus water in periods of high rainfall, ready for use in periods of low rainfall.

This indicator looks at the number of farms implementing water efficiency measures.

3.8.2 Data and information availability

Each year the UK Government conducts a 'Farm Business Survey' in England. This provides information on the financial, physical and environmental performance of farm businesses in England[114]. Estimates of water usage on farm are included within the Farm Business Survey; this includes the percentage of farms using various water sources, and the average proportion of water used. However, this does not include information on water efficiency measures.

In 2010, there was a specific add-on module to the Farm Business Survey which looked at water usage and irrigation[115]. This data was used in the previous update of this indicator by ADAS (2017). Communication with the Farming Evidence and Analysis team at Defra confirmed that this detailed module has not been repeated since 2010. However, in 2013-14, the Farm Business Survey began to collect data on water sources and the proportion of water used from each source, up until 2015-16. Unfortunately this data was not collected in 2016-17 or 2017-18, so only three years of data is available.

Another source of data is the 'Farm Structure Survey'. Consultation with Defra confirmed that irrigation data was collected as part of the Farm Structure Survey in 2016; including irrigable area, irrigated area, irrigation method, and water source. This data is expected to be published in 2019.

A 2016 study commissioned by the Agriculture and Horticulture Development Board (AHDB) collected data on water sources, irrigation methods, storage facilities, water management technologies, and actions to manage water shortages and/or improve water use efficiency across four sectors: potatoes, field horticulture, protected horticulture, and outdoor containerised plants (AHDB, 2016). The majority of respondents in this study were located in England, with some representation of growers in Scotland and Wales also included. The data available within this report is also captured within the available evidence base in this analysis.

3.8.3 Evidence base and implications for climate resilience

3.8.3.1 *Farm Business Survey*

Data derived from the Farm Business Survey (Defra, 2017) shows that the percentage of farm businesses using different water sources has stayed relatively similar from 2013-14 to 2015-16, shown in Table 3-2. There has been a slight increase in the percentage of farms using rivers, streams and springs for abstraction for immediate use from 2013-14 to 2015-16. The percentage of farms using rainwater storage and ponds, lakes and reservoirs remained low across the three years of available data.

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[114] https://www.gov.uk/government/collections/farm-business-survey

[115] https://webarchive.nationalarchives.gov.uk/20110912030732/http:/www.defra.gov.uk/statistics/files/defra-stats-foodfarm-farmmanage-fbs-waterusage20110609.pdf

Table 3-2 – The percentage of farm businesses sourcing water from various water sources, using data from the Farm Business Survey. Source: Farm Business Survey.

Water source	Percentage of farm businesses (%)		
	2013-14	2014-15	2015-16
Mains water	86	86	85
Rivers, streams, springs for abstraction (immediate use)	28	29	31
Boreholes	24	25	25
Rainwater storage	7	7	8
Rivers, streams, springs for abstraction (storage)	5	4	5
Ponds/lakes/reservoirs	3	2	2

3.8.3.2 *AHDB Study*

The AHDB (2016) study also looked at water sources, but for irrigation water only. Participants were asked to estimate their highest annual volume of irrigation water applied per year from 2011 to 2015, by source. This study found that the majority of irrigation water applied was sourced from groundwater (58%, or 30.4 million m^3) followed by surface water (Figure 3.20).

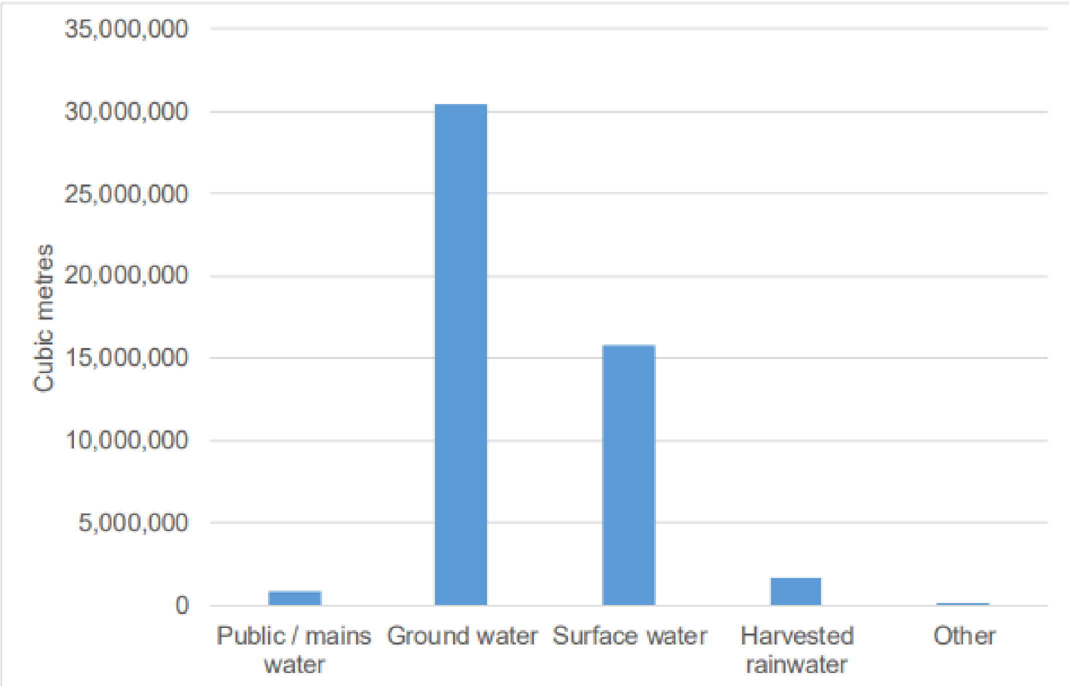

Figure 3.20 – The highest volume of irrigation water applied per annum from 2011 to 2015 by source, in cubic metres (excluding unexplained outliers and watercress production). Where respondents grew crops in more than one production sector, their applied water quantity is counted in each of those production sectors. There were 503 responses to this question, from growers of potatoes, field horticulture, protected horticulture, and outdoor containerised plants. Source: AHDB (2016).

The participants in the AHDB (2016) study were asked about the irrigation methods they use, the water storage facilities they have available to them, the technologies they use for water management, and the actions they are taking to manage water shortages and/or improve water use efficiency.

For irrigation methods, respondents were asked the percentage of irrigation water need satisfied by each method used (options included rain gun or boom, sprinkler, trickle/drip, glasshouse flood and ebb, hydroponic, capillary sand bed, capillary matting, closed recycling system, or other). Across all sectors (potato, field horticulture, protected horticulture and outdoor containerised plant growers) rain guns/booms were the main method of irrigation; although differences were seen between sector, with protected horticulture and outdoor containerised plants mainly using sprinklers and trickle/drip irrigation. Where rainguns or booms were used, these provided 91% of the total irrigation water used (on average, based on 344 respondents). This was compared to sprinklers which, when used, satisfied 55% of the irrigation water need (based on 122 respondents) and trickle/drip, 64% (based on 119 respondents). For the other options, less than 25 respondents commented, therefore these do not provide a representative example (AHDB, 2016).

Figure 3.21 shows the different water storage facilities that respondents used, with 67% indicating their farm had some type of water storage facilities. Reservoirs were the most prevalent storage facility, with 50% of those who had storage facilities making use of reservoirs.

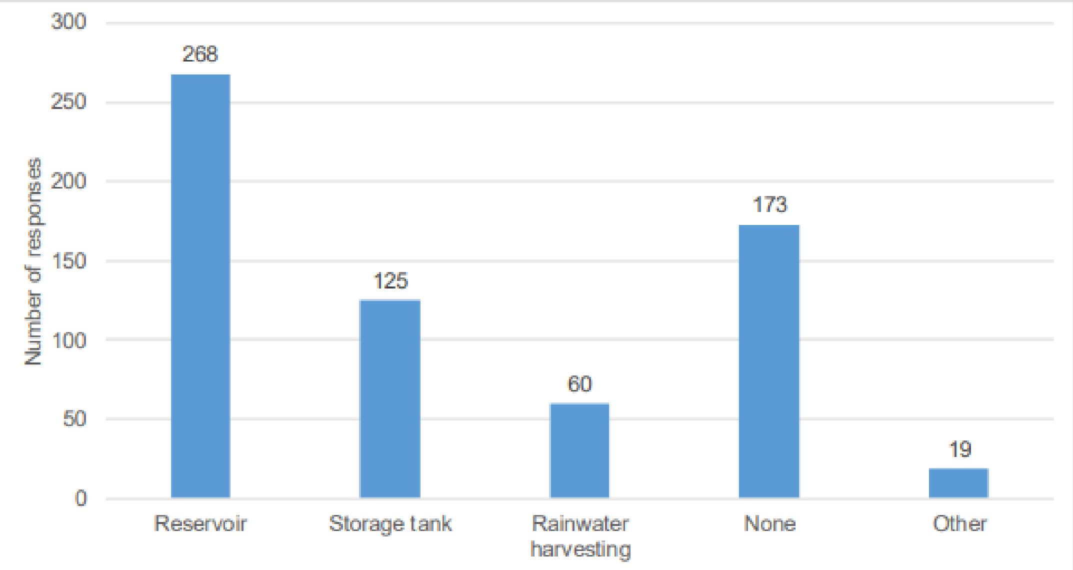

Figure 3.21 – The water storage facilities used by 527 respondents from the potato, field horticulture, protected horticulture, and outdoor containerised plants sectors. Source: AHDB (2016).

When asked what technologies for water management the participants use on their site, 250 of 386 (65%) stated that they use professional irrigation scheduling services or software (Figure 3.22). Other frequently used technologies were soil or substrate moisture monitoring, and timing systems. Drones (for crop/nutrient mapping) and recirculation of drainage water were the least frequently used technologies.

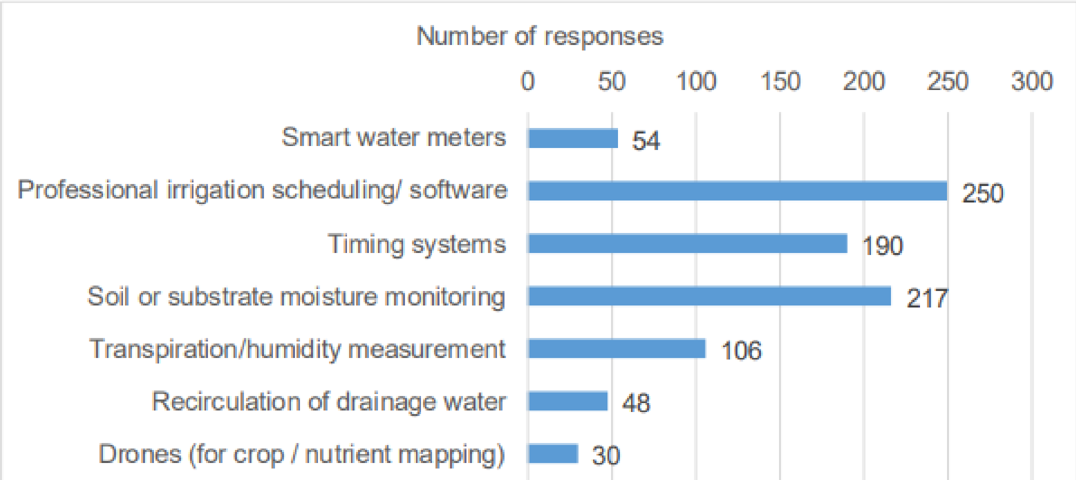

Figure 3.22 – Bar chart presenting the number of responses to the question *'does the site currently use the following? Please tick all that apply'.* There were 386 responses to this question from growers of potatoes, field horticulture, protected horticulture, and outdoor containerised plants. Source: AHDB (2016).

Figure 3.23 presents the actions that respondents had taken to manage water shortages and/or improve water use efficiency. The most commonly used actions were night irrigation, improved monitoring and scheduling of crop water use, installing new irrigation technologies/systems, and prioritising irrigation of different crops. Lesser used actions included trading water with other users, adjusted abstraction periods/extended licences, installing rainwater harvesting/recycling, and applying voluntary restrictions during shortages.

