Research to provide updated indicators of climate change risk and adaptation action in England

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Executive Summary

The Climate Change Act 2008 incorporated the issue of climate change into UK legislation, and requires the UK Government to publish a UK-wide Climate Change Risk Assessment (CCRA) every five years, the first of which was published in January 2012, with the second (CCRA2) published in January 2017. In addition, a National Adaptation Programme (NAP) is also published every five years, the first of which was published in July 2013, with the second (NAP2) due in 2018.

In addition, the Act established the Committee on Climate Change (CCC), an independent statutory body to advise the UK government on mitigation (setting and meeting carbon budgets); and the CCC's Adaptation Sub-Committee (ASC), specifically to provide advice to the UK and devolved governments on climate change risks, opportunities and adaptation (preparing for climate change and improving resilience) priorities.

The CCC and ASC provide advice to the UK Government and Devolved Administrations on emissions targets and the current and future risks to the country from climate change; and report to Parliament on progress made in reducing greenhouse gas emissions and preparing for climate change.

In order to provide robust and informed advice, the CCC and ASC conduct independent analysis into climate change science, economics and policy, and engages with a wide range of organisations and individuals to share evidence and analysis.

The ASC has a statutory duty to report to Parliament with an independent assessment of the UK Government's progress in implementing the NAP. The first statutory assessment of the NAP was published in June 2015 as part of the report CCC presented to Parliament, "*Reducing emissions and preparing for climate change: 2015 Progress Report to Parliament*". This report assessed the extent to which progress was being made in adapting to climate change across England.

The ASC is required to produce a second progress report on the NAP by the end of June 2017. This report will consider any changes in policy and action since the first report was produced in 2015, and include any updates in the evidence base, as well as updates to the ASC's existing indicator set.

In the ASC's first ever statutory report in 2015, progress was reported through a series of adaptation priorities. Each priority was given a traffic light score to represent whether appropriate plans were in place, actions were occurring as set out, and trends in vulnerability were moving in the right direction.

The ASC's analysis that underpinned its 2015 report was based on a mixture of policy appraisal and indicators to show how preparedness is changing over time. This set of indicators included the ASC's indicator set, made up of 182 metrics that measure observed changes through time in three core components of adaptation: indicators of risk, indicators of adaptation action, and indicators of climate impact.

For this contract, the ASC identified 70 of the 182 adaptation indicators that were perceived harder to measure. These indicators either required updating since the CCC 2015 Progress Report to Parliament, or previously had poor data availability.

The overall aim of this study was to assist the ASC in updating this subsection of the existing indicator set and to provide data to populate new indicators where possible.

Indicators assessed in this study

Indicators updated

In total, 70 indicators identified by the ASC were assessed. A further 10 indicators identified by ADAS and the ASC were also assessed (marked with 'X' refs in Table 1). The underlying data for each indicator was varied, with some indicators having previously been constructed or discussed in previous reports (e.g. Committee on Climate Change, 2015; HR Wallingford, 2015), whilst other indicators had no known datasets previously identified.

Table 1 outlines the status of each indicator in this project:

- **Updated** - These indicators were updated and/or created based on available datasets and information.
- **Limited Info** – These indicators were partially updated using the limited information available. In the absence of comprehensive data, these indicators include a summary of the available literature or information, or a case study indicating relevant findings.
- **Not Updated** – These indicators were not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

Table 1. Update status of indicators assessed in this project

Ref	Indicator description	Status	Page
BE7	Area/proportion of built-up areas covered with impermeable surfaces	Updated	1
BE8	Net gain/loss in area/proportion of urban green/bluespace	Updated	3
BE21	Number of households in flood risk areas retrofitting property-level flood protection measures	Not updated	5
IN2	Number of NSIP applications a) approved contrary to EA objection b) not carrying out a satisfactory FRA c) not satisfactorily applying the sequential test.	Updated	6
IN3	Number of NSIPs approved with EA conditions	Updated	10
IN6	Total abstraction of water (surface, groundwater, estuarine and sea) for energy	Updated	11
IN7	Amount of electricity generation capacity (MWh) lost due to temporary abstraction restrictions	Not updated	14
IN8	Number of customer minutes lost due to severe weather	Not updated	14
IN9	Amount of actual and planned investment in resilience measures by water companies	Updated	14
IN10	Leakage (Ml per year)	Updated	16
IN18	Annual number and length of delays to a) rail d) strategic road network caused by severe weather	Updated	19
HCR2	Proportion of healthcare workers not aware of risk from heat stress	Limited info	24
HCR3	Number of hot days per year	Updated	25
HCR5	Area of urban greenspace	Updated	29

Ref	Indicator description	Status	Page
HCR6	Number of air conditioning units bought or fitted (domestic/commercial)	Not updated	29
HCR7	Number of buildings retrofitting passive cooling measures	Not updated	30
HCR8	Number of planning applications with a) conditions requiring passive cooling measures and b) implementing conditions in final development	Not updated	30
HCR9	Number/area of green roofs installed in urban areas	Limited info	30
HCR10	Proportion of sales/installation of air conditioning units (meeting EU ecodesign requirements (domestic/commercial))	Not updated	32
HCR11	Numbers of hospitals/care homes/surgeries implementing heatwave plans	Not updated	32
HCR12	Number of local authorities implementing heatwave plans	Not updated	32
HCR13	Proportion of hospitals/care homes/ schools/ work places that experience overheating	Limited info	32
HCR25	Number of air quality warnings issued	Updated	35
HCR26	Number of people living with chronic respiratory conditions	Updated	39
HCR28	Uptake of public awareness measures on UV risks	Updated	42
HCR31	Distribution/spread of pathogens or vectors across England	Updated	46
HCR32	Number of incidents of Harmful Algal Blooms	Updated	50
HCR33	Spend on surveillance for new/emerging pathogens	Limited info	52
HCR39	Number of camping and caravan sites with evacuation or flood plans in place	Limited info	63
HCR40	Number of working/school days lost from flooding/severe weather events	Limited info	67
HCR41	Number of people suffering mental health impacts following a flood or severe weather event	Limited info	70
HCR42	Average length of time between flood events and people returning to their homes	Limited info	71
HCR43	Number of emergency service stations/hospitals/GP surgeries/ care homes/ schools flooded	Limited info	75
HCR46	Numbers of EA, fire and police officers (related to required capability)	Limited info	79
AF2	Total water demand for crop irrigation and livestock	Updated	83
AF3	Volume of abstraction for agriculture from catchments at risk of water scarcity	Updated	91
AF4	Amount of crop production in climatically unsuitable areas	Updated	95
AF5	Agricultural losses from drought	Updated	110
AF6	Total number of farms implementing water efficiency measures	Updated	116
AF7	Total on-farm water storage capacity	Limited info	118
AF8	Investment in research into water efficiency for cropping/livestock	Updated	119
AF14	Area of agricultural land covered by crops at high-risk of soil erosion	Updated	126
AF15	Area of agricultural land covered by crops at low-risk of soil erosion	Updated	128
AF16	Area of agricultural land losing soil organic carbon, by grade	Not updated	130
AF17	Area of agricultural land converted to development, by grade	Updated	131
AF18	Area of agricultural land under minimum/no tillage, by grade	Not updated	135
AF19	Area of agricultural land covered by soil conservation measures	Updated	135
AF20	Investment in research into soil conservation	Not updated	137

Ref	Indicator description	Status	Page
AF21	Agricultural losses from soil erosion	Updated	137
AF22	Agricultural losses from pests/pathogens	Updated	142
AF23	Timber losses from pests/pathogens	Limited info	147
NE8	Area of blanket bog SSSI with consents in place that allow burning	Updated	151
NE9	Area of deep peat covered by catchment-scale restoration programmes	Limited info	152
NE10	Annual greenhouse gas emissions/carbon losses from degraded peatlands	Limited info	153
NE11	Colour levels (hazen) in raw water for drinking water supplies	Updated	154
NE12	Dissolved Organic Carbon concentrations in upland water bodies	Updated	157
NE27	Number of catchments with partnerships in place	Updated	160
NE28	Number of low river flow (Q95) incidents	Not updated	162
NE30	Proportion of Marine Protected Areas (SACs/SPAs/SSSIs/MCZs) in unfavourable condition	Updated	162
NE35	Change in area of heathland	Updated	164
NE36	Change in area of bog or fen	Updated	167
NE37	Change in area of coastal habitats	Limited info	168
NE38	Area of priority habitat created in order to meet BD2020 Outcome 1B	Updated	170
NE41	Area covered by 'landscape-scale' conservation initiatives	Not updated	172
NE42	Habitat connectivity in the wider countryside	Not updated	172
BUS5	Proportion/number of businesses at risk of flooding taking up property-level flood protection measures	Not updated	173
BUS12	Water abstraction and consumption of public water supply by industry	Updated	173
BUS15	Number of businesses affected by Hands off Flow conditions	Updated	174
BUS16	Uptake of water efficiency measures by water-intensive industries	Not updated	178
BUS18	Number of patents registered by UK companies for adaptation technologies and products each year	Not updated	178
X1	Number of wine producing vineyards	Updated	178
X2	Land use in fluvial flood plains	Updated	122
X3	Uplands, what are they used for?	Updated	140
X4	Rates of inspection and enforcement of basic payment schemes	Updated	180
X5	Average lengths of farmer tenancies	Updated	185
X6	RNLI Capability for responders in-shore	Limited Info	80
X7	Number of days with High Air Pollution	Updated	54
X8	Number of flood warnings issued on FWD	Updated	76
X9	Number of registrations for FWD	Not updated	78
X10	Particulate Pollution	Updated	58

Contents

1 Built Environment

1.1 Surface water flood management

BE7: Area/proportion of built-up areas covered with impermeable surfaces

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. 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.

Methodology

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.

To define the urban (built-up) area, MasterMap Address Base 2 was used to calculate the property density per 1km grid cell. A density of >500 properties per 1km cell provided a good match with the boundaries of urban areas of England in the methodology developed by HR Wallingford (2012), however larger areas of greenspace within cities and towns were missed by this method. HR Wallingford therefore improved their approach by taking 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.

The urban creep method (Gill et al., 2008) used the property density to assign a housing class to each grid cell (Table 2). The impervious fraction of the "Multiple" areas were then estimated 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 3) and then adding this the impervious pitched fraction to get a total impervious fraction.

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

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 3. 2001 baseline data for surface type percentages of domestic gardens by housing class. Source: Gill et al. (2008).

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

Results

The area of built-up areas covered by impermeable surfaces is shown for the current analysis (2016) and previous results (HR Wallingford, 2012) for comparison in Table 4. The results show that the overall impermeable fraction of built-up areas has not increased since 2011, remaining stable at an estimated 44% in 2016. The manmade area alone has increased however, increasing by 28 thousand hectares since 2011 (32% vs. 31% of total). This is likely to represent urban expansion, but note the slight increase in total area covered by the urban definition (Figure 1) due to the use of the 'improved' Wallingford method (see methods section).

Table 4. Area of built-up areas covered by impermeable surfaces as estimated using OS MasterMap and using assumptions of urban creep. Source: ADAS for ASC (2016 data); HR Wallingford (2012) (2001-2011 data).

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

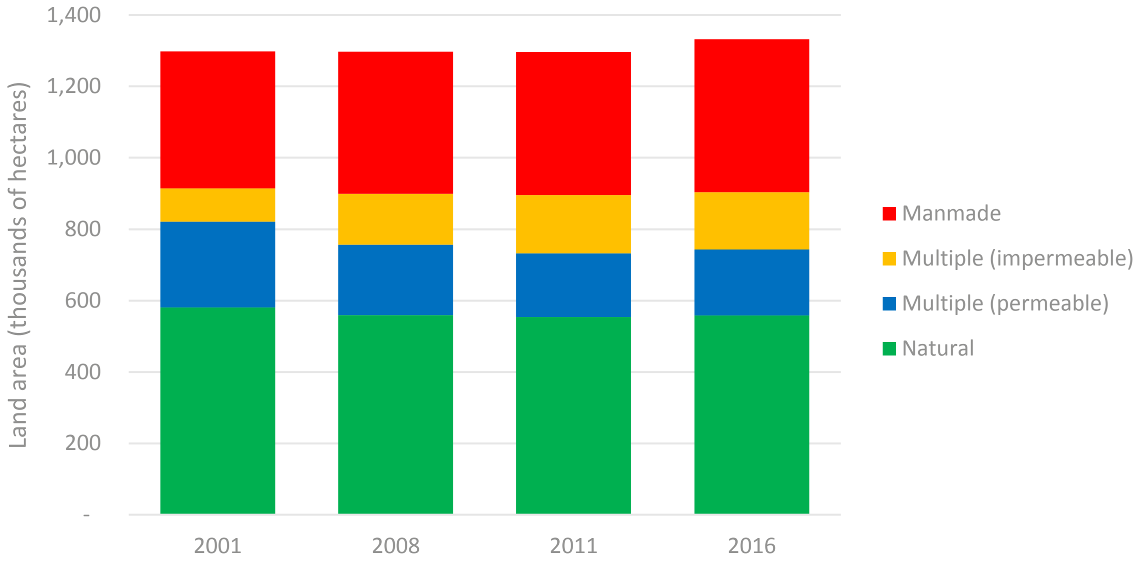

Figure 1. Time series of fractions of land areas of different 'makes' in urban areas. Source: ADAS for ASC (2016 data) and HR Wallingford (2012) (2001-2011 data)

Robustness

Ordnance Survey MasterMap is considered to be the definitive source of highly-detailed geographic data of Great Britain[1]. 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 method for definition of urban areas was changed slightly for the 2016 calculations. Also, 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 2016 and earlier years should therefore be made with caution.

BE8: Net gain/loss in area/proportion of urban green/bluespace

Introduction

This indicator is closely related to BE7, but provides the opposite perspective in that it tracks change in the natural/ semi-natural areas within towns and cities. Green and blue space within urban areas can provide a sustainable means of storing or dissipating flood water or run-off following storms. Towns and cities are increasingly using sustainable urban drainage systems in

[1] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

their new developments and tracking the proportion of the urban area that comprises these adaptive features is important to help quantify the magnitude of the effect they are having.

Methodology

The method used was similar to that used for BE7, but with the area of greenspace in urban areas estimated from the area of the "Natural" material plus the permeable fraction of "Multiple". The area of bluespace in urban areas was estimated using the "Water" theme in MasterMap Topographic layer.

Results

The area of built-up areas covered by permeable surfaces (greenspace) is shown for the current analysis (2016) and previous results (HR Wallingford, 2012) for comparison in Table 5. The results show that the permeable fraction of built-up areas has remained stable between 2011 and 2016 at an estimated 56%, but note the slight increase in total area covered by the urban definition (Figure 1) due to the use of the 'improved' Wallingford method (see methods section of BE7). The 'Natural' fraction has decreased slightly from 43% in 2011 to 42% in 2016.

Table 5. Area of built-up areas covered by permeable surfaces (greenspace) as estimated using OS MasterMap and using assumptions of urban creep. Source: ADAS for ASC (2016 data); HR Wallingford (2012) (2001-2011 data).

Thousand ha	2001	2008	2011	2016
Multiple (permeable)	240	198	178	185
Natural	581	559	554	558
Fraction of total	*0.63*	*0.58*	*0.56*	*0.56*

The urban area covered by bluespace (water) totalled 37 thousand hectares in 2016. This was not comparable (much higher) to results obtained in previous years for unknown reasons.

Robustness

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 bluespace and greenspace (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 greenspace area, but should be consistent across years. The method for definition of urban areas was changed slightly for the 2016 calculations. Also, 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 2016 and earlier years should therefore be made with caution.

1.2 Residual flood risk of existing buildings

BE21: Number of households in flood risk areas retrofitting property-level flood protection measures

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

2 Infrastructure

2.1 Design and location of new infrastructure

IN2: Number of NSIP applications a) approved contrary to EA objection; b) not carrying out a satisfactory FRA; and c) not satisfactorily applying the sequential test.

Introduction

The planning process for dealing with proposals for nationally significant infrastructure projects, or 'NSIPs', was established by the Planning Act 2008. The Planning Act 2008 process was introduced to streamline the decision-making process for nationally significant infrastructure projects.

The National Infrastructure Planning website contains documents related to proposed major infrastructure projects within England and Wales within their 'register of applications'. This register is required in accordance with Section 39 of the Planning Act 2008. The National Infrastructure Planning website is managed by the Planning Inspectorate, the government agency responsible for examining planning applications for NSIPs. Links are provided on this website to view further information and documents for each project including adequacy of consultation representations and the decision to accept the application for examination. The environmental documents such as screening and scoping opinions can be accessed from within the documentation area of the relevant project page.

Flood risk needs to be taken into account in the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at highest risk. The decision-maker should be satisfied that where relevant:

- The application is supported by an appropriate Flood Risk Assessment (FRA);
- The Sequential Test has been applied as part of site selection;
- A sequential approach has been applied at the site level to minimise risk by directing the most vulnerable uses to areas of lowest flood risk; and
- In flood risk areas the project is appropriately flood resilient and resistant, including safe access and escape routes where required, and that any residual risk can be safely managed over the lifetime of the development.

There are 3 flood zones as defined by the Environment Agency (EA); flood zone 1, 2 and 3. These areas have been defined following a national scale modelling project for the EA and are regularly updated using recorded flood extents and local detailed modelling. The flood zones are based on the likelihood of an area flooding, with flood zone 1 areas least likely to flood and flood zone 3 areas more likely to flood. The definitions of the different flood zones are set out in (Table 6).

Table 6. Flood Zone definitions (Source: Environment Agency[2])

Zone	Definition
Zone 1 Low Probability	Land having a less than 1 in 1,000 annual probability of river or sea flooding. (Shown as 'clear' on the Flood Map – all land outside Zones 2 and 3)
Zone 2 Medium Probability	Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding; or land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding. (Land shown in light blue on the Flood Map)
Zone 3a High Probability	Land having a 1 in 100 or greater annual probability of river flooding; or Land having a 1 in 200 or greater annual probability of sea flooding.(Land shown in dark blue on the Flood Map)
Zone 3b The Functional Floodplain	This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. (Not separately distinguished from Zone 3a on the Flood Map)

The Planning Act 2008 makes the Environment Agency a statutory consultee for all NSIPs. For most NSIPs there is a National Policy Statement (NPS) and the EA checks (for matters in their remit such as flood risk) if the application meets the requirements of the relevant NPS, as well as the NPPF (which also applies to NSIPs). The EA don't enforce planning policy, this is the responsibility of the Local planning Authority (LPA) and the relevant Secretary of State for NSIPs. In terms of how the EA respond to NSIPs, rather than object, it provides comments at pre-app stage regarding the key issues and what it feels should be done to address them in the DCO application.

In order that flood risk is taken into account in the planning process, a Flood Risk Assessment (FRA) is required for most developments within one of the flood zones (i.e. not purely offshore developments). Consideration of the effects of climate change is one of the minimum requirements of the FRA. Because of their size, all approved NSIP projects should contain an adequate FRA where a portion of the development sits inside a flood zone.

The Sequential Test (ST) ensures that a sequential approach is followed to steer the location of a new development to areas with the lowest probability of flooding. A planning authority should demonstrate, through evidence, that it has considered a range of options in the site allocation process, using the Strategic Flood Risk Assessment to apply the sequential test. If the sequential test demonstrates that there is no reasonably alternative site for a project in Flood Zones 1 or 2, a Project can be located in flood zone 3 subject to the ***Exception Test***. The exception test requires an applicant to demonstrate the following:

[2] https://www.gov.uk/guidance/flood-risk-and-coastal-change#Assessment-to-identify-functional-floodplain

- That the Project provides wider sustainability benefits to the community (which shall include benefits, including need, for the infrastructure) that outweigh flood risk;
- That the Project is on developable, previously developed land or, where it is not on previously developed land, that there are no reasonable alternative sites on developable previously developed land subject to any exceptions set out in the technology-specific NPS; and
- That the Project will be safe, without increasing flood risk elsewhere and where possible, will reduce flood risk overall.

The EA does not determine if the ST has been passed – there are matters in the ST regarding availability of other sites that the EA cannot comment on, so it would be up to PINS to assess this and advise the Secretary of State to inform their decision making. Where it is not clear if the ST has been passed, the EA reminds the decision maker they should check it has.

It is important to note that if an FRA is unsatisfactory or ST has not been passed, this does not necessarily reflect on the climate change assessment component of these assessments/tests.

Methodology

As of January 2017 there were 75 projects listed on the 'register of applications' going back to August 2010.[3]

- Three were in the examination stage
- Two were at recommendation
- Four were at decision
- Four were refused
- 57 were granted
- Five were withdrawn and all records removed from the site

Of the 57 NSIP applications which have been granted, 48 are in England. The chapter on flood risk in the ***Examining Authority's Recommendation Report*** for all 48 granted applications in England from the register of applications was reviewed.

<u>This review collated data on:</u>

- Any outstanding objections from the EA regarding flood risks
- The flood zone classification of the development site
- Details on the FRA and subsequent response from the EA
- Details of the sequential test and exception test – if required, were they applied in line with EA expectations?

[3] https://infrastructure.planninginspectorate.gov.uk/projects/register-of-applications/

In certain cases, suitable information was not available in the Examining Authority's Recommendation Report. Where available, documentation surrounding the FRA was also reviewed. For six of the applications reviewed, documentation on the FRA was not readily available.

Results

Approved contrary to EA objection

No approved project from the list of register of applications were approved with outstanding objections from the EA. All applications, through a process of engagement with the EA, resolved any outstanding objections held by the EA, before the application was submitted to the Secretary of State for a decision.

Flood zone classification

Details were collated on the flood zone classification of the development site as this influences the requirements of the sequential and exception test (Figure 2). The flood zone was not mentioned for certain offshore developments (where this would not be relevant). Where the site crosses multiple flood zones the zone of higher risk was included.

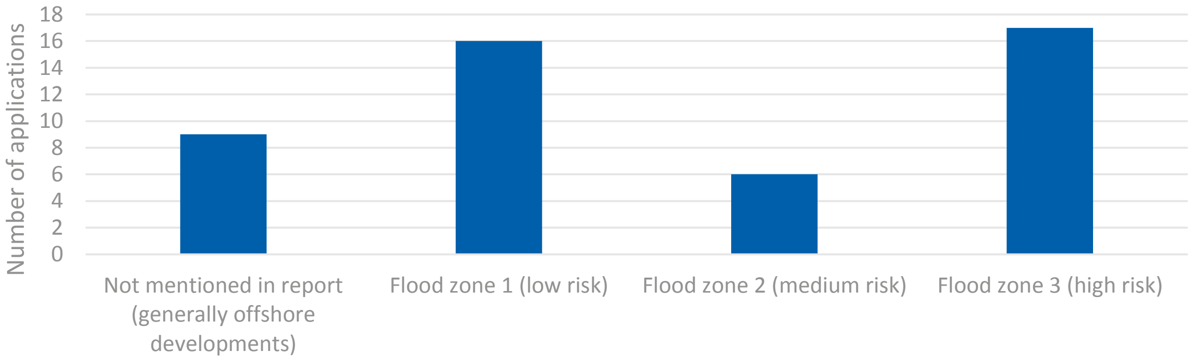

Figure 2. Flood zone classification for NSIP application sites. Source: ADAS for ASC.

Flood Risk Assessment (FRA) | All approved NSIP projects should contain an adequate FRA.

- 45 out of the 48 approved applications contained details of an FRA. The three that did not were offshore developments and therefore may not have required the completion of an FRA. That said, three more recent offshore developments have included details of an FRA. However, this may be due to the inclusion of land based units (substations) located in one of the flood zones.
- In 39 of the 45 FRAs reviewed, the Examining Authority's Recommendation Report includes specific text stating that the EA was satisfied with the method, scope and findings contained within the FRA. In the other six reports no specific reference was made indicating the satisfaction of the EA.

The sequential test and exception test | Details of the sequential test was provided in 33 of the 45 applications that contained a FRA. In the remaining 12 applications the sequential test was either a) not required as part of the application as the development was already situated in a low risk flood zone b) conducted but not documented or c) required but not conducted. Based on the information available it would appear that eight of the applications did not require the sequential test to be applied. In one application a request was made by the EA for the sequential test to be followed, but there is no evidence that this has occurred. Not enough information is provided for the remaining three applications to make any conclusions as to the reason for the absence of details on the application of the sequential test.

Details of the exception test were provided in 19 of the 45 applications. The Examining Authority's Recommendation Report or documentation on the FRA clearly states that the exception test was not required on a further 21 of the approved applications in England. Not enough information is provided for the remaining five applications to make any conclusions on whether the exception test was required or not, or if it had or hadn't been completed.

IN3: Number of NSIPs approved with EA requirements (Development Consent Order (DCO) 'requirements')

Introduction

A consent by a Minister for a Nationally Significant Infrastructure Project (NSIP) will take the form of a Development Consent Order (DCO). This will combine a grant of planning permission with a range of other separate consents.

For EA requirements that are part of the DCO, the Environment Agency (EA) determine any conditions to attach to the DCO. The EA makes recommendations on what these requirements should be and the Planning Inspectorate (PINS)/Secretary of State (SoS) would decide whether or not to include them. The EA would then be consulted on discharge of DCO requirements.

Although not all the requirements that the EA recommends to be attached to DCOs are necessarily for flood risk issues or relate to climate change adaptation aspects of flood risk this indicator focuses on just those requirements. It should be noted that the majority of EA consents are not part of a DCO and are decided separately.

Methodology

Analysis of this indicator was completed in parallel with the previous indicator IN2 and a similar methodology was followed. This time the Examining Authority's Recommendation Reports were reviewed for EA recommend requirements which specifically mention flood risk issues or relate to climate change adaptation aspects of flood risk.

Results

Additional EA requirements which specifically focus on flood risk were identified in 12 of the 47 approved applications. It is not possible to say that the remaining 35 applications did not come with requirements from the EA, but if they did they were not explicitly expressed in the section on flood risk in the Examining Authority's Recommendation Reports.

The text associated with the EA requirements identified can be viewed in the accompanying Excel workbook. The requirements vary considerably.

The most frequently occurring requirement is ongoing consultation with the EA on specific matters, for example: *"Condition 17 of the Transmission Assets DMLs* (Deemed Marine Licences) *within the recommended DCO* (Development Consent Order) *provides for consultation with the EA by the MMO* (Marine Management Organisation) *before the start of any decommissioning activities. This would provide the opportunity for advice using the best available information at the time and when there is a likelihood of a better understanding of the long-term impacts of climate change on marine processes and flood defence assets. Subject to this condition, the EA has no outstanding concerns relating to this issue [REP2-007]."* Hornsea Offshore Wind Farm (Zone 4) - Project Two, Examining Authority's Recommendation Report. [4]

2.2 Resilience of energy infrastructure services

IN6: Total abstraction of water (surface, groundwater, estuarine and sea) for energy

Introduction

Water is important to the generation of electricity in England and Wales, but water resources are facing increasing pressures from population growth and are projected to do so in the future from climate change. Thermoelectric generation (such as fossil fuels and nuclear) contributes to 80% of global electricity production (Byers et al., 2014). These facilities often require cooling for efficient and safe operation. This is typically achieved using water abstracted from the natural environment. In England, the electricity sector is responsible for approximately 20% of water abstractions from all sources (except tidal), with use predominantly for cooling. Although most of this water is returned to the environment, some is lost in the production process, and is therefore consumed.

Climate projections indicate that the UK is expected to see higher temperatures in the summer, coupled with a greater likelihood of reduced rainfall (Murphy et al., 2009). This means that there is increased risk of water scarcity through the summer months, leading to increased competition with other users for water.

Records of water abstraction licences are held in the National Abstraction Licensing Database (NALD). The responsible data holder is the Environment Agency (and Natural Resources Wales). This dataset is not currently available as open data as some of the information is considered

[4] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010053/EN010053-002072-Hornsea%20Project%202%20-%20Recommendation%20Report.pdf

confidential. The Department for Environment, Food & Rural Affairs (DEFRA) provide summary information from the NALD on their website in the form of water abstraction tables. Data on the number of licenses held and estimates of average abstraction in millions of cubic metres are presented for non-tidal waters (groundwater and non-tidal surface waters) and tidal waters, and by the following purpose categories:

- public water supply
- spray irrigation (agricultural and non-agricultural)
- agriculture (excl. spray irrigation)
- electricity supply industry
- other industry
- fish farming, cress growing, amenity ponds
- private water supply
- other

Methodology

Data was extracted from DEFRA's water abstraction tables (last updated 3 February 2016). The table used was entitled 'estimated abstractions from all sources except tidal by purpose and Environment Agency/NRW charge region: 2000 – 2014'. Except tidal was selected as we are only looking at fresh water (as its availability may be affected by climate change). This data represented a continuation of the dataset used in the previous ASC indicator report. The estimated abstraction figures for the electricity supply industry for England were extracted from these tables (Table 7).

Table 7. Estimated abstractions from all sources (except tidal) for electricity in England: 2000 – 2014

Estimated abstractions from all sources except tidal for electricity in England: 2000 – 2014 Units: million cubic metres								
Year	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***
Abstraction	2391	3499	3119	2190	2195	1725	1086	1085
Year	***2008***	***2009***	***2010***	***2011***	***2012***	***2013***	***2014***	
Abstraction	1672	1515	1788	1433	2048	1805	2152	

A distinction should be made between withdrawal and consumption. Water withdrawn from the environment, in that it is abstracted from the ground or diverted from a surface-water source, does not necessarily get consumed. Consumptive use is defined as the part of water withdrawn that is not returned, i.e. it is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Although it is not possible with the available data sources to quantify the consumptive use, the combination of available data and knowledge of the types of energy generation have been used to highlight where consumptive use is likely to be occurring.

Results

The overall trend in abstraction for electricity supply from 2000-2014 shows a decreasing trend (Figure 3). Over the period investigated, abstraction rose to a high of 3,499M m^3 in 2001, before falling to 1,085M m^3 in 2006 and 2007 before returning to 2,152M m^3 in 2014. Owing to a lack of a detailed breakdown by use category (e.g. hydroelectric) for all years the drivers behind these fluctuations cannot be accurately identified.

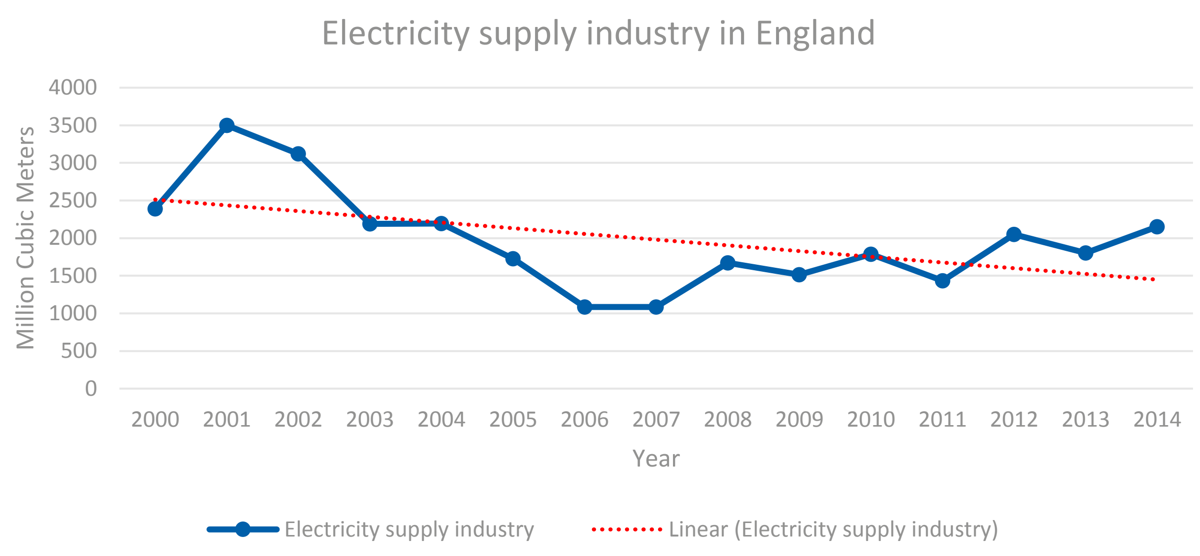

Figure 3. Estimated abstractions from all sources except tidal for electricity in England: 2000 – 2014. Source: DEFRA ENV15 - Water abstraction tables (last updated 3 February 2016).

Consumptive and non-consumptive use

Based on the licenced abstraction volumes provided by the EA for 2016:

- Hydroelectric power generation makes up almost 47% of licenced abstractions for the electricity supply industry - this is all ***non-consumptive use***.

The remaining 53% is used for cooling (predominantly for thermal generation, but a proportion of this will be used for other industrial cooling). This is separated into a number of sub-classifications;

- Evaporative cooling (3%) – A high proportion of this water goes for consumptive use.
- General Cooling (Existing Licences Only) (High Loss) (0.2%) – High loss indicates that a large proportion of this water goes for consumptive use.
- General Cooling (Existing Licences Only) (Low Loss) (15%) – Low loss indicates that a small proportion of this water goes for consumptive use.
- Non-Evaporative Cooling (35%) - Non-consumptive use.

This data indicates that a relatively small proportion of the total water withdrawn for electricity production is actually consumed with the rest returned to the system.

Robustness

There is a lack of transparency as to which 'use category' reside under each 'purpose category'. ADAS made a number of assumptions in this process. Please see accompanying excel workbook for further details.

IN7: Amount of electricity generation capacity (MWh) lost due to temporary abstraction restrictions

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

IN8: Number of customer minutes lost due to severe weather

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

2.3 Resilience of public water infrastructure services

IN9: Amount of actual and planned investment in resilience measures by water companies

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. They check that the water companies can continue to deliver services to customers and that planned investment in services is delivered as promised. Ofwat figures[5] indicate that over the last 3-4 years, total investment by the water and sewerage and water only companies in England and Wales equated to approximately £5 billion per annum, with the companies having now invested about £122 billion in services since privatisation of the water sector by Government in 1989. Some of this investment will have been attributed to improving resilience.

In 2013, Ofwat requested all water and sewerage and water only companies in England and Wales to submit summary tables of expenditure between 2008-09 and 2013-14 to prepare for the 2014 price review (see August Submission Data Guidance[6]). A line captured in this expenditure information was the "capital expenditure to improve resilience". This related to the expenditure to manage the risk of giving consumers an appropriate level of service protection in

[5] http://www.ofwat.gov.uk/regulated-companies/comparing-companies/performance/companies-performance-2014-15/

[6] http://www.ofwat.gov.uk/wp-content/uploads/2015/11/pap_gud_pr14augsubmission.pdf

the face of extreme events caused by hazards that are beyond their control. This indicator assesses the annual total investment on resilience by each water company in England and Wales.

Methodology

Individual submission tables of company accounts for each water company were sourced from the Ofwat website[7]. This included 10 water and sewerage companies (Anglian, Dwr Cymru, Northumbrian, Severn Trent, Southern, South West, Thames, United Utilities, Wessex and Yorkshire) and 8 water only companies (Affinity, Bristol, Dee Valley, Portsmouth, Sembcorp Bournemouth, South East, South Staffordshire and Sutton and East Surrey).

For analytical purposes, due to the clear variability in the scale of investment in resilience by the different companies, analysis concentrated on the six water companies (Anglian, Bristol, Severn Trent, Thames, Wessex and Yorkshire) with greatest spend, accounting for 95% of all investment in resilience. The other 12 companies (Affinity, Dee Valley, Dwr Cymru, Northumbrian, Portsmouth, Sembcorp Bournemouth, South East, South Staffordshire, South West, Southern, Sutton and East Surrey, and United Utilities) were combined into a group named 'other', accounting for 5% of the total spend.

Results

The dataset for the seven year period (2008-09 to 2014-15) shows that a total of £371.6 million has been invested in resilience, ranging from between £35.7 million in 2008-09 to £88.4 million in 2013-14, shown in Figure 4.

The total amount invested by each water company in the seven year period varies considerably, from £0 up to £166.1 million. This is likely influenced by several factors including the size of the company, area of the catchment and the way each company defines spend on resilience (e.g. a response by Wessex Water to a consultation on Ofwat's role on resilience identified at least five different definitions of resilience from key organisations including the Cabinet Office, UKWIR and Ofwat[8]). Severn Trent, Anglian and Wessex account for 77% of all spend on resilience, with total spend from these companies (in the time series) of £166.1 million, 60.2 million and 59.3 million respectively. Thames, Yorkshire and Bristol accounted for a further 18% combined of total investment on resilience, exhibiting a total spend in the time series of £28.3 million, £23.8 million and £14.4 million respectively. The other 12 companies each had a total spend on resilience of under £4 million and combined, made up 6% of the total spend on resilience by all water companies.

[7] http://www.ofwat.gov.uk/publications/companies-updated-cost-and-performance-august-submission-data/

[8] https://www.ofwat.gov.uk/wp-content/uploads/2015/07/WSX-Response-to-resilience-consultation.pdf

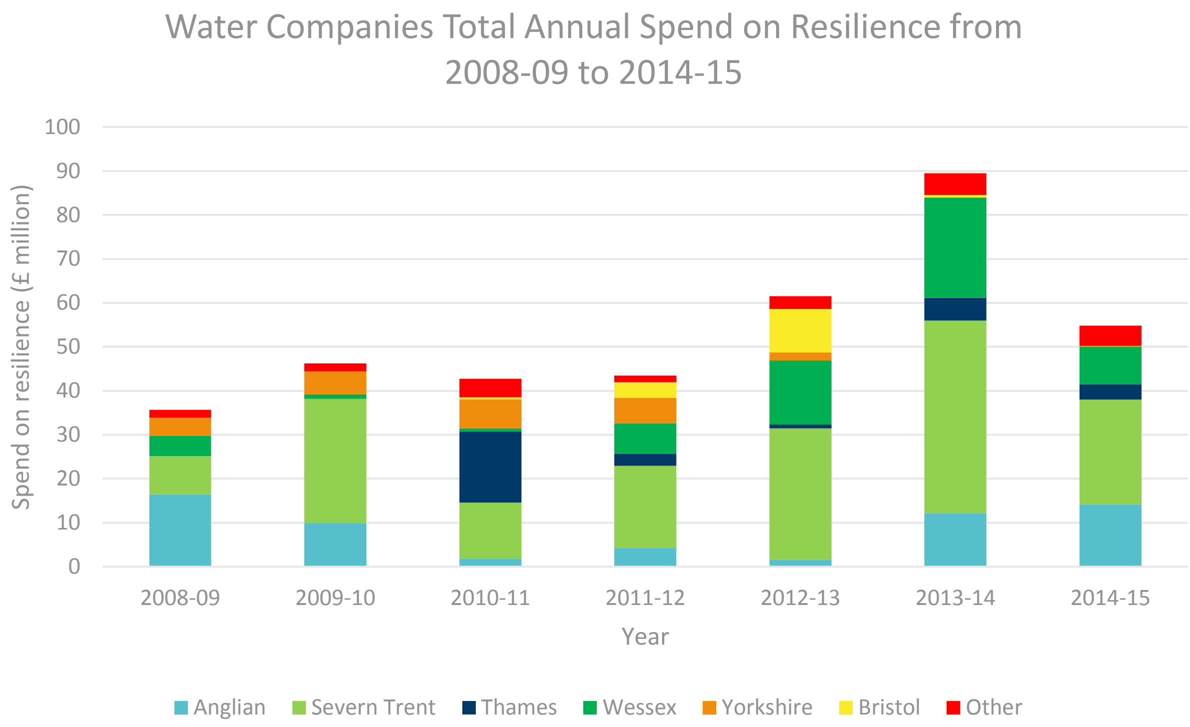

Figure 4. Total annual spend on resilience by all water companies and water and sewerage companies in England and Wales, as reported to Ofwat. Source: ADAS for ASC.

Robustness

This indicator provides a relatively robust time series of investment on resilience by each of the water companies in England and Wales. However, despite the time series being robust in terms of the water companies' submissions, there may be differences in how companies define resilience in their own organisations, meaning comparisons between spend for individual water companies, as well as total spend, may not fully represent actual spend on resilience. The data sourced was available and freely accessed on the Ofwat website. It is not clear how regularly these tables of data are updated, as the August 2013 submission guidance was a standalone exercise to collect both current and historical data, with updated data provided in 2014.

IN10: Leakage (Ml per year)

Introduction

OFWAT (The Water Services Regulation Authority) is the economic regulator of the water and sewerage sectors in England and Wales. In England and Wales, leakage is defined as treated water lost from the distribution system. It includes water lost from the companies' distribution networks and supply pipe losses from consumers' pipes. Reducing water losses from leakage reduces the pressure on water resources. Leakage is affected by:

- operational strategies (for example pressure management)

- network characteristics (for example length of mains)
- asset condition (for example age) and
- customer base composition (for example rural or urban).

Some leaks in water pipes are inevitable as pipes can wear out or be damaged by freezing weather or the weight of traffic on roads. The water companies have individual targets to reduce leakage based on the characteristics of their distribution network. If companies do not meet their leakage targets OFWAT can take action against them.