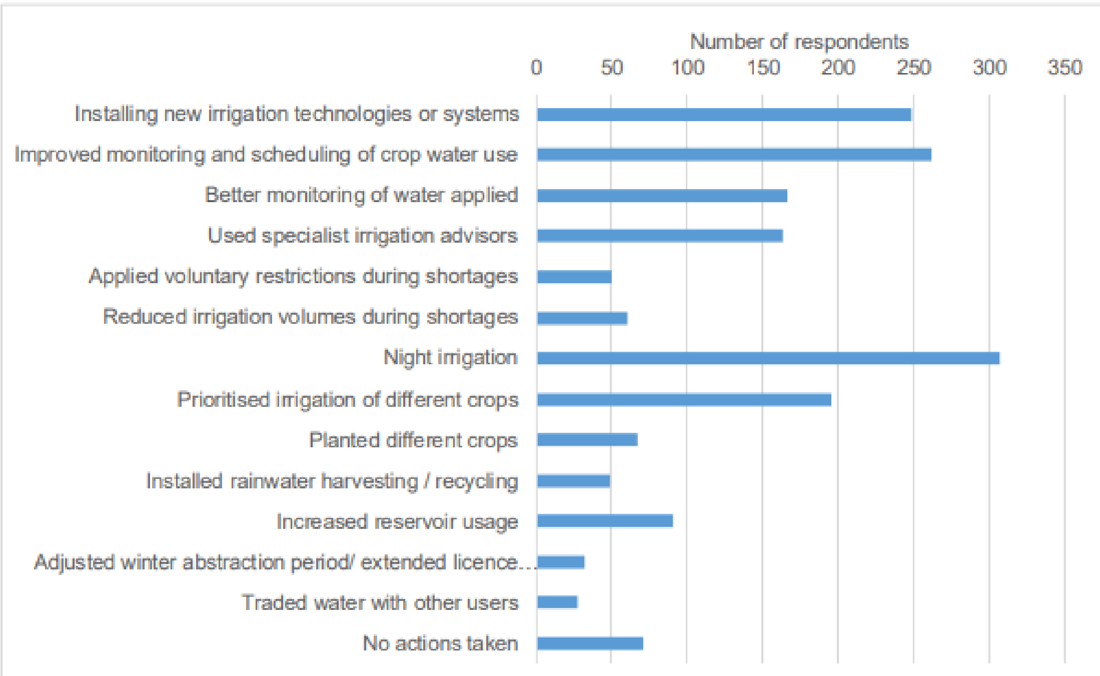

Figure 3.23 – Bar chart presenting the number of responses to the question *'In the last 5 years, what actions have you taken to manage water shortages and/or improve your water use efficiency? Please tick all that apply'.* There were 503 responses to this question from growers of potatoes, field horticulture, protected horticulture, and outdoor containerised plants. Source: AHDB (2016).

The available evidence base suggest that a range of irrigation measures are being utilised in the industry to implement more efficient use of water. However, due to a lack of robust datasets, it is not possible to draw any conclusions on the long-term changes in the number of farms implementing water efficiency measures (e.g. drip irrigation, on-farm reservoirs).

3.9 Displacement due to flood events

Description: *Average length of time between a flood event and people returning to their homes*

Type: *Realised Impact*

3.9.1 Introduction

Heavy or frequent rainfall can lead to both localised and widespread flooding, which can cause damage to businesses and properties. Flooding can make homes unsafe to be occupied, either because of structural risks, or health concerns due to mould or contaminated flood water. This often means that people are displaced from their homes whilst flood repairs take place. Flood repairs can vary in length, from weeks, to months, to years. The length of time during which people are displaced from their homes can cause substantial financial and emotional stresses.

Several case studies were provided in ADAS (2017), which set out a rough timeline between householders being displaced due to a flood event and permanently returning home. This included reference to the 2007 flooding in Hull, 2014 flooding in Somerset, and 2015 flooding in Cumbria.

Here we assess what data is available for the length of time between a flood and people returning to their homes.

3.9.2 Data and information availability

No annual/repeated database was found.

The Environment Agency (EA) provided access to data outlined in the Multi-Coloured Manual (MCM)[116], a handbook that is intended to be a stand-alone "Step-by-Step" guide to assessing the benefits of flood and coastal erosion risk management, used by the Environment Agency and other professionals. Data for this analysis was provided from the 'Data and Techniques' section of the MCM (Chapter 4 – Residential Property), which provides an indication into the percentage of people evacuated and the mean duration of evacuation in relation to the maximum depth of the flood in the house.

In addition, a study by Munro *et al.,* (2017) was also used in this analysis, which provides evidence on the durations of displacement of those affected by the 2013/14 winter floods in Gloucestershire, Wiltshire, Surrey, Somerset and Kent who were included within the National Study of Flooding and Health.

3.9.3 Evidence base and implications for climate resilience

The data provided by the EA and found within Munro *et al.,* (2017) was used to create Figure 3.24 and Figure 3.25 respectively.

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[116] https://www.mcm-online.co.uk/manual/

The MCM provides an indication of typical disruption to those whose properties were flooded. The manual indicates that the percentage of people evacuated following a flood event, and the mean duration of evacuation, increases with the depth of the flood in the house, shown in Figure 3.24. In addition, the manual indicates that the average length of displacement is about 19.5 weeks (~5 months).

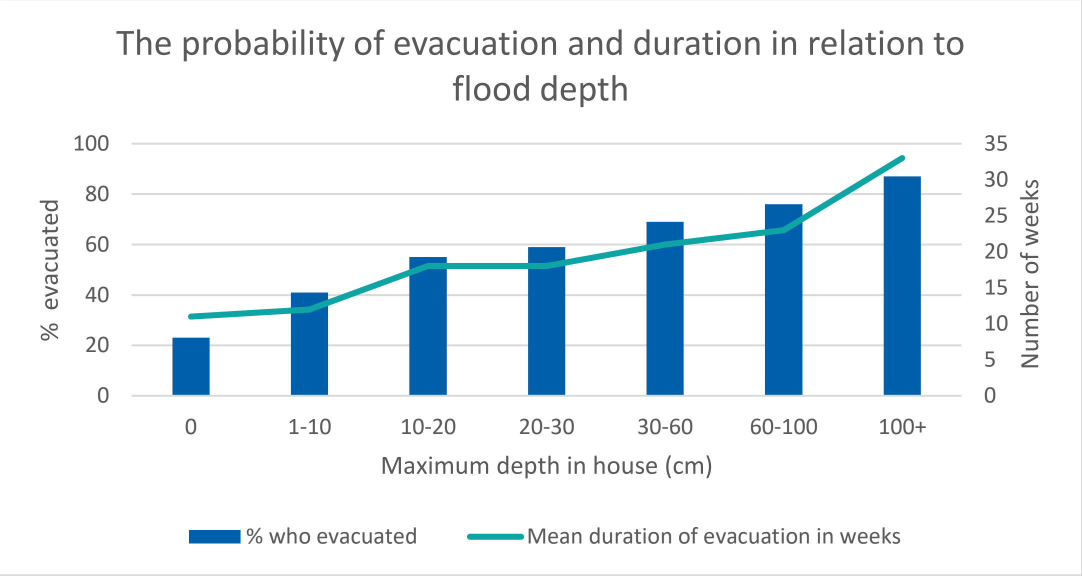

Figure 3.24 – The probability of evacuation and the estimated mean duration of evacuation (in weeks) against the maximum depth of flood in the house (cm). Data provided by the Environment Agency from the Multi-Coloured Manual. Source: ADAS for CCC.

A Public Health England study by Munro *et al.,* (2017) looked at the duration of displacement of those affected by the 2013/14 winter floods in Gloucestershire, Wiltshire, Surrey, Somerset and Kent. Figure 3.25 shows that over 50% of participants in the study were displaced for more than 6 months. Figure 3.26 shows the distribution of the duration of displacement, with some being displaced for up to 400 days (approximately 13 months).

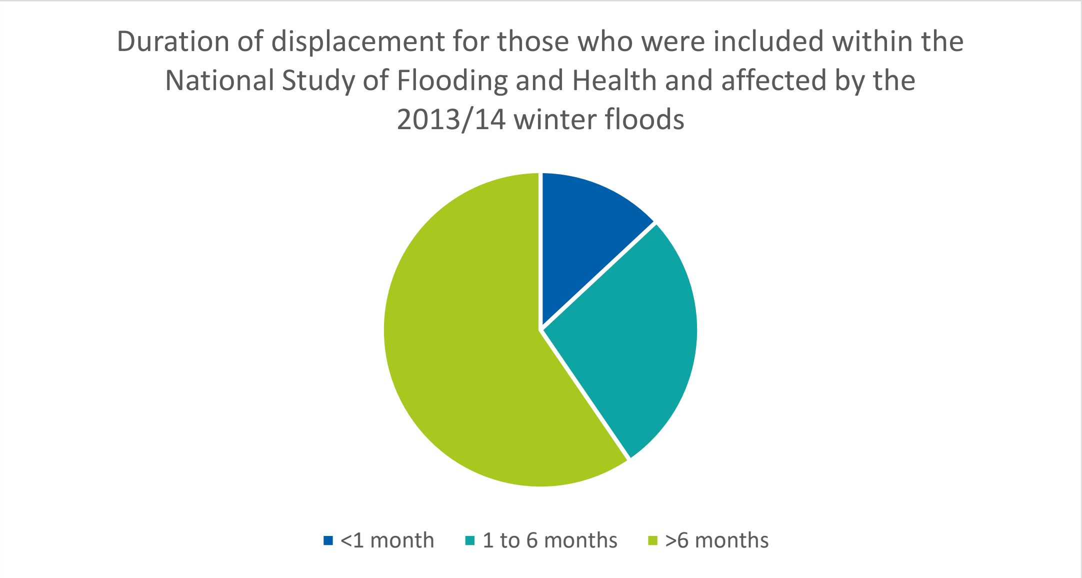

Figure 3.25 – The duration of displacement of those affected by the 2013/14 floods in Gloucestershire, Wiltshire, Surrey, Somerset and Kent and part of the National Study of Flooding and Health, data sourced from Munro *et al.,* (2017). Source: ADAS for the CCC.

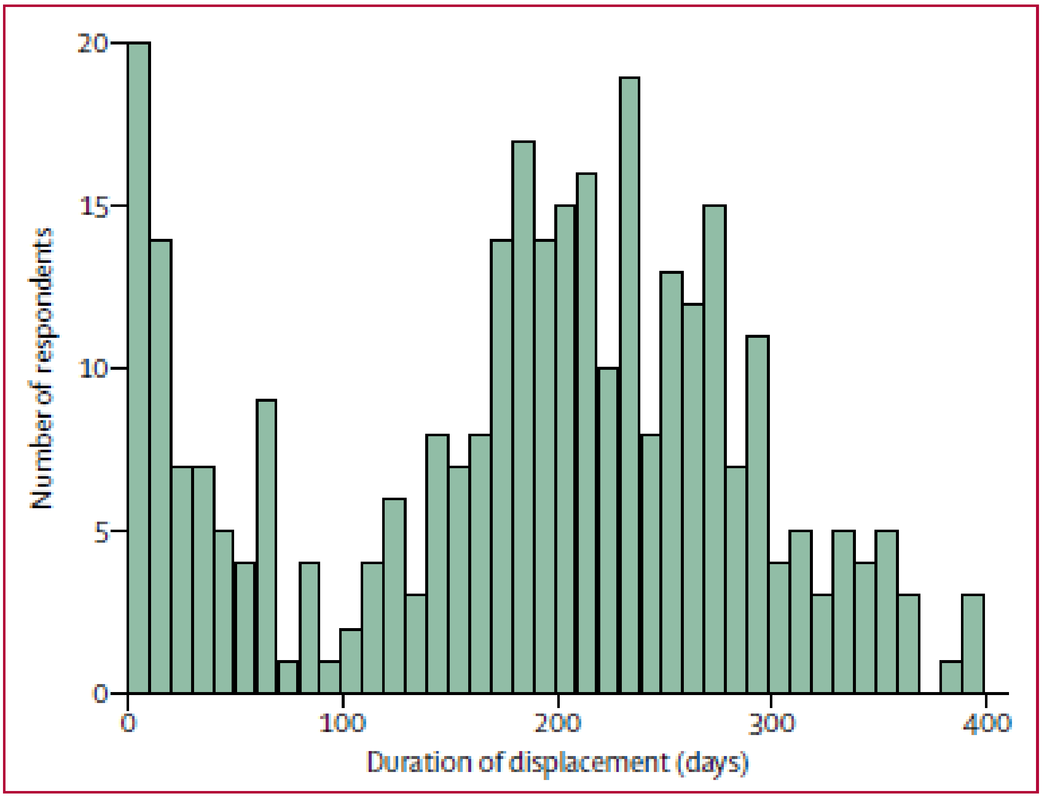

Figure 3.26 – The duration of displacement (in days) for those who were flooded and displaced within the Public Health England study into the mental health impacts of flooding. Source: Munro *et al.,* (2017).