Methodology

In the past, data was collated by OFWAT. This data was is separated by, 'Distribution losses' and 'Supply pipe losses'. Data from 1992 to 2011 was published by Defra (DEFRA, 2012a), this indicator than extends that data through to 2016. Until 2010-11, each company submitted detailed information about their performance each year to OFWAT. This annual data submission (or 'June return') was published to allow customers and stakeholders to understand each company's performance. The reporting process changed in 2011 and the figures from 2011 to 2016 were found by summating the leakage data for each company, with data for 2011 to 2014 taken from OFWAT's web archive, whilst data for 2015 and 2016 taken from the 'Discover Water' website. The Discover Water website was established in 2015. Through this platform OFWAT will be publishing information on company performance in their annual service delivery report which will contain actual data on performance - including leakage data.

Results

Water companies have made progress in reducing leaks, and leakage is down about a third from its 1994-95 high. Leakage is affected by the weather, especially in cold winters, and so may rise or fall from one year to the next. A summary of leakage data between 1992 and 2016 can be seen in Table 8.

Table 8. Summary of leakage data

	Year	1992/3	1993/4	1994/5	1995/6	1996/7	1997/8	1998/9	1999/00
Distribution input	Mega-litres per day (Ml/d)	16,252	16,236	16,590	17,027	16,365	15,683	15,056	15,058
Distribution losses		3,600	3,693	3,866	3,685	3,295	2,955	2,618	2,432
Supply pipe losses		1,181	1,195	1,246	1,295	1,233	1,034	933	875
Total leakage		4,781	4,888	5,112	4,980	4,528	3,989	3,551	3,306
	Year	**2000/01**	**2001/02**	**2002/03**	**2003/04**	**2004/05**	**2005/06**	**2006/07**	**2007/8**
Distribution input	Mega-litres per day (Ml/d)	14,991	15,326	15,404	15,658	15,378	15,356	14,994	14,755
Distribution losses		2,365	2,527	2,606	2,625	2,584	2,611	2,545	2,468
Supply pipe losses		878	888	999	1,024	1,024	966	873	823
Total leakage		3,243	3,414	3,605	3,649	3,608	3,575	3,418	3,291
	Year	**2008/9**	**2009/10**	**2010/11**	**2011/12**	**2012/13**	**2013/14**	**2014/15**	**2015/16**

	Year	1992/3	1993/4	1994/5	1995/6	1996/7	1997/8	1998/9	1999/00
Distribution input	Mega-litres per day (Ml/d)	14,605	14,594	14,770					
Distribution losses		2,493	2494	2559					
Supply pipe losses		798	787	802					
Total leakage		3,291	3281	3361	***3016****	***3097****	***3109****	***3121****	***3084****

*OFWAT Data for these years no longer separated the leakage data in terms of 'Distribution losses' and 'Supply pipe losses'. A different method was used in calculating 'total leakage'.

The overall trend in leakage in England and Wales over the past 11 years has been downward (Figure 5). This reduction has been driven by the leakage reduction targets set by OFWAT, for each water company. In the final determinations for the review of prices in England and Wales by OFWAT for the period 2015 to 2020, some companies have agreed financial and non-financial Outcome Delivery Incentives (ODI's) which relate directly and indirectly to leakage levels, with a system of penalties for missing targets and rewards for outperforming them. OFWAT will be publishing information on ODI performance in their 'Service Delivery' report which will be accompanied with the PC/ODI spreadsheet containing data on actual performance. This is published annually on the OFWAT website. In determining incentives, OFWAT use an approach called the Sustainable Economic Level of Leakage (SELL) which requires water companies to fix leaks, as long as the cost of doing so is less than the cost of not fixing the leak. This is to ensure value for money of any maintenance. The cost of not fixing a leak includes environmental damage and the cost of developing new water resources to compensate for the water lost through leaks.

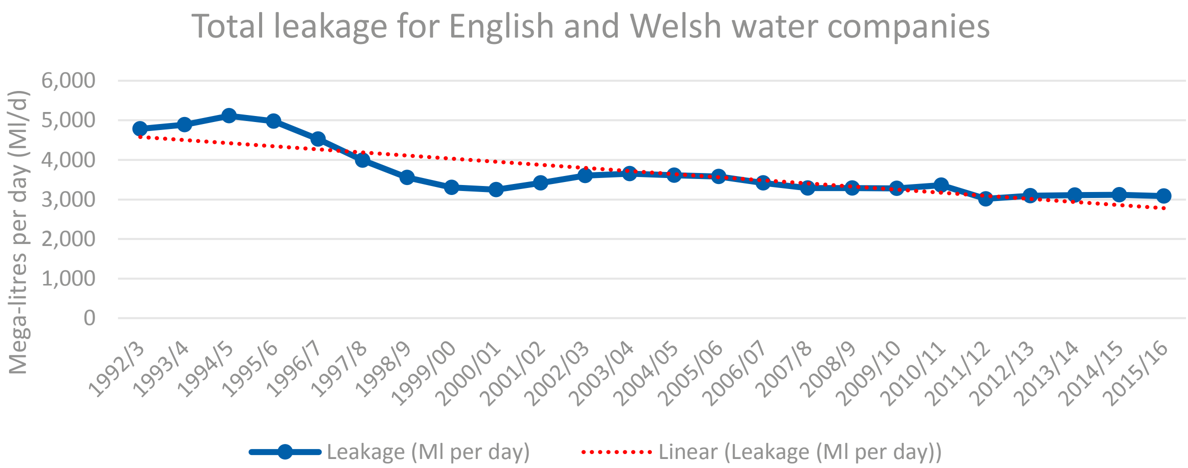

Figure 5. Leakage (Ml/day) in England and Wales. Source: ADAS for ASC.

Robustness

Good repeatable dataset – from 2015 onwards data to be released annually on the 'Discover Water' website.

2.4 Resilience of road and rail network infrastructure services

IN18: Annual number and length of delays to rail and strategic road network caused by severe weather

Introduction

Severe weather events can cause travel disruption to both rail and road networks, resulting in closures, delays and in some instances, severe and ongoing damage to key infrastructure.

Delays to strategic road network

Highways England, also known as the Highways Agency (HA) are responsible for the construction and maintenance of motorways and major trunk roads in England, which are recognised as the strategic network of roads used to move people and freight around the country[9]. Trunk roads and motorways in Scotland are the responsibility of Transport Scotland and those in Wales of the Welsh Government. HA monitor and provide traffic information for England's strategic road network, detailing incidents on major routes and the associated delays caused. On occasions, these delays are caused by severe weather, such as flooding, heavy rainfall, snow and ice, and strong winds. HA has recently submitted its latest report to Defra, Highways England climate adaptation risk assessment progress update: 2016 (Highways England, 2017), which sets out their progress in adapting to the current and future predicted effects of climate change on their organisation[10].

Delays to rail network

Network Rail is responsible for maintaining, renewing and enhancing the railway infrastructure, including all the tracks, signalling, overhead wires and other equipment needed so that trains can run on the railway safely. Severe weather can impact on rail services, either directly through damage, or delays due to disruption (e.g. blocking of the lines). Network Rail report that adverse weather conditions have resulted in an average 2-3% reduction in PPM (Public Performance Measure) across the railway network compared with normal weather conditions over the past decade[11]. Furthermore, weather related delays have cost Network Rail around £50-100m per year over the past decade with the cost to the railway and economy as a whole much higher when the impact of cancellations, timetable changes and damage are accounted for. Network Rail has recently published its Weather Resilience and Climate Change Adaptation Strategy 2017-2019 (Network Rail, 2017) to help adapt to projected changes in climate and severe weather.

This indicator assesses the annual number of reported delays to rail and strategic road network caused by severe weather.

[9] http://webarchive.nationalarchives.gov.uk/20140603112028/http://www.highways.gov.uk/our-road-network/our-network/

[10] https://www.gov.uk/government/publications/climate-adaptation-reporting-second-round-highways-england

[11] https://safety.networkrail.co.uk/home-2/environment-and-sustainable-development/wrcca/

Methodology

Strategic road network

Data was provide by the HA for road network delays caused by severe weather events. A comprehensive time series was available for 2007 to 2015, with partial data for 2006 and 2016. For each incident, information was provided on the date and region, the impact duration, the highway name, overall incident description and the closure type. The data provided was for total closure (both carriageways) and whole carriageway closed (one direction only). Data was not obtained on the number of delays due to either a single lane being closed, or a slip road being closed, which may or may not have caused transport delays for some travellers. Incidents were recorded for four types of weather:

- Flooding;
- Heavy rain;
- Snow, ice and freezing rain;
- Strong winds (e.g. bridge or exposed road closures).

The analysis concentrates on the 2007 to 2015 data series, providing nine complete years of information.

Rail network

Data was provided by Network Rail for rail delays caused by severe weather events. A comprehensive time series was available for 2006 to 2015. Information was provided on the total number of incidents recorded by Network Rail, and the number of incidents broken down by nine types of weather:

- Adhesion (i.e. 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 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 (Actual delays caused by damage from strikes – generally affecting 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. the impact of the wind, trampolines, sheds and trees on the track, branches/plastic bags on overhead lines, reduced speed in high winds for safety reasons).

Results

Strategic road network

A total of 303 incidents were reported by HA between 2007 and 2015 that resulted in the total closure, or carriageway closure of strategic roads due to severe weather. The number of incidents fluctuate each year, ranging from 14 incidents in 2007 to 66 incidents in 2013, shown in Figure 6. The prominent cause of these incidents also varies year to year, with for example, incidents in 2012 and 2015 largely dominated by flooding, whilst incidents in 2009 and 2010 were largely dominated by snow and ice, and incidents in 2008 and 2011 largely dominated by strong winds.

Relative to the time series available, the years of 2012 and 2013 exhibited particularly high number of incidents, with more than double the number of closures to that of each year between 2007 and 2011. However, the time series is too short to determine if the number of incidents has been increasing over time due to e.g. climate change.

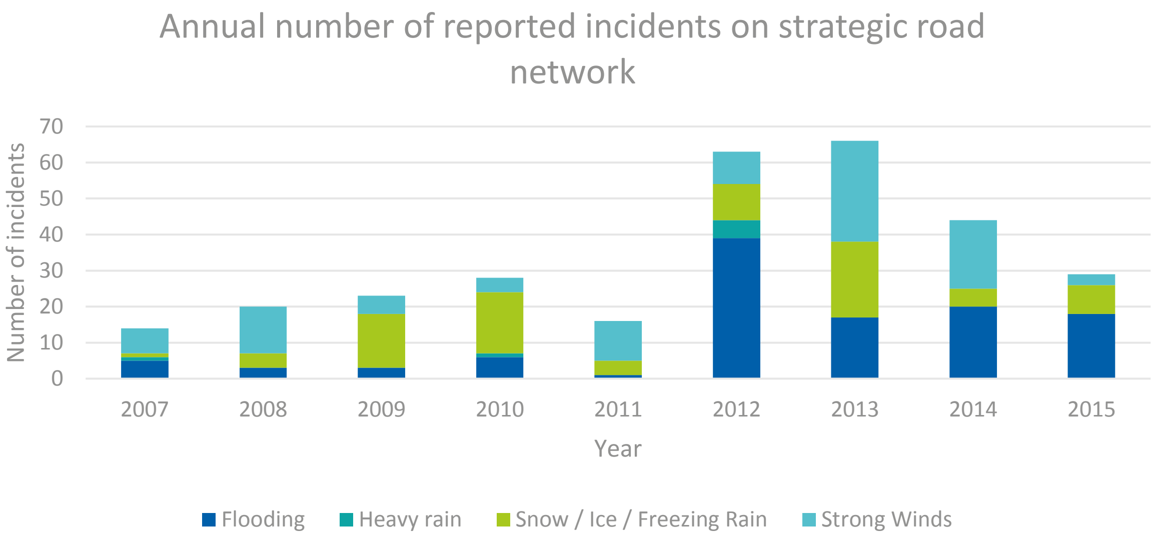

Figure 6. Number of incidents reported by Highways England that resulted in road closures due to severe weather in England. Source: ADAS for ASC.

Detail on the length of closure for each incident was incomplete, but rough estimates indicate that typically the impact duration of flooding incidents were 9 hours 44 minutes, heavy rain incidents were 5 hours 14 minutes, snow and ice incidents were 9 hours 32 minutes, and strong winds were 14 hours 9 minutes.

Rail network

Network Rail recorded a total of ~3.37 million incidents between 2006 and 2015, with the number of incidents relatively consistent each year, averaging ~337 thousand and ranging between ~309 and ~415 thousand incidents. Network Rail estimate that 5.3% (~180 thousand) of these incidents are weather-related incidents (including adhesion), or just under 1% (~32 thousand) if excluding adhesion. Due to adhesion being a seasonal event rather than a severe weather event, as well as representing almost 82% of all weather-related incidents recorded by Network Rail, shown in Figure 7, we exclude adhesion from this analysis.

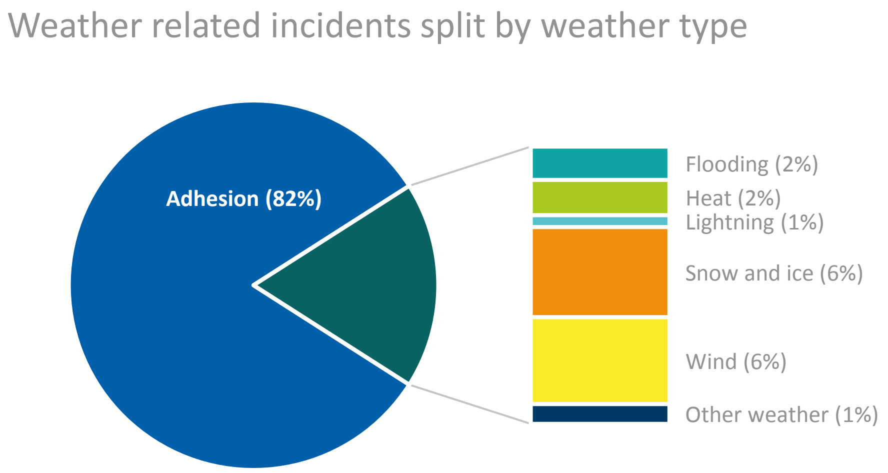

Figure 7. Split of weather-related incidents by weather type reported by Network Rail between 2006 and 2015. Other weather include subsidence and fog. Source: ADAS for ASC.

A total of 32,434 incidents associated with severe weather (excluding adhesion) were reported by Network Rail between 2006 and 2015. The number of incidents fluctuate each year, ranging from 1,433 in 2015 to 4,670 in 2009. In addition, the prominent weather type that caused these incidents varies from year to year. For example, similarly to the strategic road network, rail incidents in the years 2009 and 2010 were dominated by snow, shown in Figure 8.

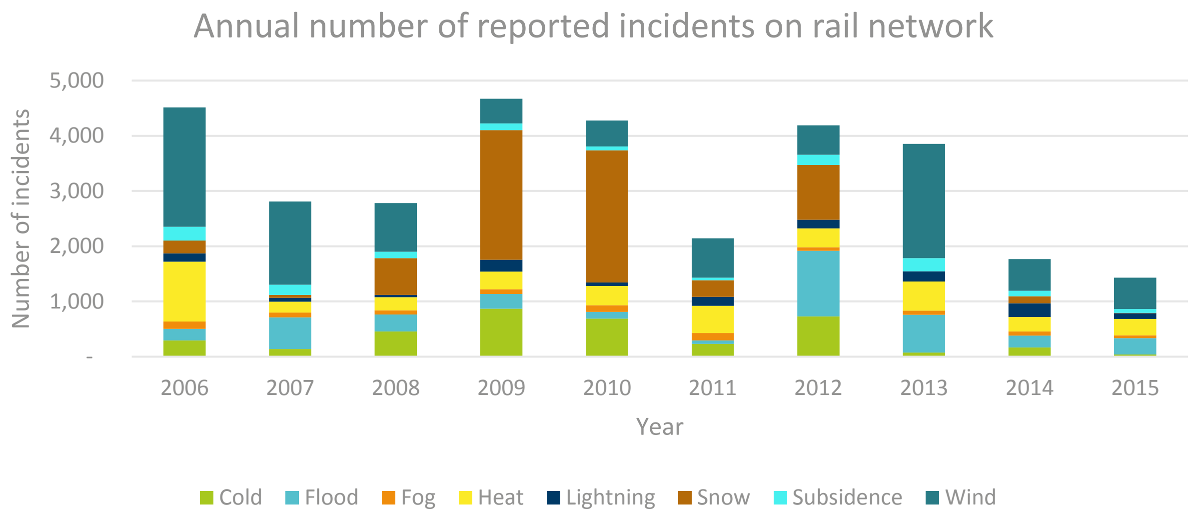

Figure 8. Number of incidents reported by Network Rail that resulted in disruption to rail services due to severe weather. Source: ADAS for ASC.

Robustness

Good data is available on the number of incidents relating to severe weather for both the rail and strategic road networks. Data sourced through contacts within the relevant organisations.

3 Healthy and resilient communities

3.1 Public understanding of climate risks

HCR2: Proportion of healthcare workers not aware of risk from heat stress

Introduction

Heatwaves are projected to become more frequent and more severe in the coming decades due to a warming climate. The Heatwave Plan (HP) 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. By improving preparedness, the aim is that adverse health impacts of heatwaves will be reduced, such as heat stress or excess mortality.

Despite guidance and information being made available, it is anticipated that some healthcare workers are not aware of the risk from heat stress. This indicator seeks to assess the proportion of healthcare workers not aware of risk from heat stress through a brief review of the literature.

Methodology

Consultation with Public Health England (PHE) indicated that there was very limited data on the proportion of healthcare workers not aware of risk from heat stress. The most likely data source for this information would be through the annual NHS survey to health workers[12]. To date however, these surveys have not contained questions that can be used to infer the proportion of healthcare workers aware of risk from heat stress. Recently, PHE and the Department of Health (DH) representatives requested the inclusion of two questions on a range of issues relating to overheating in the annual NHS survey, but this request was declined. As such, there are no known datasets available at the time of publication to provide an indicator, nor or there any upcoming changes to the annual NHS survey which might provide data for an indicator in the foreseeable future.

A brief review of the peer-reviewed literature was conducted to provide insight into the proportion of healthcare workers not aware of risk from heat stress.

Results

Research conducted by Abrahamson and Raine (2009) at University College London looked at the health and social care responses to the Heatwave Plan. The qualitative study assessed the feasibility and perceptions of the plan amongst frontline health, social and voluntary staff in a community setting. Semi-structured interviews and focus groups with 109 health, social care and voluntary staff from three London Boroughs found that most participants were unaware of the document and perceived heatwaves as a low threat. Staff also highlighted the complexities associated with defining vulnerability and identifying vulnerable individuals as well as barriers to implementation of the Plan. Respondents suggested a multi-faceted approach to interventions

[12] http://www.nhsstaffsurveys.com/Page/1056/Home/NHS-Staff-Survey-2016/

including a public health campaign, community engagement and increasing the responsiveness of statutory services.

More recent research conducted by the National Health Service (NHS) looked to understand how effectively the Heatwave Plan is disseminated within an acute hospital and to identify any barriers to its use (Boyson et al., 2014). The study conducted two focus groups with frontline clinical staff and five interviews with senior managers in South East England. The research found that although hospital managers showed good awareness of the plan, many frontline staff did not, and all deemed the Heatwave Plan a low priority in this particular hospital. However, frontline staff were familiar with the dangers of excess heat and felt that they individualised care accordingly. The study also highlighted that communication of information between managers and frontline staff was a problem during heatwaves, as well as highlighting issues with inadequate building stock and equipment, which limited effective implementation of the Plan. The study concluded that increased awareness and improved communication could help better integrate the NHP into the clinical practice of English hospital-based healthcare professionals.

These studies suggest that there is a proportion of healthcare workers that are not fully aware of the risk from heat stress, particularly with regards to the heatwave plans. The proportion of healthcare workers that this applies to cannot be inferred or quantified from the limited information available.

Robustness

No datasets were available to provide a clear indication of the proportion of healthcare workers not aware of risk with heat stress. A brief review of the literature provided an insight into the proportion for specific, localised case studies. However, these studies were not large enough to allow inference at a national level. The Department of Health has commissioned a Heatwave Plan Evaluation that will include data collection from frontline staff and which may provide further insight that could feed into this indicator in the future.

3.2 Heat-related health impacts

HCR3: Number of hot days per year

Introduction

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) estimates that the globally averaged combined land and ocean surface temperature has warmed by 0.85°C over the period 1880 to 2012. It is also very likely that the number of cold days and nights has decreased and the number of warm days and nights has increased on the global scale.

The 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. These daily and monthly temperatures "are representative of a roughly triangular area of the United Kingdom enclosed by Lancashire, London and Bristol"[13].

This indicator assesses the number of days per annum where daily temperatures in Central England exceeded certain temperature thresholds.

Methodology

This indicator uses the HadCET dataset[14] of maximum daily temperature in Central England. Data was provided in the format of daily Central England Temperature (CET) values expressed in tenths of a degree. The daily mean-temperature series begins in 1772. 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).

The data in this analysis was multiplied by 0.1 to provide data in degrees Celsius to 1 decimal place. E.g. a daily value of 198 (expressed in tenths of a degree) represented 19.8°C. This provides a raw figure of the number of days each year which fell within each range.

The Met Office forecasts day-time and night-time maximum temperatures, which are monitored regionally. When certain heat thresholds are passed, a warning is issued and sent to relevant health professionals and people working in social care as well as displayed on the Met-Office website. Threshold maximum day and night temperatures defined by the Met Office National Severe Weather Warning Service (NSWWS) vary from region to region, but the average threshold temperature is 30°C during the day and 15°C overnight[15]. Public Health England (PHE) provides the heat-health watch service, and issues health advice for the public and healthcare workers in England, according to levels of heat forecast/measured by the Met Office (The Heatwave Plan for England, 2016).

Using a temperature threshold of 30°C (the defined maximum day threshold temperature for South West, Eastern, West Midlands, East Midlands and the North West), the number of days where daily maximum temperatures exceeded this threshold each year were assessed to provide an indication of the number of 'hot' days per year. Furthermore, the number of days that daily maximum temperature exceeded 25°C were also assessed to understand if the number of 'warm' days has changed over time.

[13] http://www.metoffice.gov.uk/hadobs/hadcet/index.html
[14] http://www.metoffice.gov.uk/hadobs/hadcet/index.html
[15] http://www.metoffice.gov.uk/public/weather/heat-health/#?tab=heatHealth

Results

Figure 9 shows that the annual number of days where the maximum temperature exceeded 30°C has increased slightly in the latter half of the time series, although the statistical significance of an increasing trend over the period is weak, with many years exhibiting no days above 30 °C. 1976 showed the greatest number of hot days in a single year, with nine days exhibiting temperatures greater than 30°C.

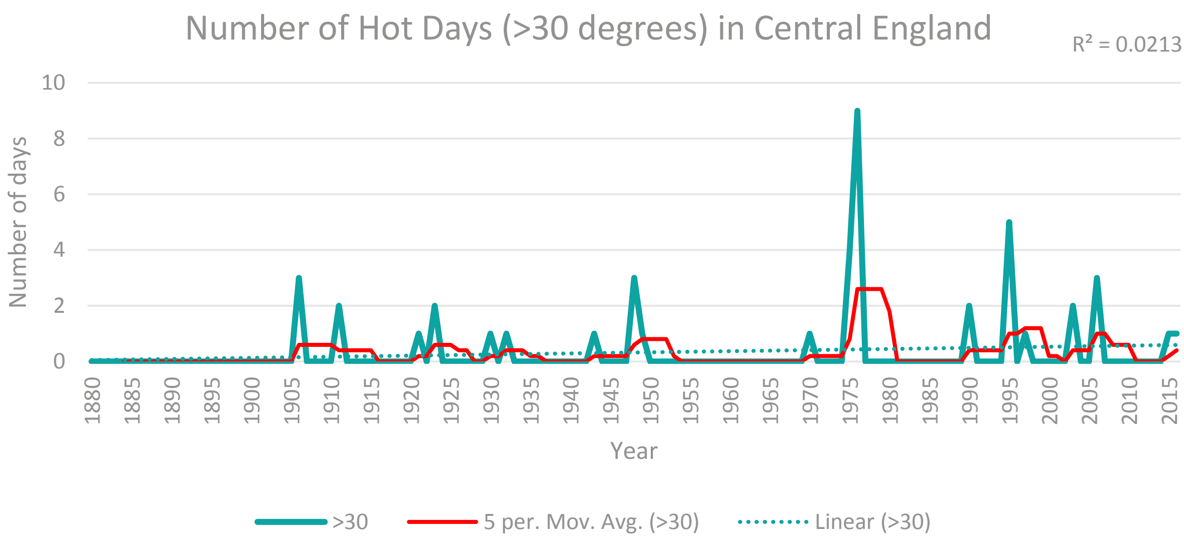

Figure 9. Number of hot days (Maximum temperature >30 Degrees Celsius) in Central England between 1878 and 2016 (blue line); five year moving average (red line); and linear trend line (dotted blue line) to show increase over the period. Data sourced from the Hadley Centre Central England Temperature (HadCET) dataset of mean maximum daily data, which are representative of a roughly triangular area of the United Kingdom enclosed by Lancashire, London and Bristol. Source: ADAS for ASC.

The number of warm days (defined here as over 25°C) also show an increasing trend, shown in Figure 10. This arbitrary threshold was selected and analysed to understand if there had also been an increase in the number of days close (within 5 degrees) to the 30°C threshold. The figure shows that the number of days over 25°C (estimated using a linear trend line) has increased from an average of 5-6 days at the beginning of the time series to an average of 8-9 days at the end of the time series, although considerable inter-annual variability is prevalent.

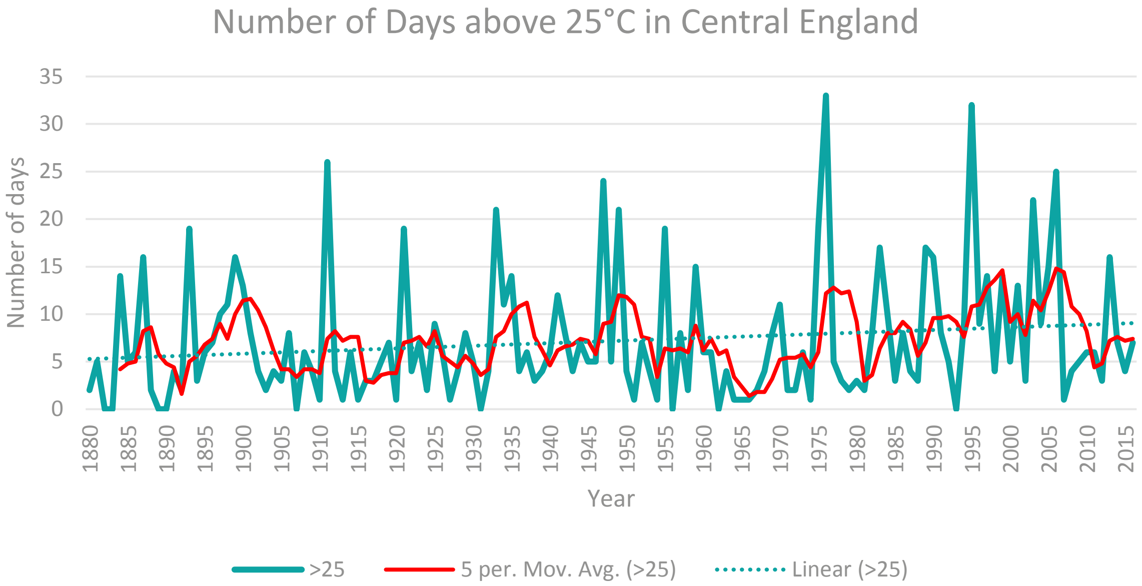

Figure 10. Number of days above 25°C Degrees Celsius in Central England between 1878 and 2016. Data sourced from the Hadley Centre Central England Temperature (HadCET) dataset of mean maximum daily data, which are representative of a roughly triangular area of the United Kingdom enclosed by Lancashire, London and Bristol. Source: ADAS for ASC.

The results are in line with the 2009 UK Climate Projections (UKCP09)[16], which indicate that on average, England will receive more frequent and more intense hot days due to a warming climate. For example, under a medium emissions scenario by the 2080s, the UK Climate Projections (2009) indicate that mean daily maximum temperatures will increase in all UK regions, with increases in the summer average by up to 5.4°C (2.2 to 9.5°C) in parts of southern England and 2.8°C (1 to 5°C) in parts of northern Britain. In central England, e.g. the East Midlands, under Medium emissions by the 2050s, the central estimate of increase in summer mean daily maximum temperature is 3.4°C (it is very unlikely to be less than 1.3°C and is very unlikely to be more than 5.9°C.

Robustness

The Met Office Hadley Centre Central England Temperature (HadCET) dataset provides a robust indicator for the number of days where CET exceeded certain thresholds. The daily maximum temperature data is updated onto the HadCET website frequently and the time series available is one of the most complete and consistent in the world.

[16] http://ukclimateprojections.metoffice.gov.uk/

HCR5: Area of urban greenspace

Introduction

Greenspace in urban areas has important health benefits and regulating services to urban communities. Particularly faced with the prospect of a warmer, wetter climate in England, greenspace can provide functions for sustainable urban drainage to reduce flooding risk by aiding infiltration and slowing the flow of water. Trees can help mitigate the effects of urban warming, store carbon and improve air quality.

Methodology

See BE8

Results

The area of built-up areas covered by permeable surfaces (greenspace) is shown for the current analysis (2016) and previous results (HR Wallingford, 2012) for comparison in Table 9. The results show that the permeable fraction of built-up areas has remained stable between 2011 and 2016 at an estimated 56%, but note the slight increase in total area covered by the urban definition (Figure 1) due to the use of the 'improved' Wallingford method (see methods section of BE7). The 'Natural' fraction has decreased slightly from 43% in 2011 to 42% in 2016.

Table 9. Area of built-up areas covered by permeable surfaces (greenspace) as estimated using OS MasterMap and using assumptions of urban creep. Previous years' data (2001-2011) were taken from HR Wallingford (2012).

Thousand ha	2001	2008	2011	2016
Multiple (permeable)	240	198	178	185
Natural	581	559	554	558
Fraction of total	*0.63*	*0.58*	*0.56*	*0.56*

Robustness

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 greenspace (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 method for definition of urban areas was changed slightly for the 2016 calculations. Also, 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 2016 and earlier years should therefore be made with caution.

HCR6: Number of air conditioning units bought or fitted (domestic/commercial)

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

HCR7: Number of buildings retrofitting passive cooling measures

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

HCR8: Number of planning applications with a) conditions requiring passive cooling measures; and b) implementing conditions in final development

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

HCR9: Number/area of green roofs installed in urban areas

Introduction

Green roofs in urban areas can have an array of benefits, from aesthetic improvement, improved environmental conditions and as a method to adapt to the impacts of climate change. The benefits for climate change adaptation and environmental improvement include water management (e.g. green roofs can retain rainfall), moderation of temperatures (e.g. reduction in temperatures during summer months), improved air quality (e.g. capturing pollutants) and increased biodiversity.

In England, the implementation of green roofs is most prominent in London, supported by the London Plan policy[17] to build a greener London. The Greater London Authority (GLA) define living roofs to include green roofs, roof terraces and roof gardens and which comprise intensively vegetated (intensive) to semi-intensive to extensively vegetated (extensive). Intensive green roofs are those made up of lush vegetation and based on a relatively nutrient rich and deep substrate. Extensive green roofs normally have a shallow growing medium and are designed to be relatively self-sustaining (Greater London Authority, 2008).

There is currently no consistent dataset available that has monitored the area of green roof installations in England, although some estimates have been made. Data on the area of installations in London is slightly better, supported by The Green Roof Map[18], produced by GLA and the Green Roof Consultancy by studying aerial images of London taken in 2013 (by The Geoinformation Group), although no dataset has been published to date.

This indicator provides an outline of the best estimates for the growth in green roof installations in recent years.

[17] https://www.london.gov.uk/what-we-do/planning/london-plan

[18] https://www.london.gov.uk/WHAT-WE-DO/environment/parks-green-spaces-and-biodiversity/green-roof-map

Methodology

Indicative figures on area were sourced from the Livingroofs[19] and GLA websites and consultation with industry experts at Livingroofs. Detail on the number of green roofs in London was taken from the GLA Green Roof Map.

Results

The Green Roof Map, based on a central activity zone in greater London, showed 678 known green roofs in early 2013, but anticipated the true number to be much higher, with an estimated area of green roofs at the time of over 175,000 m^2. New work is currently being undertaken to update this.

New, unpublished research (Livingroofs) indicate that, subject to estimations being correct, the growth and number of installations of green roofs in London have been increasing year on year at a rate of between 15% and 19% annually since 2010. Furthermore, it is estimated that London represents at least 42% of the market for all green roofs installed in the UK. This may be primarily because London has a distinct policy where the City Corporation actively encourages the installation of green roofs and green walls for their many environmental benefits[20]. The City of London Local Plan sets out the City Corporation's vision, strategy, objectives and policies for planning in the City of London. Policy DM 19.2 addresses biodiversity and urban greening and states that developments should promote biodiversity and contribute to urban greening by incorporating a number of measures, one of which include the installation of green roofs and walls[21].

Robustness

The current data available is incomplete and inconsistent, predominately sourced from best estimates. The data provided provide insight into the current area, but are not robust enough to provide a reliable representation of the area of green roofs currently installed in England. New work by Livingroofs.org in partnership with others are undertaking the first full green roof market assessment - UK Green Roof Market Survey 2016, due to be published in 2017. The Green Roof Map is currently being updated by an intern at the GLA who is replicating the analysis from 2013. This data will likely be available in late 2017.

[19] https://livingroofs.org/

[20] https://www.cityoflondon.gov.uk/services/environment-and-planning/planning/design/sustainable-design/Pages/green-roofs.aspx

[21] https://www.cityoflondon.gov.uk/things-to-do/green-spaces/city-gardens/wildlife-and-nature/Documents/city-of-london-biodiversity-action-plan-2016-2020.pdf

HCR10: Proportion of sales/installation of air conditioning units (meeting EU eco-design requirements (domestic/commercial))

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

HCR11: Numbers of hospitals/care homes/surgeries implementing heatwave plans

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project. See HCR2 for summary of information on Heatwave Plans.

HCR12: Number of local authorities implementing heatwave plans

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project. See HCR2 for summary of information on Heatwave Plans.

HCR13: Proportion of hospitals/care homes/ schools/ work places that experience overheating

Introduction

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

The UK Climate Projections 2009 (UKCP09[22]) suggest that on average, England is more likely to experience hotter, drier summers, with an increased frequency and intensity of heatwaves. In London for example, central estimates for the 2050s under high emissions indicate an increase in summer mean temperature of 3.1°C; and an increase in summer mean daily maximum temperature of 4.3°C. For the 2080s, these estimates are even greater, with the central estimate under high emissions indicating an increase in summer mean temperature of 4.9°C; and an increase in summer mean daily maximum temperature of 6.7°C.

Public Health England note that "*the evidence about the risks to health from heatwaves is extensive and consistent from around the world. Excessive exposure to high temperatures can kill. During the summer heatwave in Northern France in August 2003, unprecedentedly high day- and night-time temperatures for a period of three weeks resulted in 15,000 excess deaths. The vast majority of these were among older people. In England that year, there were over 2,000 excess*

[22] http://ukclimateprojections.metoffice.gov.uk/

deaths over the 10 day heatwave period which lasted from 4 to 13 August 2003, compared to the previous five years over the same period" (Public Health England, 2015).

This indicator provides insight into the proportion of hospitals, care homes, schools and work places that experience overheating.

Methodology

A search of literature and consultation with PHE and NHS indicated that there was little information on the proportion of specified buildings that experience overheating. Some information on overheating in hospitals was obtained through consultation with Cambridge University based on the Design and Delivery of Robust Hospital Environments in a Changing Climate (DeDeRHECC) project. Limited information on schools was extracted through the Education Funding Agency (2014). Limited information on care homes was extracted through a recent report funded by the Joseph Rowntree Foundation (JRF), 'Care provision fit for a future climate, May 2016'[23], which assessed the risks of summertime overheating, and investigated the preparedness of care settings, both now and in the future. No information was sought on work places.

Results

Hospitals

There is very limited information on the proportion of hospitals which experience overheating. Consultation with PHE noted that all NHS Trusts are required to complete an annual Estates Returns Information Collection (ERIC) each year. However, to date, this has not included any reporting on clinical area overheating. As part of the consultation process to improve the scope of data collection, reporting on clinical area overheating incidents is being added to the ERIC this financial year at a Trust level. Under these reforms to the ERIC, Trusts will now be asked to report on a) overheating incidents in wards; b) overheating incidents triggering a risk assessment; and c) percentage of clinical space monitored for temperatures. These changes will allow PHE to understand the reach of overheating monitoring processes and to measure the risk and risk mitigation of clinical areas overheating across NHS Trusts. This should provide data for an indicator in the future.

Other relevant research, led by Cambridge University, is the Design and Delivery of Robust Hospital Environments in a Changing Climate (DeDeRHECC), which provides some insight into the proportion of hospitals that experience overheating (Cook et al., 2013). The study investigated the impact of summer overheating in the built estates of four National Health Service (NHS) Acute Trusts from 2009 until 2013, and measured internal temperatures and various other environmental phenomena. The selected buildings were then modelled in some detail against current and projected climate data. Results showed that all of the selected buildings overheated

[23] https://www.jrf.org.uk/report/care-provision-fit-future-climate

against the 28 degree criteria, with the pre-war Nightingale ward buildings being the most resilient and easiest to adapt with significantly lower costs than new-build alternatives and also quicker to deliver, whilst lighter weight '60s buildings were shown to be most vulnerable. Outputs from the DeDeRHECC were published across several articles (e.g. Cook et al., 2013; Giridharan et al., 2013; Lomas et al., 2012; Short et al., 2012; Short et al., 2014; and Short et al., 2015).

Further research led by Cambridge University following the close of the DeDeRHECC project provided an extrapolation of the case studies across the NHS England Acute Estate. Unpublished findings suggest that up to 90% of hospital wards [by floor space], are vulnerable to overheating during periods of high temperatures due to the type and design of buildings[24].

Care homes

Gupta et al. (2016) conducted a study that aimed to examine how far existing care homes and other care provision facilities in the UK are fit for a future climate, and to consider the preparedness of the care sector (both care and extra care settings) in light of the consequences of climate change, with a focus on overheating. The research incorporated a literature review and four case studies (two in residential care and two in extra care schemes). The study found that there was a general lack of awareness of the impacts of overheating, and the prevalence of the overheating risk both now and in the future across all those involved, from designers to frontline care staff and residents. Currently there is no statutory maximum internal temperature for care schemes and the study found that overheating is a risk in the care sector that is likely to be exacerbated in future due to climate change, yet there is currently little awareness and implementation of suitable and long-term adaptation approaches (such as external shading, provision of cross-ventilation). Due to the small sample size, it is not possible to provide an indication of the proportion of care homes in England that experience overheating.

Schools

No datasets or research was identified that looked at the proportion of schools in England that experience overheating. Information on design requirements and performance standard for the avoidance of overheating in school buildings is outlined on the gov.uk website[25] - Building Bulletin issue 101, giving information about ventilation for school buildings. These guidelines detail three parameters that have been developed which indicate when overheating is likely to be problematic; and will ensure that the design of future schools is not dictated by a single factor as previously but by a combination of factors that will allow a degree of flexibility in the design of the school. These standards apply outside the heating season and are for the occupied period of 09:00 to 15:30, Monday to Friday, from 1st May to 30th September. The three parameters are a) the number of hours for which a threshold temperature is exceeded; b) the degree to which the

[24] Consultation with Alan Short, based on findings due to be published in Chapter 9 of his new book – Short, A. (2017) The Recovery of Natural Environments in Architecture: Air, Comfort and Climate, Taylor and Francis, 404 pp
[25] https://www.gov.uk/government/publications/building-bulletin-101-ventilation-for-school-buildings

internal temperature exceeds the external temperature; and c) the maximum temperature experienced at any occupied time.

The performance standards for summertime overheating in compliance with Approved document L2[26] (building regulation in England setting standards for the energy performance of new and existing buildings), for teaching and learning areas are:

a) There should be no more than 120 hours when the air temperature in the classroom rises above 28°C
b) The average internal to external temperature difference should not exceed 5°C (i.e. the internal air temperature should be no more than 5°C above the external air temperature on average)
c) The internal air temperature when the space is occupied should not exceed 32°C.

The guidance states that in order to show that the proposed school will not suffer overheating, two of these three criteria must be met. Schools designed on the basis of these guidelines will be at less risk of experiencing classroom overheating (Montazami and Nicol, 2013).

Robustness

No datasets were identified that could provide a good basis for this indicator. Some research has been conducted that provides insight into the proportion of hospitals, care homes and schools that experience overheating, but all are based on either small sample sizes or limited information and are not representative of the wider issue or provide a national coverage for England.

3.3 Pathogens, air pollution and UV radiation

HCR25: Number of air quality (ozone) warnings issued

Introduction

Information on air pollution in England is available through the Department for Environment, Food and Rural Affairs (Defra), which provides air quality information online, via its UK Air Information Resource website (UK-AIR)[27].