This data on displacement and length of time before returning home is similar to estimates by the National Flood Forum (NFF, 2018) who suggest that the average length of time to be out of the home following a flood is 6-18 months. However, in some cases this can be much longer and extend to three years (or more). The example of Storm Desmond (December 2015) was given, where some people had still not returned to their homes by early 2019. Another example was the flooding in Hull in 2007, which saw many people out of their homes for up to three years.

The NFF felt that sixth months was a very conservative estimate and that the length of time between a flood and being able to return to the home would be much longer than this. In addition, the NFF highlight implications of householders returning to a home too soon after a flood. This is because the property may not have dried out properly and could experience 'secondary flooding' which would result in displacement from the home again.

Other factors that might affect the length of time between a flood and people returning to their homes include whether the flood was a couple of just a few centimetres, or a couple of metres (e.g. up to ceiling height). This is supported by Figure 3.24. For example, in the rare circumstance that there is flooding up to the second floor, this would more than often require major work and structural repairs before people return to the home.

The NFF suggest that insurance companies are the biggest reason for delays in residents returning to the property following a flood. This can be because of questions over whether the insurer will pay, the level of damage that is required to be fixed, and the availability of workforce. Consequently, the average length of time before return should not be rushed until the property is safe to move back into. For example, around 2012 there was a lot of pressure on insurance companies to get people back into homes quicker. However this caused additional problems as fast drying techniques created issues for timber houses and subsequently further damage. In particular, older properties may need more time to dry out (NFF, 2018).

3.10 Mental health impacts of flooding

Description: *Number of people suffering mental health impacts following a flood or severe weather event*

Type: *Realised Impact*

3.10.1 Introduction

Heavy or frequent rainfall events can lead to localised and widespread flooding, resulting in substantial disruption, including injury or illness; damage to and loss of property, businesses and possessions; and in some instances, impacts on or loss of family, friends and pets. These impacts are generally associated with large amounts of financial and/or emotional stresses, which can negatively impact on mental health.

While the experience of a flood can be distressing, events that occur after a flood can also be a source of stress (PHE, 2015). They include:

- Difficulties accessing continuing healthcare and prescription medications;
- Difficulties with getting healthcare for new health problems
- Disruption to normal household activities and separation from family and friends
- Loss of school facilities and interrupted attendance at school
- Feelings of loss of control and worry that flooding may reoccur
- Seeking compensation, recovery and re-building of homes, submitting an insurance claim, loss of employment and /or income, and loss of physical possessions.

This indicator assesses the evidence base on the impact that flooding can have on mental health.

3.10.2 Data and information availability

There is currently limited data available on the impacts on mental health from flood events. New research that started in 2014 – BMC Public Health National Cohort study – is one key source of insight into the impacts of flooding on Mental Health.

There are two years of data available (2015 and 2016) from the BMC Public Health National Cohort study into flooding and mental health. The first study (Waite *et al.,* 2017) provides data for one year after flooding, with the second study (Jermacane *et al.,* 2018) providing data for two years after flooding. Both studies use participants who were living in neighbourhoods affected by flooding between December 2013 and March 2014. This includes Gloucestershire, Wiltshire, Surrey, Sedgemoor, South Somerset, and Tonbridge and Malling local authorities.

Using the data from this research, the prevalence of mental health outcomes (as a percentage of participants) was plotted on graphs to show the difference between one and two years following the flood.

3.10.3 Evidence base and implications for climate resilience

The mental health impact of flooding is greater where the individual has been flooded, rather than disrupted (Figure 3.27). Post-traumatic stress disorder (PTSD) was the most prevalent mental health outcome of flooding; with 36.2% of participants who were flooded experiencing PTSD one year after flooding. This remained prevalent two years after flooding, with 24.5% of participants flooded continuing to experience this in 2016.

The percentage of respondents experiencing mental health outcomes as a result of being flooded or disrupted decreased between one and two years after flooding. This decrease ranged from 32% (PTSD in participants who were flooded) to 57% (depression in participants who were disrupted).

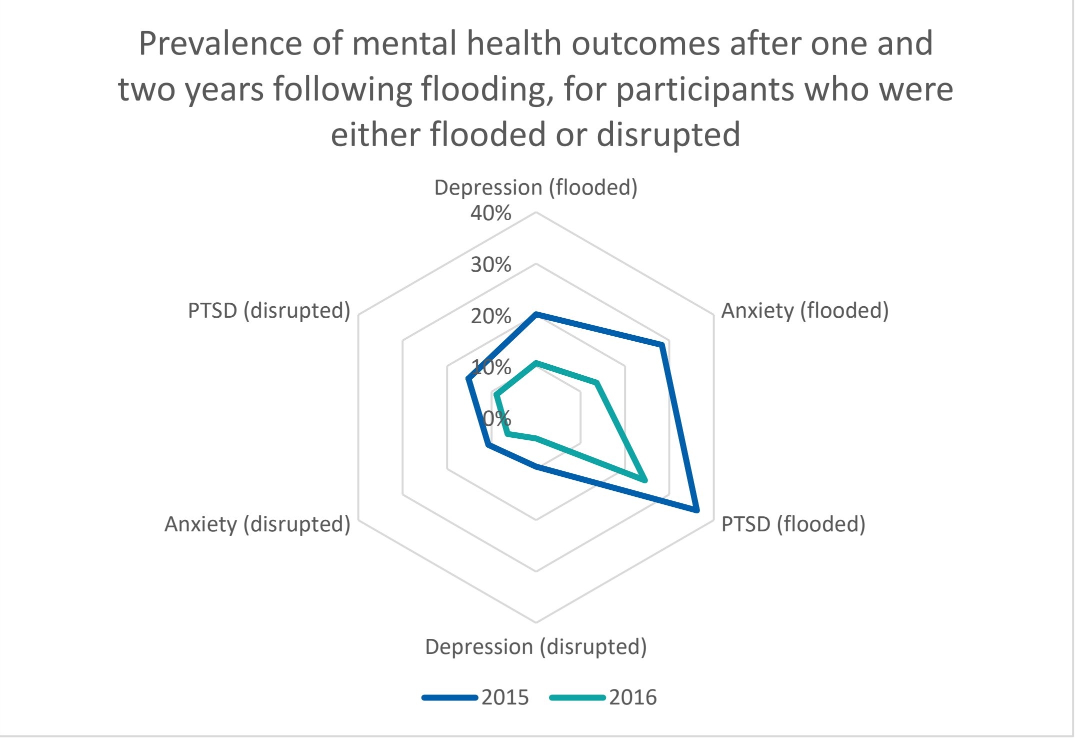

Figure 3.27 – The prevalence of mental health outcomes (PTSD, anxiety, and depression) after one and two years following flooding, for participants who were either flooded or disrupted, using data from Waite *et al.,* (2017) and Jermacane *et al.,* (2018). Source: ADAS for the CCC.

Figure 3.28 show that participants who experienced persistent damage were more affected by depression, anxiety and PTSD than those who experienced no persistent damage.

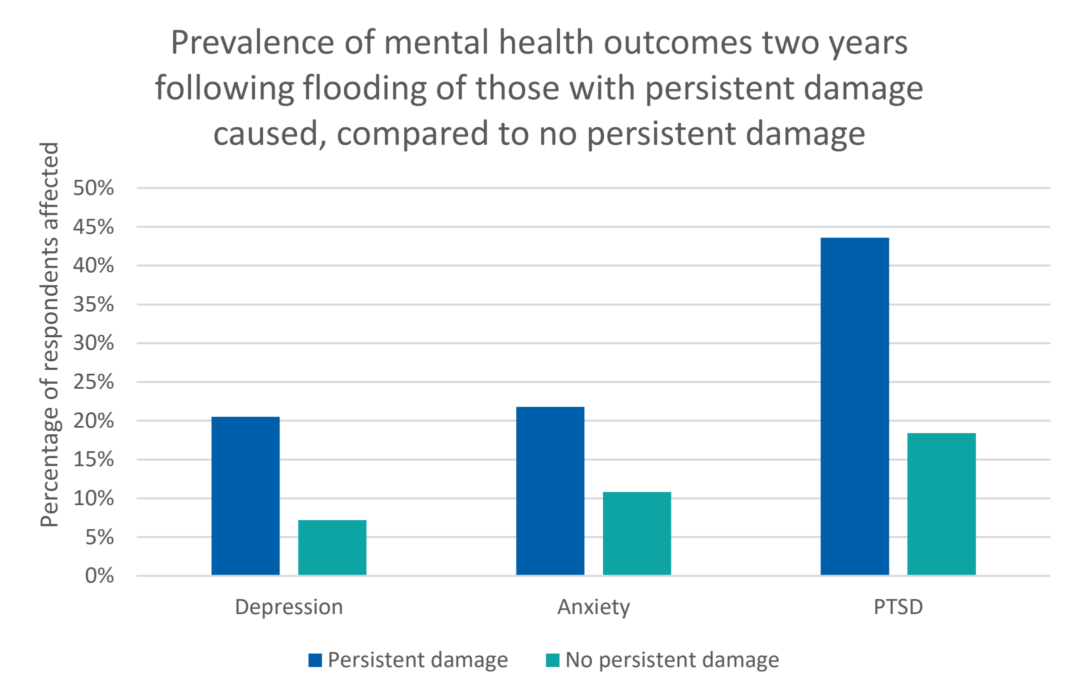

Figure 3.28 – The prevalence of mental health outcomes (post-traumatic stress disorder, PTSD, anxiety, and depression) two years following flooding, for participants who either experienced persistent damage, or no persistent damage, using data from Jermacane *et al.,* (2018). Source: ADAS for the CCC.

Consultation with the National Flood Forum (2018) indicates that the impact of flooding on mental health can be huge, and suggested that in some extreme circumstance, several people have committed suicide as a result of severe or repeat flooding. For example, the NFF were aware of at least three suicides which occurred after Storm Desmond.

The NFF commented that flooding is life changing, and the psychological recovery period is difficult as a lot of people get a 'homeless' feeling and do not know where to go when they are flooded. The insurance process was also raised as being an influencer on mental health; with this often causing increasing anxiety and stress. The NFF suggest that a lot of people are left with long term anxiety around flooding and may also show signs of anxiety during times of heavy rainfall - due to concerns of repeat flooding.

These studies show that the mental health impact from a flood event decreases with time, but that there are lasting effects of flooding on mental health, which can continue long after the flood waters have receded.

3.11 Heat-related deaths per year

Description: *Number of heat-related deaths per year*

Type: *Realised Impact*

3.11.1 Introduction

UK Climate Projections 2018 (UKCP18) indicate that heatwaves are predicted to increase in frequency and intensity as a result of climate change. The health impacts of these events can be significant, particularly for vulnerable populations when excess mortality can occur.

The UK Government recognise that older people are particularly vulnerable to the heat and suffer increased fatalities from cardiac and respiratory disease during heatwaves. The average number of heat-related deaths in the UK is expected to more than triple to 7,000 a year by the 2050s (House of Commons Environmental Audit Committee, 2018).

The impact of heatwaves are likely to become considerably greater in the future, as higher temperatures, combined with an aging population, and difficulties in controlling temperature in buildings that have not been built to withstand high temperatures, exacerbate the number of people at risk. PHE warn that excess heat-related deaths may begin to become apparent when ambient temperatures exceed 24.5 degrees[117].

Public Health England (PHE) issues health advice for the public and healthcare workers in England. As part of this, PHE provides the heat-health watch service, run by the Met Office, which provide levels of heat forecast/measured[118]. The Met Office heatwave warnings operate in England from 1 June to 15 September each year.