Air pollution alerts are issued on UK-AIR when any of the following thresholds in Directive 2008/50/EC are exceeded:

- Ozone Information 180 µg/m^3 for 1 hour
- Ozone Alert 240 µg/m^3 for 1 hour
- Sulphur dioxide Alert 500 µg/m^3 for 3 consecutive hours over 100km^2 area

[26] https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l
[27] http://uk-air.defra.gov.uk/

- Nitrogen dioxide Alert 400 µg/m^3 for 3 consecutive hours over 100km^2 area

Of particular interest from an adaptation perspective is ozone (O_3), a climate sensitive gas that occurs naturally in small (trace) amounts in the upper atmosphere[28]. Ozone is both beneficial and harmful to humans[29]. In the upper atmosphere, ozone filters out incoming radiation from the sun in the cell-damaging ultraviolet (UV) part of the spectrum, protecting life on Earth. Ozone depletion in the upper atmosphere presents a real risk to life on the Earth's surface.

Conversely, at ground-level, surface ozone is created by chemical reactions between air pollutants from vehicle exhaust, gasoline vapours, and other emissions. Heal et al. (2013) note that ozone is a secondary pollutant which is not directly emitted into the atmosphere, but is created and destroyed by these chemical reactions. The most important of these precursors are methane (CH_4) and carbon monoxide (CO), and which, with emissions of nitrogen oxides, contribute to a general hemispheric 'background' of O_3 and non-methane volatile organic compounds which influence O_3 formation on a regional and local scale. High concentrations of surface O_3 are toxic to people and plants and exposure is associated with excess mortality and respiratory morbidity (Heal et al., 2013).

The main concern for climate change effects on health through air pollution relate to ground level ozone. Typically, increases in ground-level ozone concentrations in urban areas occur during periods of hot and calm weather (Kovats and Osborn, 2016). Hotter drier summers may therefore increase the frequency, or exacerbate ground-level ozone increases. Research suggest that for a 5°C temperature increase, ozone-related deaths increase by around 500 on the 2003 baseline mortality of around 11,900 (Vardoulakis and Heaviside, 2012). However, the UK CCRA Chapter 5 notes that more research is needed to understand the influence of climate change on ground-level ozone (Kovats and Osborn, 2016).

This indicator assesses the number of times per annum where ground-level concentrations of ozone exceeded the recommended levels in England and thus an indication of when an air quality warning would have been issued. It should also be noted that although the indicator focuses on levels at which warnings will be issued, there are negative health implications associated with elevated background levels of ozone too, which are not captured in this indicator.

Methodology

Data on annual and exceedance statistics for ozone were extracted from the UK-AIR data archive. The archive provides annual ozone data from 1973 to present. For consistency in the data extracted for analysis, the parameter group used was the 'Automatic Urban and Rural Monitoring Network (AURN)' and the region chosen was by country, with the sub region England. Two statistics were chosen for analysis:

[28] https://ozonewatch.gsfc.nasa.gov/facts/SH.html
[29] https://uk-air.defra.gov.uk/research/ozone-uv/ozone-depletion

- EC Population Information Threshold (O_3) 1-hour mean > 180 µg/m^3
- EC Population Warning Value (O_3) 1-hour mean > 240 µg/m^3

The data provided by AEA on behalf of UK-AIR provides the number of exceedances that occurred for each statistic, by monitoring station, for each year. Due to the high level format of the data, it is not clear whether exceedances at separate monitoring sites in the same year occurred on different days or the same day. Also, it is not clear whether exceedances at a particular monitoring site, in a given year, occurred within the same day, or different days. Consequently, it is not possible to determine how many days per year that exceedances occurred. Instead, a total number of 1 hour exceedances (within a given year) is indicated.

For example: In 1995, two monitoring stations observed exceedances of 'EC Population Warning Value (O3) 1-hour mean > 240 µg/m^3'. There were 11 exceedances in Lullington Heath and 3 exceedances in Yarner Wood. As a result, in the analysis, a total of 14 exceedances are recorded for 1995. It is not known whether these 14 exceedances occurred on 14 separate days, 14 consecutive hours or somewhere in-between.

Results

Ozone Information is published on UK-AIR to warn when ozone levels are projected to exceed a mean value of 180 µg/m^3 for 1 hour. Archived data (across all sites and all years from 1973-2016) show that this threshold was exceeded on a total of 3,625 occurrences across 85 monitoring sites. Figure 4 shows the total number of 1-hour mean exceedances recorded each year across all sites. The greatest number of exceedances occurred in 2003 and 2006 with 415 and 493 exceedances respectively.

An ozone warning is published on UK-AIR to warn when ozone levels are projected to exceed a mean value of 240 µg/m^3 for 1 hour. Archived data (across all sites and all years from 1973-2016) show that this threshold was exceeded on a total of 253 occurrences across 17 monitoring stations. Figure 11 shows the total number of 1-hour mean exceedances recorded each year across all sites. The greatest number of exceedances occurred in 1981 and 1990 with 46 and 52 exceedances respectively.

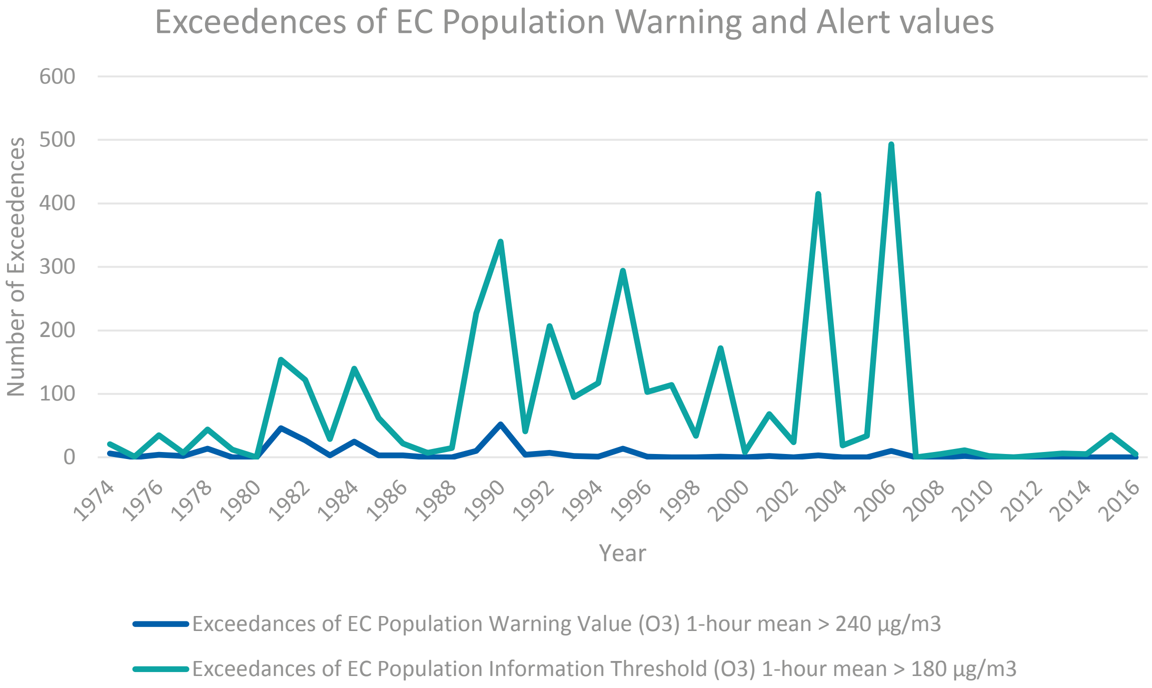

Figure 11. Exceedances of a) EC Population Information Threshold (O3) 1-hour mean > 180 µg/m^3 (1973 to 2016); and b) EC Population Warning Value (O3) 1-hour mean > 240 µg/m^3 (1973 to 2016). Source: ADAS for ASC.

The number of ozone warning exceedances per decade has been decreasing over the last four decades. In the last decade (2007-2016), ozone only exceeded the 'EC Population Warning Value (O3) 1-hour mean > 240 µg/m^3 twice, both at the St Osyth monitoring station in 2009. In the previous decade (1997 to 2006) this threshold was exceeded on 16 occasions, whilst 1987 to 1996 exhibited 91 exceedances, and 1977 to 1986 exhibited 123 exceedances.

Since 2008, both the number of ozone information alerts and ozone warnings have remained low, indicating a recent improvement in ozone levels at ground level. It should be noted that this analysis only assesses the extremes in ozone concentrations, looking at exceedances of the one hour ozone metric. Variations between ground-level ozone concentrations in urban areas (shown here) and background ozone in rural areas may differ.

The sudden reduction in ozone exceedances coincides, and is likely a product of, changes in policy to manage and improve air quality, largely driven by EU legislation. The 2008 ambient air quality directive (2008/50/EC), which replaced nearly all previous EU air quality legislation and was made law in England through the Air Quality Standards Regulations 2010, sets legally binding limits for concentrations in outdoor air of major air pollutants that impact public health. These pollutants include particulate matter (PM10 and PM2.5) and nitrogen dioxide (NO2) and as well as having direct effects, these pollutants can combine in the atmosphere to form ozone, a harmful air pollutant and potent greenhouse gas[30].

Robustness

The UK-AIR Annual and Exceedance Statistics provide a relatively robust dataset, which provides a strong indication of when EC thresholds have been exceeded. The data available is high level and cannot be directly linked to the number of ozone air quality warnings issued. However, the dataset provides a good insight into instances where ozone levels have been exceeded, and thus when warnings should have been published.

HCR26: Number of people living with chronic respiratory conditions

Introduction

The British Lung Foundation (BLF) funded a three-year epidemiological research project: *The respiratory health of the nation*. The results are presented in 'The battle for breath: the impact of lung disease in the UK' (2016). The report aims to provide information to help improve respiratory health and inform the development of strategies to reduce the impact of lung disease. The compiled data also provide baseline information against which the effectiveness of strategies can be measured. The report provides details of the overall extent and impact of lung disease across the UK and looks in more detail at 15 lung conditions. The two most commonly diagnosed complaints are asthma and chronic obstructive pulmonary disease (COPD) and these are the conditions of interest for establishing indicators of number of people living with chronic respiratory conditions.

Methodology

The data presented here is based on information presented in the BLF report and provides time line data for the years 2004 to 2012. These statistics on asthma and COPD in the UK were compiled as part of the Respiratory Health of the Nation project by teams at St George's, University of London, Nottingham University and Imperial College London. The study team used a range of data sources to compile data relating to: prevalence (number of people living with or previously diagnosed with the disease) and incidence (number of new diagnoses each year) full details can be found in the statistics section of the BLF website[31] for each disease and the 'Battle for Breath' report (British Lung Foundation, 2016). Prevalence and incidence data were estimated from The Health Improvement Network (THIN) database[32] which comprises 12.6 million patient records from 591 GP surgeries and represents approximately 5% of the population.

[30] https://uk-air.defra.gov.uk/air-pollution/uk-eu-policy-context
[31] https://statistics.blf.org.uk/
[32] http://www.inps.co.uk/vision/health-improvement-network-thin

The THIN data were scaled up by the researchers using a process of direct standardisation to estimate the number of people newly or ever diagnosed with each condition. This was done by first assessing the annual rates recorded by THIN (broken down by age group, gender and region), and then multiplying these by the total number of the UK population in each subgroup in that year (using mid-year population estimates from the Office of National Statistics). These results were then added together to produce overall estimates.

The research notes that THIN data is commonly considered to be the most accurate available (when looking at prevalence and incidence of disease presenting to GPs), but there are a number of limitations to both the accuracy of the source data and the extrapolated UK level estimates. These include the accuracy of GP recording and coding of diagnoses (and the reporting back from hospitals to GPs), the possibility of errors resulting from taking a sample of GP practices rather than all practices, and variations in the practices which report each year. It is not clear how population growth was taken into account and we were unable to attain a full dataset. Consequently, we were unable to show all the data as number of people per 100,000 of the population.

Results

<u>Asthma</u>

Asthma is the most commonly diagnosed lung condition in the UK and triggers can include; exercise, stress, cold air and breathing in substances such as smoke, pollution and pollen. The BLF (2016) study found that the total number of people who are living with or have previously ever been diagnosed with the disease in the UK increased by ~0.5 million people between 2004 and 2008. However since 2008, the study found that the number of people living who have had a diagnosis of asthma is plateauing with ~8 million people (~12% of the population) identified in each year between 2009 and 2012 (i.e. those who are living with or have previously been diagnosed with the disease in the UK in each specified year), shown in Figure 4.

The data shows some minor variations between years, for example an increase in 2011 and decrease in 2012. These are suggested by the study to be attributed to variations in the medical practices providing data, rather than changes in the overall numbers of people with the condition. Consequently, the headline findings are that the total numbers of people with asthma has remained static at ~8 million in recent years. It should be noted however that not all of these individuals that have been diagnosed are actually currently living with the condition, since many children diagnosed with asthma will grow out of it in later life.

With regards to incidence rates (the number of new diagnoses made each year), the BLF study suggests incidence rates went down by around 10% between 2008 and 2012, shown in Figure 12. The reasons for this are unclear, but could include asthma genuinely becoming less common, reduced misdiagnosis (of e.g. COPD) and a reduction in the backlog of diagnoses. The data is not robust enough to determine any clear factors for this due to uncertainty in the data collected, uncertainty in extrapolation of the results, and variability in the centres that provide data each year. Furthermore, the BLF study authors indicate that the number of deaths of people with the disease do not roughly equal the number of new cases each year, but instead are a result of variability in the centres providing data.

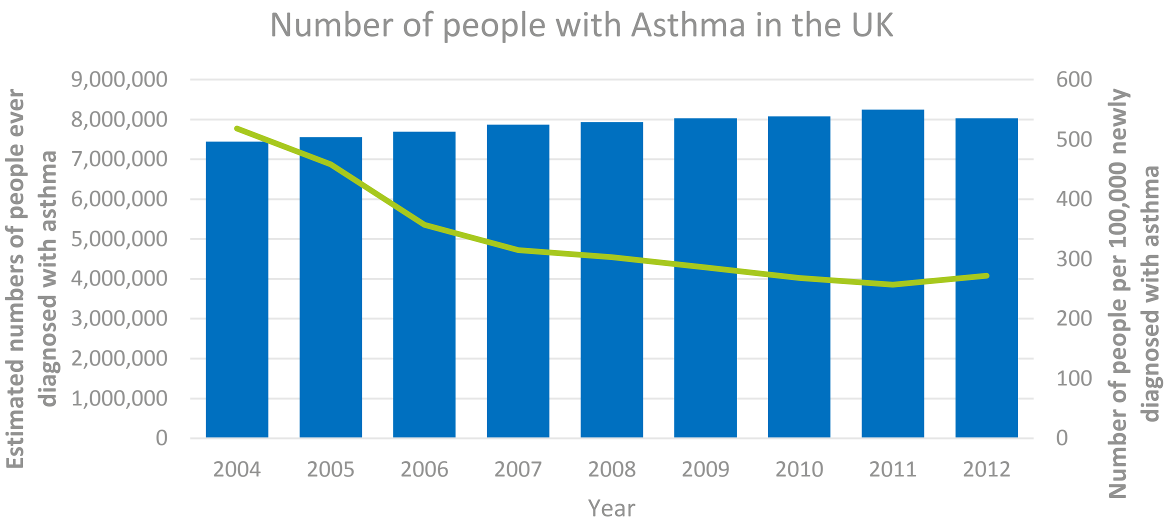

Figure 12. Estimated total numbers of people who are living with or have previously been diagnosed with asthma (blue columns); and the number of people per 100,000 who are newly diagnosed with asthma each year (green line), between 2004 and 2012. Source: ADAS for ASC, based on British Lung Foundation, 2016.

Chronic obstructive pulmonary disease

Chronic obstructive pulmonary disease (COPD) describes a number of conditions including emphysema and chronic bronchitis. Although smoking is the main cause of COPD it can also be caused by long-term exposure to fumes and dust from the environment. The British Lung Foundation (2016) study suggests that prevalence is growing with the number of people who are living with a COPD diagnosis increasing in the last decade of the study period, from just under 1 million people in 2004 to ~1.2 million people in 2012, shown in Figure 5. This could be as a result of the disease becoming more common, improved diagnosis or potentially changes to record keeping.

With regards to incidence rates (the number of new diagnoses made each year), the BLF study suggests around 115,000 people are diagnosed with COPD each year. Incidence rates of COPD fell from 212 to 185 per 100,000 in the five year period from 2004 to 2008. Since 2008, incidence rates have remained relatively stable, exhibiting values between 186 and 197 per 100,000, shown in Figure 13. The data contrast with the rise in prevalence over the same period.

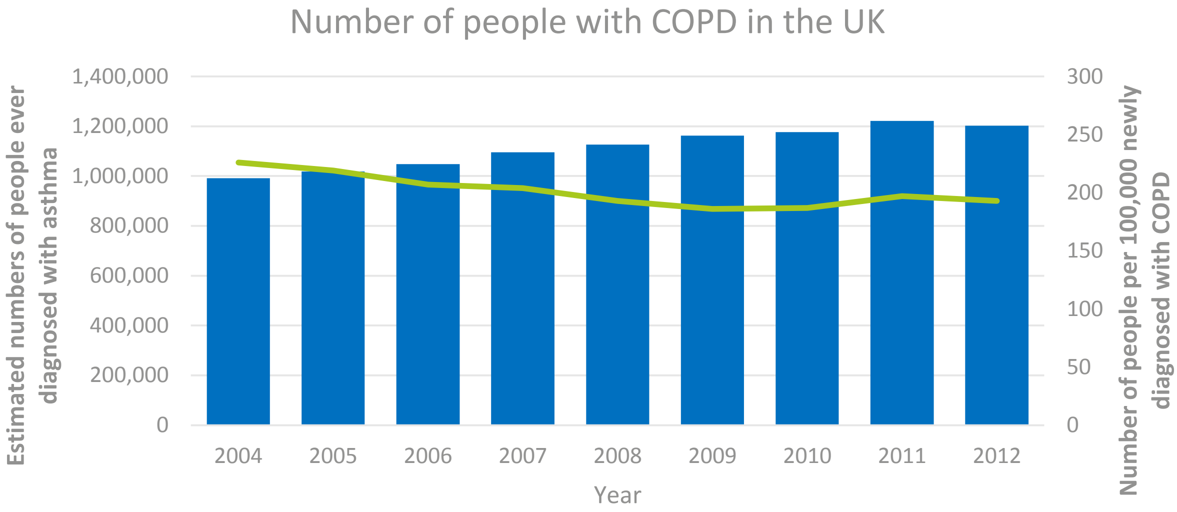

Figure 13. Estimated total numbers of people who are living with or have previously been diagnosed with COPD (blue columns); and the number of people per 100,000 who are newly diagnosed with COPD each year (green line), between 2004 and 2012. Source: ADAS for ASC, based on British Lung Foundation, 2016.

The British Lung Foundation[33] suggest that approximately one in five people in the UK has ever developed asthma, COPD or another long-term respiratory illness. Lung diseases are responsible for more than 700,000 hospital admissions and over 6 million inpatient bed-days in the UK each year. The potential role of air quality in lung health was specifically raised in one of the BLF study recommendations: invest in prevention by tackling smoking, obesity, physical inactivity and air pollution.

Robustness

The data provides an indication into the current picture of the number of people living with chronic respiratory conditions in the UK. Due to the methodology to extrapolate data to UK level, as well as the limitations detailed in the BLF study, interpretation of the results should be used with caution.

HCR28: Uptake of public awareness measures on UV risks

Introduction

Information on awareness of UV risk has been published by Cancer Research UK (2014) in a report analysing trends over the period 2003 to 2013. Between 2003 and 2012 Cancer Research UK led a skin cancer prevention programme (SunSmart), funded by the UK Health Departments. The main aims of the programme and associated campaigns were to maintain awareness of the link between UV and skin cancer, increase knowledge of risk factors associated with skin cancer,

[33] https://statistics.blf.org.uk/

increase knowledge and understanding of effective methods of preventing skin cancer and increase the number of people who take action to protect their skin from UV damage.

Methodology

From 2003, Cancer Research UK commissioned the Office of National Statistics (ONS) to run the SunSmart tracking survey to monitor trends in the public's awareness and behaviour towards sun protection. The survey ran every year between 2003 and 2013 with the exception of 2012. Survey data was extracted from a larger, Opinions and Lifestyle Survey (OLS) developed and run by ONS. The OLS sample was randomly selected and stratified by region, proportion of households with no car and socio-economic classification. One person per household (who was at least 16 years old at the time of survey) was randomly selected and was interviewed face-to-face by a trained interviewer. Specific SunSmart questions were included to assess awareness of actions and behaviour (2003-2011), importance of sun protection, and personal experience of sunbed use and sunburn (2011 and 2013). Results were published for the whole group, and then compared males and females, as well as looking specifically at the 16-24 age group. The data reported here is for the whole group.

Results

Awareness of actions to reduce the risk of skin cancer

Respondents were asked 'What actions should you take to reduce the risk of skin cancer?' It was not clear in the research whether this was a multiple choice or an open-ended question. The responses where the trend approached statistical significance, for 2003 and 2013, are summarised in Table 10. Significant positive trends are highlighted in green and significant negative trends in red. Figure 14 illustrates the trend over the 2003 to 2013 period. Some results indicate very low response rates. The reason for these low results is unclear and subsequently, figures should be used with caution.

Table 10. Awareness of actions to reduce the risk of skin cancer

	2003	2013	Significant trend	
Action	%	%		
Spend time in shade	63.6	59.5	Yes	↓
Cover up	49.7	44.4	Yes	↓
Protect children	5.2	7.1	Yes	↑
Avoid sunburn	5.5	16.0	Yes	↑
Avoid sunbeds*	11.6	21.6	Yes	↑
Use factor 15+ sunscreen	43.8	45.7	No	↑
Use any sunscreen	38.5	37.3	No	↓
Reduce time in the sun**	28.4	23.1	Yes	↓
Use UV index**	3.4	3.4	No	↑
Check moles / skin	3.3	12.8	Yes	↑
See doctor**	7.1	9.2	No	↑

*Data from 2006 onwards **Data from 2007 onwards. Source: Based on a table created by Cancer Research UK

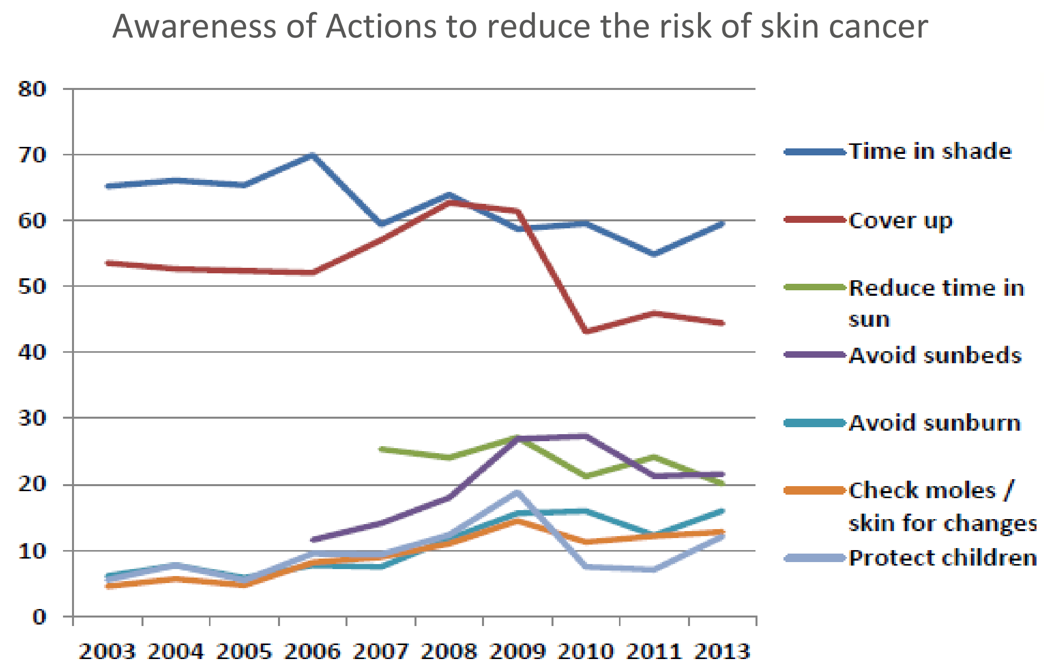

Figure 14. Significant trends over time in awareness of actions (%) to reduce the risk of skin cancer. Source: Cancer Research UK, 2014.

Reported behaviours to protect from the sun and skin cancer

To assess personal behaviours to reduce the risk of skin cancer respondents were asked; 'Do you personally do anything to protect yourself from the sun and / or skin cancer?' It was not clear in the research whether this was a multiple choice or an open-ended question. The responses where the trend approached statistical significance, for 2003 and 2013, are summarised in Table 11, with significant positive trends highlighted in green and significant negative trends in red. Figure 15 illustrates the trend over the 2003 to 2013 period. The study reported that since 2003 more than 80% of respondents consistently reported doing at least one thing to protect their skin but a significant minority of around 15% report doing nothing to protect themselves. Some results indicate very low response rates. The reason for these low results is unclear and subsequently, figures should be used with caution.

Table 11. Reported personal behaviours used to protect from the sun and/or skin cancer

	2003	2013	Significant trend	
Action	**%**	**%**		
Spend time in shade	29.2	41.7	No	↑
Cover up	22.5	33.2	Yes	↑
Use factor 15+ sunscreen	37.3	50.5	Yes	↑
Use any sunscreen	35.5	31.4	Yes	↑**
Wear a hat	21.5	31.0	Yes	↑
Reduce time in the sun	8.8	13.9	Yes	↑
Avoid sunbeds	1.1	9.8	Yes	↑
Check moles / skin	0.8	7.3	Yes	↑
See doctor	1.0	3.2	Yes	↑

	2003	2013	Significant trend	
Action	%	%		
Wear sunglasses*	13.9	16.2	Yes	↑
Wear a t-shirt*	12.5	9.9	Yes	↓
Avoid sunburn*	7.1	11.3	Yes	↑
Protect children*	4.5	5.0	No	↑
Use UV index*	1.5	0.8	No	↓

* Data from 2008 onwards. ** Although a lower figure was reported in 2013, overall this was a positive trend. Source: Based on a table created by Cancer Research UK

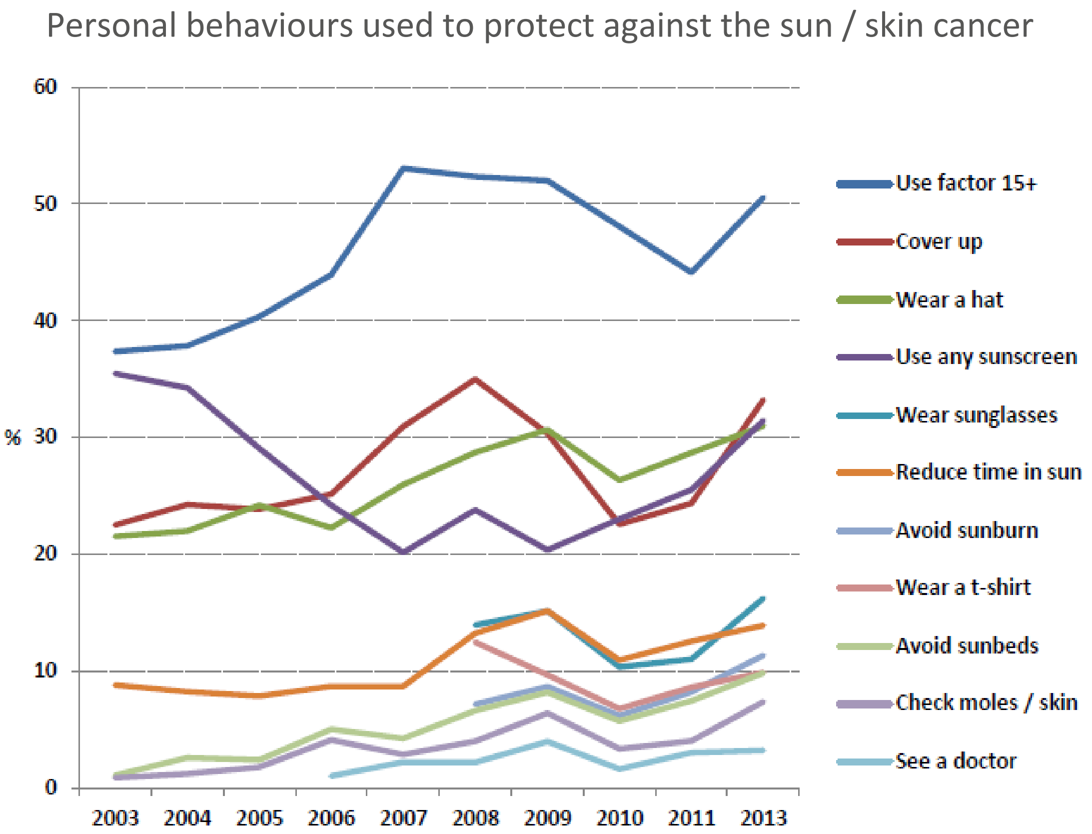

Figure 15. Significant trends 2003-2013 for personal behaviours used to protect from the sun or skin cancer. Source: Cancer Research UK (2014)

Robustness

This survey data was collected by the Office of National Statistics using a robust selection process. There is no indication that this data is being collected going forwards and therefore it may not be possible to monitor trends going forwards. Survey sizes, and therefore number of responses, decreased by more two thirds between 2003 and 2013, from 3680 respondents down to 1003 respondents respectively.

Note sample sizes (particularly for 16-24 years old) were small and therefore there are inconsistencies in responses between years.

HCR31: Distribution/spread of pathogens or vectors across England

Introduction

The Intergovernmental Panel on Climate Change report emphasises several infectious disease issues that might be exacerbated by climate change. The Health Effects of Climate Change in the UK report, published by the Department of Health and the Health Protection Agency in 2008 looked at quantifying the health effects of climate change, based on new climate change projections for the UK. Its summary findings on vector borne diseases were as follows:

"Vector-borne diseases are influenced in complex ways by the climate, land use changes and human activities, and as such it is difficult to make quantitative predictions of future changes due to climate change. However, it is likely that the range, activity and vector potential of many ticks and mosquitoes will increase across the UK by the 2080s. There is also the potential for introduction of exotic species and pathogens. Potential drivers of these changes include milder winters and warmer summers." (Vardoulakis et al., 2012).

Temperature and rainfall changes resulting from anthropogenic climate change will affect arthropod vectors and the pathogens they might transmit. Of particular focus are changes in the distribution and abundance of mosquito and tick species in the UK.

- Arthropod vector species (e.g. invasive mosquitoes) and their pathogens (e.g. chikungunya virus) are being observed in, and are establishing in areas where they had not previously occurred.
- Tick-borne diseases, such as Lyme disease, continue to increase, or, in the case of tick-borne encephalitis and Crimean-Congo haemorrhagic fever viruses, have changed their geographical distribution.

These changes are in part due to increased globalisation, with intercontinental air travel and global shipping transport creating new opportunities for invasive vectors and pathogens. However, changes in vector distributions of mosquitos are also being driven by climatic changes and changes in land use, infrastructure, and the environment. Initiatives supporting adaptation to climate change are also likely to affect the geographical distribution and incidence of vector-borne disease.

Methodology

A review was conducted by Medlock et al. (2015) of the risks posed by vector-borne diseases in the present and the future from a UK perspective, and an assessment made of the likely effects of climate change. The findings from this review are supported by vector maps[34], maintained by the European Centre for Disease Prevention and Control (ECDC), which provide up-to-date information on vector distribution, showing the distribution of the vector species at 'regional' administrative level. This indicator summarises the findings from that review.

[34] http://ecdc.europa.eu/en/healthtopics/vectors/vector-maps/Pages/vector-maps.aspx

Results

The ECDC maintain vector maps which show the distribution of key vector species. These maps include five species of mosquito and four species of tick. The ECDC maps can be used to monitor the introduction and establishment of invasive mosquito and tick species in the UK. Figure 16 sets out the current known distribution of Asian tiger mosquito *(Aedes albopictus)* - an important invasive mosquito species that can transmit dengue, chikungunya and Zika. It has established in Europe, primarily around the Mediterranean and it is expanding its range towards the English Channel. In September 2016, 37 eggs of the Asian tiger mosquito were detected in one ovitrap, in a lorry park at Folkestone service station, near Westenhanger, Kent close to the Eurotunnel. This was the first detection of the Asian tiger mosquito in the UK. Similar vector maps are available for the other species, but are not presented in this report.

Robustness

The vector distribution maps are published regularly on the European Centre for Disease Prevention and Control website to provide the ECDC stakeholders and the general public with the most up-to-date information on vector distribution, showing the distribution of the vector species at ‘regional’ administrative level.

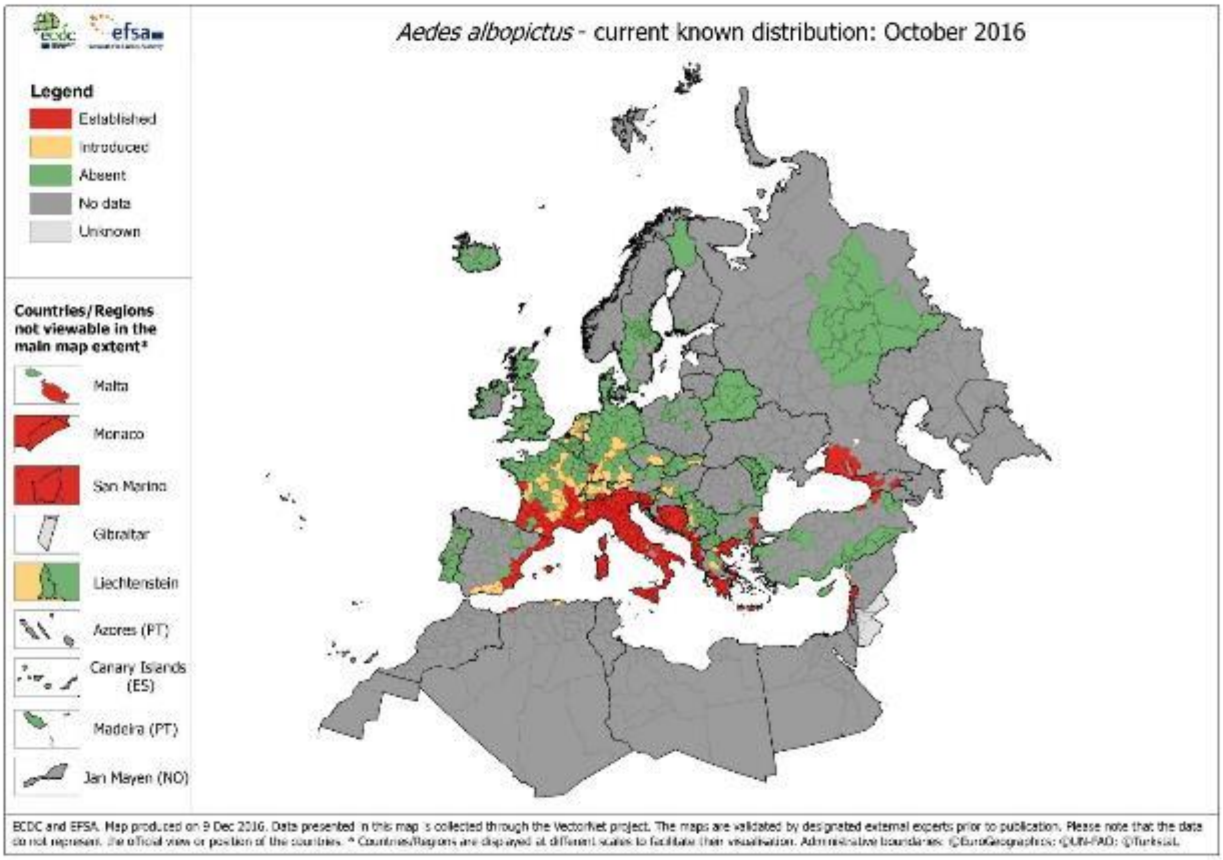

*Figure 16. Vector map – Asian tiger mosquito (*Aedes albopictus*). Source: ECDC-EFSA/VECTORNET.*

Each of the key vector species of mosquito and tick species can be a competent vector for a number of diseases. Table 12 summarises the risks posed by vector-borne diseases in the present and the future from a UK perspective, and assesses the likely effects of climate change on these risks (Medlock et al., 2015).

Table 12. The risks posed by vector-borne diseases from a UK perspective. Source: Medlock et al. (2015)

	Current situation	Temperature-change assessment (+2°C)
Dengue virus or chikungunya virus	Main vectors are invasive mosquitoes, such as *Aedes albopictus*, expected to colonise UK in the future, and *Aedes aegypti*, less able to survive through UK winter; under a current climate scenario, *A albopictus* would be able to survive across large parts of England and Wales (up to 18 weeks elapsing between egg hatching in spring and autumn diapause of eggs, and up to 27–32 weeks between egg hatching and adult die off)	Climate assessments suggest that UK climate is now suitable for *A albopictus*; climate change assessments for UK and Europe predict that southeast England will become more suitable for the establishment of *A albopictus*; an increased activity period of 1–2 weeks is expected for adult *A albopictus* in southern England by 2030–50, based on a 1°C annual temperature rise, and a 3–4 week extension of activity is expected for a 2°C annual temperature rise; an overall climate suitability increase of 15% by 2030–50 is expected, based on 1°C annual temperature change, and a suitability increase of 25–30% is expected, based on a 2°C annual temperature change); more than 80% agreement between Regional Climate Models; climate change models for chikungunya predict suitable temperatures for 1 month of chikungunya virus transmission in London by 2041 and 1–3 months of virus transmission across most of southeast England by 2071–2100; dengue risk will largely be linked to colonisation by *A aegypti*, which is not expected to become established up to 2100, and therefore the main dengue virus risk might come from *A albopictus*
West Nile virus	UK has several endemic mosquito species that could potentially act as vectors; mainly *Culex* spp mosquitoes, including recently discovered species (*Culex modestus*); West Nile virus transmission is not considered climatically limited; absence of transmission might be due to low mosquito abundance for sustained transmission and, until recently, a restricted distribution of human biting *Culex* spp mosquitoes	Climate change would affect the biology and available habitats for mosquitoes, although other factors would need to be considered in a model; a 2°C increase in temperature would affect endemic mosquitoes by shortening their gonotrophic cycle and bloodmeal digestion, thus increasing abundance and shortening generation times, leading to increased cohorts of multivoltine species; there are no models to quantify this, however some data is available for some endemic *Aedes* species: [7 and 8] larval/pupal development lasts 38 days at 8°C and 18–20 days at 12°C; bloodmeal digestion lasts 30 days at 4°C, 14 days at 8°C, and 5 days at 20°C; embryonic development lasts 42 days at 4°C, 22 days at 12°C, and 8 days at 20°C
Malaria	UK *Anophelines* are considered competent vectors, although some species are now less anthropophilic; climate modelling has confirmed that transmission of *Plasmodium vivax* (and to a lesser degree *Plasmodium falciparum*) could already occur in the UK, although no cases are reported	Increasing temperatures will directly affect the parasite's development in the mosquito; one of five malaria effect models under the most extreme scenarios consistently predicts climate in southern England suitable for sustained *P falciparum* transmission (>1 month) by 2080, whereas another model predicts some suitability by 2030s; however, the other models predict no suitability, even by 2080; under medium–high scenario, a *P vivax* model[9] predicts that southern Great Britain will be climatically suitable for 2 months of the year by 2030 and for 4 months in parts of southeast England; by 2080, regions as far north as southern Scotland will be climatically suitable for 2 months, with 4 months suitability in southern Great Britain
Lyme disease	Already endemic with more than 1000 confirmed cases each year; complex transmission cycle with positive and negative seasonal effects on tick activity from increasing temperature; tick seasonal activity is affected by changes in weather and climate; no long-term data exists on how climate has changed tick seasonality although these are being studied	Increasing temperatures will change the seasonal activity of ticks to earlier and later in the season, with reduced activity in the summer; a latitudinal and altitudinal spread is not expected to have a significant effect; evidence of latitudinal spread in central Europe of *Ixodes ricinus* from 700 m, between 1950 and 1980, to 1250 m by 2006; mean annual temperature had increased by 1·4°C between 1961 and 2005; 400 km latitudinal shift in *I ricinus* distribution in past decades in Norway and Sweden, mainly linked to milder winters, longer vegetation period, and spread of deer
Tick-borne encephalitis virus	Not endemic	Transmission of tick-borne encephalitis virus is highly reliant on co-feeding of different tick stages, which in itself is affected by weather and climate; current climate models do not predict an expansion of the range to the UK
Crimean-Congo haemorrhagic fever virus	Not endemic because the vector is not endemic, although the vector is imported each year on migratory birds	Transmission is contingent on the vector becoming established; this needs higher temperatures for tick moulting, and there are no published models that make predictions for the UK
Mediterranean spotted fever	Not endemic because the tick vector was until recently rarely found in the UK	Since relaxation of tick controls on pets, the tick *Rhipicephalus sanguineus* is now imported regularly; it does not survive outdoors, but indoor survival is possible; although there are no models that include the UK, it is expected that a 2°C temperature rise could permit outdoor survival; a 2–3°C increase in mean temperature from April to September is expected to result in its establishment in regions of northern temperate Europe.