In addition, PHE monitors heatwave mortality each year to provide information on excess deaths observed during heatwaves. This is carried out each time the Met Office issues a Level 3 heatwave alert (issued when the temperature thresholds have been exceeded), in line with the annual heatwave plan[119]. The Heatwave Plan (PHE, 2018a) for England is intended to protect the population from heat-related harm to health.

This indicator assesses the evidence base for the number of heat-related deaths per year caused by heatwaves in England according to PHE reports and other published material.

3.11.2 Data and information availability

3.11.2.1 *PHE Reports*

When a level 3 heatwave occurs in the summer months, PHE estimate excess daily mortality levels using the baseline death registration data from the General Register Office (GRO). At the end of the summer, excess daily mortality levels for the heatwave period is estimated using death registration data from the Office for National Statistics (ONS) and summarised in reports. This is considered to be a relatively robust approach for estimating the number of excess heat-related deaths during heatwaves.

3.11.2.2 *ONS Reports*

Quarterly mortality reports from the ONS provide provisional death registration and death occurrence data for England, broken down by sex and age. The reports compare mortality with the same quarter of previous years and report patterns of change in mortality; specifically, whether mortality has increased, remained stable or decreased. Whilst there are some issues with the data (i.e. registration delays mean that death occurrence data are technically never complete, as a handful of new deaths may be registered years after they occurred); they provide a consistent approach to provide an indication of 'death

117 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/711503/Heatwave_plan_for_England_2018.pdf

118 https://www.metoffice.gov.uk/public/weather/heat-health/#?tab=heatHealth

119 https://www.gov.uk/government/publications/heatwave-plan-for-england

occurrences' that could be related to, and coincided with, periods of high temperatures (heatwaves).

3.11.3 Evidence base and implications for climate resilience

Summer temperatures in England are typically warm, but relatively mild compared to the hot and/or extreme temperatures found in southern Europe. Whilst England has experienced the odd few severe heatwaves in the past, these have been relatively few and far between. However, climate change is expected to increase the frequency and magnitude of heatwaves in England. UKCP18 indicate that severe heatwaves such as in 2003, are expected to occur almost every other year by mid-end century.

3.11.3.1 *Summer 2003 Heatwaves*

The 2003 European heatwave led to the hottest summer on record in Europe since at least 1540, with France hit especially hard. The heatwave led to health crises in several countries, combined with drought to create a crop shortfall in parts of Southern Europe, and caused the excess mortality of some 20,000 people across Europe[120]. In England, temperatures reached 38.5°C during the heatwave, and there were 2,193 heat-related deaths across the UK in just 10 days (House of Commons Environmental Audit Committee, 2018).

The impacts of the 2003 heatwave, both in the UK and Europe, highlighted the potential risks that heatwaves, exacerbated by climate change, could have in the future. Following the devastating European heatwave in 2003, PHE started publishing a heatwave plan for England each year to develop and improve the ability of the health sector and its partners to deal with significant periods of hot weather.

3.11.3.2 *Summer 2016 Heatwaves*

The summer of 2016 saw three Level 3 heatwave alerts issued by the Met Office. Excess daily mortality for each of these heatwaves were estimated to be 908 excess deaths over the summer 2016 period (PHE, 2018b), shown in Figure 3.29.

- The first Level 3 heatwave (18 July to 22 July 2016) showed a cumulative total of 612 (463 to 761, 95% confidence interval (CI)) excess deaths were observed above the baseline for all-cause mortality in the 65+ year olds in England. Peak temperatures and excess deaths were seen on 19 July 2016.
- The second Level 3 heatwave (22 August to 26 August 2016) showed a cumulative total of 296 (147 to 455, 95% CI) excess deaths were observed above the baseline for all-cause mortality in the 65+ year olds in England. Peak temperatures and excess deaths were seen on 24 August 2016.
- The third Level 3 heatwave (12 to 17 September 2016) showed no cumulative excess deaths observed in the 0 to 64 years or the 65+ year olds. Peak temperatures were seen on 15 September 2016.

[120] https://www.metoffice.gov.uk/weather/learn-about/weather/case-studies/heatwave

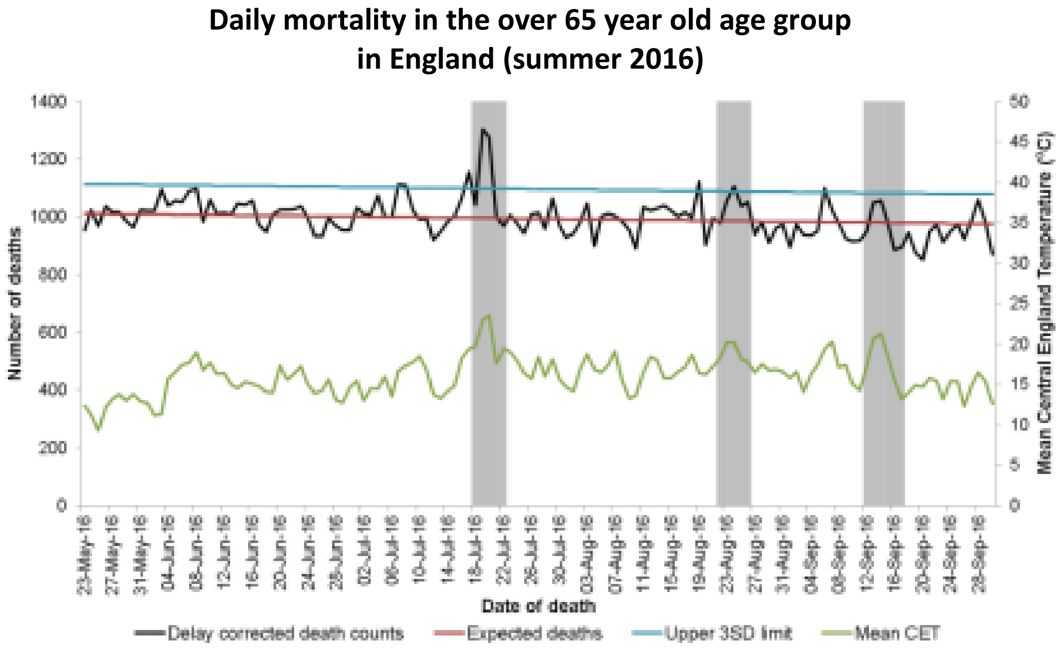

Figure 3.29 – Daily mortality in the over 65 year old age group in England in summer 2016. The number of deaths (black line) is shown Heatwave days/periods are highlighted in grey. The mean Central England Temperature (green line) is shown for reference. Source: PHE, 2018b.

3.11.3.3 Summer 2018 Heatwaves

It is expected that there will be a significant number of heat-related deaths associated with the hot summer of 2018. Whilst a report has been written by PHE monitoring mortality for the 2018 heatwaves, publication of the report has been postponed until summer 2019 to maximise impact. Consequently, we are not able to comment on or provide the findings of this report at this time.

However, insight from ONS quarterly mortality reports (ONS, 2018a; ONS, 2018b) suggest that:

- Between 18 and 19 April 2018, 243 more deaths were observed than the five-year average for the same period and rose well above the maximum number of deaths seen on those dates from 2013 to 2017. This sharp rise then fall in the number of deaths coincided with a period of higher than average temperature between 18 and 19 April 2018. Following almost immediately, between 21 and 23 April 2018, 378 fewer deaths were observed than the five-year average for the same period (ONS, 2018a).
- Between 21 and 22 June 2018, 214 fewer deaths occurred than the five-year average for the same period, followed by the occurrence of 259 more deaths than the five-year average between 25 and 26 June 2018. This sudden trough then peak in deaths coincided with a slightly colder spell between 21 and 22 June 2018 and then with high temperatures that triggered a heatwave alert from 25 June 2018 to the end of the quarter. In that time, 382 more deaths occurred than the average for the same period from 2013 to 2017 (ONS, 2018a).
- On 27 July 2018, there were 251 more deaths than the five-year average number for the same day. This period coincided with the highest reported temperature of the year reaching a maximum of 30.7°C on 26 July and 29.7°C on 27 July. In contrast, on

29 July 2018, there were 114 fewer deaths than the five-year average (2013 to 2017), with the maximum temperature at its lowest for July 2018 (20.3°C on 28 July and 21.0°C on 29 July) (ONS, 2018b).

PHE suggest that one possible explanation for a short increase in mortality and then a subsequent decrease is short-term mortality displacement. This is where an event (for example, a heatwave) occurs and the resultant high mortality causes a temporary increase in mortality among frail individuals who are especially vulnerable, that may well have passed within the following few days anyway (ONS, 2018a; ONS 2018b). Figure 3.30 shows the July example of short-term mortality displacement.

Number of deaths occurring on each day in Quarter 3 (July to September): 2018, five-year average and range, all ages, England

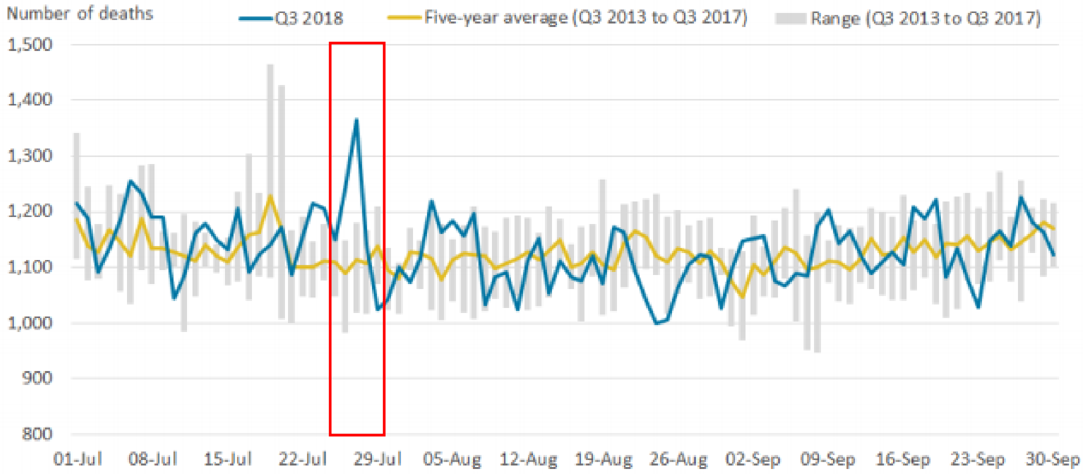

Figure 3.30 - Number of deaths occurring on each day in Quarter 3 (July to September) of 2018 (blue line), as well as the five year average (yellow line) and five year range (grey bars). The red box shows the peak in deaths, which coincided with the hottest day of July 2018, followed by the relative drop soon after. Data is for five-year average and range, all ages, England. Source: ONS, 2018b.

The available evidence suggest that there is a detectable link between some severe heatwaves and excess mortality, at least at the day to day level. However, it is not clear whether excess mortality is simply a case of people passing a few days earlier than they would have anyway, or if additional deaths that might not have happened for months or years later, were a product of the heatwaves. In either case, the data suggest that high temperatures can lead to a significant increase in the number of deaths, particularly the elderly and vulnerable.

3.12 Work or school days lost as a result of severe weather

Description: *Number of working/school days lost from flooding/severe weather events*

Type: *Realised Impact*

3.12.1 Introduction

Temporary school closures can be enforced due to severe weather events, such as heavy rainfall and associated flood events, but more often than not due to cold weather (i.e. snow and ice). School closures may be implemented due to a range of concerns, such as inaccessibility to the site, or risk of injury to staff and pupils.

The Government outline emergency planning and response guidelines for how schools and other educational settings should plan for and deal with emergencies, including severe weather and floods[121]. The guidelines advise that during severe weather, schools and early years settings should be kept open for as many children as possible, and should be re-opened as soon as possible after a closure, where it is safe to do so.

Whilst climate projections suggest that, on average, England will see a decrease in the number of snowfall events, changes in the magnitude of extreme events may result in increased impact, particularly where events become more infrequent, and thus the public and businesses become less use to dealing with such events.

In 2018, there were around 8.74 million pupils and 24,316 schools in the UK (including state funded primary and secondary schools, and independent schools)[122]. If for example a widespread snow event occurred, resulting in the closure of just 1% of schools for 1 day, this would result in approximately 87,000 school days lost[123].

This indicator looks at the available evidence for how many school days are lost in England each year as a result of severe weather.

3.12.2 Data and information availability

There is currently no central database that collects information on the number of school closures, or school days lost each year due to severe weather, as outlined in ADAS (2017). Instead each school and/or county collect and store different levels of information relating to school closures, with some holding no information at all, and others keeping relatively robust records.

Whilst the best source of information may be the schools themselves, it was not feasible to contact individual schools. Instead, all County Councils in England were contacted to determine whether they collect information on school days lost as a result of severe weather. This was typically done through Freedom of Information requests, as well as online contact forms.

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[121] https://www.gov.uk/guidance/emergencies-and-severe-weather-schools-and-early-years-settings

[122] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/719226/Schools_Pupils_and_their_Characteristics_2018_Main_Text.pdf

[123] 8,735,098 pupils / 24,316 schools = average of 359.23 pupils per school. 1% of schools (243.16) with 359 pupils closed for one day would result in 87,350 school days lost.

Thirty-three councils were contacted in total, of which: 15 confirmed that they do not collect and/or store this information; 14 councils responded with data of varying quality; one advised they had data, but it would be too time consuming to extract; and three county councils did not respond to the request. Where councils advised they did not collect or store the data requested, responses typically tended to suggest referring the question to the individual schools who may collect and/or store this data.

For the 14 councils that did provide data, the information was very variable and was not directly comparable between many of the datasets. For example, some of the councils were able to provide data for the number of school days lost due to weather alone; whereas others provided 'Code Y' data. During a severe weather event, schools are able to mark children's attendance in the register as absence code 'Y'; meaning that the schools attendance figures will not be affected. However, code Y can also include custody or detainment, so does not provide an accurate dataset for days lost due to severe weather alone.

There were also differences in the time-series of the data, with some councils only holding this information for the last year, or a couple of years, whilst others kept records for a longer duration (reaching a maximum of up to 15 years by one council). When recording the data, there were also differences in whether this was done by school year (i.e. Sep-Aug) or calendar year (Jan-Dec).

Where data was provided, the majority of councils were unable to break down the reason for closure by weather type. This information was provided by four councils; however the date ranges provided do not make for a robust comparison. Other issues included some schools closing for half, or part of a day, meaning considerable manipulation of the data would be required to fully analyse the number of school days lost.

It is also important to note that the data is not always accurate or checked, so some of the data may be prone to inaccuracies within the numbers provided by councils. One council raised that the number of closures could be exaggerated as the schools may have logged a closure where they have not been sure what the weather would be doing the following day. However, two other councils raised that the figures stated could be an underestimate, as the schools are not under an absolute requirement to report school closures to the council, and therefore they may not have been aware of all school closures within the county.

Consequently, whilst a range of data was made available, there are considerable gaps and caveats attached to it. As such, the findings in this analysis merely provide an indication into the extent of school days lost, rather than a representative example for the number of school days lost in either England or the UK, each year.

3.12.3 Evidence base and implications for climate resilience

The comparable data from 2009 to 2018 provided by nine county councils is shown in Table 3-3. This data show that 2018 had the most school days lost, likely due to the snow experienced in March 2018 caused by the 'Beast from the East'[124]. Suffolk county council confirmed that 910 of the 921 days lost in 2018 were due to snow from this event. It is estimated that the Beast from the East resulted in thousands of school closures across the UK[125]. The 1,195 lost days recorded by Cumbria, Cornwall and Devon county councils were

[124] https://www.metoffice.gov.uk/learning/atmosphere/air-masses/beast-from-the-east

[125] https://www.internetgeography.net/topics/beast-from-the-east-extreme-weather-in-the-uk/

also specifically due to snow. As shown in Table 3-3, between 2009 and 2018, estimates suggest upwards of 6,247 days lost due to severe weather within these nine councils alone.

Table 3-3 – The number of school days lost due to severe weather from 2009to 2018 for Cornwall, Cumbria, Devon, East Sussex, North Yorkshire, Suffolk, Durham, Lancashire and Norfolk county councils, as reported by the councils in 2018. Cells with no data represent data gaps.

County Council	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cornwall										396
Cumbria										379
Devon						2		20		420
East Sussex	77	1024	0	35	404	0	1	0	24	285
North Yorkshire	67		1	4	6	0	15	20	42	1009
Suffolk					5	9	2	0	11.5	921
	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Durham										733
Lancashire	288	973.7	170	10.5	279	6.5	88.5	184.5	10.5	649.5
Norfolk								2	24	1377

Due to the considerable data gaps, both in terms of council's not providing data, and gaps within the datasets where data has been provided, it is not currently possible to infer any trends in the data. However, from the data shown, school closures appear to be largely associated with cold weather (snow and ice), with flooding or other severe weather events resulting in a low number of school closures.

3.13 Businesses with weather-related business continuity plans

Description: *Number/proportion of businesses with weather-related business continuity plans in place*

Type: *Action*

3.13.1 Introduction

Business continuity management is described by the Business Continuity Institute (BCI) as: '*A holistic management process that identifies potential impacts that threaten an organisation and provides a framework for building resilience with the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value-creating activities*' (BCI, 2001)[126].

Severe weather events such as heatwaves, flooding and cold weather can result in challenges to businesses. This can include transport difficulties, power cuts, disruptions in internet or telephone connections, and damage to buildings or equipment, which all have financial implications. Having a weather-related business continuity plan in place prepares businesses for severe weather events by providing a framework for planning for and taking

126 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/376381/Expecting_the_Unexpected_Reviewed.pdf

action during an incident; ensuring that the business is back to 'business as usual' in the quickest possible time.

This indicator looks at the proportion of businesses with weather-related business continuity plans.

3.13.2 Data and information availability

Little data is available on the number/proportion of businesses with weather-related continuity plans in place, however a couple of surveys have been carried out in this area.

Firstly, the Federation of Small Businesses (FSB) – a UK organisation with around 200,000 members, conducted a study in 2015 about weather resilience planning in small businesses. Secondly, the BCI have published reports on resilience, climate change and horizon scanning. The relevant outputs from both of these studies are assessed in this analysis.

3.13.3 Evidence base and implications for climate resilience

The FSB (2015) commissioned a survey in November 2014, looking at the impacts of severe weather during the three year period preceding this. The findings reported that two thirds of small businesses were negatively affected by severe weather during those three years, with the financial cost of these events sitting at an average of just under £7,000 per affected business. The types of impact and average costs are shown in Table 3-4.

Table 3-4 – The effects of severe weather on small businesses in the three years from 2012 to 2014 inclusive. Source: Federation of Small Businesses (2015)

Impact type	Experience	Cost (average)
People (e.g. disruption for customers or staff)	45%	£3,810
Logistics (e.g. disruption to suppliers, utilities or transport arrangements)	32%	£1,944
Processes (e.g. impacts on production processes and service delivery)	17%	£6,888
Premises (e.g. impacts on maintenance, facilities management or building design and construction)	15%	£5,410
Markets (e.g. changing demand for goods and services)	14%	£6,150
Other (including impacts on investment, productivity, insurance and reputation)	9%	£3,035

In total, 93% of the businesses surveyed believed that severe weather posed a risk to some part of their organisation, yet only 27% of businesses surveyed had a severe weather plan in place (FSB, 2015). When looking at microbusinesses (defined as fewer than 10 employees), the results were similar, with only 25% reporting that a resilience plan was in place that specifically mentioned severe weather.

The proportion of small businesses with severe weather resilience plans in place by sector is shown in Figure 3.31. Health and social work was the sector with the highest proportion of businesses with weather related business plans in place (46%), followed by computer and related activities (45%) and agriculture, forestry and fishing (43%). The construction sector had the least proportion of businesses with weather related continuity plans in place (14%).

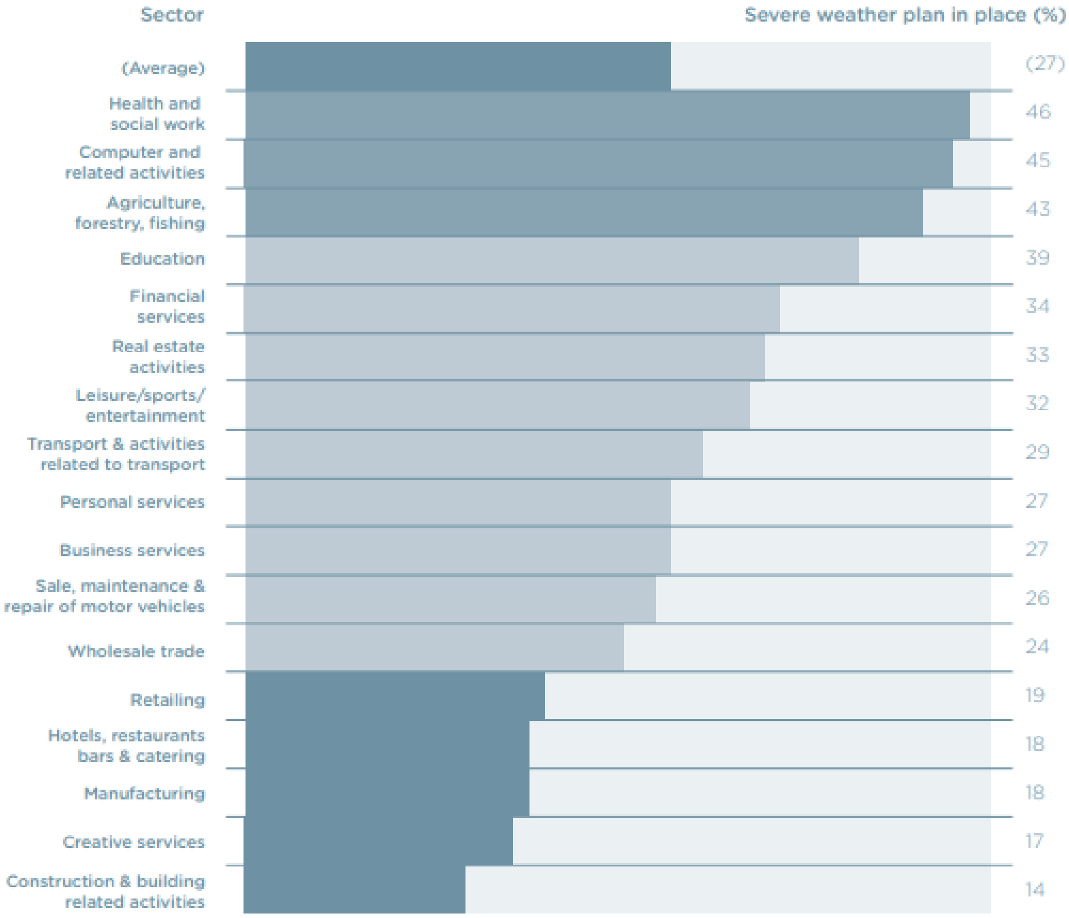

Figure 3.31 – The proportion of small businesses with business continuity plans which specifically mention severe weather by sector. Source: Federation of Small Businesses (2015).

Despite the low levels of weather-related business continuity plans, it was reported that 64% of small businesses have taken some action towards managing the risk of severe weather to some part of the business. It was also noted that the number of businesses with a severe weather plan increased where the business had experienced severe weather impacts directly within the preceding three years; from 27% to 46%.

The most common area for taking action to manage severe weather was property and assets, with 40% of firms taking action in this area. The least common area was taking action in the supply chain, with only 19% of firms taking action to manage the impact of severe weather on their supply chain, shown in Figure 3.32. A similar proportion of businesses stated that they had taken action to manage the impact on service/product delivery, staff and business reputation.