HCR32: Number of incidents of harmful algal blooms

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[35]. The phenomenon is seasonal because growth of algae is controlled by hours of sunlight and water temperature[36]. Human activity has been linked to an increased frequency of algal blooms, with increases of nitrate or phosphate in the water from agriculture, which encourages the growth of algae.

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 toxin blooms, commonly referred to as Harmful Algal Blooms (HAB). HABs typically occur during the summer or when water temperatures are warmer than usual. The optimum temperature for photosynthesis of blue-green algae is suggested to be 20–30 °C during summer (Singh and Singh, 2015) with water temperatures above 25°C optimal for the growth of Cyanobacteria as at these temperatures, blue–green algae have a competitive advantage over other types of algae whose optimal growth temperature is lower (12-15°C)[37]. 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[38].

It is possible that warmer waters due to climate change might favour the development of algal blooms, potentially increasing the frequency and/or intensity of both toxic and non-toxic algal blooms. 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.

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.

[35] http://www.fao.org/docrep/003/W3732E/w3732e06.htm
[36] http://dwi.defra.gov.uk/consumers/advice-leaflets/algal.pdf
[37] http://www.cees.iupui.edu/research/algal-toxicology/bloomfactors
[38] https://www.gov.uk/government/publications/algal-blooms-advice-for-the-public-and-landowners/algal-blooms-advice-for-the-public-and-landowners#report

- Category 3 – minor or minimal impact or effect on the environment, people and/or property.
- Category 4 – substantiated incident with no impact.

This indicator assesses the number of substantiated algal bloom incidents that have been dealt with by the EA since 2011. 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. Detail was not available on whether these incidents related to toxic or non-toxic algal blooms. This indicator therefore 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 HABs.

Methodology

The Environment Agency provided an annual time series of substantiated algal bloom incidents that have been dealt with by the EA in England. 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. The dataset records incidents in four categories of pollution incident where the environmental impact is rated from Category 1 to 4, where Category 1 represents a persistent, extensive, major impact on the environment; and Category 4 no impact.

Results

A total of 374 substantiated algal bloom incidents have been dealt with by the EA since 2011. . The majority of these incidents, 342 or 91%, 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. In addition, there were 28 category 2 pollution incidents that occurred between 2011 & 2016, with between 2 and 7 incidents typically reported each year 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 1% of all incidents falling in this category. Since, 2001, only four 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 and 2016.

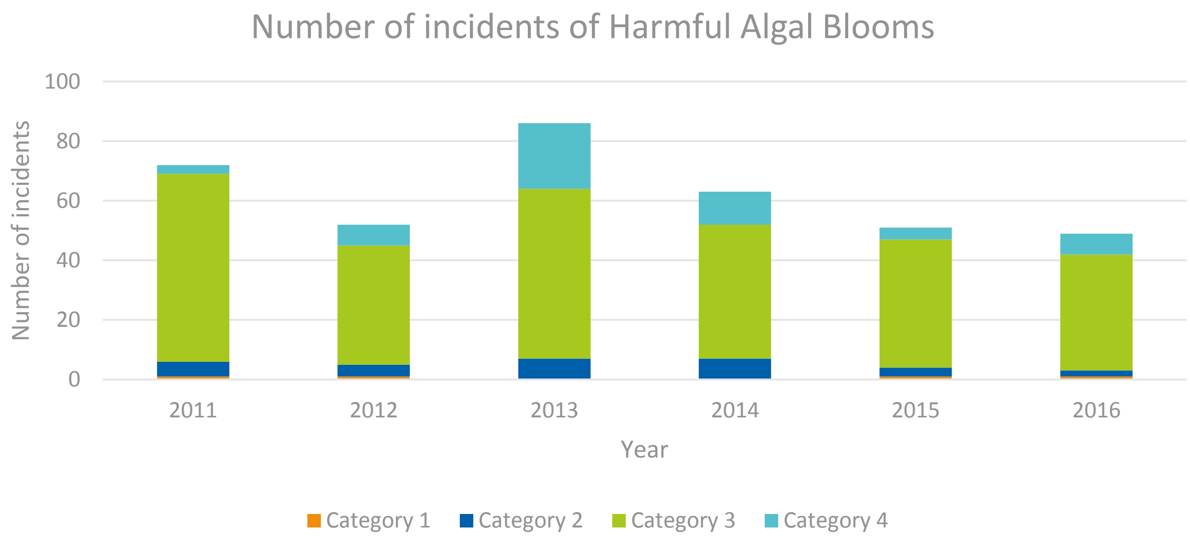

Figure 17. Number of substantiated incidents of algal blooms recorded in England between 2011 and 2016, categorised by CICS category (1 most impact, to 4 least impact). Data for 2016 is subject to change as some unclosed incidents may not yet be recorded. Source: ADAS for ASC.

The annual time series shown in Figure 17 is too short to determine any long-term trends in the number of incidents of substantiated algal blooms reported to the EA in England. Nor was it possible to attribute either the frequency or intensity of these incidents with climate change or climatic factors. In addition, we were not able to assess the number of harmful algal blooms as this detail was not available to split toxic and non-toxic blooms out from the total figures provided.

Robustness

Overall, the dataset provides a relatively robust and consistent annual series of algal blooms recorded in England. However, it should be recognised that the data provided by the EA are subject to change following incident reviews and quality assurance. In addition, it is noted that not all incidents from 2016 are currently closed, therefore there may be additional incidents from 2016 that do not appear in the data. It will be possible to get similar data in the future to allow this data set to be updated on the number of algal blooms only, not HABs, unless the EA split these out in future records

HCR33: Spend on surveillance for new/emerging pathogens

Introduction

Emerging pathogens represent an ongoing threat to the health and livelihoods of people everywhere, including England. Therefore, continuous surveillance needs to be maintained to enable their early detection so that appropriate mitigations can be adopted. There is a consensus in the academic literature that the Government should strengthen and widen existing surveillance mechanisms to monitor species of concern and the mechanisms by which invasive species arrive in the UK.[39] Comprehensive surveillance of species underpins any process that aims to determine the likely risk to public health and how the level of risk might be predicted to change over time.

Surveillance of emerging pathogens is inherently interdisciplinary, requiring co-operation between public health, clinical medicine, veterinary medicine and ecology. Each field comes with a unique knowledge base that typically focuses on either animal or human health, but rarely both. This makes compiling an overall picture on surveillance 'spend' challenging.

Public Health England (PHE), the Animal and Plant Health Agency, and Department for Environment, Food & Rural Affairs hold a substantial amount of information on 106 Infectious diseases on their website. However, the spread of only a small number of these pathogens has been linked with climate change. As discussed with the ASC, separating out climate-sensitive emerging disease surveillance was challenging and no suitable method was identified, instead a couple of examples of surveillance work are presented. PHE were consulted regarding this indicator.

Examples of current surveillance

Aligning with indicator HRC31 these examples focus on the active and passive surveillance of the new / emerging pathogens (and indicative spend where available) associated with:

- Arthropod vector species (e.g. invasive mosquitoes) and their pathogens (e.g. chikungunya virus).
- Tick-borne diseases, such as Lyme disease, continue to increase, or, in the case of tick-borne encephalitis and Crimean-Congo haemorrhagic fever viruses, have changed their geographical distribution.

The national mosquito recording scheme

Active surveillance programmes are in place as part of UK-wide efforts to detect the incursion of invasive mosquitoes. Public Health England's (PHE) Medical Entomology group have been coordinating a network of mosquito traps with UK seaports and airports monitored since 2010, in line with European Centre for Disease Prevention and Control guidelines. Since 2014, mosquito traps have been run each year between June and October and checked every 10–14 days to detect both egg (ovitraps) and adult stages of invasive mosquitoes.

No information was available regarding the levels of spend on this scheme.

Public Health England's enhanced tick recording scheme

The UK also run national surveillance on reported cases of *Lyme borreliosis* (Lyme disease) that have been confirmed with laboratory tests. Lyme disease is the most common vector-borne

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

human infection in England and Wales, with an estimated 1,000–2,000 cases of every year. As elsewhere in northern Europe, Lyme disease is transmitted by the hard bodied tick, *Ixodes ricinus*, commonly known as deer or sheep ticks. The mandatory reporting of reference laboratory diagnoses began in 2010. Laboratory-confirmed reports of *Lyme borreliosis* have risen steadily since reporting began.

The tick programme asks that people send specimens to the Government's Rare and Imported Pathogens Laboratory at Porton Down. These are then identified to provide valuable information on the distribution and abundance of the various species present across the UK, their seasonal activity and their host associations.

The University of Liverpool is collaborating with Public Health England on a tick surveillance study across England and Wales[40]. The research is being funded by the National Institute for Health Research's Health Protection Research Unit in Emerging and Zoonotic Infections. Part of this research will be to use climate based models to develop forecasting tools to predict tick bite and Lyme disease risk to the public. The NIHR Health Protection Research Unit in Emerging and Zoonotic Infections at University of Liverpool was established in April 2014 with £4M of funding from the UK Government's National Institute for Health Research (NIHR). It supports and strengthens Public Health England in its role protecting England from emerging infections and zoonoses (i.e. those which spread from animals to humans)[41].

There is no consistent data set available that collates data on spend on surveillance, there is some data on current research spend on a range of pathogens and their vectors, but not all of these are affected by climate change, and the research is not focused on surveillance therefore this data is not immediately suitable to address this indicator.

X7: Number of days per year with high air pollution

Introduction

Information on air pollution in England is available through the Department for Environment, Food and Rural Affairs (Defra), which provides air quality information online, via its UK Air Information Resource website (UK-AIR)[42].

The Daily Air Quality Index (DAQI) provided on UK-AIR forecasts and monitors levels of air pollution, as well as providing recommended actions and health advice. In order to provide detail about air pollution levels in a simple way, similar to the sun index or pollen index, the DAQI index[43] is numbered 1-10 and divided into four bands of air pollution, low (1-3), moderate (4-6),

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[40] https://www.liverpool.ac.uk/infection-and-global-health/research/zoonotic-infections/tick-activity-project/
[41] https://www.liverpool.ac.uk/infection-and-global-health/research/zoonotic-infections/hpruzoonotic/
[42] http://uk-air.defra.gov.uk/
[43] https://uk-air.defra.gov.uk/air-pollution/daqi?view=more-info

high (7-9) and very high (10). The overall air pollution index for a site or region is determined by the highest concentration of five pollutants (i.e. the highest index value threshold reached out of the five pollutants), nitrogen dioxide, sulphur dioxide, ozone and particles < 2.5µm ($PM_{2.5}$) and < 10µm (PM_{10})[44].

Defra (2013) outlines the levels of each pollutant against the DAQI bands, shown in Table 13.

Table 13. Daily Air Quality Index (DAQI) values for five pollutants, Nitrogen Dioxide, Sulphur Dioxide, Ozone and Particles < 2.5µm (PM2.5) and < 10µm (PM10). Source: Defra (2013).

Band	Index	Ozone	Nitrogen Dioxide	Sulphur Dioxide	$PM_{2.5}$ Particles (EU Reference Equivalent)	PM_{10} Particles (EU Reference Equivalent)
		Running 8 hourly mean	hourly mean	15 minute mean	24 hour mean	24 hour mean
		μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
Low	1	0-33	0-67	0-88	0-11	0-16
	2	34-66	68-134	89-177	12-23	17-33
	3	67-100	135-200	178-266	24-35	34-50
Moderate	4	101-120	201-267	267-354	36-41	51-58
	5	121-140	268-334	355-443	42-47	59-66
	6	141-160	335-400	444-532	48-53	67-75
High	7	161-187	401-467	533-710	54-58	76-83
	8	188-213	468-534	711-887	59-64	84-91
	9	214-240	535-600	888-1064	65-70	92-100
Very High	10	241 or more	601 or more	1065 or more	71 or more	101 or more

The relationship between air pollution and climate change is complex, but since air pollution concentrations are associated with weather conditions, climate change is likely to affect air pollution. For example, elevated air pollution often occurs during heatwaves, which are likely to become more frequent due to climate change. This indicator assesses the number of days by region, per year, where DAQI levels recorded high or very high values to understand if the number of days with high air pollution has changed over time

Methodology

DAQI regional data was extracted from the UK-AIR database, which provides the overall air pollution index for a site or region, determined by the highest concentration of one of five pollutants - nitrogen dioxide, sulphur dioxide, ozone and particles < 2.5µm ($PM_{2.5}$) and < 10µm (PM_{10}). Daily data was extracted for all regions (East Midlands, Eastern, greater London, North East, North West and Merseyside, South East, South West, West Midlands and Yorkshire and Humberside) for each year between 2000 and 2016, providing an annual time series of 17 years. Data was grouped into the four bands (low, moderate, high and very high) to provide a total number of days which fell into each band per annum. It should be noted that the DAQI value is

[44] https://uk-air.defra.gov.uk/air-pollution/daqi?view=more-info

triggered by the highest threshold value from one or more of the five pollutants. One drawback of using this index is that no information is given as to which pollutant is causing the alert, and subsequently the extent and risk from air pollution may differ from one day to another, despite the DAQI being the same.

Results

Findings show that there is considerable variability year to year between the numbers of days recorded on the DAQI with high and very high levels of air pollution, indexed as 7-10 on the DAQI scale. Due to data not being available on which of the five pollutants triggered the DAQI index value observed each day, interpretations should be made with caution.

High levels of air pollution

On the UK-AIR website, recommended actions and health advice is provided. During periods where air quality exhibits a high level of pollution (DAQI values 7-9), the advice suggests that:

- 'At risk' individuals (i.e. adults and children with lung problems, and adults with heart problems) should **reduce** strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also **reduce** physical exertion.
- General population should **consider reducing** activity, particularly outdoors, if experiencing discomfort such as sore eyes, cough or sore throat.

DAQI records from UK-AIR show that the annual number of high air pollution days (i.e. DAQI values of 7-9) typically ranged from 0-10 days per year, but can be much greater in particularly bad years. Figure 18 illustrates that 2009 and 2010 received particularly low numbers of days with high air pollution across all regions, whilst 2003 and 2006 showed a much higher number of days with high air pollution, with all regions experiencing at least 5 days with DAQI values of 7-9, categorised as high. Yorkshire and Humberside, and Greater London typically record more days of high air pollution compared with e.g. East Midlands and the North East. In the last decade (2007-2016), apart from the South East in 2012, no regions in England experienced more than 9 days of high air pollution in any one year.

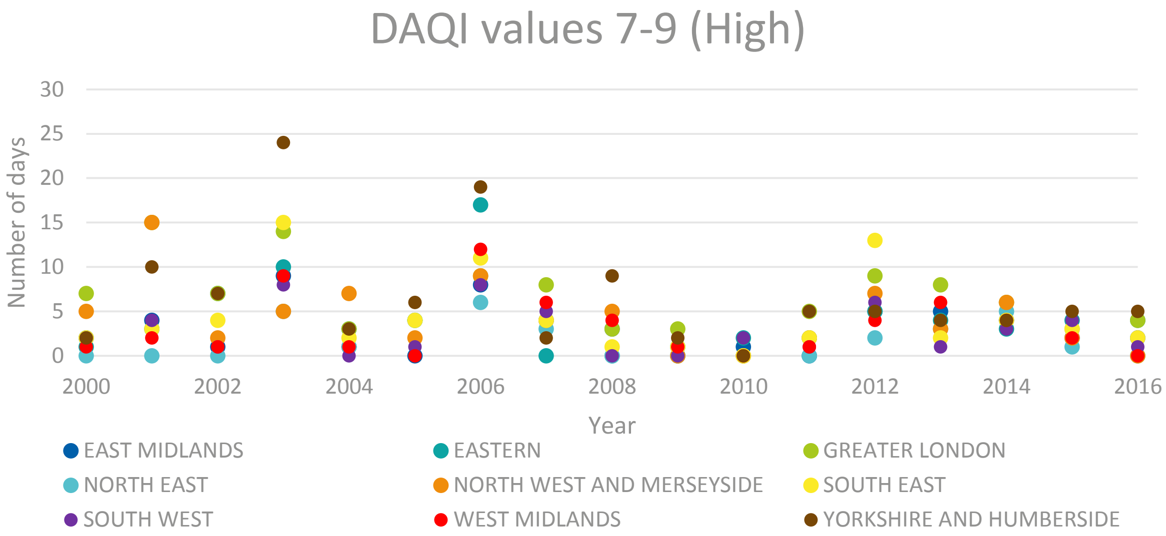

Figure 18. Number of days, by region, per year that DAQI recorded values that exhibited high (index value 7-9) levels of air pollution. Data sourced from UK-AIR. Source: ADAS for ASC.

Very high levels of air pollution

During periods where air quality exhibits a very high level of pollution (DAQI value 10), the UK-AIR advice suggests that:

- 'At risk' individuals (i.e. adults and children with lung problems, adults with heart problems, and older people) should **avoid** strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.
- General population should **reduce** physical exertion, particularly outdoors, and especially if experiencing symptoms such as cough or sore throat.

DAQI records from UK-AIR show that the annual number of days with very high air pollution (i.e. DAQI values of 10) typically occur between 0-4 days per year, but can be much greater in particularly bad years. Figure 19 illustrates that the North West showed 9 days in 2001 and 6 days in 2004 where pollution levels were very high, with more than double the number of days of very high air pollution compared with other regions. Typically the highest levels of pollution were recorded in the North West and Merseyside, and Yorkshire and Humber, whilst the South West and East Midlands most frequently recorded the lowest levels of pollution. In the last decade (2007-2016), no regions in England have experienced more than 3 days of very high air pollution in any one year.

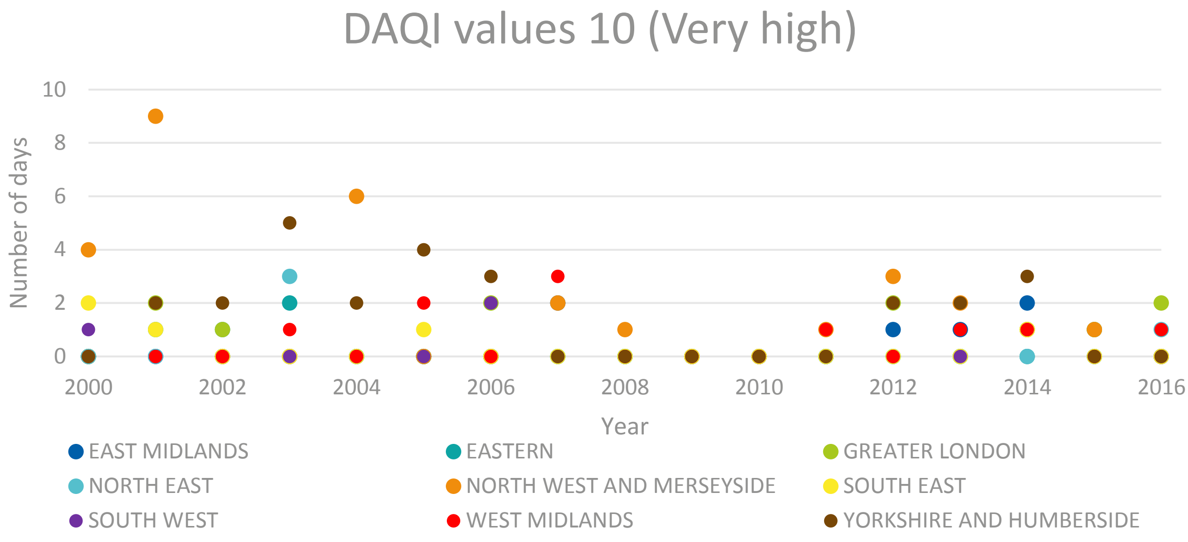

Figure 19. Number of days, by region, per year that DAQI recorded values that exhibited very high (index value 10) levels of air pollution. Data sourced from UK-AIR. Source: ADAS for ASC.

Robustness

The dataset of recorded DAQI values on UK-AIR provides a very robust dataset of daily values captured over a long time series. Data from 2000 is very comprehensive with no missing values in the time series. Data is available for some year's pre-2000, but this is subject to gaps in the dataset on some days in some regions. Data is added to the UK-AIR historic record portal frequently, allowing this indicator to be updated in future years.

X10: Particulate pollution levels

Introduction

Particulate matter (PM), also called particle pollution, is the term used to describe condensed phase (solid or liquid) particles suspended in the atmosphere. Particulate matter has the potential for causing health problems, directly linked to the size of the particles.

Particles come in a wide range of sizes[45]:

- Coarse dust particles, referred to as PM_{10}, are 2.5 to 10 µg in diameter. Sources include crushing or grinding operations and dust stirred up by vehicles on roads.
- Fine particles, referred to as $PM_{2.5}$, are less than 2.5 µg in diameter, and can only be seen with an electron microscope. Fine particles are produced from all types of combustion,

[45] https://airnow.gov/index.cfm?action=aqibasics.particle

including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning and some industrial processes.

A growing body of research has pointed towards the smaller particles, $PM_{2.5}$, as a metric more closely associated with adverse health effects than PM_{10}[46]. People with heart or lung diseases, older adults and children are most likely to be affected by particle pollution exposure, but healthy people may also feel temporary symptoms if exposed to high levels of particle pollution. Numerous scientific studies connect particle pollution exposure to a variety of health issues, including irritation of the eyes, nose and throat; coughing, chest tightness and shortness of breath; reduced lung function; irregular heartbeat; asthma attacks; heart attacks; premature death in people with heart or lung disease.

The EU's Air Quality Directive, the Directive on Ambient Air Quality and Cleaner Air for Europe (2008/50/EC), defines standards by which air pollution can be assessed and establishes specific air quality objectives. The UK has four core Air Quality Strategy Standards for $PM_{2.5}$ and PM_{10}, outlined in Table 14.

*Table 14. Air quality standards for $PM_{2.5}$ and PM_{10}**

	Pollutant	Time period	Standard	To be achieved by
UK	$PM_{2.5}$	annual mean	Objective of 25 µg m^{-3}	2020
		three-year running annual mean	15% reduction in average urban background concentrations against a 2010 baseline	2020
	PM_{10}	24-hour mean	Objective of 50 µg m^{-3} not to be exceeded more than 35 times a year	2005
		annual mean	Objective of 40 µg m^{-3}	2005

** Table from a report prepared for the Department for Environment, Food and Rural Affairs; Scottish Executive; Welsh Government; and Department of the Environment in Northern Ireland - Fine Particulate Matter (PM2.5) in the United Kingdom. Source: Air Quality Expert Group, 2012.*

This indicator assesses the number of times these objectives are known to have been exceeded in monitoring records produced by UK-AIR, particularly in London where historical records are more comprehensive and pollution levels are typically greater, compared with other areas of England.

46 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69635/pb13837-aqeg-fine-particle-matter-20121220.pdf

Methodology

Data was extracted from the UK-Air Annual and Exceedance Statistics for England, measured by the Automatic Urban and Rural Monitoring Network (AURN), for pollutants a) $PM_{2.5}$ particulate matter (daily measured) and b) PM_{10} particulate matter (daily measured). It is noted that the AURN use urban roadside sites, which are typically less relevant to climate change than that of background sites. Data from the rural (background) network was not available for this study.

A full dataset was available from the AURN from 2001 to 2016, providing a 16 year time series. The statistics chosen for analysis correspond with three out of the four air quality strategy standards:

- Air Quality Strategy Objective ($PM_{2.5}$) Annual mean > 25 µg/m^3
- Air Quality Strategy Objective (PM_{10}) Annual mean > 40 µg/m^3
- Air Quality Strategy Objective for 2004 (PM_{10}) daily mean > 50 µg/m^3 on more than 35 days

Data could not be located for the fourth standard which monitors $PM_{2.5}$ three-year running annual mean. Furthermore, this standard could not be calculated due to the way the data was presented –as annual mean data for years in which exceedances occurred (i.e. years where more than 35 days were recorded), whilst years with lower (e.g. 32 days) returned a null value, meaning an inconsistent dataset to calculate a three-year running mean.

Results

Air Quality Strategy Objective ($PM_{2.5}$) Annual mean > 25 µg/m^3

The data extracted from UK-AIR showed records for the annual mean $PM_{2.5}$ levels for 11 monitoring stations in England. However, the majority of these stations only held values for a selection of years, not a consistent time series. The longest and most complete time series were for London. In the 2001 to 2016 time series, the *Air Quality Strategy Objective ($PM_{2.5}$) Annual mean > 25* µg/m^3 was exceeded in 5 out of the 16 years in the time series, all at the London Marylebone Road monitoring station. The other ten monitoring stations show no exceedances in the AIR-UK historical records, dating back to 2001. It is not clear whether this was due to a lack of data being recorded for some years, or because there were simply no exceedances. As such, analysis was concentrated on the London monitoring stations. Figure 20 shows that the exceedances at London Marylebone Road all occurred before 2009, after which annual mean levels of $PM_{2.5}$ then showed considerably lower levels.

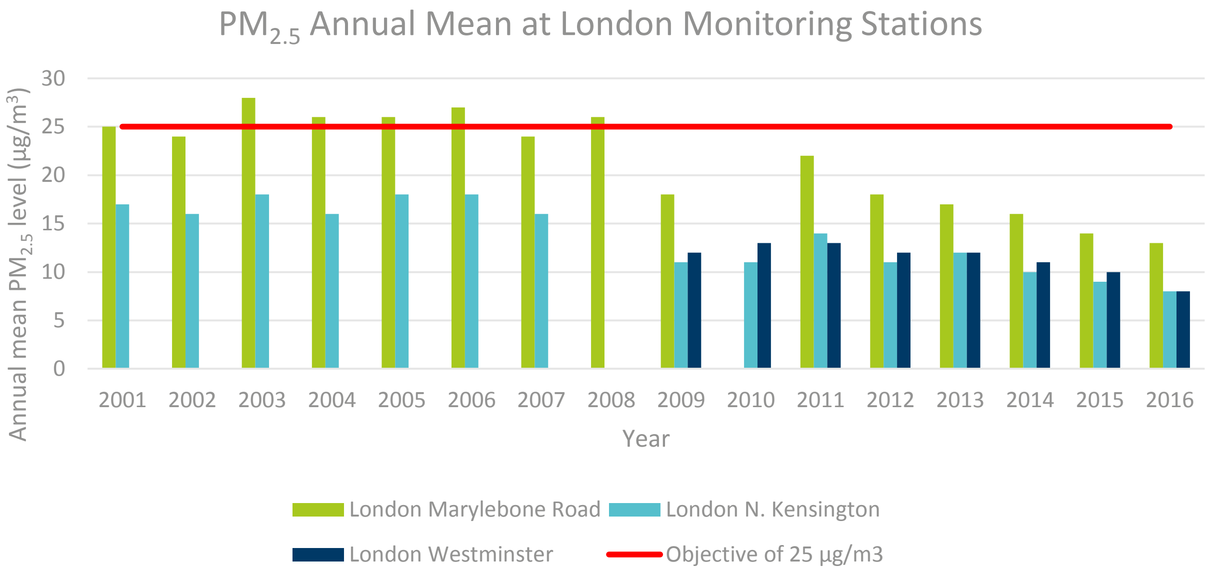

Figure 20. Shows the annual mean $PM_{2.5}$ level for three monitoring stations across London, relative to the Air Quality Strategy Objective ($PM_{2.5}$) Annual mean > 25 µg/m^3. Source: ADAS for ASC.

Air Quality Strategy Objective (PM10) Annual mean > 40 µg/m^3

Annual mean PM_{10} levels across 10 monitoring stations in England were obtained. However, the majority of these stations only held values for a selection of years, not a consistent time series. The longest and most complete time series were for London. In the 2001 to 2016 time series, the *Air Quality Strategy Objective (PM_{10}) Annual mean > 40* µg/m^3 was exceeded in 3 out of the 16 years in the time series, all at the London Marylebone Road monitoring station. The other nine monitoring stations showed no exceedances in the AIR-UK historical records dating back to 2001. As such, analysis was concentrated on the London monitoring stations. Figure 21 shows that these exceedances at London Marylebone Road all occurred before 2007, and all in years where $PM_{2.5}$ levels were also exceeded. The last decade shows an ongoing gradual decrease in annual mean PM_{10} levels.

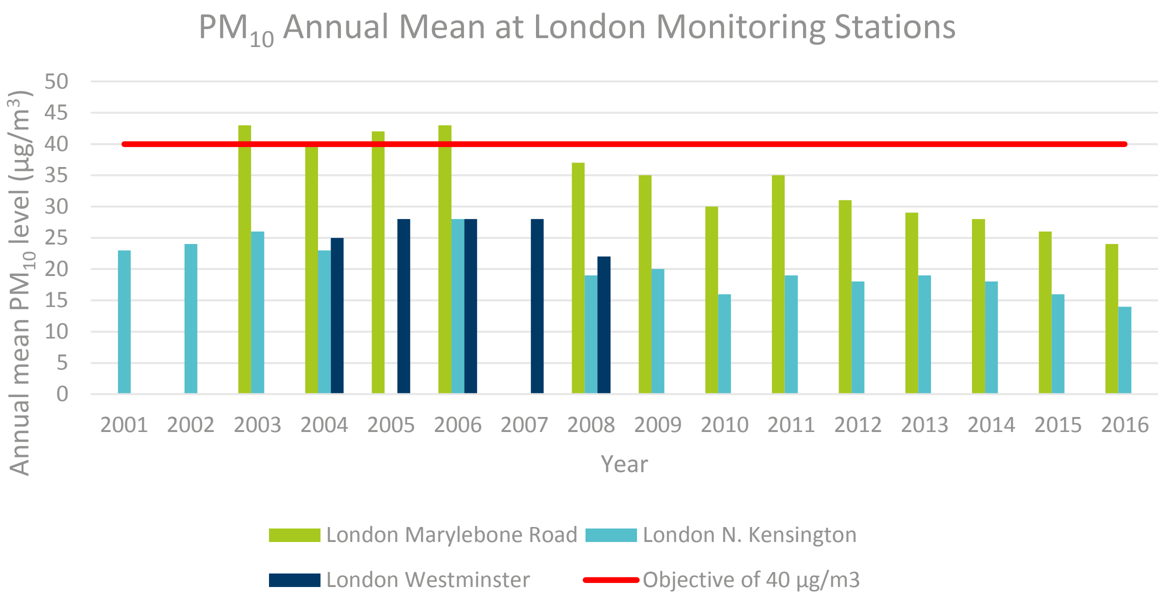

Figure 21. Graph shows the annual mean PM_{10} level for three monitoring stations across London, relative to the Air Quality Strategy Objective (PM_{10}) Annual mean > 40 µg/m^3. Data is shown for a) London Marylebone Road for 2003 to 2006, and 2008 to 2016, no data was available for 2007; b) London North Kensington for 2001 to 2004, 2006, and 2008 to 2016, no data was available for 2005 and 2007; and c) London Westminster for 2004 to 2008, data not available for any other years. Source: ADAS for ASC.

Air Quality Strategy Objective for 2004 (PM10) daily mean > 50 µgm^{-3} on more than 35 days

The UK has an objective to achieve no more than 35 days per year where daily mean PM_{10} levels exceed 50 µg/m^3. Data extracted from UK-AIR show that exceedances of this standard have occurred at four monitoring sites in England. Figure 22 shows that these exceedances occurred in half (8) of the 16 year time series, predominantly at London Marylebone Road monitoring station.

The largest number of days over the 35-day threshold was in 2003, with PM_{10} daily mean levels greater than 50 µg/m^3 on 82 days of the year, 47 days more than 35-day threshold in *Air Quality Strategy Objective for 2004 (PM10) daily mean > 50 µg/m^{3}on more than 35 days*. Recent years show no exceedances of this standard, suggesting that levels of PM_{10} are being maintained within the EU thresholds set.

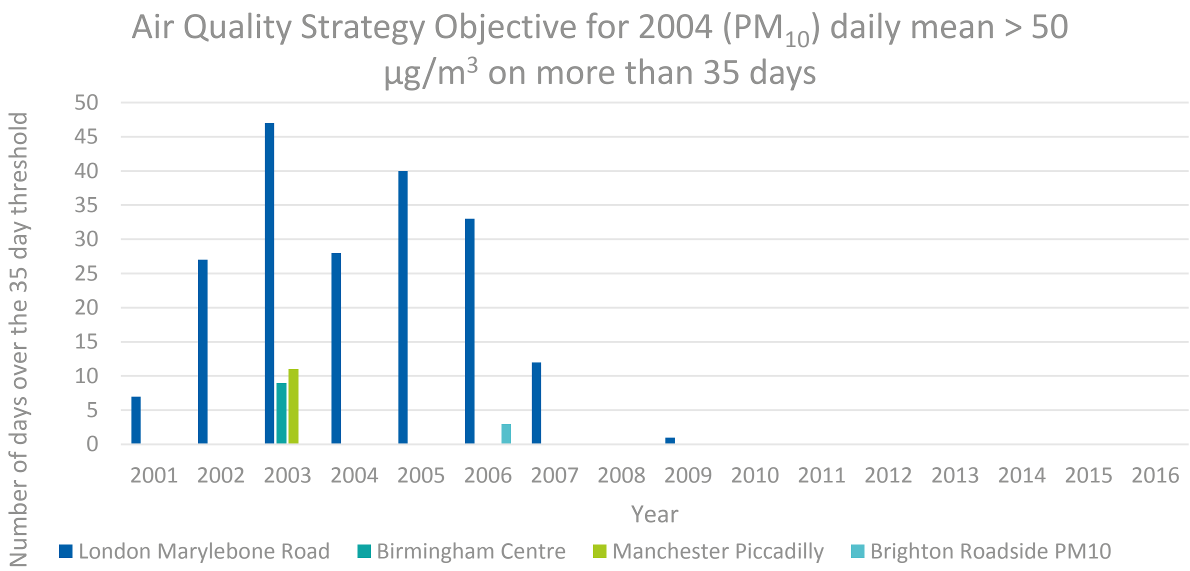

Figure 22. Shows the number days above the 35-day threshold, that daily mean PM_{10} levels exceeded 50 µg/m^3. Data is shown for four monitoring stations across England and relates to the Air Quality Strategy Objective for 2004 (PM_{10}) daily mean > 50 µg/m^3 on. Source: ADAS for ASC.

Robustness

The UK-AIR Annual and Exceedance Statistics provide a relatively robust dataset which provides a strong indication of when EU Air Quality Strategy Objectives have been exceeded. The consistency of records varies between monitoring sites, with some being much more consistent than others during the time series. Data is added to the UK-AIR historic record portal frequently, allowing this indicator to be updated in future years.

3.4 Ability of people to recover from flooding

HCR39: Number of camping and caravan sites with evacuation or flood plans in place

Revised indicator name: Number of camping and caravan sites in flood zone 3

Introduction

Camping and caravanning are popular choices for holidaying in England and there are hundreds of sites throughout England which offer a variety of standards and facilities. Many campsites and caravan parks are situated in idyllic places, near to the coast, lakes and rivers. Consequently, many of these sites are also at risk from coastal and fluvial flooding.

To ensure the safety of the workers and visitors to these sites, evacuation or flood plans should be developed which detail the procedures that should be implemented in the event of a flood event. Evacuation planning and/or response fall within the remit of Local Resilience Forums (LRFs) and local authority emergency planners; although it is ultimately a responsibility on the site owners. The Environment Agency gives advice and works in partnership with the Local Authority to encourage caravan and campsite owners / managers to prepare plans. Evidence included from the Environment Agency (EA) in a Defra (2012) report suggested that EA local flood incident management staff were only aware of five percent of camping and caravan sites at flood risk that had started work on producing a flood evacuation plan, with the majority of those being at sites in the Midlands and Wales (Defra, 2012b). Although the number of sites that have now implemented such plans will likely have increased, no follow up work has been conducted and it is therefore unclear what proportion of sites have evacuation or flood plans in place.

This indicator assesses the number of caravan and camping sites located in flood risk areas, in order to provide an indication of the number of sites which should have an evacuation or flood plan in place to ensure the safety of a site's workers and visitors to the site.

Methodology

To identify camping and caravanning sites in England, information was extracted from OS AddressBasePlus[47] (point dataset) for sites that fell within the following three categories; 'Commercial Leisure Holiday/Campsite' (CL02); Camping sites (CL02CG); and Caravanning sites (CL02CV). Many of the records in this dataset represent plots or fields on caravan sites, therefore the data were dissolved on business ID (USRN) so that there was only one point per caravan/ camping site. This data was then overlaid with two datasets obtained from the Environment Agency:

1. **Flood Map for Planning (Rivers and Sea) Areas benefiting from defences** covers areas that benefit from the presence of defences in a 1 in 100 (1%) chance of flooding each year from rivers; or 1 in 200 (0.5 %) chance of flooding each year from the sea. If the defences were not there, these areas would flood in a 1 in 100 (1%)/ 1 in 200 (0.5 %) or larger flooding incident. It should also be noted that the dataset does not show all areas that benefit from all flood defences. Some defences are designed to protect against a smaller flood with a higher chance of occurring in any year, for example a flood defence which protects against a 1 in 30 chance of flooding in any year. Such a defence may be overtopped in a flood with a 1 in 100 (1%)/ 1 in 200 (0.5%) chance of occurring in any year, but the defence may still reduce the affected area or delay (rather than prevent) a flood, giving people more time to act and therefore reduce the consequences of flooding (Environment Agency, 2016a).
2. **Flood Map for Planning (Rivers and Sea) Flood Zone 3** covers Flood Zone 3. It is the EA best estimate of the areas of land at risk of flooding, when the presence of flood defences is ignored and covers land with a 1 in 100 (1%) or greater chance of flooding each year from Rivers; or with a 1 in 200 (0.5%) or greater chance of flooding each year from the Sea (Environment Agency, 2016b).

[47] https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-plus.html

Using fluvial, tidal and fluvial/tidal models, figures were obtained for the number of camping and caravanning sites in a) Flood Zone 3 minus the area protected by flood defences; and b) Flood Zone 3 only (natural floodplain). Flood Zone 2 was not used in this analysis.

Results

The model results identified 704 camping and caravan sites that were located in the natural floodplain (Flood Zone 3), of which 303 were at risk from tidal flooding, 342 were at risk from fluvial flooding and 83 were at risk from both fluvial and tidal flooding.

The number of camping and caravan sites in Flood Zone 3, excluding the area protected by flood defences, are 595. Of these, 220 were at risk from tidal flooding, 326 were at risk from fluvial flooding and 66 were in the fluvial/tidal floodplain. All of these camping and caravan sites should have adequate evacuation and flood plans in place to ensure the safety of its workers and visitors.

Figure 23 illustrates the spatial distribution of the 704 camping and caravan sites located in the Flood Zone 3.

Research in June 2010, which was based on responses to an internal Environment Agency survey with Flood Incident Management staff, found that only 37 sites were known to have flood evacuation and emergency plans in existence (Defra, 2012b). This number is likely to have increased in the last few years since the survey was conducted, however, a further survey is required to understand the current number of sites with plans in place.

Robustness

The data on flood risk is deemed robust and it is the EA's best estimate of the areas of land at risk of flooding. The method for identifying camping and caravan sites is also deemed relatively robust, however there is a chance that some sites are not captured within the three categories assessed from AddressBasePlus. However, this method is not able to identify what proportion of these sites actually have flood risk or evacuation plans in place.

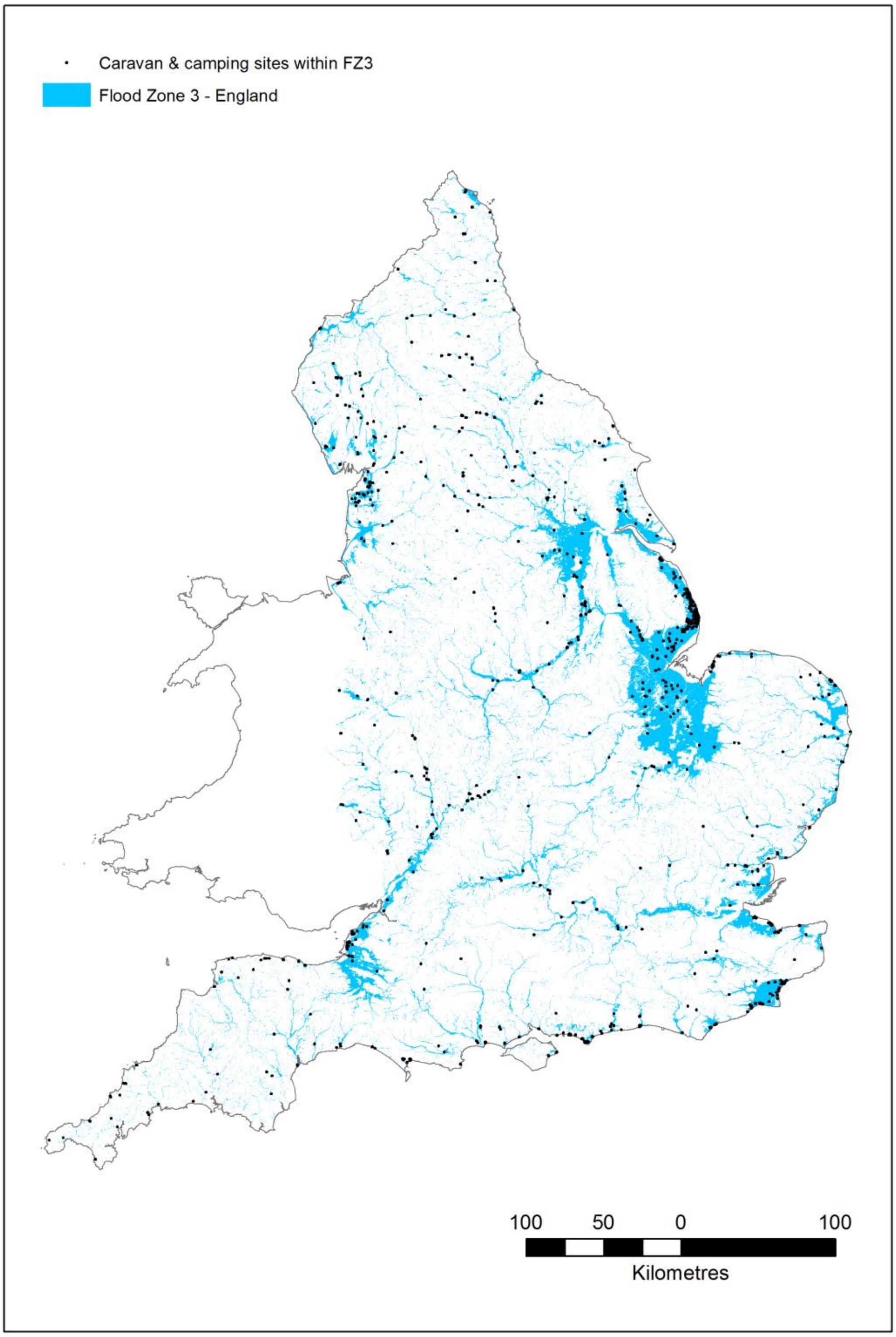

Figure 23. Camping and caravan sites located in the Environment Agency Flood Zone 3. These sites exhibit a high flood risk (1 in 100 or greater chance of flooding each year from Rivers; or with a 1 in 200 or greater chance of flooding each year from the Sea) when the presence of flood defences are ignored. Source: ADAS for ASC.

HCR40: Number of school days lost from flooding/severe weather events

Introduction

Extreme weather events, such as heavy rainfall and associated flood events, as well as snow and ice, can cause schools to temporarily close due to inaccessibility or risk of injury. Projected climate changes may exacerbate some of these events, although it is uncertain whether the number of school days lost from severe weather events will change. For example, the number of school days lost from snow and ice may decrease due to milder winters, whilst projections for wetter winters and more intense summer rainfall events may increase the number of days lost to flooding. Furthermore, there could be an increased risk of school closures from heatwaves or very hot days, where school buildings are not adequately designed or prepared to cope with very hot conditions.

How schools and other educational settings should plan for and deal with emergencies, including severe weather and floods is outlined on the Gov.uk website[48]. It is the responsibility of individual schools to implement adequate procedures to respond to severe weather events and often it is the discretion of the head teacher of the school who is responsible for closing their school due to inaccessibility or risk of injury. Nottinghamshire County Council has been at the forefront of effective emergency planning and between 2009-11, worked with other local authorities on the 'Developing community resilience through schools' project, with the aim of creating emergency planning resources for schools that could be used nationally, including a school emergency plan template and accompanying guidance for other schools and local authorities to use[49].

Despite good preparation material being available for schools to plan, the actual reporting of school closures is not so well documented. Neither the Department for Education, nor any other organisation known to the author at time of publication, collect information specifically on the number of school closures nationally due to severe weather. In addition, schools are under no obligation to report any closures due to flooding or other severe weather events to any government or local government department. Consequently, there is no central national database of the number of school days lost to severe weather.

Typically, schools report closures to their county councils, which provide information of all school closures (within their district) on their websites. Some of these councils (e.g. North Yorkshire County Council) retain records of school closures due to severe weather, whilst others (e.g. Nottinghamshire County Council) may be advised of school closures which would be available on their website at the time, but the Council does not retain this information.

It is likely that many, but not all schools retain records, indicating that no complete historic national dataset is achievable. The total number of schools in England was reported to be 24,288

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[48] https://www.gov.uk/guidance/emergencies-and-severe-weather-schools-and-early-years-settings
[49] http://www.nottinghamshire.gov.uk/planning-and-environment/emergencies-and-disruption/school-emergencies

in January 2016[50], with each school open for an estimated 190 days per year[51]. This indicator provides a case study for North Yorkshire County Council.

Methodology

A data request was put into North Yorkshire County Council (NYCC). The Council only hold records of school closures back to 2009 and was subsequently able to provide an annual time series of school closures (due to severe weather) for 2009, and 2011 to 31st January 2017. NYCC do hold a list of school closures for 2010, but the reasons for closure have not been recorded and subsequently it cannot be ascertained which closures were due to severe weather and which were not. For years available, school closures are reported in either half days, or full days, along with the reason for closure (snow or flooding).

Case Study - NYCC

There are an estimated 375 educational establishments in NYCC[52]. Assuming each one of these establishments is open for 190 days per year, this equates to 71,250 school days per year, or 570,000 school days in the last eight years (2009-2016) in total. The records provided by NYCC show that since 2009, at least 126.5 school days (0.02%) are known to have been lost due to severe weather up to the end of January 2017, or 114.5 school days (0.02%) between 2009-2016, although this number is likely to be slightly higher due to no data being available in 2010 and the likelihood that not all closures from all schools being fully reported. The calendar year of 2014 exhibited no reported closures in NYCC.

In total, 112.5 school days were reported to be lost due to snow and 14 school days due to flooding. The majority, 71% or 10 school days, lost due to flooding related to the closure of two schools on 4th January 2016, both for 5 consecutive days. The majority, 59% or 66 school days, lost due to snowfall occurred in 2009, shown in Figure 24.

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50 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/552342/SFR20_2016_Main_Text.pdf

51 http://researchbriefings.files.parliament.uk/documents/SN07148/SN07148.pdf

52 http://www.northyorks.gov.uk/media/219/List-of-establishments/pdf/SCHOOLS201617.pdf

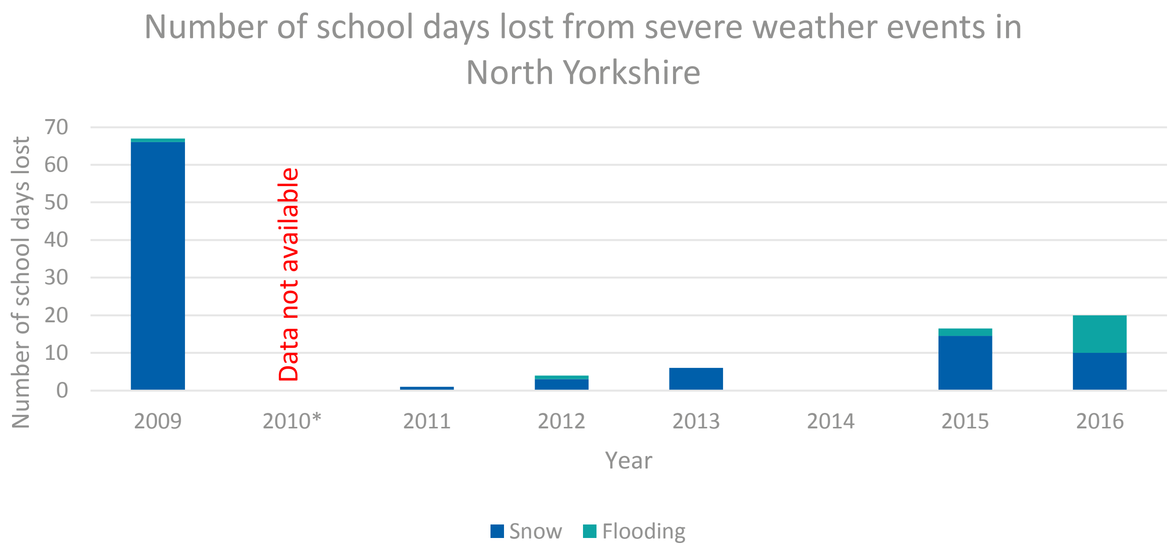

*Figure 24. Number of school days lost from severe weather in NYCC. *Data was not available for 2010. 2014 had no reported school closures attributed to severe weather. Source: ADAS for ASC.*

Further analysis showed that all 66 school days lost in 2009 due to snowfall occurred on the same day, Friday 18 December. A news report from The Guardian[53],[54] notes that on this day, heavy snowfall crippled Britain, with airport closures and severe disruption on major roads and rail services. The Met Office issued severe weather warnings of heavy snowfall in the North East, Yorkshire and Humber, the East Midlands, the East of England, London and South East England. On this day, more than 2,000 schools were forced to close across the country as heavy snow and freezing temperatures made roads impassable and caused heating systems to break down. Kent and Hertfordshire were worst hit, with ~350 schools closed. Other badly hit areas and indicative number of schools closed include Suffolk (~220), Essex (~275), East and West Sussex (~200), Buckinghamshire (~170), East Anglia (~140), Cambridgeshire (~100). It should be noted that the 18th December was also the last day of term for many schools, so the number of closures may have been higher than, for example, a typical mid-week day in the middle of term.

The results from NYCC indicate that long-term trends would be very difficult to assess at a local level (and perhaps even national level) due to the robustness of data and the influence a single severe weather event can have.

Robustness

A full dataset is not available to assess the number of school days lost to severe weather in England. However, incomplete records held from various Councils and/or schools can provide an indication.

[53] https://www.theguardian.com/uk/2009/dec/18/snow-england-north-east-south
[54] https://www.theguardian.com/education/2009/dec/18/snow-schools-closed

The data provided by NYCC give an indication of the number of school closures. However, it must be noted that although NYCC schools are asked to notify the local authority (LA) of any school closures, it is up to the discretion of the head teacher whether the LA is, or is not, notified of incidents and closures. The data provided is therefore based on records held by the LA where they have been informed by the school, and should not be held as a complete record of all school closures within NYCC due to severe weather for the specified years.

HCR41: Number of people suffering mental health impacts following a flood or severe weather event

Introduction

Severe weather impacts can be exhibited in many forms, including periods of extreme cold, snow and ice; heavy rainfall events and associated flooding; periods of intense hot weather, heatwaves and drought; and strong winds associated with storms. Each of these severe weather events can have very real and disruptive impacts on the public, both in terms of physical and mental health and exacerbated by damage and loss of property, businesses and possessions, and in some instances, impacts on or loss of family, friends and pets.

To date, there has been little research on the mental health impacts that individuals suffer following severe weather events, and no known databases are held that record the number of people or type of mental health impacts exhibited. This indicator provides an overview of a recent study which looked to investigate the longer-term impact of flooding and related disruptions on mental health and wellbeing.

Methodology

Research on a national cohort study of flooding and health in England (Waite et al., 2017) provides a cross-sectional analysis of mental health outcomes at year one of the study[55]. We provide here a brief overview of the study and highlight the key findings.

Results

The study looked at participants living in neighbourhoods affected by flooding in the south of England between 1 December 2013 and 31 March 2014. Data was collected through a 36-item questionnaire, which included a bespoke 19 item exposure assessment, to understand if participants had been flooded, or affected by flooding. Participants were allocated to one of three categories:

a) Unaffected participants, who reported no flooding or disruption to their lives from flooding in their area;
b) Disrupted participants, defined as those who reported no floodwater in the liveable rooms of their home and at least one of the following disruptions: evacuation; flooding

[55] http://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-016-4000-2

of non-liveable areas, garages, gardens or the street; interruption to household utilities (electricity, gas, oil, water, drainage, septic tank); loss of communications (postal or telecommunications); interruption to health or social care access, in or away from the home; difficulty accessing work, own or children's education; and interruption to other amenity e.g. getting to shops or social activities;

c) Flooded participants, who reported floodwater in at least one liveable room of their home.

The results indicate that both flooding and certain forms of disruption from flooding are associated with elevated high risk of psychological morbidity, with rates of psychological morbidity among flooded participants one year after flooding at 20.1% for depression, 28.3% for anxiety and 36.2% for PTSD. Amongst those disrupted by flooding but without floodwater in the home, disruption to work and education was shown to be a more important predictor of psychological morbidity than in those who were flooded.

The findings indicate that people may suffer mental health impacts following flooding for many months after an event, even if not directly flooded themselves. However, due to the study only being based on flooding, and regionalised to the south of England, it is not possible to interpret the number of people that suffer mental health impacts due to severe weather events (e.g. snow, drought, flooding etc.) in England and how this has changed over time. The research does however give insight into some of the effects on people from flooding.

Robustness

No robust data was attained to develop an indicator. The study provides insight into the mental health impacts from flooding, and reports that it is the first to have examined the impact on people living in areas which experienced flooding but who did not have floodwater in their own homes and the first to examine associations between psychological morbidity and particular disruptions.

HCR42: Average length of time between flood events and people returning to their homes

Introduction

Homes are more than just a place where one lives, homes hold a strong degree of personal significance for their occupants. When flooding of homes occurs it generally forces occupants to leave their home in search of temporary housing bringing with it a widely reported financial cost, but also a human cost - disrupting people's lives causing considerable emotional distress as found in the English national cohort study of flooding and health (Waite et al., 2017).

Flood repairs can take weeks, months or even years to complete, especially if there has been widespread flooding. It takes time to dry out a property and settle insurance claims before repairs can start. The full extent of damage caused by floodwater may not be apparent on the surface, so the cleaning process may be extensive. If repair work is being completed through an insurer, they will inform the occupant when it's safe to move back in to the house. Depending on the level of damage, this could be a matter of weeks, or it could be a year or more.

After the floods of December 2013 - January 2014 across southern England, 60% of flood claims were fully settled within six months, almost three quarters within nine months and the vast majority were home after 12 months (Association of British Insurers, 2016).

It is thought that the shorter the time between flood events / evacuations and people returning to their homes can mitigate the emotional distress caused by the flood event. In 2014 the Government put in place a new scheme, the 'Repair and Renew Grant', which provides funding of up to £5,000 to homeowners and businesses affected by flooding to fund work to improve their property's resistance to future adverse weather conditions[56]. It is hoped that these grants will shorten the length of time that people are displaced from their home after future flood events.

Methodology

No comprehensive data set was identified. Three methods were included in support of this indicator:

A. Evidence presented by Milojevic et al. (2014) on population displacement after the 2007 floods in Kingston-upon-Hull, UK based on the Hull City Council flood database (Flood Support System: FloSS).
B. The probability of evacuation and duration in relation to flood depth taken from the Multi-Coloured Manual also known as the 'Flood and Coastal Erosion Risk Management – A Manual for Economic Appraisal', Penning-Rowsell et al. (2014).
C. An online review was conducted to inform this indicator through the use of case studies which set out a rough timeline between being evacuated from home due to a flood event and permanently returning home.

Results

A) The displacement of affected populations from their homes after a flood event is an important factor in determining its health and social impacts. A summary is provided which presents the results of Milojevic et al. (2014) on the duration of household relocations (shown in Figure 25):

- 8,790 houses in the city of Hull were affected by flooding or flood damage, of which 5,153 were displaced from their homes (59% of flooded houses).
- The proportion of flooded households displaced from their homes rose rapidly over the first two months during and immediately after flooding.
- There was then a steady fall in displaced households, but with a long tail. At 12 months after flooding, more than 20% of flooded households were still displaced, and at 24 months still 5%.

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[56] http://www.repairandrenewgrant.co.uk/

- After 32 months the total displacement time was 46,432 household-months.

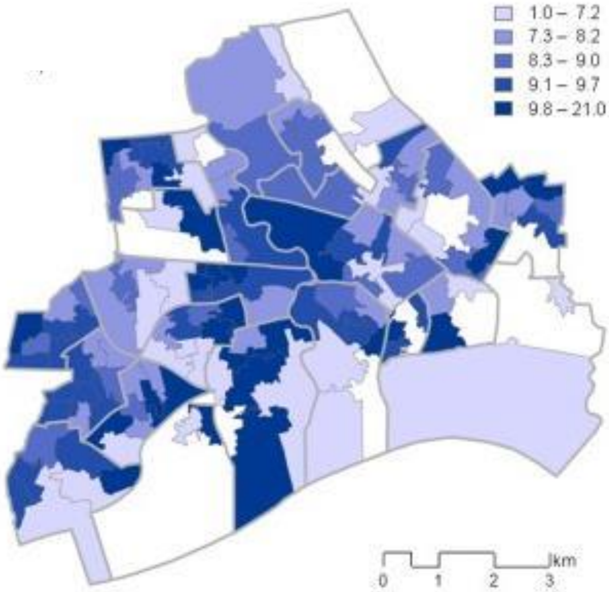

Figure 25. Displacement resulted from the 2007 floods in Hull and socio-economic status by Lower Level Super Output Area (LLSOA) - Average time (months) that families remained away from home. Ward (Local Government) boundaries are in thick light grey. Source: Milojevic et al. (2014).

- Mean duration of displacement for a displaced household ranged from 1 to 21 months and was on average 8.8 months, with standard deviation 2.9.

B) The 'Multi-Coloured Manual' produced by the Flood Hazard Research Centre at Middlesex University, UK, with support from Defra and the Environment Agency provides a manual of assessment techniques of flood risk management benefits, indirect benefits, and coastal erosion risk management benefits.

The probability of evacuation and duration varies depending on flood depth. The Multi-Coloured Manual suggest that on average, durations of displacement vary between 12 weeks for water depth up to 10cm, and 33 weeks for water depth of 1m or more[57]. This is in line with previous estimates, which put the average duration of displacement at 23 weeks[58].

C) Case studies from brief literature review

<u>Flooding in Charlton Village (2007)</u>

[57] MCM, Data and Techniques, Chapter 4 – Residential Property. Version 2 - May 2014
[58] sciencesearch.defra.gov.uk/Document.aspx?Document=FD2005_1855_TRP.pdf

Charlton, a small village near Evesham in Worcestershire, flooded in 1993, 1998 and in 2007 from the Merry Brook River, with 3, 16 and 27 houses flooded respectively. After the 2007 floods, it took up to 12 months to put homes back together (National Flood Forum, undated).

Flooding in Cumbria (2015)

Unprecedented rainfall led to rivers all across Cumbria exceeding the highest flow values ever recorded. In 48 hours, Environment Agency rain gauges had recorded totals of more than 200mm across Cumbria. This led to severe flooding for some residents. One example was a 75 year old local man, Louis Woolfson (National Flood Forum, 2016) who:

- For two days, he could only have returned home by boat.
- It took five days before he managed to speak to someone and learn that his policy would cover the flood damage.
- He was allocated a loss adjustor and was able to start the drying process two months after his house was flooded.
- Five months after the floods receded, the house was properly dried out.
- The property stood empty for almost two months whilst he sourced the contractors he wanted to use.
- After 11 months, the property was fully restored.

Flooding of Somerset Levels (2014)

In January 2014 the South West of England were flooded after the heaviest January rainfall for 250 years. More than 600 homes and 17,000 acres of farmland were inundated with quickly rising waters. However despite some government support on a clean-up, around 96 families were still unable to move back into their homes over 10 months after the event[59]. For some, the total time before being able to safely return home was significantly longer.

Cumbria flooding (2015)[60]

Storm Desmond, the third major storm to hit Cumbria in a decade, brought record rainfall, with 341.4 mm (13.4 inches) falling at Honister Pass in Borrowdale in a 24-hour period.

More than 2,000 properties in Kendal were directly affected by flooding. Flimby, Seaton and Maryport had about 40mm of rain in just a few hours, with more than 100 homes hit. One year on:

- More than 700 families (35% of the total families affected) had still not returned home 12 months after the flood event. Many more had returned home but were still dealing with the consequences.

[59] http://www.telegraph.co.uk/news/weather/11206875/Somerset-Levels-flooding-half-of-residents-still-unable-to-return-home.html
[60] http://www.bbc.co.uk/news/uk-england-cumbria-38194698

- Even a year after the event, hundreds of farmers were still waiting for emergency funding to restore agricultural land.

HCR43: Number of emergency service stations/hospitals/GP surgeries/ care homes/ schools flooded

Introduction

Severe flood events can cause closures to the UK's national infrastructure and put tremendous strain on emergency services because of the threat they pose to life, a need for the safe evacuation of residents form their homes and maintenance of important / critical infrastructure. This strain is exacerbated when the civil national infrastructure (the fire stations, the hospitals etc.) are forced to close or are severely impeded by the flooding. This indicator looks to examine such closures and be indicative of the vulnerability of the UK's national infrastructure to flood events.

Methodology

Suitable annualised data were not identified to support this indicator. The most suitable method identified to support a partial indicator was through a literature review surrounding a specific case study. The literature review focused on the closures caused by the Cumbrian floods in December 2015.

Case Study - Cumbria flooding (2015)

Storm Desmond, the third major storm to hit the county in a decade, brought record rainfall, with 341.4 mm (13.4 inches) falling at Honister Pass in Borrowdale in a 24-hour period[61]. Cumbria was particularly badly affected.

School closures

Schools across Cumbria faced weeks of closure and extensive clean-up operations[62]. In total, 36 schools were closed for at least one day as a result of flooding. Of these, four remained shut for a further 4 days, and two remained shut for several weeks as council bosses and school staff assessed damage and co-ordinated efforts to dry out classrooms.

Hospitals

Two main hospitals in Lancaster and Carlisle, were running on emergency generators for a number of days due to power failure[63]. These hospitals continued to run essential services, but were forced to cancel all routine appointments and operations.

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[61] http://www.bbc.co.uk/news/uk-england-cumbria-38194698
[62] http://schoolsweek.co.uk/storms-shut-schools/
[63] https://www.theguardian.com/uk-news/2015/dec/07/chaos-cumbria-floods-lake-district-turn-lives-upside-down

- Most non-urgent elective operations were cancelled at the Royal Lancaster Infirmary and Westmorland General Hospital for Monday 7 December 2015.
- By Wednesday the 9th of December most services at the Royal Lancaster Infirmary (RLI) returned to normal, however outpatient clinics were limited due to power stability concerns. Westmorland General Hospital was running as normal.

General Practitioners

The number of practices affected was not recorded. The public were asked to contact their GP surgery to seek advice should they be attending a routine appointment or treatment[64].

Emergency services

No evidence of closures was identified as part of a brief online review. This may simply be because closures were not reported, or readily identified in the literature search, rather than an indication of emergency services not being affected by flooding.

X8: Number of flood warnings issued on Floodline Warnings Direct (FWD)

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. Floodline Warnings Direct (FWD) is a free service run by the Environment Agency (EA) that provides flood warnings by phone, text or email to home owners and businesses. A dataset is held by the EA with a listing of all Severe Flood Warnings, Flood Warnings and Flood Alerts issued since the FWD service went live in January 2006. This indicator assesses the number of flood warnings issued on FWD.

Methodology

The EA dataset was sourced from the Environment Agency and includes flood warnings issued for flooding from rivers and the sea and, for a limited number of locations, for groundwater flooding. There are four key codes used on FWD. Three flood warning codes are used to define the severity of a flood event and associated danger to life, and a notification code is applied when warnings are removed. The codes have the following connotations:

- **Severe Flood Warning**: Severe flooding. Danger to life.
- **Flood Warning**: Flooding is expected. Immediate action required.
- **Flood Alert**: Flooding is possible. Be prepared.
- **Warning no longer in force**: Flood warnings and flood alerts that have been removed in the last 24 hours.

[64] http://www.ncuh.nhs.uk/news/2015/december/cumbria-floods---latest-information-.aspx

Analysis was conducted for the time series by warning type and by region to understand if the number of warnings had changed over time. Six regions are detailed in the dataset, Anglian (referred hereon in as the 'East'), Midlands, North East, North West, South East and South West.

Results

In total, 37,386 warnings were issued on FWD between 31 January 2006 and 2 October 2016. Of these, 72.3% (27,019) refer to Flood Alert warnings being issued, 24.3% (9,069) refer to Flood Warnings being issued, 1.1% (403) refer to Severe Flood Warnings being issues, and 2.4% (895) refer to updates on flood warnings.

There is considerable variability in the number of warnings issued each year, with 2011 exhibiting a particularly low number of warnings, whilst 2012 and 2014 exhibited a much greater number, with roughly four times as many warnings to that of 2011, shown in Figure 26. The distribution of these warnings by region is also relatively variable year to year. Figure 27 shows that typically, more warnings are issued in the South West and South East than for example the East of England.

The differences observed in the number of warnings issued by region and 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. This is related to new areas being added, and some areas being split up into more precise segments.

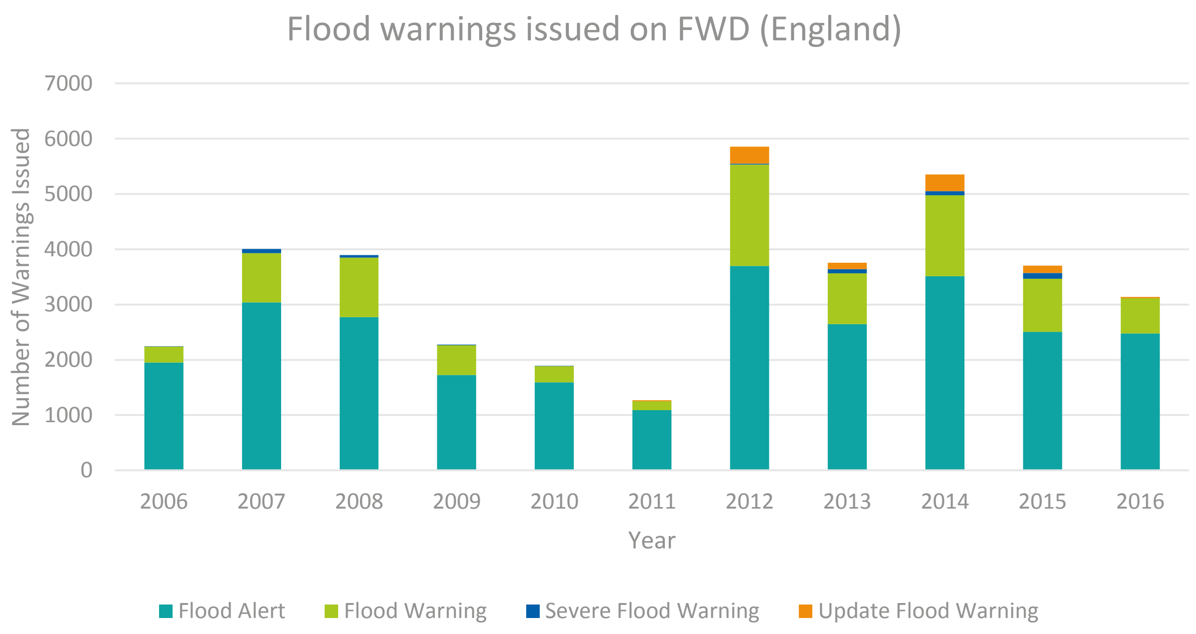

Figure 26. Shows the number of flood warnings issued by type (Alert, Warning, Severe, Update). This includes both surface level and groundwater Flood warnings in England. The 2006 data is a partial year from 26/01/06 to 31/12/06. The 2016 data is a partial year from 01/01/16 to 02/10/16. Source: ADAS for ASC.

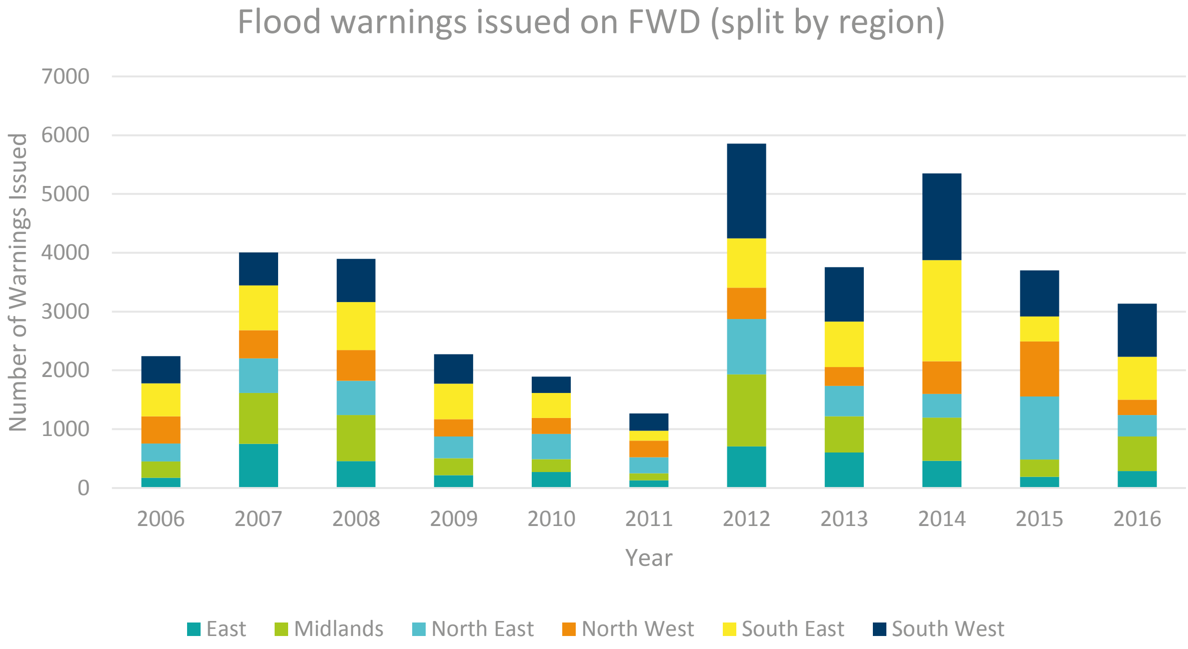

Figure 27. Shows the annual number of flood warnings issued in each region in England. The 2006 data is a partial year from 26/01/06 to 31/12/06. The 2016 data is a partial year from 01/01/16 to 02/10/16. Source: ADAS for ASC.

Robustness

This indicator provides an indication into the number of warnings issued on FWD, however, the data is not robust enough to interpret trends over time 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 Environment Agency noted that the number of flood warning areas had increased. However, detail was not available on the exact number of flood warning areas each year, limiting the potential to present the data differently (e.g. proportion of flood areas experiencing flooding) to help with cross interpretation between years.

X9: Number of registrations for FWD

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

3.5 Capability of the emergency planning system

HCR46: Numbers of EA, fire and police officers related to required capability

Introduction

In response to the impacts of extreme weather events, Environment Agency (EA) officers, police officers and fire and rescue officers may be called upon. The number of trained officers available on the respective workforces will influence the resource and capabilities of these services to respond to such events and assist the public in responding accordingly. At the time of publication, it is not clear what the national level of capability for weather-related hazards should be and to date there has been no comprehensive national assessment of the amount and type of resources that should theoretically be available to deal with weather-related hazards.

This indicator assesses the trends in the number of fire and police officers in England to provide insight into the available resource that might be available in response to a national extreme weather event.

Methodology

Data on the number of police officers[65] and fire officers[66] in England was sourced from annual statistics published on the UK Government website. Data on the police workforce was extracted for the period 2009-2016 and data on the fire and rescue service was extracted for the period 2002-2016. Fire and rescue staff numbers were published in a single table in the fire statistics report. Police workforce data in England was collated from annual reports, which break the force down by area and region. Information was not available on the required capability of the police workforce or fire and rescue authorities to respond to the impacts of extreme weather events. Data was not collected for Environment Agency officers.

Results

Findings show that the number of full time equivalent (FTE) staff in post employed by fire and rescue authorities in England on 31 March 2016 was 42,347, of which 81% (34,395) were fire officers (either whole time or retained duty system) and 19% were in other roles including fire control and support staff. Both the number of fire officers, and the total fire workforce, have decreased in recent years, with FTE numbers now at their lowest point in the last 15 years. The number of FTE fire officers currently employed by the fire and rescue authorities has decreased by almost 23% since levels peaked at 42,679 fire officers in 2004.

The number of FTE police officers on the police workforce in England in 2016 was 117,450. The number of FTE police officers has been decreasing year on year since 2009, with a 14% reduction on levels exhibited in 2009 of 136,403.

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[65] https://www.gov.uk/government/collections/police-workforce-england-and-wales

[66] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/563118/fire-rescue-operational-statistics-201516-hosb1216.pdf

The total number of FTE fire officers in England and FTE police officers in England has recently been decreasing year on year from around 181,000 officers in 2009 down to 154,000 officers in 2016, shown in Figure 28.

No information was available on the number of officers deemed appropriate to meet the required capability for incident response. Subsequently, it is unclear whether this observed trend would impact on the response rate and efficiency of the services to respond to national events, either caused directly or indirectly by extreme weather, or incidents of other natures.

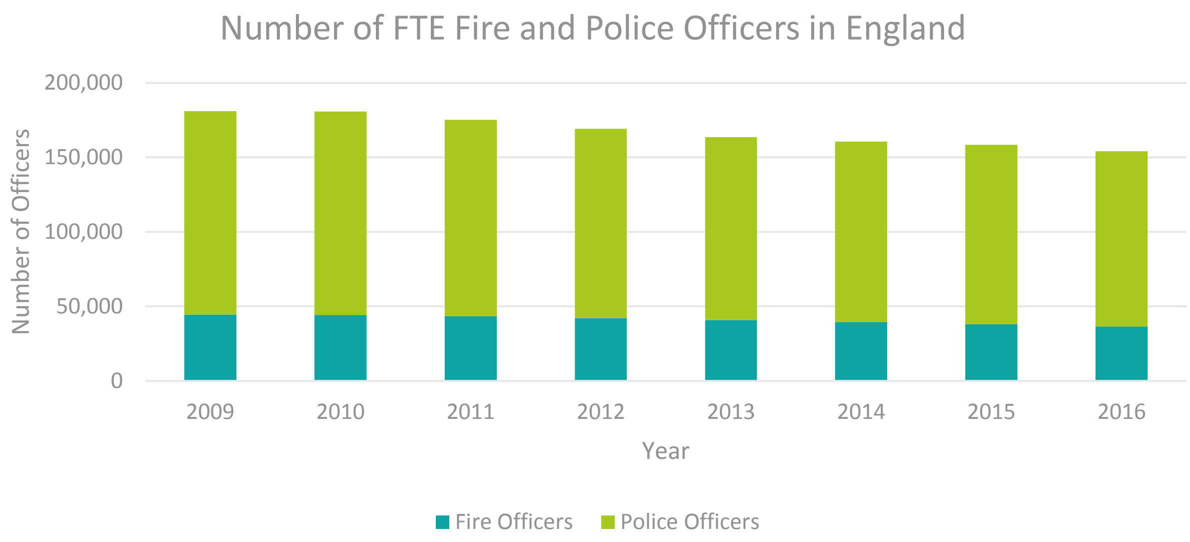


Figure 28. Number of full time equivalent (FTE) fire officers and police officers employed by the respective services in England between 2009 and 2016. Source: ADAS for ASC.

Robustness

This indicator provides a record of the number of FTE fire and police officers employed each year in England. No data was obtained for EA officers. No information was available on the required capability of the police workforce or fire and rescue authorities to respond to the impacts of extreme weather events. Consequently, this indicator does not provide a robust method to assess the number for EA, police and fire officers against required capability, but instead shows general trends in the number of officers that are employed each year.

X6: RNLI capability for responders to flood events

Introduction

The Royal National Lifeboat Institution (RNLI) Flood Rescue Team carry out search and rescue operations wherever severe flooding puts lives at risk. The team is made up of volunteers from across the RNLI, including lifeboat crew and operational staff, all specially trained in swift water rescue. The RNLI flood rescue volunteers are strategically placed within regional flood rescue teams so that they can reach anywhere in the UK and Ireland. Among the RNLI flood rescue volunteers are doctors, paramedics, logistics operatives, linguists, HGV and forklift drivers and mechanics. The team also include trained flood rescue team members, all qualified Defra Module 4 boat operators who can operate vessels for responding to in-shore flood events (see Table 15). The RNLI Flood Rescue Team support other emergency services and agencies as required during flood events, which include the Fire and Rescue Service (FRS), the Maritime and Coastguard Agency (MCA) and the Armed Forces.

Table 15. Defra module training courses for flood rescue boat operators and responders. Source: ADAS adapted from Rescue3Europe[67].

Defra Module	Defra title	Defra description
1	Water Awareness	General water safety awareness training and basic land-based rescue techniques.
2	Water First Responder	To work safely near and in water, using land-based and wading techniques.
3	Water Rescue Technician	Specialist rescue operation.
4	Water Rescue Power Boat Operator	Rescue boat operation
5	Water Incident Management	Water-related operational and tactical incident command relating to local incidents
6	Subject Matter Advisor	Tactical, strategic and logistical advice at major or widespread flooding incidents, requiring National assets

In spring 2006, Defra undertook a detailed capability assessment of flood emergency planning and preparedness in England and Wales. The analysis clearly showed a shortfall in capability to rescue people when compared against the planning assumptions for a severe east coast flood (Defra, 2012b). The Flood Rescue National Enhancement Project (Defra, 2012c) outlines the role and responsibilities of Government Departments in flooding. There are a range of partners involved in planning for, and dealing with, flooding events at the national, regional and local levels. Regionally, the lead planning role falls to the government offices for the regions working with local authorities, the Environment Agency and emergency services (police, fire, ambulance, and coastguard).

The duty to coordinate inland flood rescue lies with the Police and they will have primacy during major flood events. It is fully recognised that during a major flood event flood rescue assets will be deployed from a wide range of organisations including emergency services provided by

[67] http://www.rescue3europe.com/index.php/rescue-training/training-courses/7-training-courses/118-defra-modules-of-rescue-3-europe-courses

volunteers (RNLI, Mountain Rescue, Lowland Search and Rescue, Cave Rescue etc.). This indicator only outlines the capability of the RNLI to support and respond to flood events.

Methodology

Enquires were made with stakeholders at the RNLI whom provided summary information on the RNLI's current capacity to respond to flood and/or extreme weather events in-shore. There is not enough information to produce a full indicator. However, the information received provides useful insight to give an indication of current capacity to respond.

Results

In 2016, the RNLI reported 237 operating lifeboat stations that were able to respond to sea rescues. Of these, 126 stations are all-weather lifeboat stations with the ability to respond in extreme weather. In addition, the RNLI have seven Flood Rescue Teams[68] with Type B (Powered Boat and Advanced Water Rescue) boats strategically located around the UK. This includes 100 fully trained flood rescue team members, all Defra Module 4 boat operators. Of these 100 team members, 25 are DEFRA Module 5 Water Managers, and 4 are DEFRA Module 6 Tactical Advisors (Table 3).

Deployment of the RNLI Flood Rescue Teams is largely determined by how the police in a flood hit area choose which response agency to send to a flood. The response capability therefore is driven by demand, rather than what the team can actually achieve. In the last 3 years, the RNLI Flood Rescue Team have scaled back capability from 16 Type B (Powered Boat and Advanced Water Rescue) boat teams to 7 due to the teams' full capability not being utilised. The RNLI Flood Rescue Team could increase capability in the future to meet demand if asked by Government.

Robustness

A robust dataset was not available for this indicator. Instead, the indicator provides a snapshot in time based on information gathered from stakeholders at the RNLI.

[68] https://rnli.org/what-we-do/flood-rescue

4 Agriculture and forestry

4.1 Water demand by agriculture

AF2: Total water demand for crop irrigation and livestock

Introduction

A changing climate could increase the need for 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.

Methodology

Irrigation water demand

Knox et al. (2013) modelled and mapped crop irrigation needs spatially based on a correlation between irrigation needs calculated with the IRRIGUIDE model (Bailey and Spackman, 1996; Silgram et al., 2007) and a nationally mapped climatic dataset. The maximum potential soil moisture deficit at each of 11 selected weather stations was calculated and correlated against the corresponding irrigation need of a design dry year for different soil types. The regression equations were used to calculate the theoretical irrigation need of each crop based on the climatic characteristics of the area where they are grown.

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 Jerry Knox (Cranfield University). Regional agricultural survey statistics from Defra for 2010 and 2015 were used to estimate the area of each of these crop groups within each EA region.

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[69] 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 2015 would also have been applied, but such a factor was not readily available. This limitation of the method is acknowledged. The

[69] http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwi3_K6B9rDTAhVjB8AKHUhOBBkQFggnMAA&url=http%3A%2F%2Fwww.swarmhub.co.uk%2Findex.php%3Fdlrid%3D4088&usg=AFQjCNGNRi-s_6dcMQ7iH-FeDE5owl5BFQ

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 irrigated crop areas for 2015 within each region to obtain updated figures for irrigation water demand for the Defra June Survey year 2015.

Livestock water demand

Knox et al. (2013) modelled and mapped livestock water demand across England and Wales. Defra agricultural census/survey data for the years 2000, 2004, 2009 and 2010 aggregated onto a 1km grid were multiplied by estimates of water demand per head of livestock to give a total demand per 1km grid square for each survey year and livestock category. Estimates of water demand per head of Defra census livestock category originate from Defra projects WU0101 and WU0132 and account for the age and size of animals, the composition of their diets, production levels and ambient temperatures.