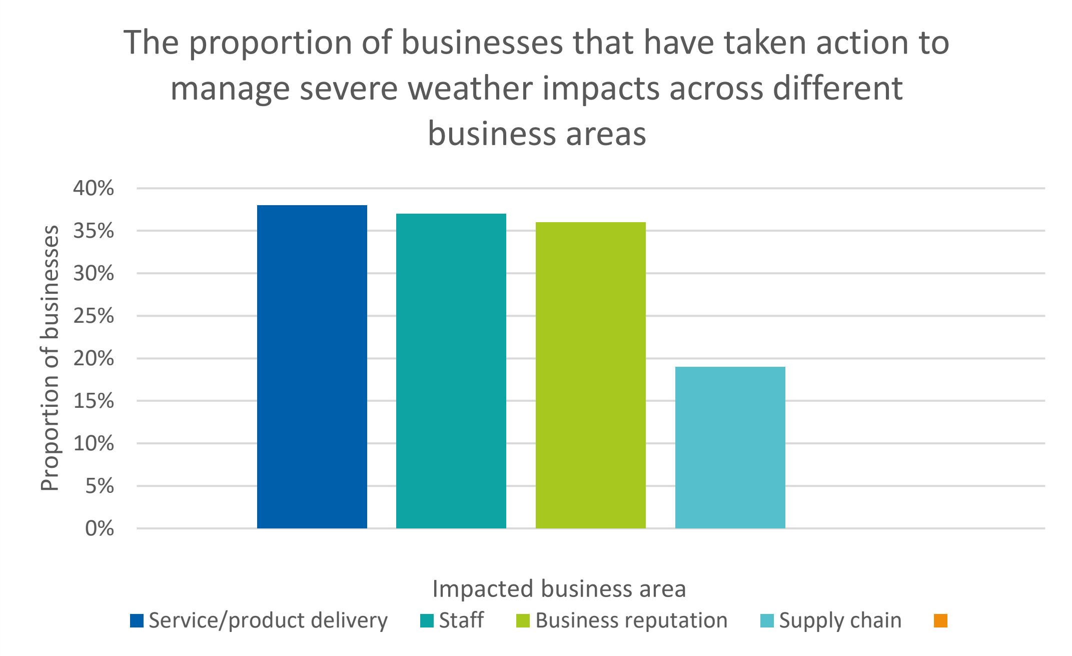

Figure 3.32 – The proportion of small businesses that have taken action to manage severe weather impacts across different business areas, as reported in Federation for Small Businesses (2015). Source: ADAS for the CCC.

Where assessing future business risk to climate change, information can be gleaned from a report by the BCI (2018), which carried out a survey of 657 businesses in 76 countries (50% of respondents from Europe) to produce a horizon scanning report. This study found that adverse weather is rated as the fifth biggest threat to businesses. When asked about the concern of adverse weather (defined as windstorms/ tornadoes, flooding, snow, drought etc.) to their business, 48% were either extremely concerned or concerned about adverse weather (Figure 3.33).

However, the study also found that 50% of participants had experienced disruption due to adverse weather during the prior 12 months; making adverse weather the second biggest disruptor to businesses, second only to unplanned IT and telecom outages.

Looking at responses from Europe only, adverse weather was not rated in the top three disruptors of businesses within the prior 12 months. However, it was the number one disruptor for North America, Central & Latin America, Canada, India and Asia, the number two disruptor in Australia, and the number three disruptor in Sub-Saharan Africa. This shows that currently, adverse weather is causing and/or perceived as a greater impact to businesses outside of Europe.

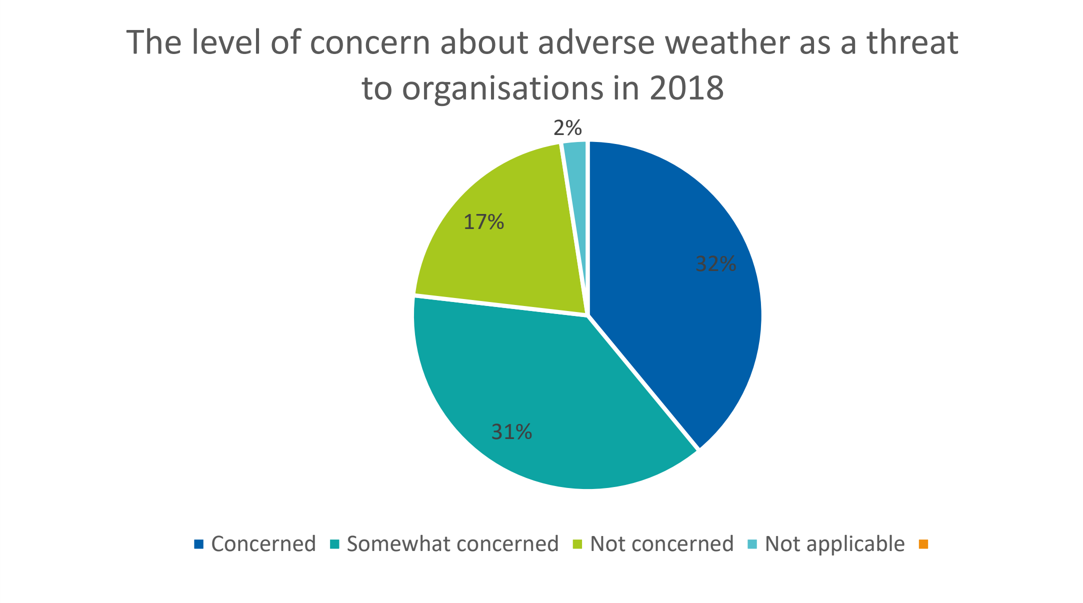

Figure 3.33 – The level of concern about adverse weather as a threat to organisations based on 595 answers to the question 'how concerned are you about the following threats to your organisation in 2018?'; adverse weather was included amongst a list of threats and defined as e.g. windstorm/tornado, flooding, snow, drought. Data taken from Business Continuity Institute (2018). Source: ADAS for the CCC.

Looking at continuing investment in continuity programmes, 77% of respondents said they would either maintain (52%) or increase (25%) their investment in continuity programmes in 2018 (BCI, 2018).

3.14 Sales of adaptive measures / products

Description: *Sales of air conditioning units, permeable paving, green roofs, water efficient appliances, tinted window film, external shutters*

Type: *Action*

3.14.1 Introduction

In order to adapt effectively to a changing climate, a number of measures can be taken or implemented to either reduce the impact, or increase resilience. This indicator looks at the sales of different items/building materials that provide an indication in progress for preparing for a changing climate.

Air conditioning units are used to keep environments cool, and it is anticipated that there will be an increased demand for these as average and/or extreme temperatures increase. Other measures that can be implemented to regulate temperature are **tinted window films** and **external shutters**.

Impermeable surfaces are at risk of flooding as excess water cannot soak away into the soil. Such surfaces can also cause flooding in nearby catchments due to increased run-off of water. Sales of permeable paving give an indication as to whether the ratio of permeable to impermeable surfaces is changing.

Green roofs have a range of benefits, from improving the aesthetics and environmental conditions of an area, to acting as a method to adapt to the impacts of climate change. The latter can include water management, temperature moderation, improved air quality, and increased biodiversity.

Water efficient appliances can be installed to conserve water. This will be increasingly important as the demand for water increases with population growth, exacerbated by climate change.

3.14.2 Data and information availability

No data was found for water efficient appliances, tinted windows or external shutters, therefore the evidence base has not been updated for sales of these items.

3.14.2.1 Air conditioning units

Data was found on the Statista website[127] for overall demand for air conditioners in the UK from 2011 to 2017, recorded in thousand units. This data originates from a study by the Japan Refrigeration and Air Conditioning Industry Association who estimate air conditioner (AC) demand in various countries around the world. This includes the total AC demand for houses, buildings, and other structures comprising demand of “Room Air Conditioners (RAC)”, including window type and small-sized split type ACs as well as “Packaged Air Conditioners (PAC).” No data was found for air conditioning sales.

3.14.2.2 Permeable paving

Harley and Jenkins (2014) report sales of permeable and impermeable block paving from 2008 to 2013. The number of companies included varies for the different years; for 2008 data was included for three companies, for 2009 this was four companies, 2010 and 2011 included data for five companies, and 2012 and 2013 included data for six companies. The data includes sales of concrete block paving, and domestic and commercial sales of concrete block permeable paving. The authors of this report were contacted, but they were unaware of any more recent data available without the commission of an additional study.

3.14.2.3 Green roofs

Living Roofs (2017) contains data on the value of the green roofs market and the equivalent area of substrate sold for green roofs in 2015 and 2016. This was referred to within the 2017 update by ADAS (ADAS, 2017). A recently published report by Living Roofs (2019) provides data for 2017.

3.14.3 Evidence base and implications for climate resilience

3.14.3.1 Air conditioning units

Demand for air conditioning units has grown by 17% between 2011 and 2017, shown in Figure 3.34. In 2017, there was demand for 188,000 air conditioning units; compared to 161,000 units in 2011. This increase could be expected due to a combination of increased

[127] https://www.statista.com/statistics/721558/ac-demand-units-uk/

housing coupled with a warming climate. The value of the UK air conditioning market was estimated at US $1.07 billion in 2014[128].

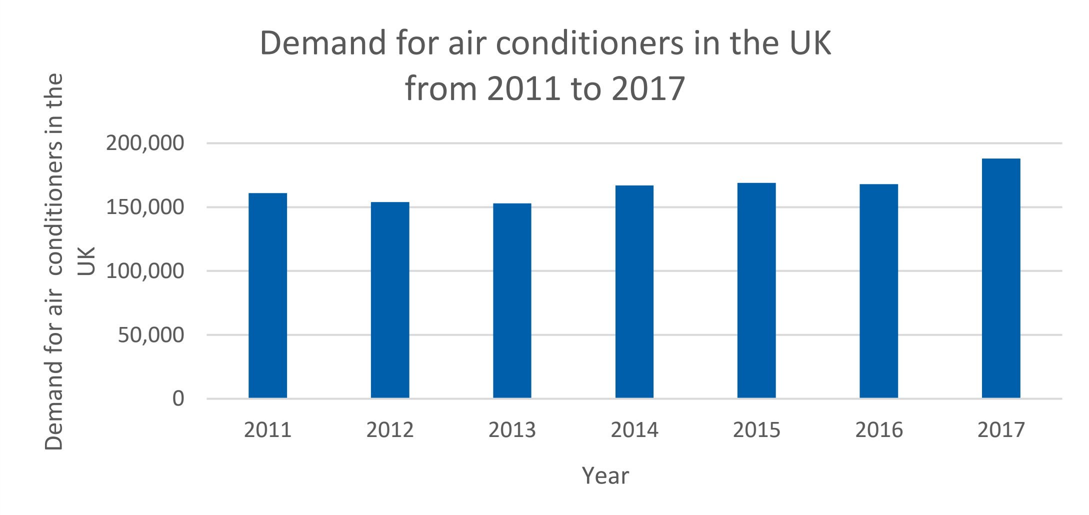

Figure 3.34 - Bar chart showing the demand for air conditioners in the UK from 2011 to 2017, as reported by Statista. Source: ADAS for the CCC.

3.14.3.2 Permeable paving

The Harley and Jenkins (2014) report demonstrates that there has been a 306% increase in sales of concrete block permeable paving (CBPP) from 267,038 m^2 in 2008 to 1,084,583 m^2 in 2013 (Figure 3.35). This is compared to a 1.8% decrease in sales of concrete block paving (CBP). However, sales of CBPP remain considerably lower than sales of concrete block paving, shown in Figure 3.36.

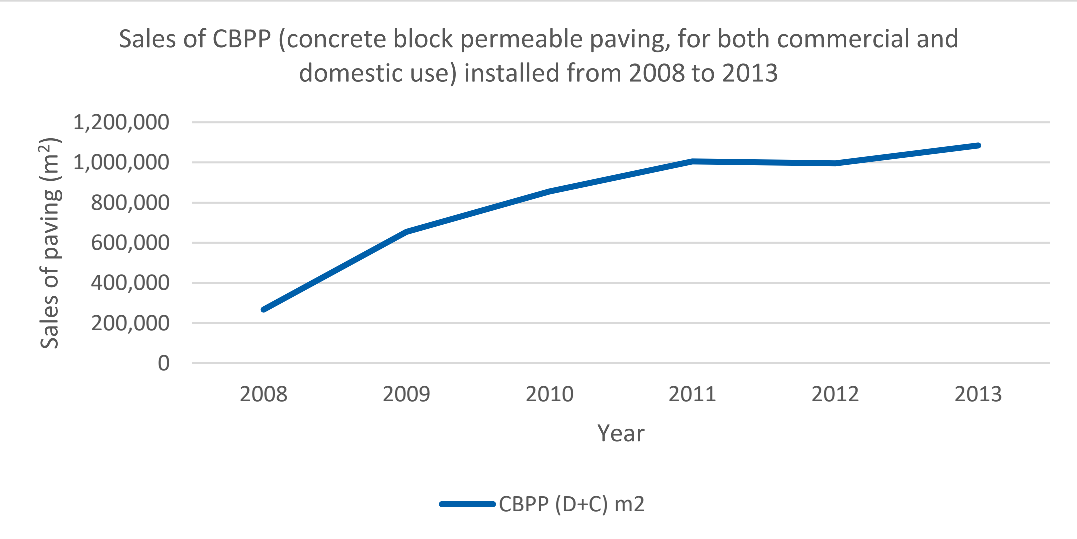

Figure 3.35 – Sales of concrete block permeable paving (for both commercial and domestic use) from 2008 to 2013, using data found in Harvey and Jenkins (2014). Source: ADAS for the CCC.