The update of this sub-indicator uses ADAS 1km gridded livestock data for the agricultural survey year 2014. This is the most recent year for which the spatially processed data are available. Following the method of Knox et al. (2013), 1km survey data estimates of livestock numbers for 2014 were multiplied by estimates of water demand per head of livestock (Table 16) to give a total water demand per grid cell for each livestock type. Some livestock categories that were separate in the 2010 census had been grouped in the 2014 survey (laying flock and breeding flock for poultry; fattening pigs including barren sows for pigs). In these cases, the livestock category in the water requirements table with the highest water use was used. The updated methodology therefore has some differences to the original method and should be interpreted with caution when making comparisons between years.

Table 16. Water requirements used for the livestock analysis. Source: After Knox et al. (2013).

Livestock type	Livestock category	Cycle duration (days)	Drinking water per head per day (l)	Wash water per head per year (l)	Alignment with 2014 Defra survey categories
Cattle	Dairy cow herd	365	90.61	29	K206, K209, K211
	Beef cows & heifers	365	20	0	K205, K208, K210
	Dairy & beef bulls	365	20	0	K204, K207
	Cattle <1yr	365	12.5	0	K201, K202, K203
Poultry	Broilers	133	0.09	1.14	N10
	Ducks, geese & other birds	56	0.2	2.71	N13, N14, N16
	Turkeys	406	0.2	0.24	N15
	Pullets	406	0.22	0.47	
	Laying hens – caged	322	0.19	0.94	
	Laying hens – non caged	63	1.22	4.13	N2N33 (laying flock)
	Broiler breeders, layer breeders, cocks	140	0.58	4.37	N5N7 (breeding flock)
Pigs	Sows	365	13.73	453.22	L1, L2, L3
	Maiden gilts	365	5.5	0	L5
	Barren sows	365	5.5	0	

Livestock type	Livestock category	Cycle duration (days)	Drinking water per head per day (l)	Wash water per head per year (l)	Alignment with 2014 Defra survey categories
	Weaners (20kg)	365	1.8	104.39	
	Growers (50kg)	365	4.2	135.42	L8 (fattening pigs)
	Finishers	365	5.6	0	
	Boars	365	4.56	0.75	L4
Sheep	Ewes	365	4.56	0.75	M1, M4, M7
	Lambs	365	2.65	0.75	M17
	Rams and other adult sheep	365	3.3	0.75	M9, M20

Results

Irrigation water demand

Table 17 shows the demand for irrigation water estimated using 2015 Defra survey statistics by EA region and crop category. Table 18 shows the equivalent estimates for 2010 for comparison. The percentage change from 2010 to 2015 is shown in Table 19. 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 for 2010 and 2015. The vast majority of the irrigation requirements are in the Anglian region (Figure 29). The overall irrigation requirements for this region are estimated to have decreased by about 8% from 2010 to 2015. This is largely due to a decrease in sugar beet area.

Table 17. Estimated volumetric water demand (m^3/1000) for irrigation, by crop category, by EA region, based on 2015 land use. Source: ADAS for ASC.

Crop category	Anglian	Midlands	North East & Yorkshire	North West	South East	South West	Total
Potatoes	34,179,435	6,546,692	6,285,252	1,312,582	2,434,831	578,974	55,123,745
Cereals	953,481	116,720	27,213	2,066	102,746	586	1,243,982
Sugarbeet	7,159,110	313,517	143,452	48	145,633	-	7,933,962
Vegetables	3,193,731	521,506	204,408	79,883	617,718	97,377	5,214,871
Softfruit	235,697	94,064	40,738	587	1,121,352	91,085	1,625,719
Grass	5,220,262	131,958	22,841	4,870	3,101,730	353,604	9,087,931
Total	**50,941,717**	**7,724,458**	**6,723,903**	**1,400,036**	**7,524,010**	**1,121,625**	**80,230,211**

Table 18. Estimated volumetric water demand (m^3/1000) for irrigation, by crop category, by EA region, based on 2010 land use. Source: J. Knox.

Crop category	Anglian	Midlands	North East & Yorkshire	North West	South East	South West	Total
Potatoes	35,582,506	7,154,324	6,611,609	1,317,759	2,908,485	445,836	57,195,962
Cereals	934,138	115,420	26,014	1,833	100,868	526	1,199,613
Sugarbeet	9,783,572	389,049	197,070	21	35,703	-	10,409,260
Vegetables	3,262,462	521,294	176,982	78,091	834,845	76,851	5,146,715
Softfruit	246,006	82,700	37,648	489	979,671	78,160	1,473,703
Grass	5,326,347	132,335	22,285	4,769	3,213,437	354,951	9,082,023
Total	**55,135,056**	**8,399,982**	**7,074,203**	**1,403,147**	**8,073,035**	**956,417**	**84,521,396**

Table 19. Percentage change in volumetric water requirement for irrigation from 2010 to 2015, by crop category and region

Crop category	Anglian	Midlands	North East & Yorkshire	North West	South East	South West	Total
Potatoes	-4	-8	-5	0	-16	30	-4
Cereals	2	1	5	13	2	11	4
Sugarbeet	-27	-19	-27	133	308	-	-24
Vegetables	-2	0	15	2	-26	27	1
Softfruit	-4	14	8	20	14	17	10
Grass	-2	0	2	2	-3	0	0
Total	-8	-8	-5	0	-7	17	-5

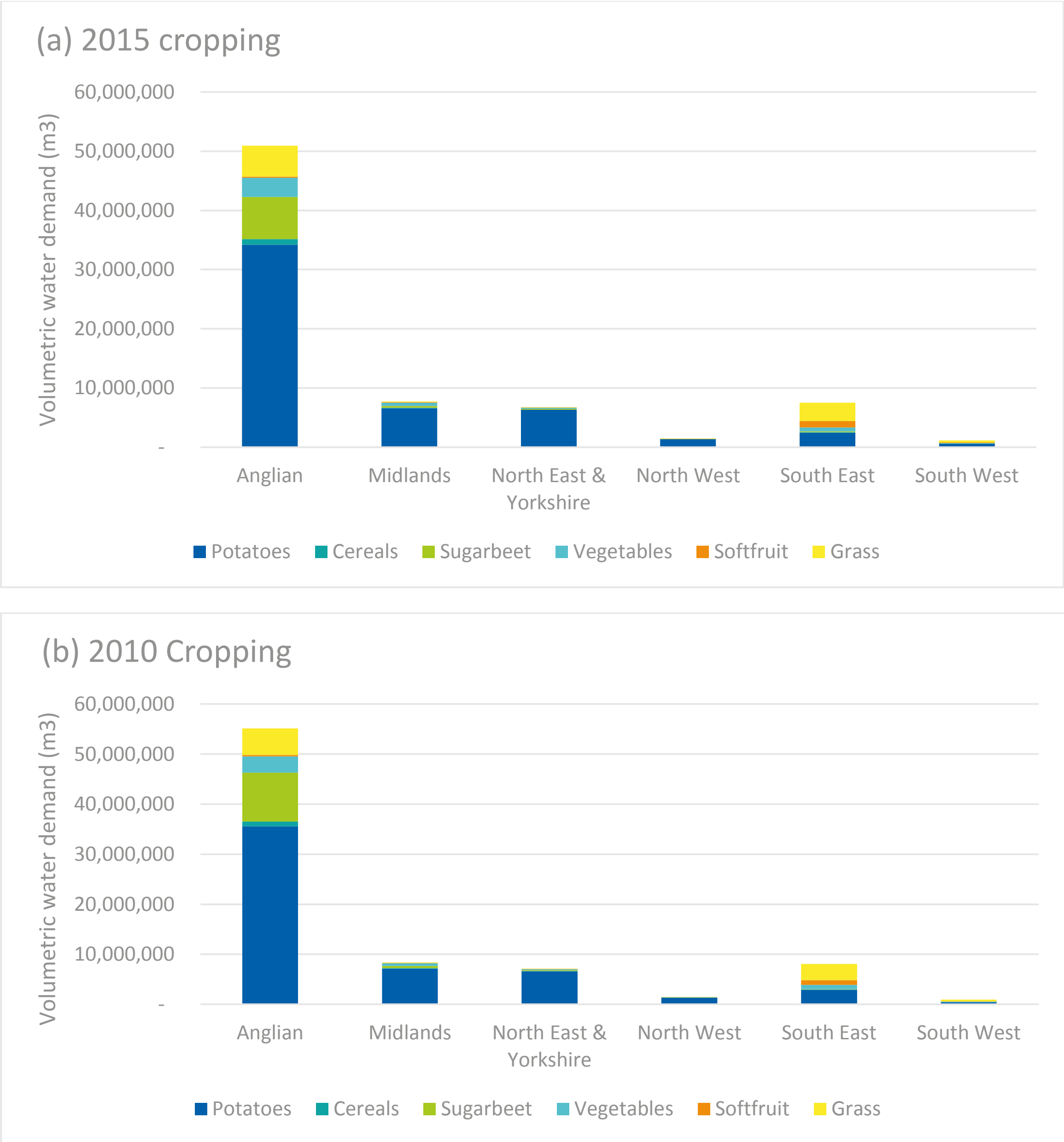
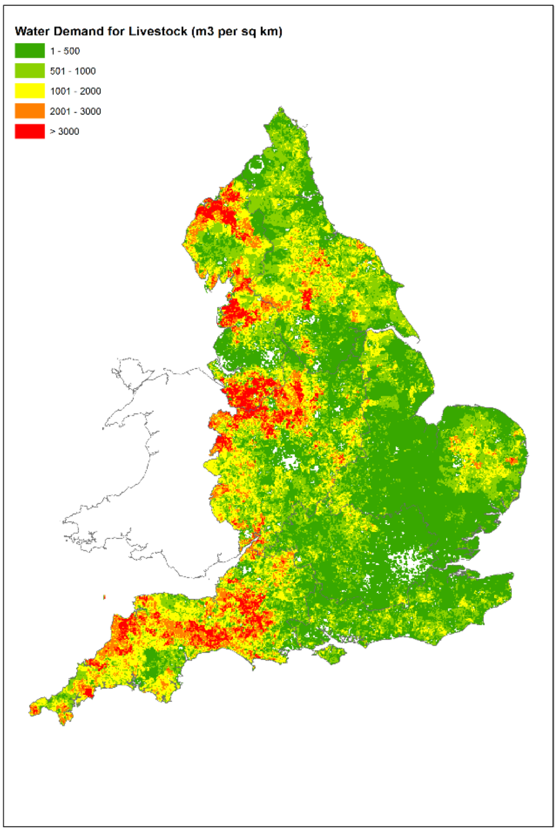


Figure 29. Comparison of volumetric water demand (m^3) for irrigation for (a) 2015 and (b) the baseline year 2010 (Knox et al., 2013), by crop category and EA region. Source: ADAS for ASC.

Livestock water demand

Volumetric water demand for livestock is mapped at 1km grid square resolution in Figure 30. This shows a very similar spatial pattern of demand when compared to the 2010 baseline mapped in Knox et al. (2013), but note that the 2010 map was plotted on 2x2km grid squares and therefore values will be approximately four times larger than those in Figure 30.



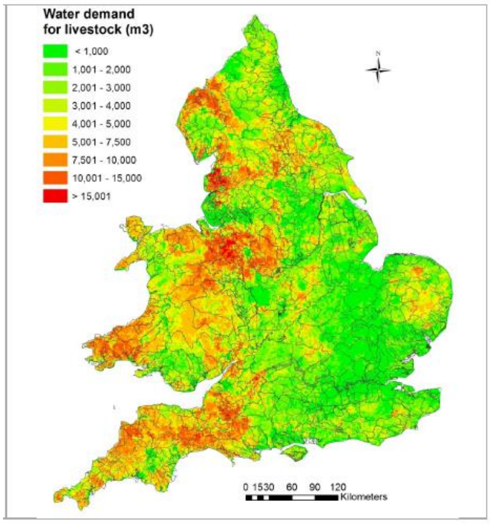


Figure 30. Total volumetric water demand (m³) for livestock in England, based on 2014 land use (left). Source: ADAS for ASC. The smaller map (right) shows the total volumetric water demand for livestock in England and Wales based on 2010 land use for comparison (from Knox et al, 2013). Note that the scales are different.

The 2014 water demand for livestock is summarised by sub-sector and EA region in Table 20. The equivalent table from the 2010 baseline (Knox et al., 2013) is replicated in Table 21. The percentage change from the baseline to 2014 is shown in Table 22. Demand was generally lower in 2014, with a 1% decrease overall, due to lower livestock numbers. The exceptions are (i) poultry in the Midlands, which is almost the same; (ii) sheep in Thames, for which demand has increased by 6%; and cattle in Midlands, North West and South West, for which demand has increased between three and 18%. The largest regional increases (10%) are in the North West and the South West, whereas Anglian and Southern regions show a decrease of 15-16%.

Table 20. Summary volumetric water demand (m^3/1000) for livestock, by sub-sector, by EA region, based on 2014 land use

Sub-sector	EA Region							
	Anglian	Midlands	North East	North West	South West	Southern	Thames	Total
Sheep	1025	4090	5178	3819	3729	1041	831	**19714**
Poultry	4418	1823	975	643	1248	223	401	**9731**
Pigs	2544	749	2617	265	729	193	262	**7359**
Cattle	3262	17421	8987	17084	26148	3149	2723	**78774**
Total	**11250**	**24082**	**17757**	**21811**	**31854**	**4606**	**4217**	**115578**

Table 21. Summary volumetric water demand (m^3/1000) for livestock, by sub-sector, by EA region, based on average of 2000, 2004, 2009 & 2010 land use. Source: Knox et al. (2013).

Sub-sector	EA Region							
	Anglian	Midlands	North East	North West	South West	Southern	Thames	Total
Sheep	1499	5474	5922	4151	3864	1220	781	**22911**
Poultry	4727	1821	1245	992	1457	629	438	**11309**
Pigs	2703	906	2382	312	845	213	400	**7761**
Cattle	4349	16978	9261	14457	22664	3453	3076	**74238**
Total	**13278**	**25179**	**18810**	**19912**	**28830**	**5515**	**4695**	**116219**

Table 22. Percentage change in volumetric water requirement for livestock from 2010 to 2014, by sub-sector and EA region

Sub-sector	EA Region							
	Anglian	Midlands	North East	North West	South West	Southern	Thames	Total
Sheep	-32	-25	-13	-8	-3	-15	6	**-14**
Poultry	-7	0	-22	-35	-14	-65	-8	**-14**
Pigs	-6	-17	10	-15	-14	-9	-35	**-5**
Cattle	-25	3	-3	18	15	-9	-11	**6**
Total	**-15**	**-4**	**-6**	**10**	**10**	**-16**	**-10**	**-1**

The values in Table 20 and Table 21 are shown graphically in Figure 31.

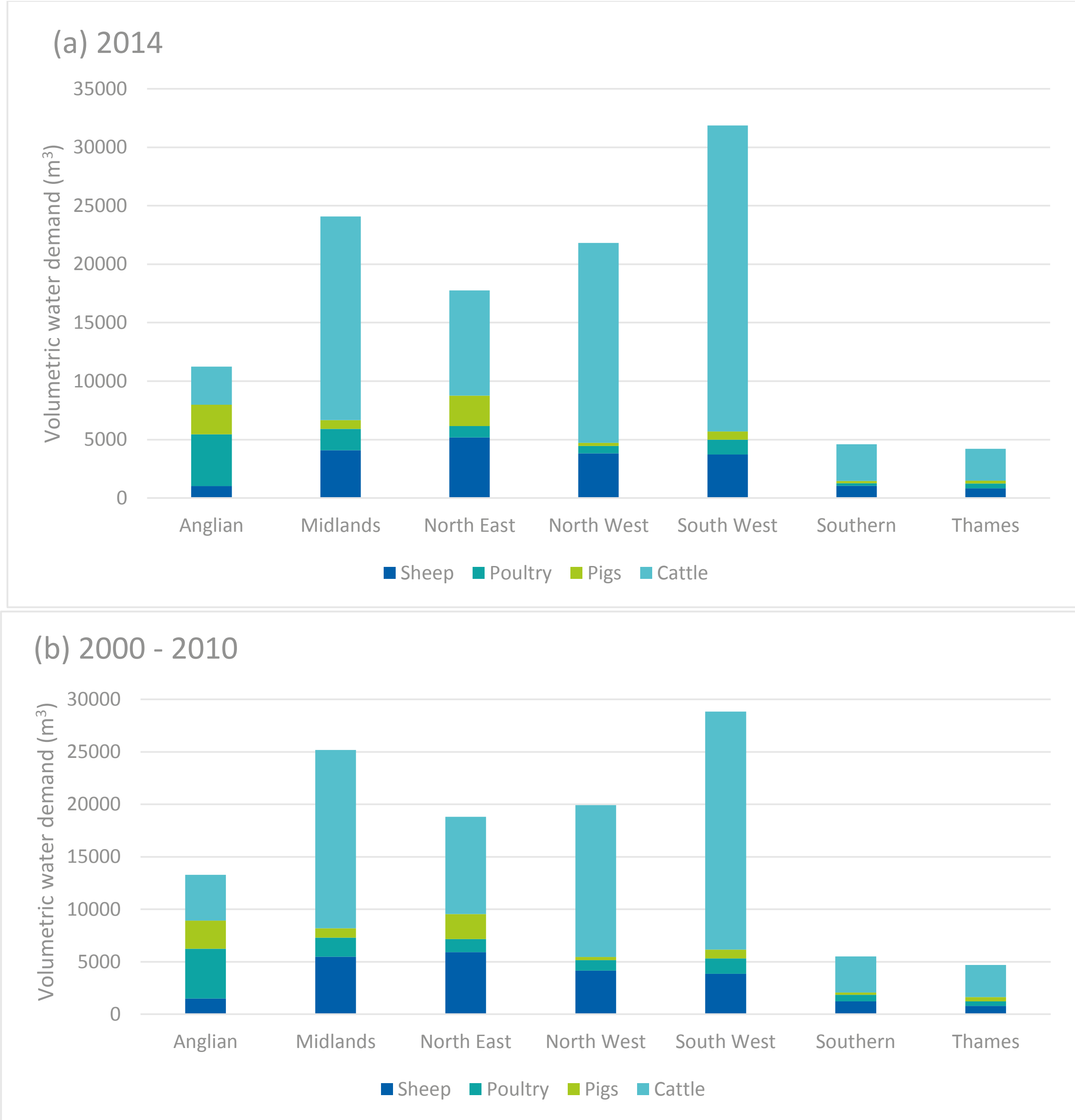


Figure 31. Comparison of volumetric water demand (m^3/1000) for livestock for (a) 2014 and (b) the baseline period 2000-2010 (Knox et al., 2013), by sub-sector and EA region. Source: ADAS for ASC.

Robustness

Irrigation: Irrigation Survey statistics were only available by crop group at a national scale, therefore national irrigated proportions were used to estimate irrigated crop area per region. This will introduce some error in estimates of irrigated areas, although the main irrigated crops tend to be concentrated in the more arid areas of the country where irrigation is required. The assumption was made that climate was similar in 2010 and 2015, whereas this may not be the case. The Met Office compared the 2015 annual weather in the UK with the 1981 to 2010 average[70]. The mean temperature was 0.4°C above the 1981-2010 average; rainfall was 110% of the 1981-2010 average (mostly due to winter rainfall) and sunshine was 106% of the 1981-2010 average. The use of regional Defra June Survey statistics ensures that a time-series will extend into the future.

Livestock: The ADAS 1km land use database is a statistical disaggregation of Defra June Agricultural Census/Survey returns at holding level. Holding level statistics (cropping and livestock) were aggregated to parish and distributed over the landscape according to the location of non-agricultural and agricultural land from Ordnance Survey mapping and other land cover datasets (Comber et al., 2007). It is considered robust at areas equal to or greater than 10x10km^2. Currently, the most recent dataset is for 2014. This could be updated in the future if the holding level data were made available by Defra.

AF3: Volume of abstraction for agriculture from catchments at risk of water scarcity

Introduction

There are concerns regarding the potential impacts of water abstractions for agriculture (amongst other uses) on the environment, particularly in catchments where water resources are under pressure. In many catchments, summer water resources are already over-committed and existing summer sources are increasingly unreliable.

This indicator provides a measure of authorised quantities of abstractions for agricultural usage, summarised by estimated water resource availability. Both of the data sources used are updated periodically, which will enable the indicator to be re-calculated at future time-points. This will provide a measure of how much water demand there is from agriculture on water resources where these are limited.

Methods

The Environment Agency's abstraction statistics (ABSTAT) provide details of the licensed abstractions in place in England (as of 24th February 2017), along with the grid coordinates of these licenses and the associated maximum annual and daily abstractions allowed in cubic metres. The dataset does not provide details of the actual amounts abstracted. The licenses are categorised by usage, one of which is agriculture. Agricultural water abstraction licenses, along with their licensed volumes, were filtered from the database and plotted in a Geographic Information Systems (GIS) map. For this indicator, the main grid coordinate of the license was used; secondary locations were ignored.

[70] http://www.metoffice.gov.uk/climate/uk/summaries/2015/annual

The Environment Agency has assessed the availability of water resources at a Water Framework Directive Cycle 2 catchment level for England. Each catchment has been defined according to its resource status and allocated to one of four categories;

1. GREEN - Water available for licensing – There is more water than required to meet the needs of the environment. New licenses will be considered.
2. YELLOW - Restricted water available for licensing – Full licenced flows would cause availability to fall below the level of the Environmental Flow Indicator. If all licensed water is abstracted there will not be enough water left for the needs of the environment. No new licenses will be granted.
3. RED - Water not available for licensing – Recent actual flows are below the Environmental Flow Indicator (below the indicative requirement to help support Good Ecological Status as required by the Water Framework Directive). No new licenses will be granted.
4. GREY - Heavily modified water bodies (and/or discharge rich catchments) - These waterbodies have a modified flow that is influenced by reservoir compensation releases or they have flows that are augmented by discharges from other sources. These are often known as 'regulated rivers'. They may be managed through an operating agreement, often held by a water company. The availability of water is dependent on these operating agreements. There may be water available for abstraction.

Water resource availability is estimated at the four levels of the Environmental Flow Indicator (EFI): Q30, Q50, Q70 and Q95. The EFI is a percentage deviation from the natural river flow represented by a flow duration curve[71]. The Catchment Abstraction Management Strategy (CAMS) process expresses water resource availability as a surplus or deficit of water resources in relation to the EFI. This is calculated by taking the natural flow of a river, adding back discharges and taking away existing abstractions. The difference between this fully licenced scenario flow and EFI gives the amount of water available for abstraction and when it is available. The EA abstraction regime uses fixed 'hands-off flows', which put in place licence conditions to cease abstraction at set flows, but enable abstraction when more water is available. The percentages of flow that can be abstracted at three different sensitivities to abstraction at different EFIs are shown in Figure 32.

[71] http://webarchive.nationalarchives.gov.uk/20140328084622/http:/cdn.environment-agency.gov.uk/LIT_7935_811630.pdf

	high flow	→		low flow
Abstraction Sensitivity Band	**Q30**	**Q50**	**Q70**	**Q95**
ASB3. high sensitivity	24%	20%	15%	10%
ASB2. moderate sensitivity	26%	24%	20%	15%
ASB1. low sensitivity	30%	26%	24%	20%

Figure 32. Percentage allowable abstraction from natural flows at different abstraction sensitivity bands. Source: Environment Agency, 2013.

License locations were assigned to their nearest catchment in a GIS. Licensed volumes (annual and daily) were summed by resource status at each EFI for England.

Results

The *maximum* annual and daily licensed water abstractions for agricultural usage in England (as of February 2017) for each EA resource status category are shown for each flow percentile in Table 23 to Table 26. These volumes are summarised graphically in Figure 33 and Figure 34. The results show that for the Q50 EFI, 1,909,895 Mega litres of water are licensed to be abstracted annually for agricultural use in yellow and red (at risk of water scarcity) catchments. This represents 37% of the licensed volume for agriculture in non-modified water bodies. In reality, abstractions will be restricted for yellow and red catchments. At lower flows, more catchments fall into these categories and therefore the actual allowed abstractions will be lower. At high flows, the allowed abstractions will approach the maximum licenced.

Table 23. Maximum annual and daily licensed abstractions for agricultural usage in England in Mega Litres, by catchment resource availability at the Q30 EFI (high flows)

Resource Availability at Q30	Max Annual (Ml)	Max Daily (Ml)
Green	4,172,087	31,983
Yellow	735,936	11,823
Red	233,611	8,989
Grey	929,062	29,868

Table 24. Maximum annual and daily licensed abstractions for agricultural usage in England in Mega Litres, by catchment resource availability at the Q50 EFI

Resource Availability at Q50	Max Annual (Ml)	Max Daily (Ml)
Green	3,220,569	23,393
Yellow	1,253,189	14,955
Red	656,706	13,891
Grey	940,233	30,424

Table 25. Maximum annual and daily licensed abstractions for agricultural usage in England in Mega Litres, by catchment resource availability at the Q70 EFI

Resource Availability at Q70	Max Annual (Ml)	Max Daily (Ml)
Green	632,994	14,246
Yellow	3,329,352	16,532
Red	1,167,090	21,400
Grey	941,261	30,484

Table 26. Maximum annual and daily licensed abstractions for agricultural usage in England in Mega Litres, by catchment resource availability at the Q95 EFI (low flows)

Resource Availability at Q95	Max Annual (Ml)	Max Daily (Ml)
Green	289,124	5,714
Yellow	982,371	7,181
Red	3,801,917	37,783
Grey	997,283	31,985

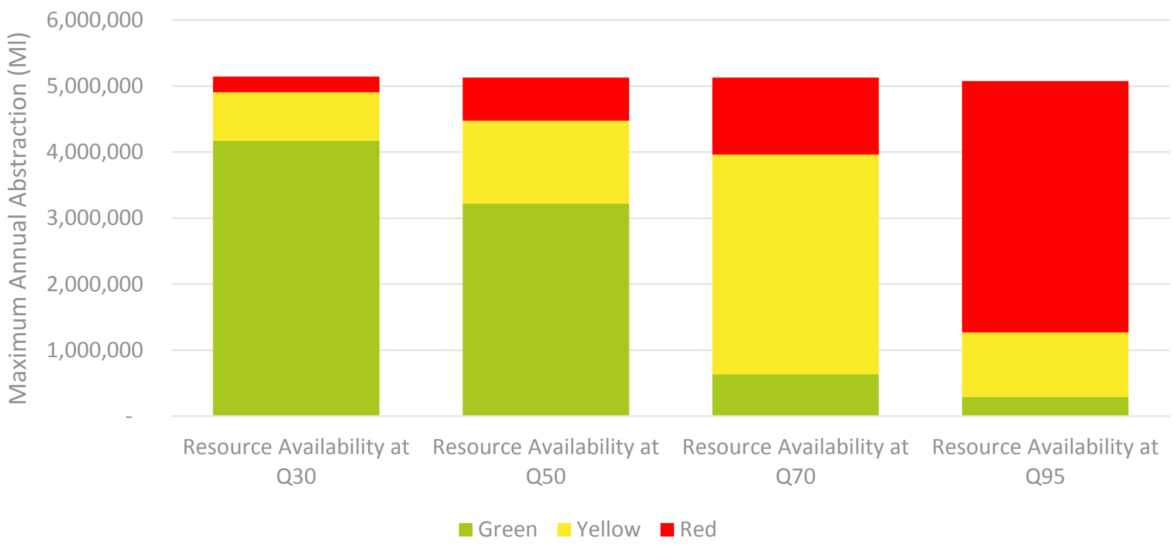


Figure 33. Maximum annual licensed abstractions for agricultural usage in England, by catchment resource availability and EFI. There is a maximum annual (and daily) licenced abstraction amount for each catchment. This maximum remains the same, but licence conditions mean that abstractions are limited at times when flows are lower. When flows are lower, more catchments will be red or yellow. Water will not be allowed to be abstracted from red catchments, and amounts below the maximum for yellow catchments. Source: ADAS for ASC.

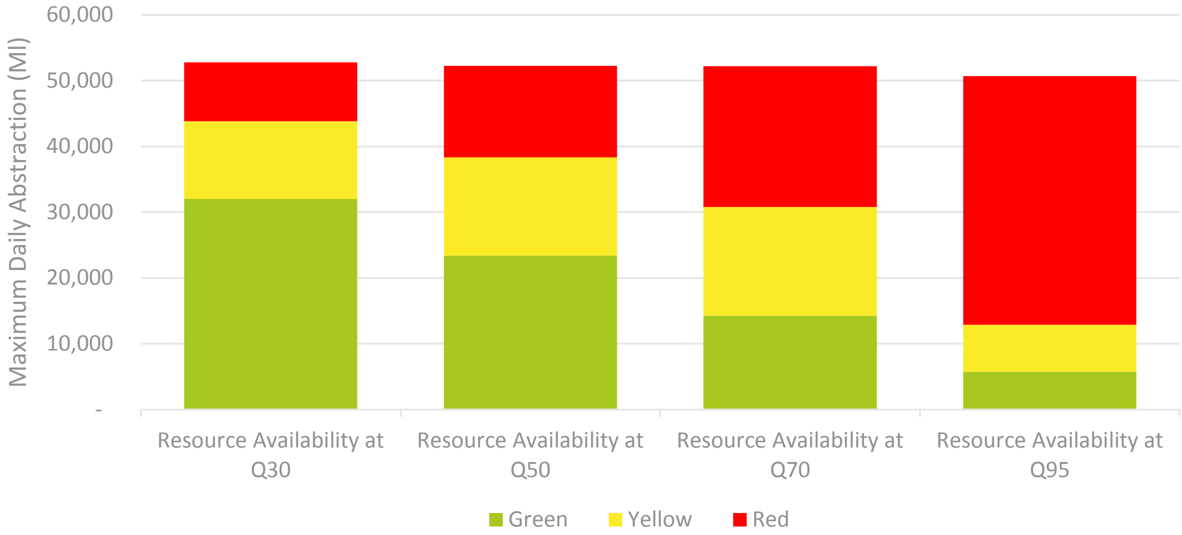


Figure 34. Maximum daily licensed abstractions for agricultural usage in England, by catchment resource availability and EFI. Source: ADAS for ASC.

Robustness

The ABSTAT database is the best available estimate of abstractions for agricultural usage, however it only records maximum licenced abstraction volumes not actual amounts abstracted. Actual amounts allowed will vary by flow level and environmental sensitivity. It does not include unlicensed abstractions.

AF4: Amount of crop production in climatically unsuitable areas

Introduction

The aim of this indicator is to track how the distribution of crops in England is changing over time and to relate this to potential future threats on agricultural productivity and also vulnerability of the land to environmental damage such as erosion. It shows how crop distribution has changed in recent years for high erosion risk crops like maize and high water demand crops like potatoes. By 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.

Methods

Each June, the Department for the Environment, Food and Rural Affairs (Defra) carries out a survey of agricultural holdings in England. ADAS have a time-series of 1km gridded land-use data based on the results of this survey. The ADAS land use database aggregates the raw survey data describing cropping and grassland to a suitable larger area (the agricultural district), and then reallocates this land across the rural landscape within that district, using a regular 1 x 1 km grid. To do so, it uses other datasets to define the areas where agricultural land is certainly *not* present (data on roads, urban areas, water features, forestry, etc.), and satellite derived data describing the approximate distribution of arable and grassland in those areas classed as rural. An estimation of the crop distribution is made at the parish scale, and a number of algorithms ensure that the final result matches the crop distribution and total areas in the agricultural survey at the district level exactly, so that outputs from any modelling exercises carried out using the database can be compared with results derived using the raw data, or other available summarised datasets. The result of this exercise is a 'best estimate' dataset of the distribution of agricultural land and crops (Comber et al., 2007).

The crops wheat, winter barley, spring barley, main crop potatoes, maize, root crops, temporary grassland and permanent grassland were mapped from the ADAS land use database for the years 2000, 2010 and 2014. The percentage change between 2010 and 2014 was also mapped. The years 2000 and 2010 were mapped in order to provide a time-series with a consistent methodology. ECI et al. (2013) used a very different method to map land uses and therefore is not directly comparable. ECI et al. (2013) allocated holdings from the June Agricultural Census to 10km grid cells and aggregated the crop areas for each cell. The ADAS method uses a more sophisticated land allocation technique that does not make the assumption that land belonging to a farm is located within the vicinity of the registered holding, and uses broad land cover mapping to distribute crops according to where arable and grassland is located.

The area of each of these crops within the grades of the ALC scheme was calculated from the 1km gridded data using area-weighted intersection methods in a GIS. Agricultural land within the ALC scheme can be 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' and Grade 5 is 'very poor quality land'. Each has increasing limitations in terms of pressures on cropping. The national 'provisional' ALC map is available to download from the MAGIC data repository[72].

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. Twelve UKCP09 climate change scenarios were investigated, these being the low, medium and high emissions scenarios for the decades with mid-points of 2020, 2030, 2050 and 2080. ALC classification was calculated using 5 km grid map for 10 criteria, with the final ALC grade being determined by the most limiting criterion. Future UK climate projections (periods 2050 and 2080) show that areas of the UK are likely to experience similar climatic conditions to those in present-day mainland Europe. For example by the 2050 period grain maize, which is currently widely grown in western France, could become an important crop in the UK.

[72] http://www.magic.gov.uk/

For the purpose of the current project, the area of each of the indictor crops for 2000, 2010 and 2014 were summarised by ALC grade in the low and high emissions scenarios for 2050. These maps split grade 3 land into 3a (good) and 3b (moderate); unlike the provisional map.

Results

Maps of the change in distribution of the indicator crops for years 2000, 2010, 2014 using the ADAS land use database at 1km grid scale are shown below. Wheat is mapped in Figure 35, winter barley in Figure 36, spring barley in Figure 37, main crop potatoes in Figure 38, sugar beet in Figure 39, root crops in Figure 40, maize in Figure 41, temporary grassland in Figure 42 and permanent grassland in Figure 43. Figure 44 shows how the proportion of each of the indicator crops differs across current ALC grades and years. Figure 45 shows how the proportion of each of the indicator crops differs across future (2050 high emissions climate projection) ALC grades and years. Figure 46 shows how the proportion of each of the indicator crops differs across future (2050 low emissions climate projection) ALC grades and years.

Robustness

The ADAS 1km land use database is a statistical disaggregation of Defra June Agricultural Census/Survey returns at holding level. Holding level statistics (cropping and livestock) were aggregated to parish and distributed over the landscape according to the location of non-agricultural and agricultural land from Ordnance Survey mapping and other land cover datasets (Comber et al., 2007). It is considered robust at areas equal to or greater than 10x10km^2. Currently, the most recent dataset is for 2014. This could be updated in the future if the holding level data were made available by Defra.

The Provisional ALC map used to aggregate cropping statistics is based on reconnaissance field surveys (1966 -1974) and contemporary climate data. It is only suitable for strategic purposes, is not sufficiently accurate for use in assessment of individual sites, and should not be used other than as general guidance. More recent work has produced a predictive map of 'likelihood of Best and Most Versatile (BMV) land' that does not break down area by grade, but identifies areas which are likely to have >60%, 20-60% and <20% BMV land (Entec, 2010). This could not directly give an area measurement of the amount of BMV land at risk, but could for example identify the area of land having a 'high likelihood of BMV' being at risk. The use of this map could be considered in future iterations of this indicator.

This indicator has assumed that the location and area of crops will be the same for a 2050 climate as currently, since the indicator is mapping the suitability of land for that crop in the future rather than the actual location and abundance of the crop in the future. In reality, crops grown and their distributions are likely to change as a result of adaptation, not least irrigation requirements.