[128] http://www.modbs.co.uk/news/archivestory.php/aid/14607/The_UK_market_for_air_conditioning_heats_up.html

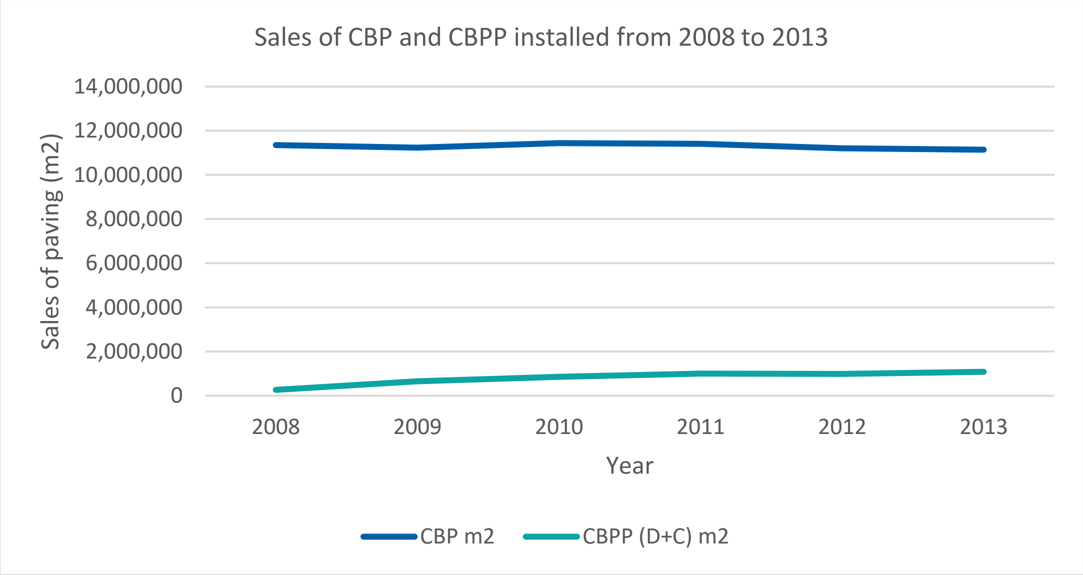

Figure 3.36 – Sales of concrete block paving (CBP) and concrete block permeable paving (CBPP) (for both commercial (C) and domestic (D) use) from 2008 to 2013, using data found in Harvey and Jenkins (2014). Source: ADAS for the CCC.

3.14.3.3 Green roofs

Figure 3.37 shows that the green roof market has increased by 33% from £26.2 million in 2015, to £34.9 million in 2017. Growth slowed slightly between 2016 and 2017, at 13.5%, compared to growth of 17% between 2015 and 2016. The equivalent area of substrate delivered increased by 28% from 394,540m^2 in 2015 to 504,902m^2 in 2017. Similarly to the market value, this growth was greater between 2015 and 2016 (17%), than between 2016 and 2017 (9%). Based on the data in Figure 3.37, the cost of green roofs per m^2 was approximately £66 in 2015 and 2016; increasing to approximately £69 in 2017.

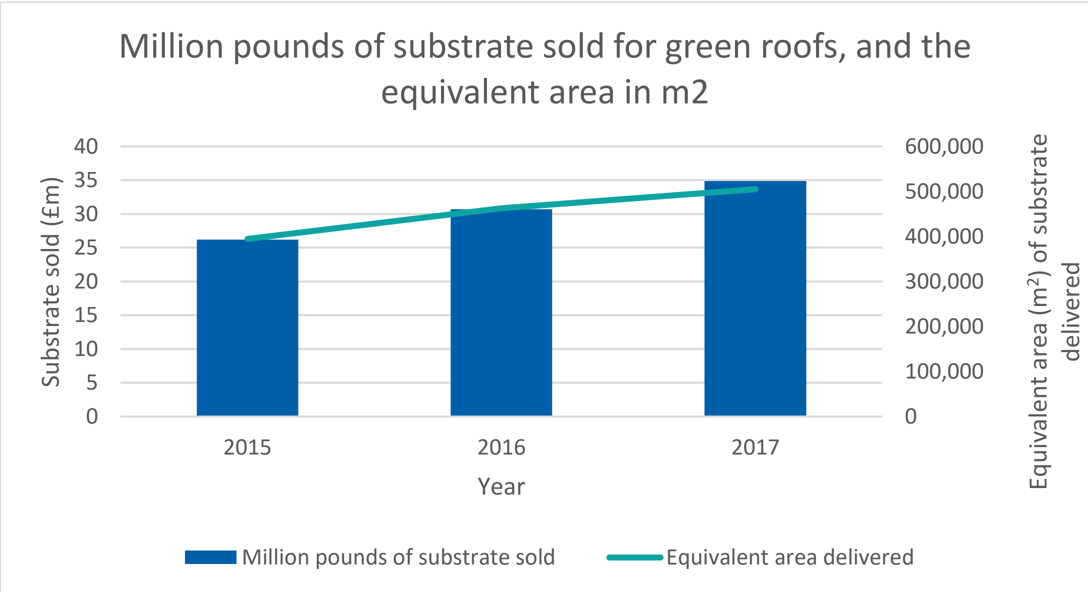

Figure 3.37 – Bar chart showing the change in market of green roof sales from 2015 to 2017, in million pounds of substrate sold, against equivalent area delivered in m^2, using data from Living Roofs (2017 and 2019). Source: ADAS for the CCC.

There are two types of green roofs: extensive and intensive. Extensive green roofs are lightweight and require less maintenance than intensive green roofs. They are also easier and less costly to install[129]. Intensive green roofs are similar to parks and gardens, and require frequent maintenance[130].

In 2015 and 2016, extensive green roofs made up 55% of the market (based on £m of substrate sold). This dropped to 48% in 2017. In 2017, the approximate installed price of extensive green roofs was £52 per m^2, compared to £100 per m^2 for intensive green roofs (Living Roofs, 2019). Figure 3.38 shows that, in line with these cost differences, the equivalent area of substrate sold for extensive green roofs was much greater than for intensive green roofs.

The growth in equivalent area of substrate sold between 2015 and 2016 was 17% for both extensive and intensive green roofs. However, the growth pattern changed between 2016 and 2017, with the equivalent area of substrate sold for intensive green roofs increasing by 29% from 138,785 m^2 in 2016 to 179,402 m^2 in 2017, compared to only a 0.5% increase in the equivalent area of substrate sold for extensive green roofs, from 323,832 m^2 in 2016 to 325,500 m^2 in 2017 (Figure 3.38).

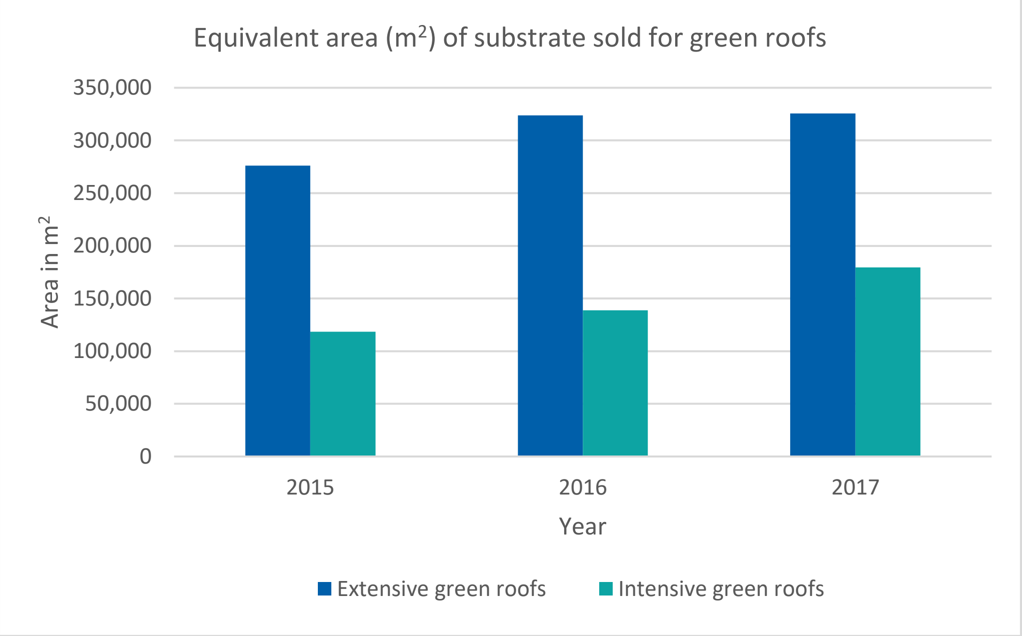

Figure 3.38 – The equivalent area of substrate sold for extensive and intensive green roofs. Data from Living Roofs (2019). Source: ADAS for the CCC.

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[129] https://livingroofs.org/extensive-green-roofs/

[130] https://livingroofs.org/intensive-green-roofs/

3.15 Economic impacts of hot weather, cold weather, flooding and drought

Description: *Annual economic losses and impacts from flooding / severe weather events (e.g. hot weather, cold weather, flooding and drought)*

Type: *Realised Impact*

3.15.1 Introduction

According the European Environment Agency (2017), recorded losses from climate change extremes in Europe during the period 1980 to 2013 amounted to more than €393 billion, with an estimated 75,000 deaths attributed to heatwaves, 4,400 from floods, 3,300 from storms, and a similar number from cold weather, drought and forest fires.

The estimated economic losses for the UK alone during this time period was €46.05 billion; the fourth highest losses after Germany (€78.72 billion), Italy (€59.62 billion) and France (€53.18 billion). These top four countries account for 60% of all economic losses from climate change extremes in Europe.

The number of recorded climate-related extremes has increased in recent years, however, this could in part be driven by better reporting and socio-economic factors.

3.15.2 Data and information availability

There is little evidence available on the economic impacts of weather. However, the Environment Agency and Defra published reports on the impact of flooding and drought respectively. Evidence from these reports, as well as additional information sourced through parliamentary records and news articles have been used to update this evidence base.

3.15.3 Evidence base and implications for climate resilience

3.15.3.1 Hot weather

Parliamentary records[131] state that the main risks of hot weather are: decreased productivity due to overheating; loss of work days due to transport failures; substantial costs to the healthcare sector; and high maintenance costs to roads and public transport. Conversely, it was noted that there may be some opportunity for the economy due to increased tourism and greater demand for services located near beaches and outdoor leisure centres.

In 2010, approximately five million staff days were lost because of temperatures over 26°C. This can be estimated at a loss of £770 million based on an average staff cost of £150 per day (CCC, 2017b).

3.15.3.2 Cold weather

An article in the Guardian in 2018 comments on the impact of cold weather in the UK[132]. The article reports that cold weather in December 2010 was considered the worst on record for the economic damage that it caused; with the Office for National Statistics calculating that 0.5 points were knocked off gross domestic product (GDP) growth due to the extreme

[131] https://publications.parliament.uk/pa/cm201719/cmselect/cmenvaud/826/82607.htm

[132] https://www.theguardian.com/uk-news/2018/mar/03/freezing-weather-storm-emma-cost-uk-economy-1-billion-pounds-a-day

weather. Cold weather can result in delays on motorways, train cancellations, disruption to work, and reduced footfall in shops, restaurants and leisure facilities which can impact on the economy and GDP growth. During the ‘Beast from the East’ in March 2018, it was estimated at the time that the construction industry could lose up to £2 billion during the three worst days due to sub-zero temperatures, creating unsuitable working conditions. However, GDP could be increased through increased energy use in the home, increased purchasing of perishable goods, and because of councils buying grit to spread on the roads[132,133].