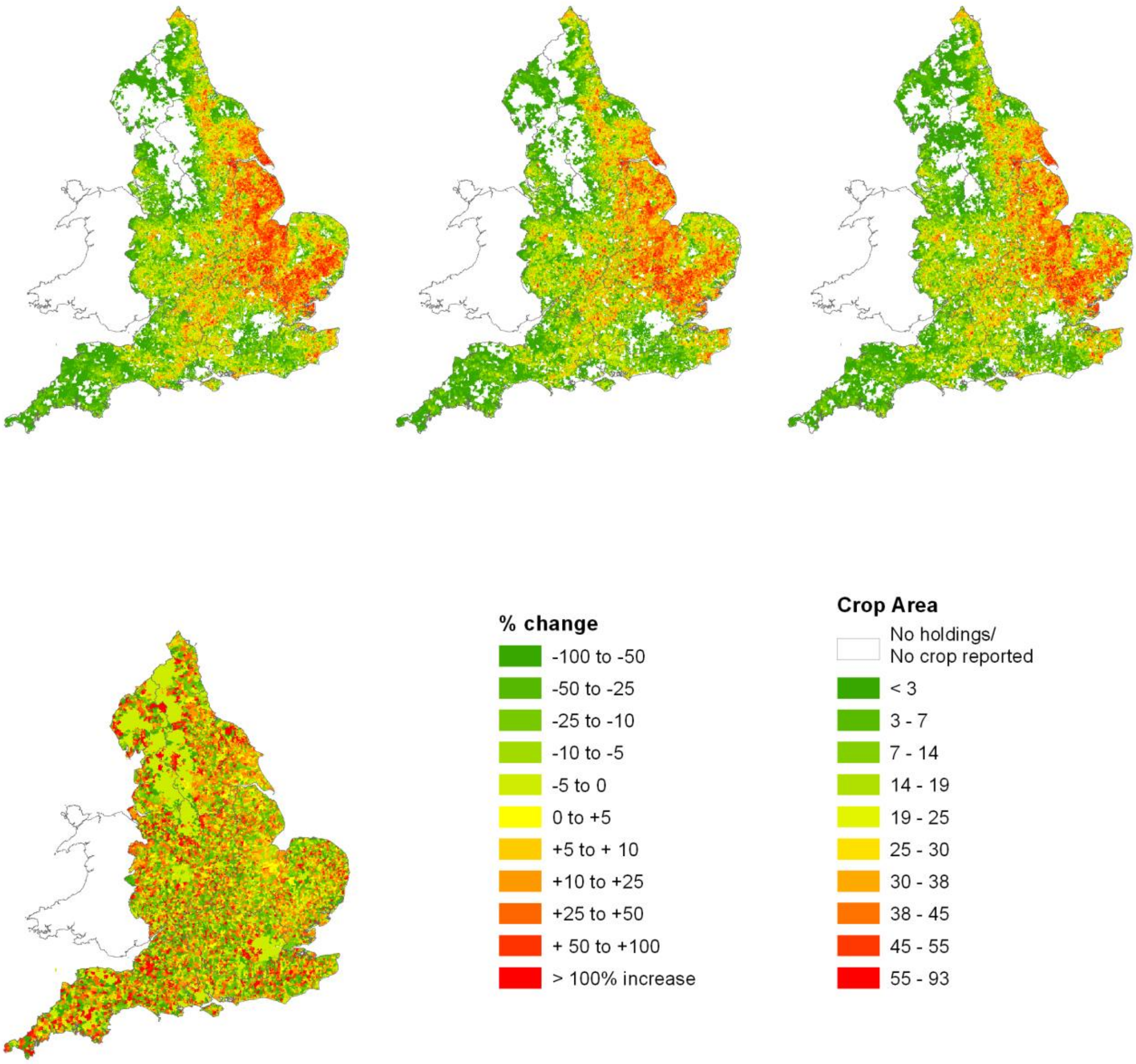


Figure 35. Distribution of wheat in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

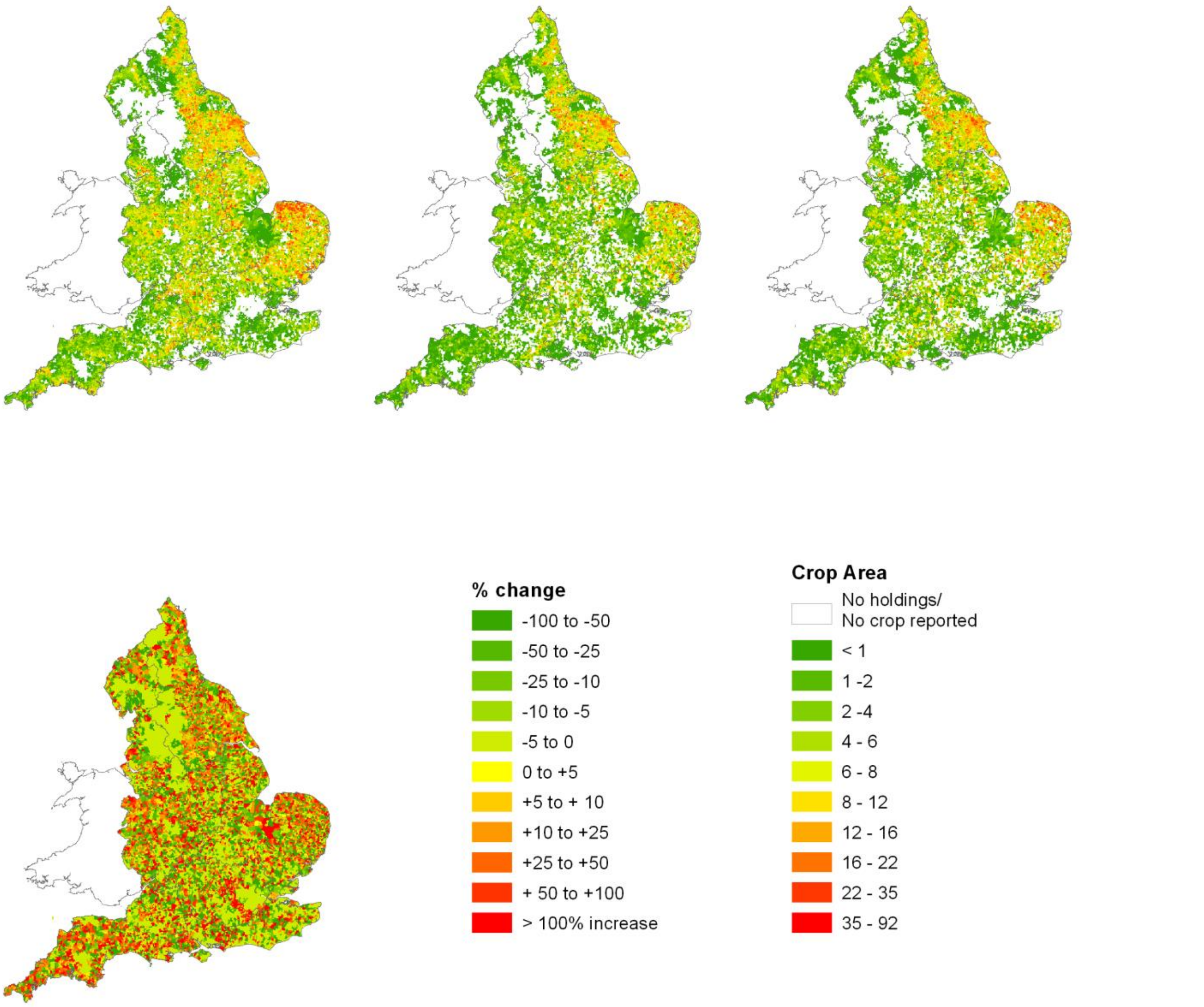


Figure 36. Distribution of winter barley in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

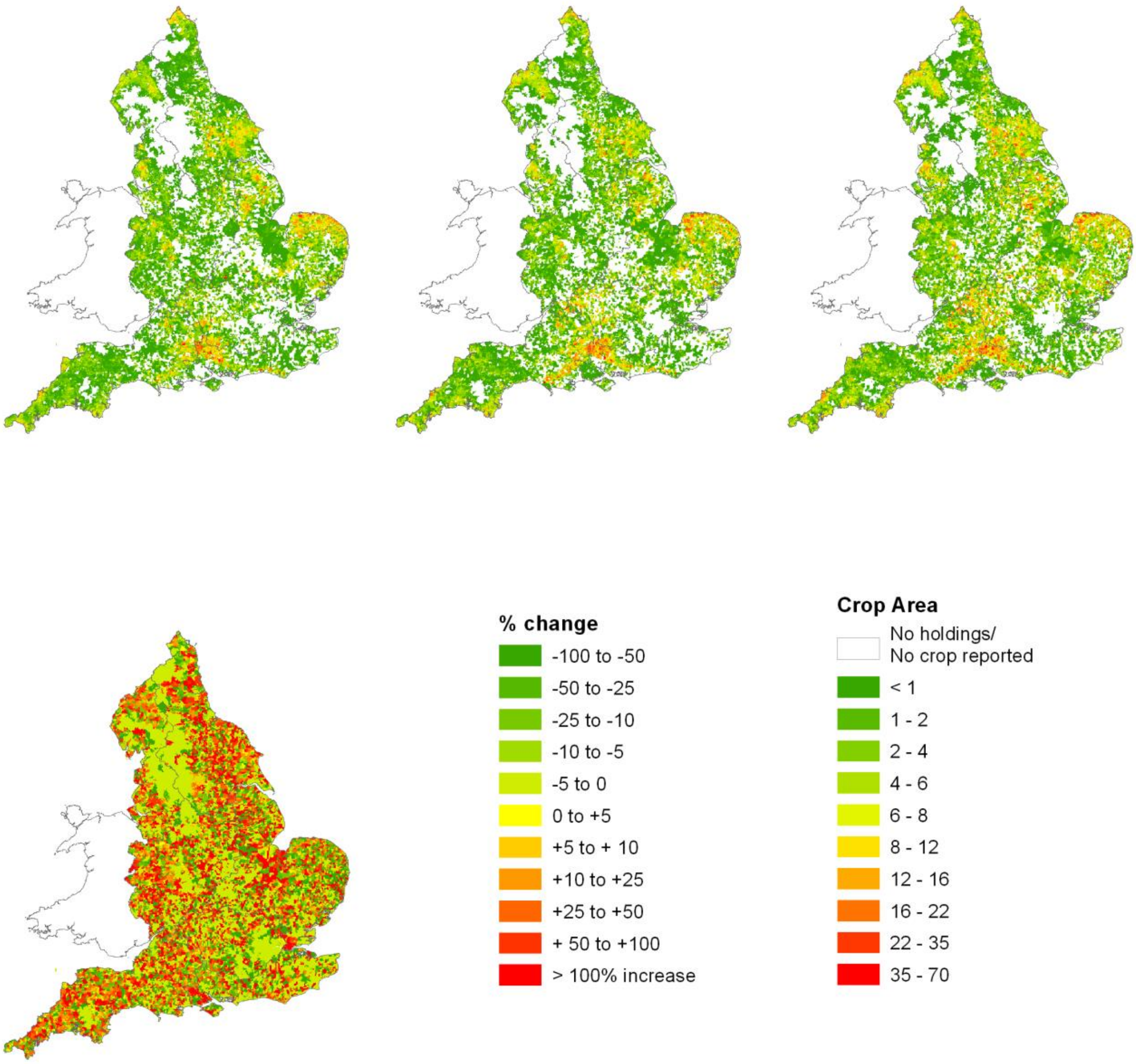


Figure 37. Distribution of spring barley in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

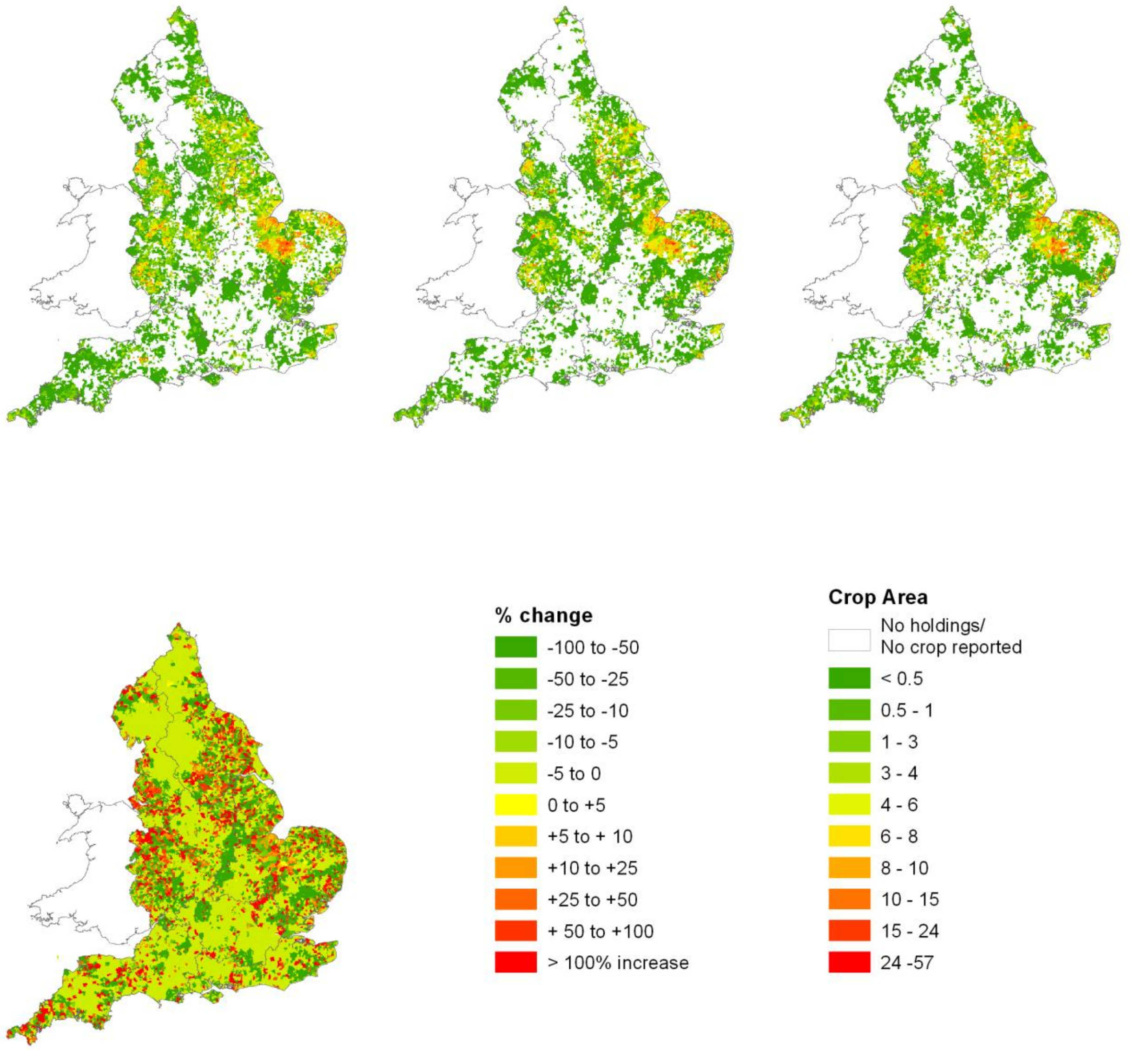


Figure 38. Distribution of main crop potatoes in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

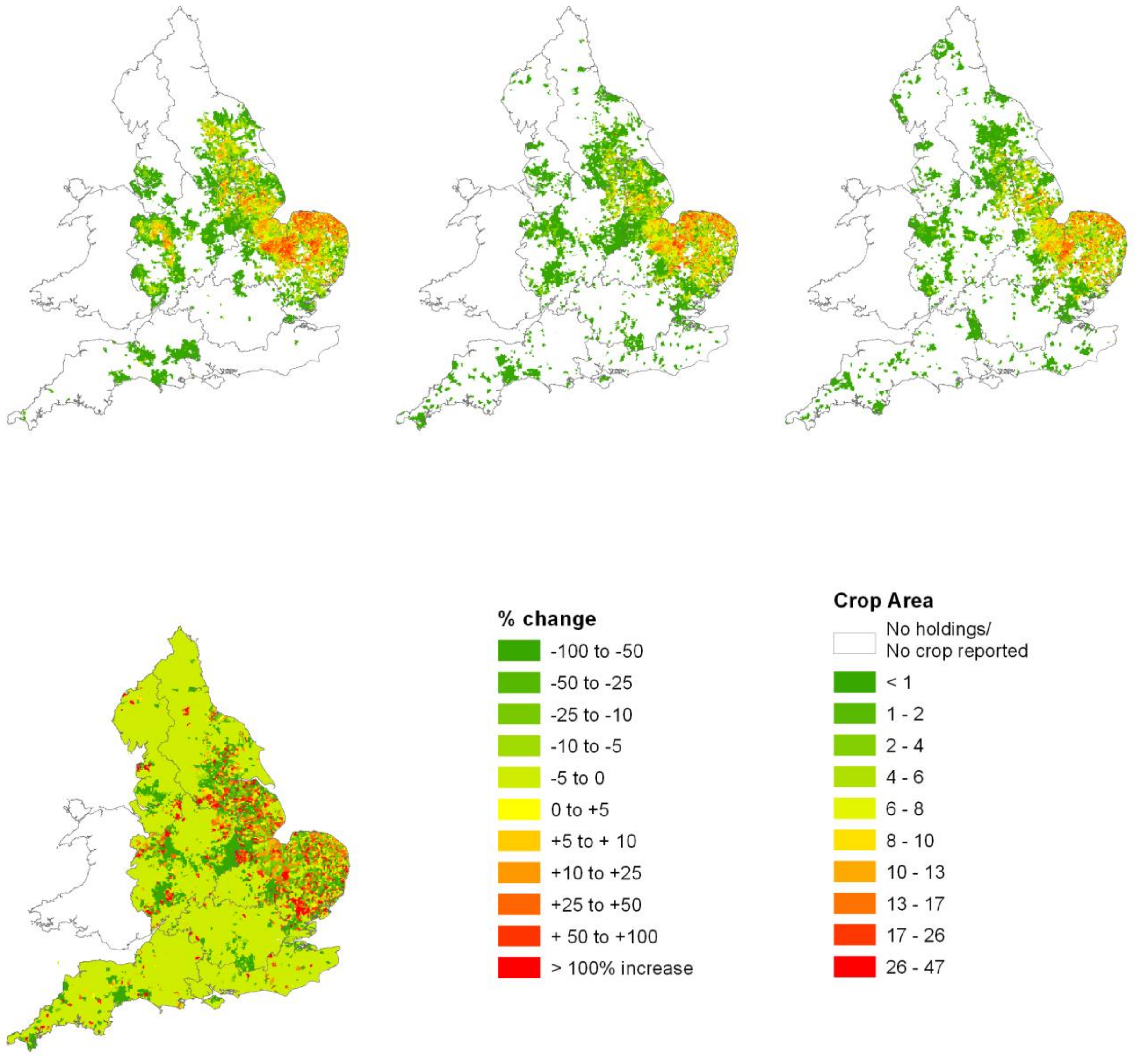


Figure 39. Distribution of sugar beet in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

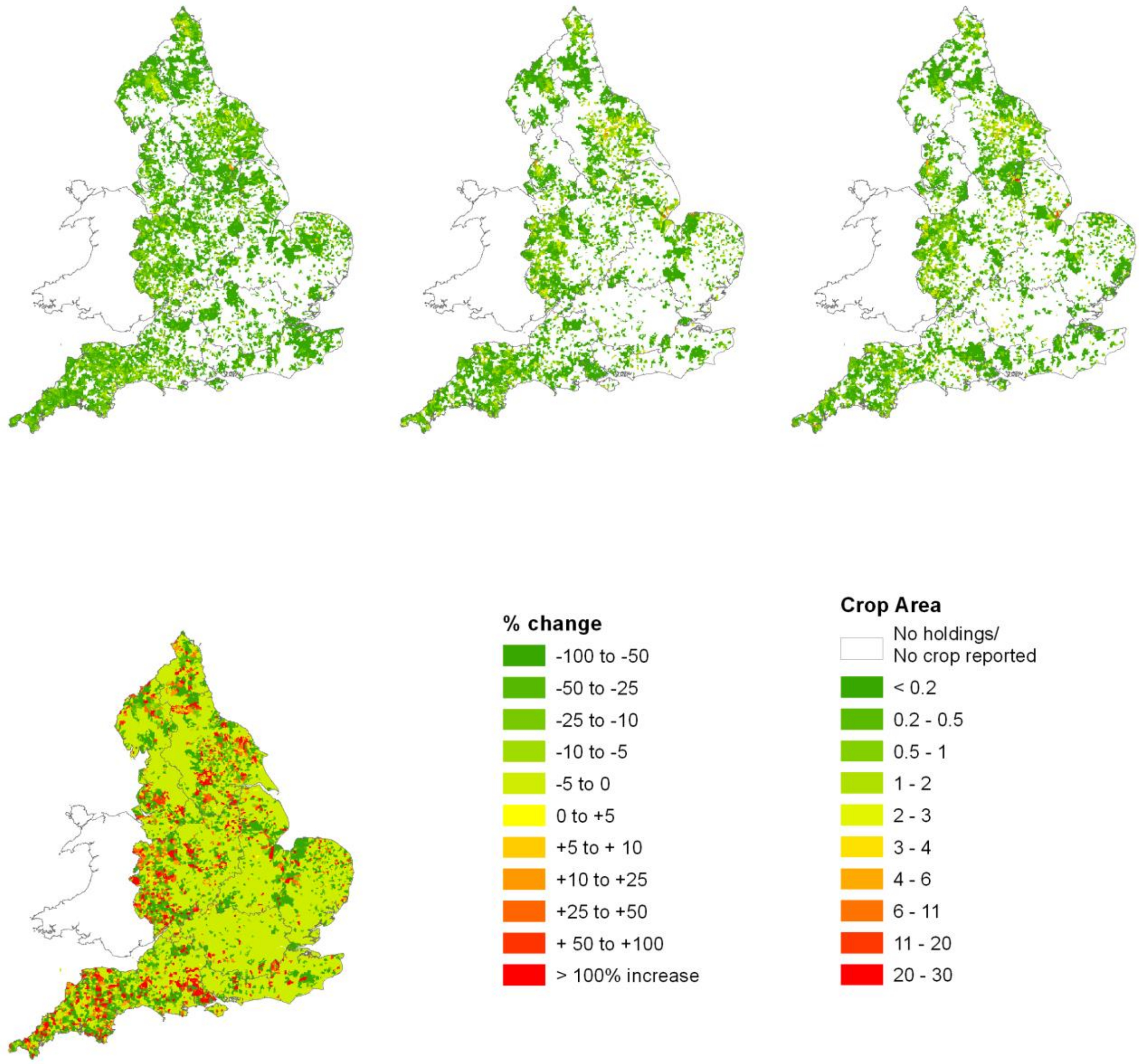


Figure 40. Distribution of root crops in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

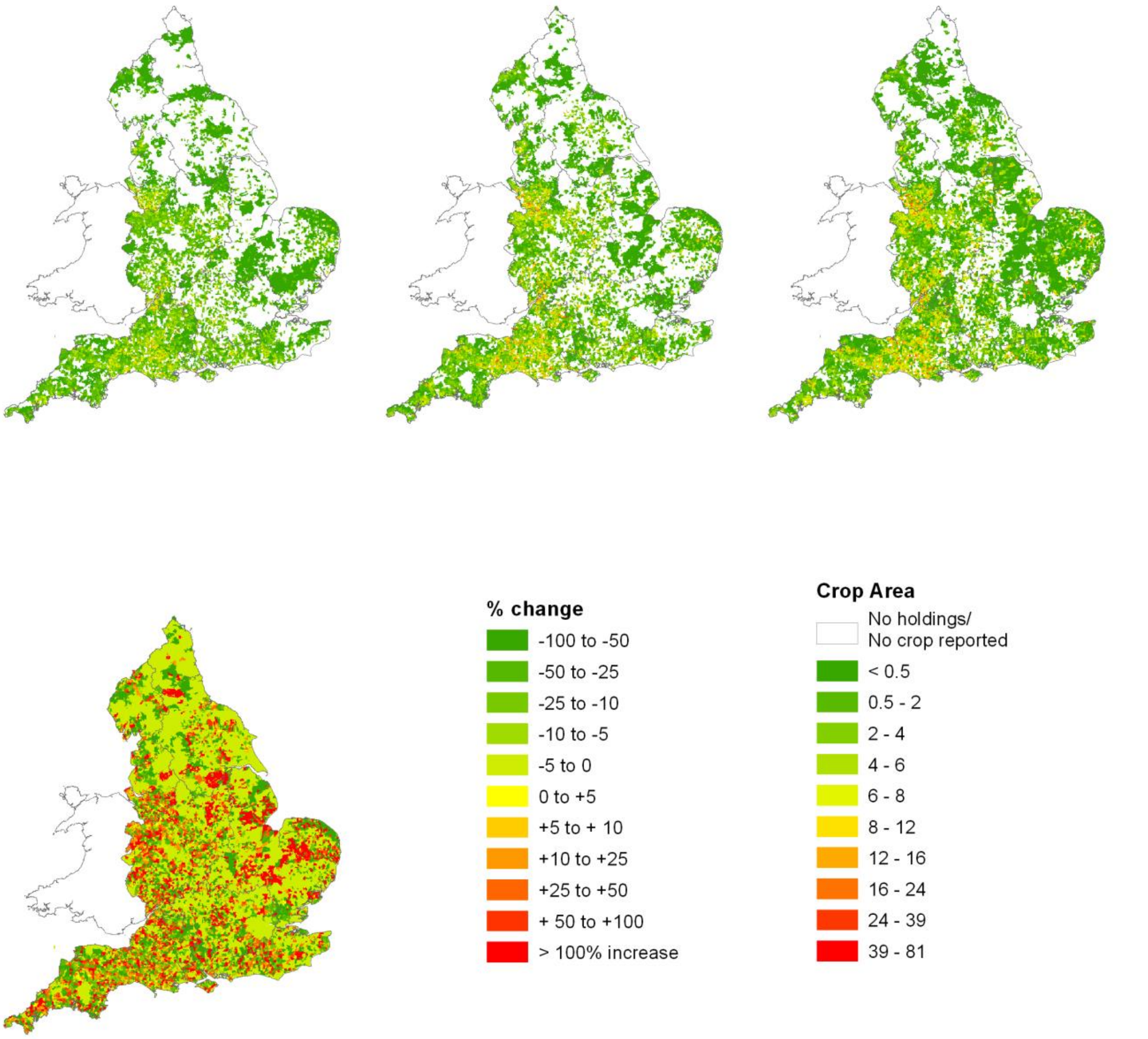


Figure 41. Distribution of maize in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

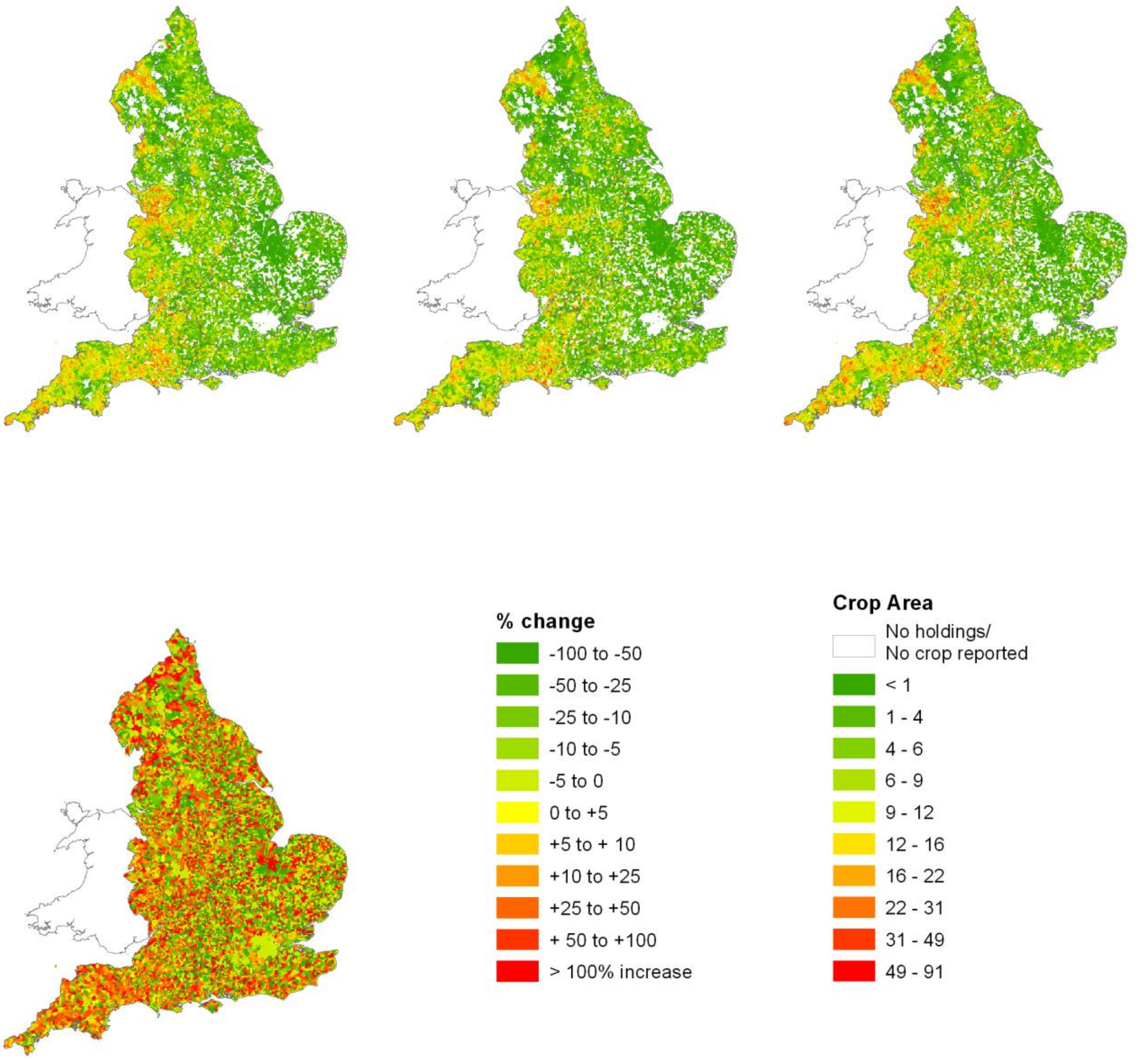


Figure 42. Distribution of temporary grassland in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

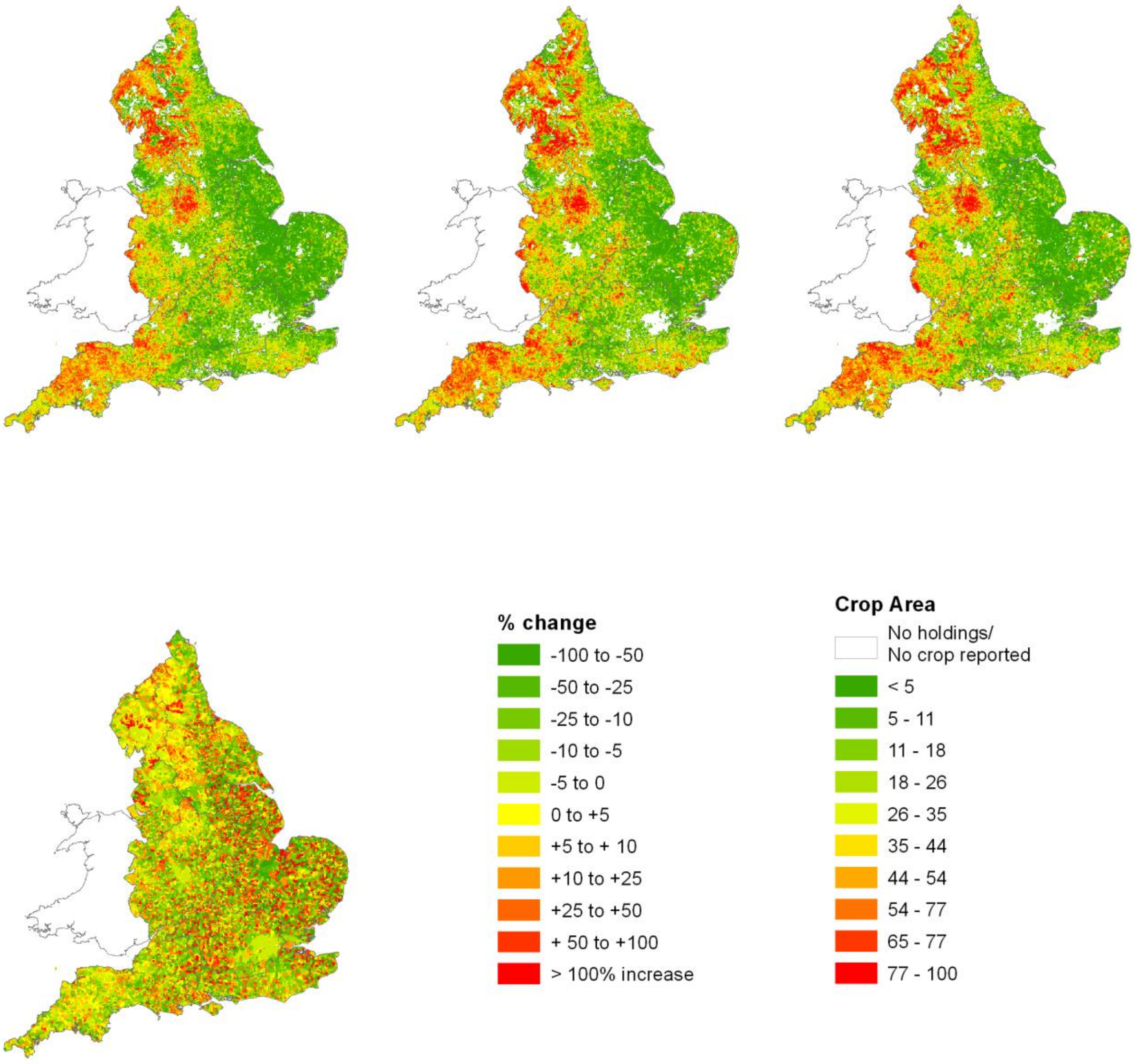


Figure 43. Distribution of permanent grassland in 2000 (upper left), 2010 (upper central) and 2014 (upper right) and the percentage change in area between 2010 and 2014 (lower left). Source: ADAS for ASC.

Figure 44. Change in proportion of indicator crops within provisional ALC grades in England. Source: ADAS for ASC.

Figure 45. Change in proportion of indicator crops within each future (2050) ALC grade (low emissions scenario) in England. Source: ADAS for ASC.

Figure 46. Change in proportion of indicator crops within each future (2050) ALC grade (high emissions scenario) in England. Source: ADAS for ASC.

AF5: Agricultural losses from drought

Introduction

Within the UK there is no single definition of drought, however, all definitions are characterised as a period of water shortage for people, the environment, agriculture or industry (Environment Agency, 2015). The main factors contributing to drought include; lack of rainfall, poor water retaining environments which can lack underground storage and hot weather resulting in an increase in evaporation.

The impacts of drought on UK agriculture depend on a number of factors; e.g. the timing and duration of the drought, the soil type (and its water retaining capacity) and crop type. Light soil types typically have an available water capacity of about 100mm/metre[73], whilst heavier soil types can hold 200mm/metre, medium soils fall somewhere in the middle. Wheat is the most widely grown crop in England averaging about 1.68 million hectares per year. Wheat crops have a water requirement of about 160-180mm (of rainfall) from May to harvest in August (AHDB Wheat Growth Guide), this is the period in which they are most vulnerable to drought as they lose on average 3mm per day through transpiration. Any limitation in water availability during this period will impact yield. Water limitations earlier in the season may impact on crop establishment and early growth, but wheat is usually able to compensate through increased ears per plant or larger ears, meaning that early drought is rarely yield limiting. In other crops such as barley the ability to compensate for poor establishment is lower and these crops may be more vulnerable to drought. The most recent droughts affecting UK agriculture took place during 2004 to 2006 and 2010 to 2012 (Environment Agency 2015).

There are a number of horticultural crops such as potatoes and vegetable crops that are highly sensitive to summer drought conditions. However, these crops tend to be grown using supplementary irrigation (over 50% of potatoes – Potato Council) if needed and national level drought impact is difficult to determine. This indicator therefore focuses on the UK cereal crops as an indicator of yield losses from drought.

Methodology

Yield is a complex subject with many factors having an influence including climate, weed, pest and disease burden, variety and soil type. In order to create an indicator regional wheat yields (from Defra statistics) were plotted against soil moisture deficits (SMDs) on median soils under wheat for four MORECS squares (Met Office Data[74]). These were plotted in a time series from 2000 - 2016 to identify high and low yielding years and compare them to the SMDs in each region (during the high risk grain fill period May-July) to identify whether there are any links between yield and high soil moisture deficits. For each MORECS square the available water capacity (AWC)

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[73] http://www.fao.org/docrep/u3160e/u3160e04.htm

[74] Median soils are calculated based on the char http://www.ukso.org/pmm/soil_group.html - they have a slightly lower water holding capacity than heavy clay soils and slightly higher water holding capacity than light sandy soils therefore represent a balance across the range of soils.

is shown as an orange line, whereby when the SMD reaches this level there is no water available for the crop. A risk point was calculated (blue line) at 21mm < than AWC, this is the point at which rainfall would be needed within 7 days (wheat uses 3mm per day) to prevent SMD reaching AWC. Those points where the SMD exceeded the risk point is indicative of times where there was a risk that crops had limited access to water during periods of grain fill. In addition ADAS crop development and harvest reports (prepared for Defra and AHDB), were used to provide context on yields and identify whether there was an influence of water stress on the yield, or whether other factors were at play. Barley crops are also at increased risk of drought during this period, however they can also be impacted by dry conditions during establishment (winter barley September/October and spring barley March-May).

Results

Soil moisture deficit (SMD) data for the end of each of May, June and July was provided by the Met Office for four example MORECs squares; 94 – Yorkshire, 141 Eastern, 117 East Midlands and 170 South (Figure 47). This data is presented for median soils as in the 'typical' soil type for the region. The available water capacity (AWC) for these soils varies between the different MORECs squares ranging from 120mm in the Eastern region & East Midlands to 135mm in the South and Yorkshire. This figure is used to represent the trends in the region, although crops on light land will show moisture stress at a lower soil moisture deficit and crops on heavier soils will show moisture stress at a higher soil moisture deficit. The granularity of yield data is insufficient to match yields to specific soil types.

Figure 47. Met Office MOREC grid SMD data taken from 94 – Yorkshire, 117 East Midlands, 141 Eastern and 170 South. Source: Met Office.

The charts cover four areas across England in order to understand geographical weather differences, these include Yorkshire (Figure 48), East Midlands (Figure 49), East of England (Figure 50) and the South (Figure 51).

In Yorkshire (Figure 48) there were four years where SMDs reached the AWC 135mm (orange line) 2001, 2006, 2010 and 2011. For these years, other than 2001, yields remained around the regional average with no evidence of water stress impacting on yield. In 2001, although the period in the run up to harvest was dry, there were heavy rains during harvest which resulted in significant harvest disruptions and harvest reports from the time attribute poor yields to the difficult harvest, rather than earlier dry conditions. There were only four years where the SMD did not exceed the risk point at any point. The two wettest years (2007 & 2012) coincided with the lowest yields in the time series.

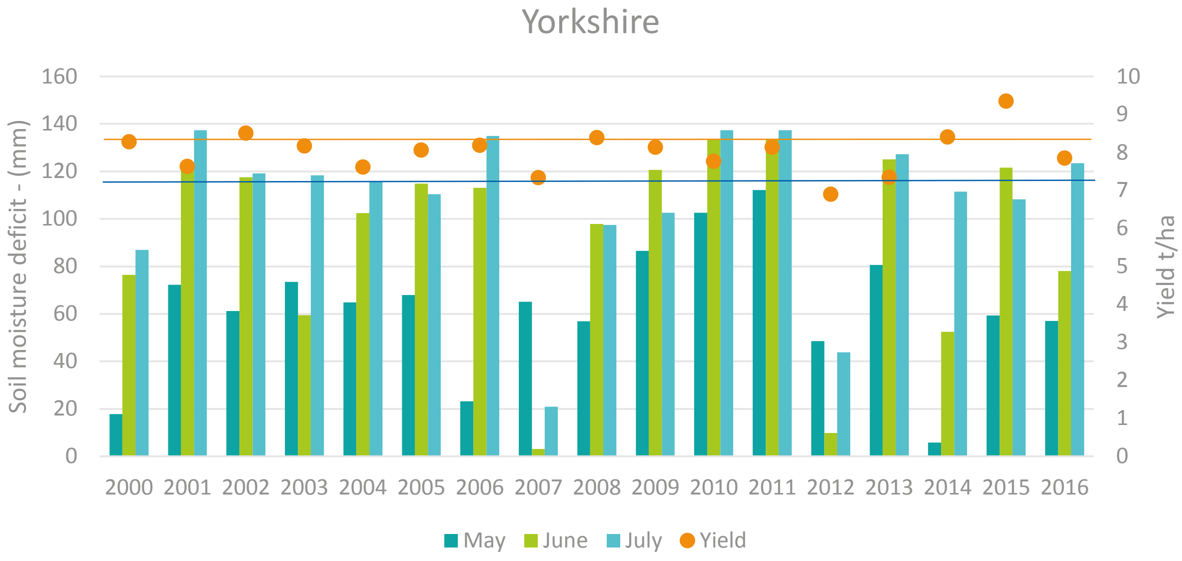


Figure 48. Soil moisture deficit on median soils (end May, June & July) plotted against regional yields in Yorkshire. Orange line is the AWC of the soil and the blue line is the risk point at which wheat crops are expected to demonstrate water stress symptoms within 7 days if rain is not received. Source: ADAS for ASC.

In the East Midlands (Figure 49) there were three years (2006, 2010 and 2011) where SMDs on median soils reached AWC. Yields were fairly average in each of these years. There were three years where SMDs did not reach the risk point (wet years) and these coincided with two of the lowest yielding years in the region.

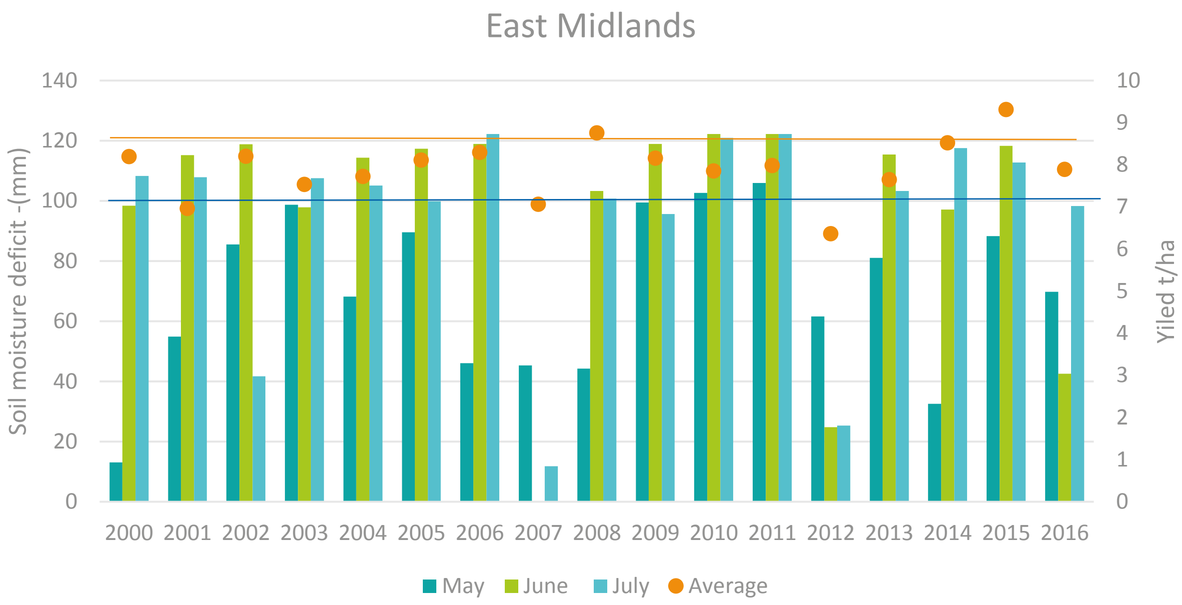


Figure 49. Soil moisture deficit on median soils (end May, June & July) plotted against regional yields in East Midlands. Orange line is the AWC of the soil and the blue line is the risk point at which wheat crops are expected to demonstrate water stress symptoms within 7 days if rain is not received. Source: ADAS for ASC.

The Eastern region showed no years where SMDs on median soils exceeded AWC of 120mm, although there were a number of years 2006, 2010, 2011, 2013 and 2015 where SMDs were very close to exceeding the AWC of the soil. In most years SMD exceeded the risk point at some stage during grainfill, but there is no evidence of this having impacted on yield. There were four years (2000, 2007, 2012, and 2016) where SMDs did not exceed the risk point – two of these years showed below average yields, whilst two showed slightly better than average yields.

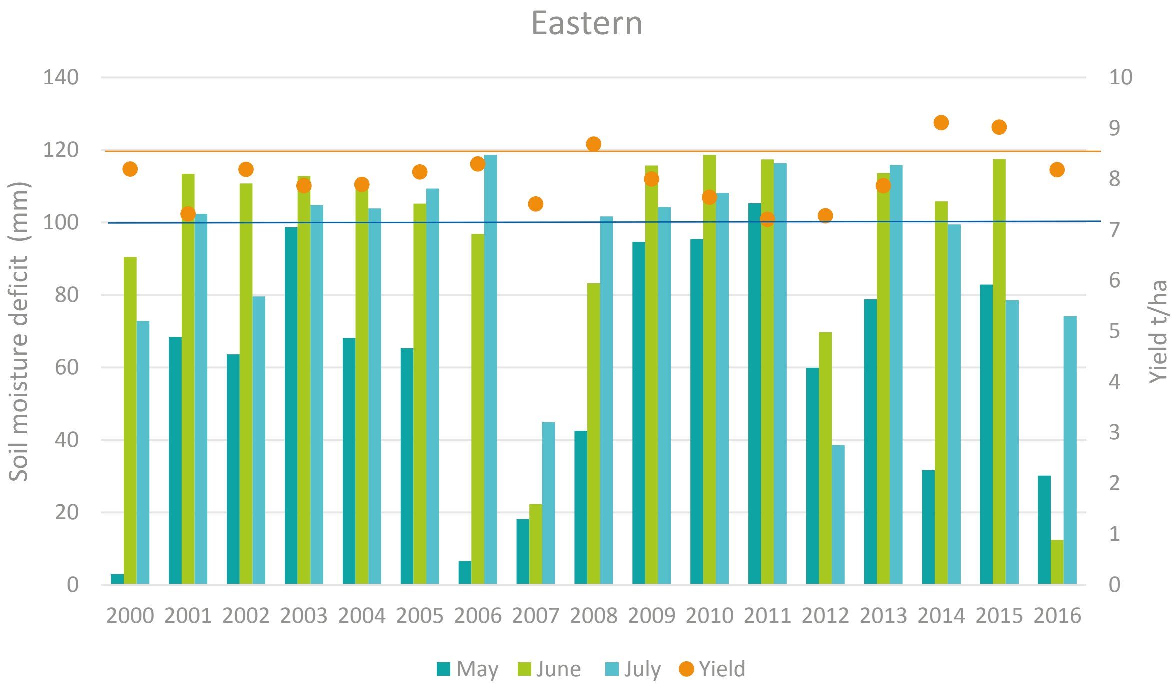


Figure 50. Soil moisture deficit on median soils (end May, June & July) plotted against regional yields in East Midlands. Orange line is the AWC of the soil and the blue line is the risk point at which wheat crops are expected to demonstrate water stress symptoms within 7 days if rain is not received. Source: ADAS for ASC.