3.15.3.3 Flooding

The Environment Agency (2016) published a report on the costs and impacts of the winter 2013 to 2014 floods. It is estimated that total economic damages from these floods cost £1.3 billion, with a range of between £1 billion and £1.5 billion to take account of uncertainty. It is estimated by the Environment Agency (2016) that the economic impact of the 2007 floods was three times greater than the 2013 to 2014 winter floods, at an estimated £3.9 billion of damages.

The greatest proportion of impact (25%) was in the household sector, where around £320 million of damage was incurred by approximately 10,465 properties. This was followed by the transport sector, with 23% of damage (predominantly to roads), and the business sector, with 21% of damage. Figure 3.39 shows the proportion of economic impact by sector.

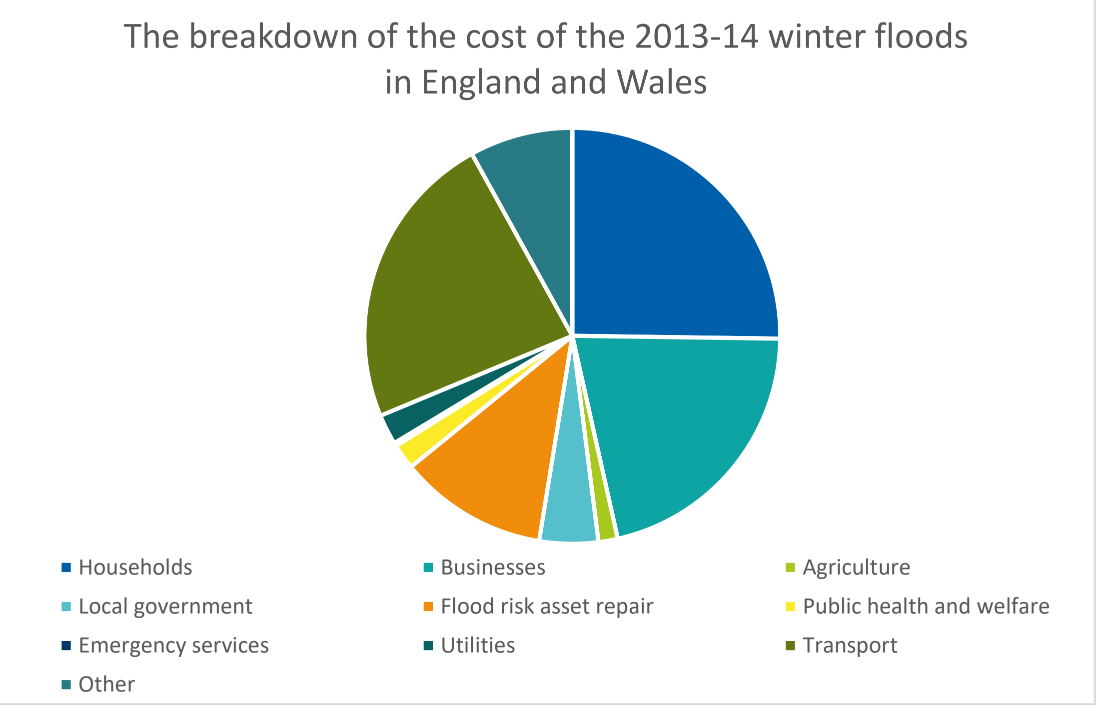

Figure 3.39 – The proportion of the cost of the winter floods from 2013 to 2014 in England and Wales by sector, as reported by the Environment Agency (2016). Utilities includes energy and water, transport includes road, rail, air and ports, and other includes temporary accommodation, cards, boats and caravans, heritage sites, tourism and recreation, wildlife sites and education. Source: ADAS for the CCC.

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133 https://www.bbc.co.uk/news/business-43287975

The Environment Agency (2018) did a similar analysis for the 2015-16 winter flood. The economic damages for this flood were higher in 2015-16 than 2013-14, as shown in Figure 3.40. In these more recent floods, economic impact was estimated at £1.6 billion, with a range of £1.3 to £1.9 billion. The most notable change between the impacts of the 2013-14 and 2015-16 floods is the much greater impacts on businesses in 2015-16. The estimated cost of the two floods, as well as the lower an upper range is shown in Table 3-5.

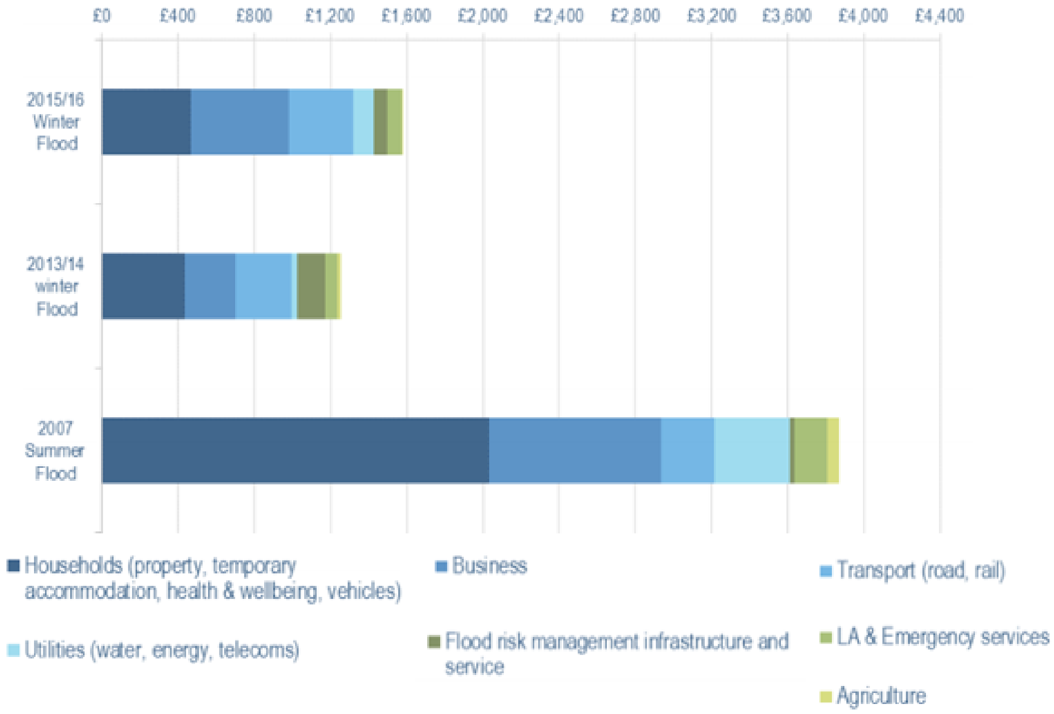

Figure 3.40 – A comparison of economic costs by flood event by grouped impact categories (2015 prices). Source: Environment Agency (2018)

Table 3-5 - The cost of the winter floods from 2013-14 and 2015-16 in England and Wales by sector in million pounds sterling (£m), as reported by the Environment Agency (2016 and 2018).

Sector	Cost in 2013-14	Lower range estimate 2013-14	Upper range estimate 2013-14	Cost in 2015-16	Lower range estimate 2015-16	Upper range estimate (2015-16
Households	**320**	**270**	**370**	**350**	**308**	**392**
Businesses	**270**	**230**	**310**	**513**	**410**	**616**
Agriculture	**19**	**12**	**25**	**7**	**6**	**8**
Local government	**58**	**49**	**66**	**73**	**55**	**92**
Flood risk asset repair	**147**	**145**	**148**	**71**	**63**	**78**
Public health and welfare	**25**	**25**	**67**	**43**	**32**	**54**
Emergency services	**3.3**	**3.3**	**8.7**	**3**	**3**	**3**
Utilities	**29.8**	**25.6**	**34**	**104**	**91**	**117**
Energy	*0.8*	*0.6*	*1*	*83*	*75*	*91*
Water	*29*	*25*	*33*	*21*	*16*	*26*
Transport	**295**	**188.2**	**366**	**341**	**268**	**414**
Other	**101.9**	**84.3**	**117.7**	**96**	**78**	**114**
Temporary accommodation	*50*	*42*	*57*	*37*	*31*	*43*
Cars, boats and caravans	*37*	*31*	*42*	*36*	*31*	*41*
Education	*1.6*	*1.2*	*2*	*4*	*3*	*5*
Heritage sites	*7.4*	*5.6*	*9.3*	*19*	*13*	*25*
Tourism and recreation	*3.5*	*2.6*	*4.4*			
Wildlife sites	*2.4*	*1.9*	*3*			

The World Wide Fund for Nature (WWF) estimates that if the UK follows a business as usual scenario, a repeat flood in 2050 could lead to £2.2 billion in damages due to the increased number of homes, businesses, schools and care homes which would be affected[134].

3.15.3.4 Drought

Defra (2013b) reported on the impacts of the 2011/12 drought in England. The impact of this drought was largely felt in the first half of 2012, when temporary use bans were introduced by water companies to restrict demand. It is estimated that approximately £165 million of revenue, and £96 million of profit was lost during the second quarter of 2012; this is broken down in Figure 3.41. The sector with the most turnover and profit foregone was the irrigated potatoes sector, where £72 million was lost in revenue and profit. Other sectors affected were landscaping services, wholesale and retail nurseries, golf, other irrigated crops, and public water supplies.

[134] https://www.wwf.org.uk/updates/tens-billions-pounds-be-lost-uk-economy-due-extreme-weather-wwf-report-warns-0

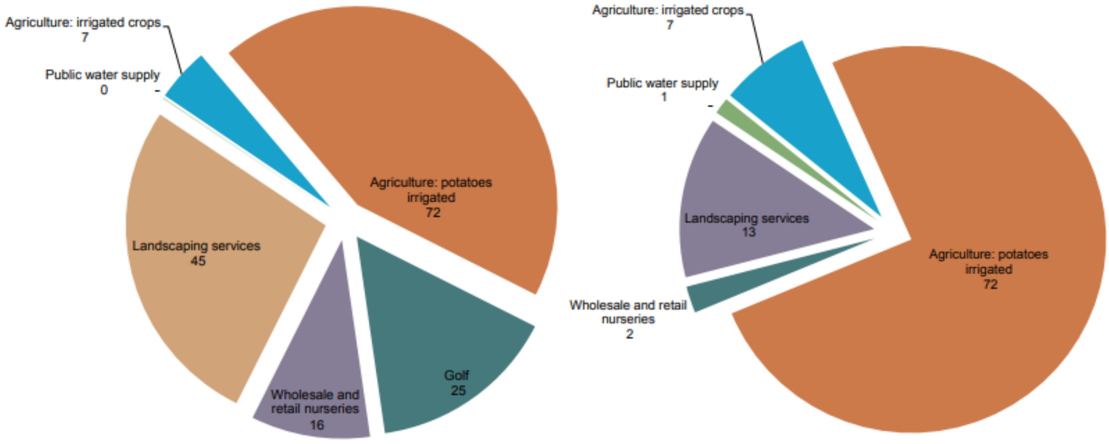

Figure 3.41 – Pie charts showing the amount of turnover (left) and profit (right) foregone during the second quarter of 2012, in £m, as reported in Defra (2013).

It was noted by Defra (2013b) that agriculture and farmers in regions not affected by drought and water use restrictions may have benefited from high prices and increased sales due to challenges faced by their competitors.

Damage is not usually caused to physical capital by drought[135]; however, there may be long-term damage, for example saltwater intrusion leading to land degradation; building damage caused by land subsidence; or damage to ecosystems due to excessive groundwater abstractions.

3.15.3.5 Overview

The economic impacts of severe weather events (e.g. hot weather, cold weather, flooding and drought) is extremely variable and dependent on both the magnitude and duration of an event. Whilst this analysis provides some insight, there is no one-size-fits-all approach to assessing past, or forecasting future, economic impacts due to severe weather events, which may be exacerbated due to climate change.

[135]https://ora.ox.ac.uk/objects/uuid:b9a0431d-7069-422e-a4de-e3b8a7cbcdb1/download_file?safe_filename=ECOLEC_2016_884.pdf&file_format=application%2Fpdf&type_of_work=Journal+article

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