In the South (Figure 51) there were seven out of the last 17 years in which SMDs exceeded AWC during the grain fill period (May-July). Many of these years were associated with average or high yields, with two of the lowest yielding years (2007 and 2012), occurring in the years where SMDs were at their lowest.

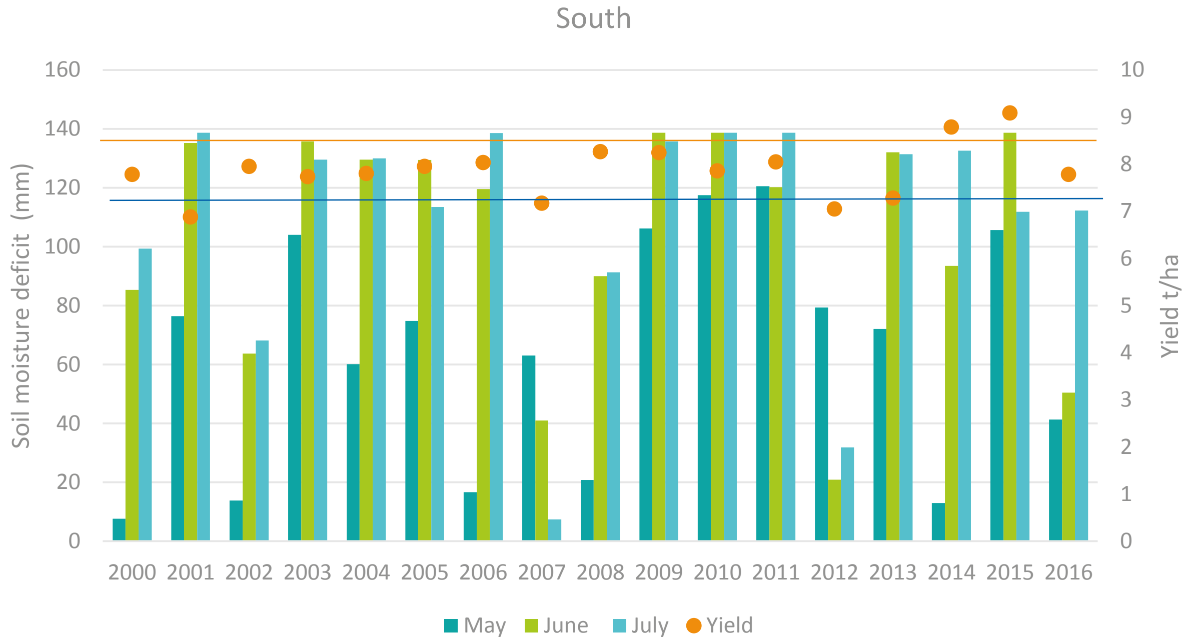


Figure 51. Soil moisture deficit on medium soils (end May, June & July) plotted against regional yields in South East. Orange line is the SMD above which wheat crops are expected to demonstrate water stress symptoms. Source: ADAS for ASC.

The fact that for each region there were two particularly wet years (2007 & 2012) that also had poor yields indicates that there may be a more of a link between high rainfall and low yields, than mild drought. This data is not able to actually confirm a link and there may be many aspects that are contributing to those low yields e.g. the rain itself, the saturation of soils causing a reduction in nutrient uptake, increased lodging, the overcast skies reducing sunlight required for grain fill or increases in disease associated with wet conditions.

Over the period 2000-2016 none of the English regions suffered a period of intense and prolonged summer drought, so although there may have been concerns at the time of potential impact on yields from shorter periods of dry weather, these did not materialise in national level yield impacts. On the contrary this data indicates that it is conditions associated with heavier summer rain that are more likely to be limiting to English wheat yields than periods of prolonged dry weather.

Robustness

This data set is repeatable with robust data on regional yields provided by Defra Statistics and robust SMD data for wheat crops on median soils available from the Met Office. Although these two data sets can be plotted together and trends regarding yields and SMD identified, it is not possible to determine cause and effect, with yields being a complex area with many factors influencing the final value.

AF6: Total number of farms implementing water efficiency measures

Introduction

Although drought is uncommon in the UK, due to the variable climate, high population levels and high demand for water from domestic, industry and agriculture, restrictions on abstraction can sometimes occur. Arable, horticultural and livestock farms all depend heavily on water for crop production and watering stock, as well as cleaning buildings. The water use on farm depends on the type of farm with some relying on natural rainfall, others abstracting water e.g. for irrigation and others using mains water e.g. for watering stock. Where mains or abstracted water is used there is the opportunity for farmers to consider how they can save water through the implementation of water efficiency measures. This will also have the added benefit of helping to ensure that they can maintain access to necessary volumes of water for business to continue without encountering economic losses.

Agricultural water is obtained from a variety of sources including mains water (both metered and non-metered) and direct abstraction (from rivers/streams and springs). Mains water supply remains the most common source of water (excluding rain) accounting for 85% of applied water usage, some farms may have more than one source of water and so abstraction from rivers/streams and springs accounts for the second most common source at 31% (farm business survey 2015/2016). If farms plan to abstract more than 20 cubic metres a day, they will need an abstraction licence from the Environment Agency.

Government bodies have put in place policies to encourage uptake of water efficiency measures, in line with the Water Framework Directive (WFD) which requires an integrated approach to managing water quality across catchments. Both quality and efficiency standards in England are monitored through catchment sensitive farming and steps are taken to improve and promote water efficiency through offering advice, grants and funding to improve water use and efficiency on farm. This indicator assesses the total number of farms implementing water efficiency measures.

Methodology

Specific data sets demonstrating the number of farms implementing water efficiency measures are not available. As data on water efficiency is limited, the majority of information for irrigation and livestock water efficiency has been taken from government statistics (Water Use Survey 2010). There has been no updated survey since this time and recent government statistics on water usage on farms for 2016 does not include numbers of farms taking up water efficiency methods. Information regarding water efficiency grants from the Rural Payments Agency has been included, however statistics on uptake and success of grants could not be identified.

In addition to the water usage survey 2010, further information regarding water efficiency within the dairy sector was extracted from two sources; the Dairy road map publication 2015 and the Dairy Co survey 2012.

Results

There was no recent publication of water use efficiency measure data. The most recent survey data was from 2010 and is presented below, based on a sample survey of 1,900 farm businesses. The Water usage survey (2010) identified that the total volume of water used within agriculture is estimated at 184 million m^3 with drinking water for livestock accounting for the majority at 41% of the total, followed closely by irrigation (38%). Results have been divided into irrigation and livestock, specifically dairy.

Irrigation

Table 27 demonstrates management practices of efficient water use within irrigation from Defra's Water Usage Survey (2010), this is a holistic look at management practices and not crop specific. Historic or more recent data was not available for comparison. This data showed that only 38% of farms who irrigated had optimised irrigation systems, whilst 49% had some other form of infield moisture measurement to aid irrigation decisions.

Table 27. Management practices for efficient water use. Source: Defra Water Usage Survey, 2010.

Management practice	Percentage of farms
Optimised irrigation system	38
Agronomic advice	30
Weather forecast/records (own and other)	59
In-field soil moisture measurement	49

In order to get a clearer picture of whether irrigation water use efficiency measures are being taken up there is a need for follow up surveys, in a similar format to those completed in 2010, in order to get a trend line.

Government water management grant

There are grants available from the RPA to improve water efficiency on farm. Although data was not available on the number of grants released and the types of projects funded this may be a potential future source of information.

Further information can be found on the Government website[75]. Figures on uptake and success of grant uptake are unknown.

Livestock

Tables from the 2010 water use survey identified only recycling of rainwater. No other data was found. The percentage of farms in 2010 utilising these measures were low at just 3% for wash down areas and 4% for drinking water, shown in Table 28.

[75] https://www.gov.uk/guidance/apply-for-water-management-grants#what-the-grant-will-fund

Table 28. Management practices for efficient water use. Source: Defra Water Usage Survey, 2010.

Management practice	Percentage of Farms
Recycling/rainwater collection systems – wash down	3
Recycling/rainwater collection systems – drinking water	4

Dairy

The Dairy Road Map report (2015) specifically looks to increase the uptake of water efficiency methods and in their latest publication for 2015, set a target of 70% of dairy farms to take up water use efficiency measures increasing this to 90% by 2020. The Dairy Road Map report found that in 2012 78% of farmers were implementing water efficiency methods, in some cases water was being reduced through multiple efficiency methods. Of the 78% of farms implementing one or more water efficiency methods, 30% were collecting rain water, 94% were re-using water from a plate cooler and 53% had diversified water supplies including using a borehole.

Robustness

There is currently no ongoing survey of practices relating to water efficiency on farm. Therefore the data presented is not part of a time series and represents the best data that is currently available, but there is no evidence of plans to complete further surveys to update figures.

AF7: Total on-farm water storage capacity

Introduction

Although most crops in England and Wales are rain fed there are some such as potatoes and vegetable crops that do rely on irrigation. In dry seasons supplemental irrigation could become more important and widespread if adequate water were available (Knox et al., 2013). Increasing demand for water, climate change and environmental needs are adversely affecting the availability of water supplies for irrigation in England and Wales. Water abstractors need to adapt to existing sourcing becoming less reliable, and licenses for summer abstractions becoming increasingly difficult to obtain and more restrictive.

For many abstractors, investment in storage reservoirs is now the preferred adaptation strategy for securing future irrigation water supplies, a strategy that is actively promoted by the water regulator (the Environment Agency) and Defra as it provides security and flexibility to irrigators, allowing them to abstract water over winter when it is plentiful, and irrigate in the summer when water is scarce. The Environment Agency (EA) licenses all abstractions for spray irrigation above 20 m^3/day. Details of these licences, including details on abstraction purpose, are captured in the Environment Agency abstraction database (NALD). This indicator estimates the availability of on farm water storage facilities based on the volume of water that is approved for abstraction over winter.

Methodology
In previous years the EA provided actual abstracted volumes (October-March) to the ASC for the estimation of storage volume. However, this data was not available for the recent period, instead abstraction licence volumes were provided. This data has the advantage of it gives an indication of the maximum volume that a farm might abstract over winter to fill a reservoir (where as actual data only shows how much was needed to top up the reservoir). However, it does not give any indication of how the water might be stored or the actual volume of storage available. It is just an indication of whether people have licences in place that allow them to abstract over winter into a storage facility.

The dataset provided details of all the abstraction licences authorised in 2016, sub divided into categories. For the purpose of this assessment the category 'spray irrigation –storage' was chosen and all the volumes in that category combined to give a total volume of water authorised for abstraction to storage facilities for the year.

This approach is not consistent with the previous approach taken – due to lack of access to complementary data sets.

Results
In 2016 there were 2945 licences authorised for "spray irrigation - storage", totalling just over 222 million cubic meters of water annually. This accounts for around 12% of the total authorised volume of license for the broader category of spray irrigation (agricultural and non-agricultural), which was 1,809 million cubic meters.

Robustness
It should be noted that using the NALD is increasingly unreliable for this use. This is because:

- The licence size need bear no relation to the reservoir volume, particularly for year-round licences.
- Storage reservoirs are not fully emptied every year, winter abstractions for storage would only indicate how much they are refilled in any given year and not their total capacity.
- Many large farm systems now mix summer and winter abstraction, storage and direct use, and abstract from surface and groundwater - the theory that a particular abstraction solely goes into filling a storage reservoir, and that the reservoir only gets water from those abstractions, is not strictly true, except in a licencing context.

AF8: Investment in research into water efficiency for cropping/livestock

Introduction
Agriculture accounts for 10-12% respectively of non-household water usage from directly abstracted and mains water sources, accounting for an estimated 239,000 megalitres of water per year in England and Wales (Kowalski et al., 2011). This abstracted and mains water is typically used for irrigation and livestock drinking water. In addition agriculture uses large amounts of

natural rainfall to provide for non-irrigated crops and some livestock drinking water. Agricultural water need will increase with increasing demands on food production, at the same time as increased populations will increase the competition for domestic supply. Therefore, it is important that research is conducted to improve the water efficiency of both cropping and livestock systems. This indicator assesses the research spend on water efficiency in agriculture.

Methodology

No single consistent data set for funding spend was available. The data that is available is not a continuous time series and could be taken as indicative of spending levels, but cannot be used to identify a trend or create an indicator – instead the available data is presented.

There are a wide range of different funding sources that may potentially be used to fund water efficiency work in agriculture. The main funding sources identified were Defra, Innovate UK and BBSRC. These each have published on their websites details of all the projects that have been funded by the different schemes. A series of search terms were used to identify relevant projects. Before inclusion in the indicator each project was checked to ensure that it was relevant to agriculture and focused on water use efficiency. Any projects that were unrelated had to be manually discarded. Information on the start year, finish year, duration of the project and total cost of the project were extracted from the database. Where the project focused on a number of areas, a judgement had to be made to estimate the proportion of spend that was relevant to water use efficiency. This is an arbitrary figure as there is insufficient detail in the project descriptions to enable accurate allocation. Therefore, a project assessing soil, water and waste would have 1/3 of total value allocated to water.

The Defra RandD report[76] database is easy to search and using WATER USE (which is already established as a category in the database) as the search term it was possible to get a relevant list of research projects. These were cross checked as above before being included in the indicator.

BBSRC[77] have a list of funded projects that has a search facility. This search requires related words to be linked with a + sign or the search will return any project with either search term in. Research term WATER returned over 600 potential projects most of them irrelevant to this indicator. The following combinations of terms were used to narrow the list, with all projects having to be manually checked before final inclusion in the indicator;

WATER+EFFICIENT – 1 project, WATER+USE – 39 projects, WATER+CROP – 0 projects, WATER+LIVESTOCK – 0 projects, EFFICIENT+CROP – 10 projects, EFFICIENT+LIVESTOCK – 0 projects

Due to the large volume of work funded the search terms were limited to current projects, hence only projects funded from 2014 onwards were detected.

[76] http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=ProjectList&Completed=0&AUID=1643
[77] http://www.bbsrc.ac.uk/research/grants-search/advancedsearch/

Innovate UK[78] have a downloadable Excel file that lists all the projects funded by Innovate UK (and Technologies Strategies Board – TSB, previously). This file contains over 27,000 projects and can be searched using the standard Excel search features. This process is cumbersome. WATER+EFFICENCY provided a single result, whilst WATER produced hundreds, many of which were unrelated to agriculture. Therefore, the results had to be manually scanned to check relevance before inclusion. For Innovate UK projects there were three project value figures available Grant Offered, Total Costs and Actual Spend. It was the total costs figure that was used, as this figure was deemed to include the contributions from the consortium as well as the grant, and therefore gave a fuller picture of the total spend on water efficiency research.

It is recognised that these are not the only source of funding for water efficiency projects, but they are some of the largest and most easily searched funding sources. NERC[79] was considered as a potential funding source, but the data sets associated with funding were very difficult to search and it was deemed impractical to identify all relevant research.

Once the list of projects were identified pivot tables were created to identify the total funding released per year (based on start date), the estimated allocation to water efficiency and the average annual estimated allocation to water efficiency in agriculture.

Results

Defra R&D funding was invested in projects relating to water use efficiency during the period 2006-2012, after that no subsequent projects appeared on the RandD web search. Projects relating to water use efficiency were funded by Innovate UK in 2014, 2015 & 2016, whilst data for BBSRC projects was only collected for current projects and therefore focuses on 2014-2016, shown in Table 29.

[78] https://www.gov.uk/government/publications/innovate-uk-funded-projects
[79] http://www.nerc.ac.uk/research/funded/

Table 29. Research spend on projects associated with increasing water efficiency in crops or livestock (note BBSRC data only collated from 2014 onwards)

	Estimated funding allocated to water efficiency projects			
All funding sources	Defra	BBSRC	Innovate UK	Total
2006	254076			254076
2007	20000			20000
2008	140573			140573
2009	85184			85184
2010	98730			98730
2011	48405			48405
2012	148868		70110	218978
2013				
2014		62,715		62715
2015		85,277	165,886	251163
2016		1,265,164	217,526	1482690

Robustness

This indicator is not considered to be very robust as there are no clear search terms that enable each of the databases to be searched consistently and definitively (it is not possible to know that every relevant project has been captured as project titles do not always include clear detail of project content and project summaries are not always available). It is rare that research is exclusive to water efficiency, with many projects focusing on improving the overall resource use efficiency of the crop, rather than specifically on water. This means that the reviewer has to make an arbitrary decision on how much of the total project cost should be allocated to the water efficiency part, based on limited details in the project description.

The dataset is also inconsistent with data from different funding sources available in different years. The driver behind funding is slightly different too, with Defra tending to commission specific pieces of work, whilst BBSRC or Innovate will have broad call descriptions that may or may not attract projects relating to water efficiency.

In order to make these searches more practical and robust the inclusion of key words in the funding databases would help (as in the Defra RandD database) to enable users to filter by water use & agriculture to narrow down the list of searches.

X2: Land-use in the fluvial flood plain

Introduction

Fluvial flood zones have been mapped by the Environment Agency across England. These Flood Zones refer to the probability of river and sea flooding, ignoring the presence of defences. The definitions of the different flood zones are set out in (Table 30).

Table 30: Flood Zone definitions (Source: DCLG[80])

Zone 1 Low Probability	Land having a less than 1 in 1,000 annual probability of river or sea flooding. (Shown as 'clear' on the Flood Map – all land outside Zones 2 and 3)
Zone 2 Medium Probability	Land having between a 1 in 100 and 1 in 1,000 annual probability of river flooding; or land having between a 1 in 200 and 1 in 1,000 annual probability of sea flooding. (Land shown in light blue on the Flood Map)
Zone 3a High Probability	Land having a 1 in 100 or greater annual probability of river flooding; or Land having a 1 in 200 or greater annual probability of sea flooding.(Land shown in dark blue on the Flood Map)
Zone 3b The Functional Floodplain	This zone comprises land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. (Not separately distinguished from Zone 3a on the Flood Map)

This indicator aimed to look at the land use in the 1 in 100 fluvial floodplain (Flood Zone 3). It quantifies the land use in both the natural (undefended) floodplain and the floodplain that is not protected by flood defences. The aim is to gain a broad understanding of what the land around the rivers is used for, especially in the context of the discussion around natural flood management, flooding of agricultural land and making space for water.

Methodology

For the purpose of this indicator, the natural floodplain was taken to be the Flood Zone 3 area, and the floodplain unprotected by defences taken to be Flood Zone 3 minus the "area protected by flood defences". Both of these are GIS data layers available from the Environment Agency. Tidal areas were not included in this assessment. Only the fluvial and the fluvial/tidal components of Flood Zone 3 were included to ensure that the mixed fluvial/tidal part of rivers is captured.

The Corine land cover 2012 dataset for the UK[81] (CLC12) was used in order to inform this indicator. Whilst this is not the most recent land cover dataset available (Ordnance Survey Master Map is updated on a rolling programme), Master Map did not have the necessary breakdowns of land use categories to distinguish agricultural from semi-natural features. CLC is a time-series providing consistent information on land cover and land cover changes across Europe derived largely from satellite imagery. 2012 is the most recent reference year. There are 44 land cover classes with a minimum mapping unit of 25 hectares. The dataset is licenced under Open Government Licence; published by the Centre for Ecology & Hydrology. Copyright rests with the European Commission.

[80] https://www.gov.uk/guidance/flood-risk-and-coastal-change#Assessment-to-identify-functional-floodplain
[81] https://data.gov.uk/dataset/corine-land-cover-2012-for-the-uk-jersey-and-guernsey

The steps in this process were;

- Land use stats (% of areas in each CLC12 class) of the fluvial part of FloodZone3.
- Land use stats of the area within the fluvial part of FloodZone3 excluding the "Area protected by flood defences"
- Land use stats (% of areas in each CLC12 class) of the fluvial/ tidal part of FloodZone3.
- Land use stats of the area within the fluvial/ tidal part of FloodZone3 excluding the "Area protected by flood defences"

Results

There are an estimated 14,000 km^2 of high probability Flood Zone 3 in England. Once the "area protected by flood defences" is removed this area drops to nearly 12,000 km^2 (approximately 85%), shown in Table 31. The areas of agriculture, semi-natural, artificial, water bodies and wetlands land covers as estimated from CLC12 for each portion of the floodplain are also shown in Table 31. These are expressed as percentages for fluvial and fluvial/tidal models separately in Figure 52 and Figure 53. The percentages were similar when excluding the areas protected by flood defences.

Table 31. Flood areas and flood areas excluding defences in England by category.

Land Cover	Sum of Area in flood zone 3 (Km^2)	Sum of Area in flood zone 3 minus area protected by defences (Km^2)	Sum of Area in FLUVIAL flood zone 3 (Km^2)	Sum of Area in FLUVIAL/TIDAL flood zone 3 (Km^2)	Sum of Area in FLUVIAL flood zone 3 minus area protected by defences (Km^2)	Sum of Area in FLUVIAL/TIDAL flood zone 3 minus area protected by defences (Km^2)
Agriculture	11,116	9,296	7,142	1,700	6,402	1,487
Semi-natural	429	410	320	17	317	16
Artificial	1,314	930	736	117	652	59
Water bodies	466	454	271	20	269	18
Wetlands	737	708	89	86	82	83
Total	***14,062***	***11,798***	***8,558***	***1,939***	***7,723***	***1,664***

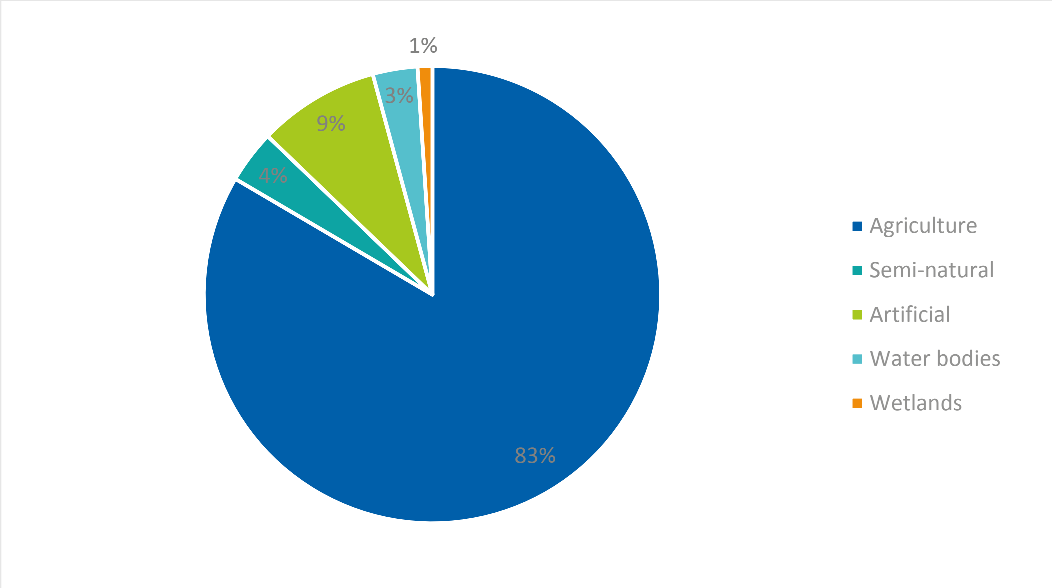


Figure 52. Percentage distribution of broad land cover classes in Flood Zone 3 (Fluvial model only) for England. Source: ADAS for ASC.

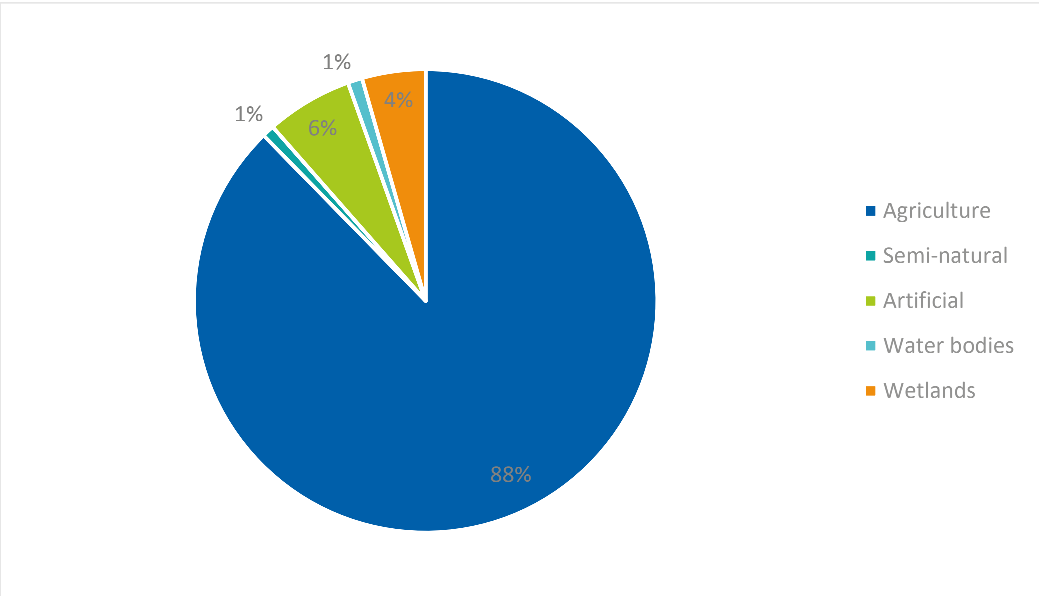


Figure 53. Percentage distribution of broad land cover classes in Flood Zone 3 (Fluvial/ tidal model only) for England. Source: ADAS for ASC.

Robustness

Corine Land Cover is a few years out of date and has a minimum mapping unit of 25ha, therefore only gives an indication of current land uses within the functional flood plain. It is recommended that the process is repeated with more recent and more spatially accurate land use datasets (classifying land according to these broad themes) when these become available. For example, CEH is working on the production of Land Cover Map 2015 (LCM2015), due for completion later in 2017[82].

4.2 Fertility of agricultural soils

AF14: Area of agricultural land covered by crops at high-risk of soil erosion

Introduction

Some crops such as maize, sugar beet and potatoes increase the risk of soil erosion due to the methods used for planting and harvesting, and the timing of these operations, resulting in the soil being left bare over winter. A key risk is the fact that these crops are harvested late (October-January) and the soil is then left bare over winter. Where the crop is harvested slightly earlier in the window it can leave time to establish a winter cereal, but otherwise soil can be left bare over winter leaving it vulnerable to heavy rainfall. Harvesting operations, especially if carried out in wet conditions can lead to compaction, which increases the risk of erosion. Sugar beet can be harvested into January meaning there is cover in some fields through autumn, but then the harvest is occurring at a time that makes the soil particularly vulnerable to structural damage and subsequent erosion.

Soil erosion can occur at a range of scales, from significant erosion events, where large parts of fields wash away due to a combination of factors (e.g. soil type, slope, rainfall and lack of soil cover) coming together at the same time, through to more gradual loss of soil in runoff as sediment. Large erosion events can have an instant impact on the farm productivity whilst it is difficult to quantify the impact of more gradual erosion.

Methodology

Time series of the area of maize, sugar beet and potatoes by Government Office Region were extracted from the archives of June Agricultural Survey (JAS) statistics (Defra). The time series has been re-calculated for earlier years as the EDINA data used in previous calculations will differ slightly from the published Defra statistics. The 1985 maize area was an estimate from the Soil Association's website[83] as there were no maize figures in the 1985 JAS.

Results

Table 32 and Figure 54 show a national time series for the area of high erosion risk crops as estimated from the June Agricultural Survey. Potatoes and sugar beet show an overall decline in their area, whereas the maize area is increasing. Since 2010, there has been a 24% reduction in the sugar beet area and a 4% reduction in the potato area. This is offset somewhat by a 19% increase in the maize area. The geographical distribution of these high erosion risk crops in 2015

[82] http://www.ceh.ac.uk/services/land-cover-map-2015
[83] https://www.soilassociation.org/media/4671/runaway-maize-june-2015.pdf

is shown by region in Figure 55. Eastern parts of the country have the highest potato and sugar beet areas, whereas maize is grown more in the south-west.

Table 32. Crop area per year recorded by the annual June Agricultural Survey (Defra) for high erosion risk crops

	Crop area per year ('000 hectares)						
Crop	**1965**	**1975**	**1985**	**1995**	**2005**	**2010**	**2015**
Maize		26.4	25	100.4	118.7	145.8	173.5
Sugar beet	180.4	197.4	204.8	196.0	148.3	118.5	90.3
Potatoes	209.3	157.0	138.9	130.0	102.4	99.9	96.3

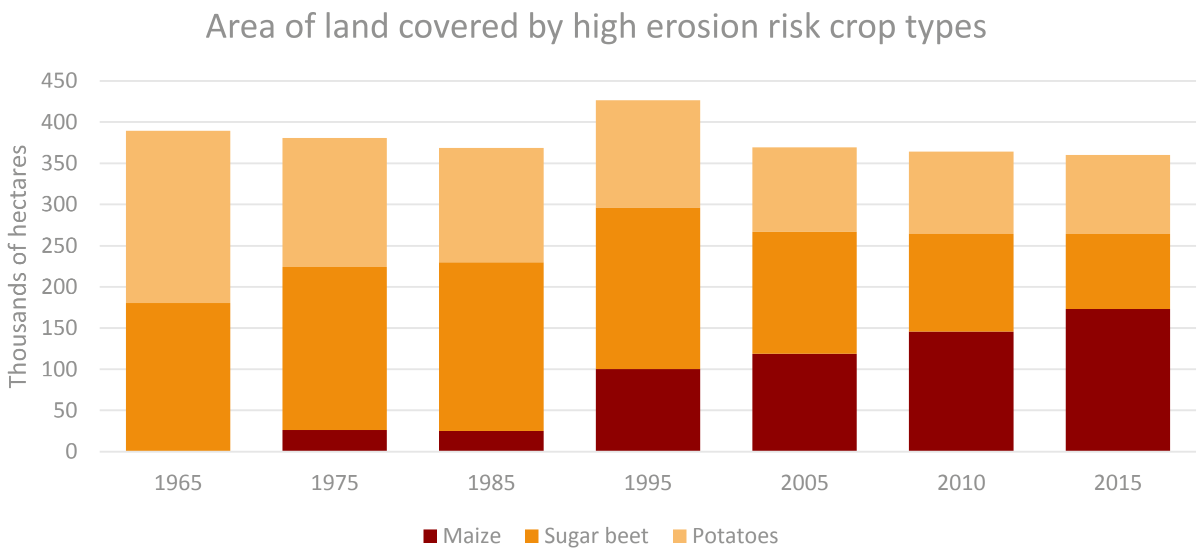


Figure 54. Crop area per year recorded by the annual June Agricultural Survey (Defra) for high erosion risk crops. Source: ADAS for ASC.

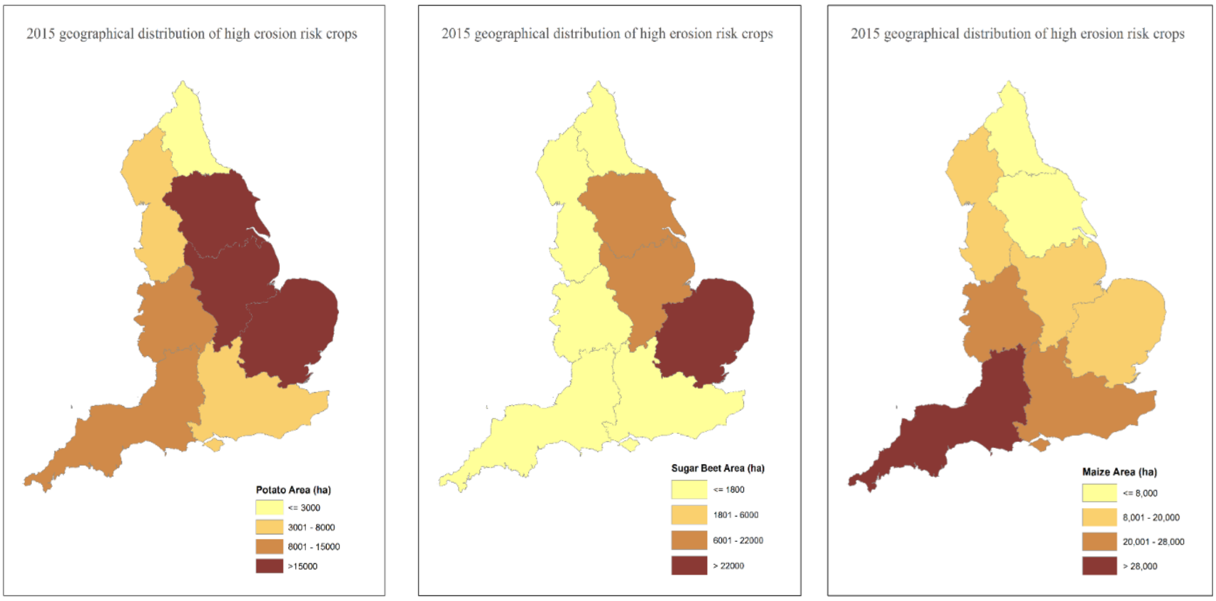


Figure 55. Geographical distribution of high erosion risk crops in 2015: Potatoes left, sugar beet centre and maize right. Source: ADAS for ASC

Robustness

Defra June Agricultural Census/ Survey statistics are the most definitive source of agricultural land-use statistics for England. The sample sizes associated with the survey vary each year depending on UK and EU requirements. In years such as 2010 and 2013 when the EU requires very detailed information, the sample size is increased. In other years the sample size is smaller to reduce the burden on farmers. There will therefore be lower confidence in the estimates for these years. Aggregating statistics to regional scale rather than a finer disaggregation will minimise this effect.

AF15: Area of agricultural land covered by crops at low risk of soil erosion

Introduction

Crops like oilseed rape (winter and spring) and winter cereals (e.g. wheat, winter barley, winter oats) have a relatively low erosion risk due to the minimal amount of tillage required and presence of over winter cover.

Methodology

A time series of the area of oilseed rape and wheat (as indicators of low risk crops) by Government Office Region was extracted from the archives of June Agricultural Survey (JAS) statistics (Defra). The time series has been re-calculated for earlier years as the EDINA data used in previous calculations will differ slightly from the published Defra statistics.

Results

Table 33 and Figure 56 show a national time series for the area of oilseed rape and wheat as estimated from the June Agricultural Survey. The rate of increase in oilseed rape has slowed but the area continued to rise from 2010 to 2015 with a 2% increase recorded in that time (however, there has since been a decrease in oilseed rape area in 2016 and 2017, not captured in this data). The area of wheat (mostly winter-sown) has seen a slight decline (5.5%) since 2010. The geographical distributions of oilseed rape and wheat in 2015 are shown by region in Figure 57. Eastern and south-eastern parts of the country have the highest oilseed rape and wheat areas.

Table 33. Crop area per year recorded by the annual June Agricultural Survey (Defra) for two low erosion risk crops

	Crop area per year ('000 hectares)					
Crop	**1975**	**1985**	**1995**	**2005**	**2010**	**2015**
Oilseed rape	38.9	271.0	299.8	480.0	599.7	610.9
Wheat	1,001	1,803	1,730	1,748	1,792	1,693

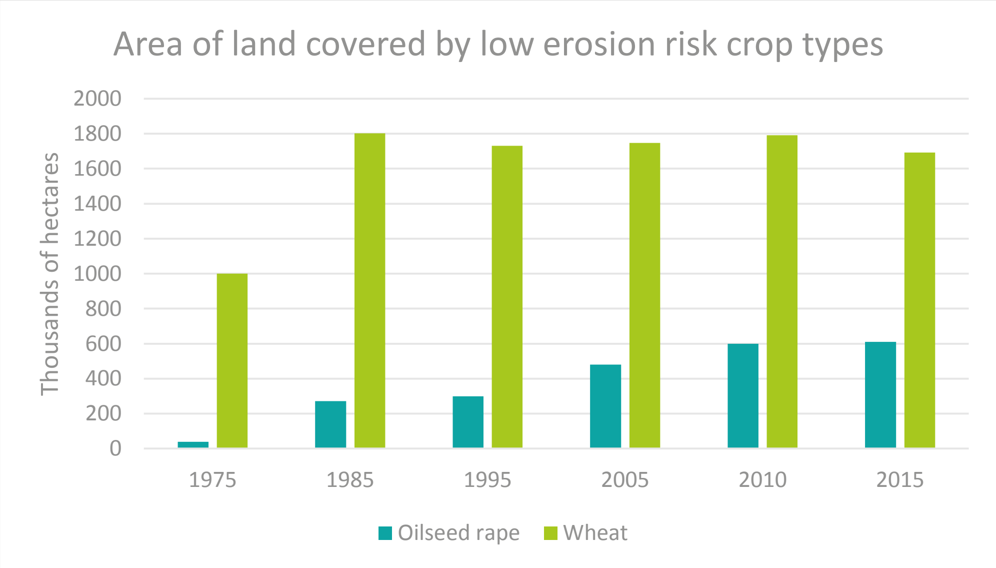
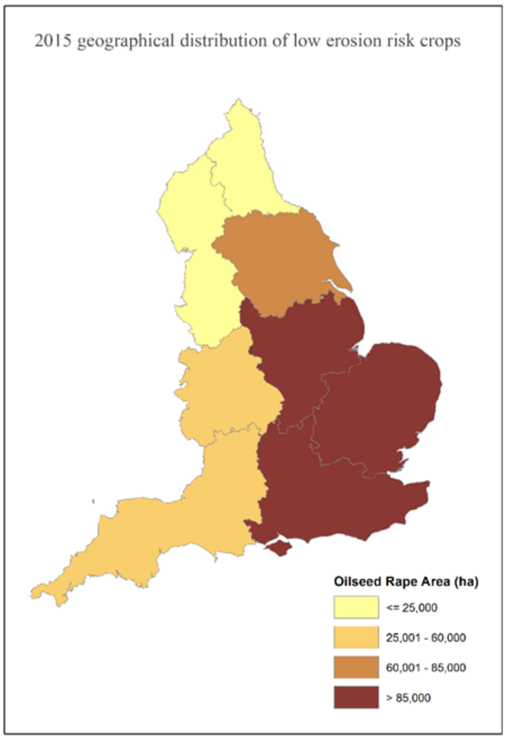


Figure 56. Crop area per year recorded by the annual June Agricultural Survey (Defra) for two low erosion risk crops. Source: ADAS for ASC.



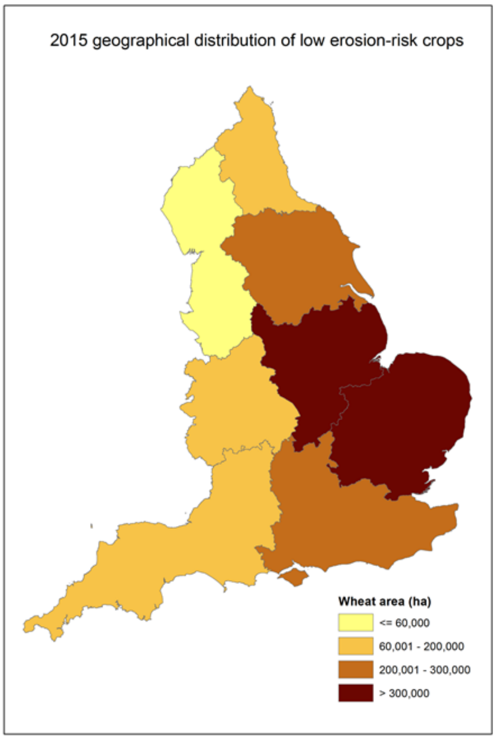


Figure 57. Geographical distribution of two low erosion risk crops in 2015. Source: ADAS for ASC.

Robustness

Defra June Agricultural Census/ Survey statistics are the most definitive source of agricultural land-use statistics for England. The sample sizes associated with the survey vary each year depending on UK and EU requirements. In years such as 2010 and 2013 when the EU requires very detailed information, the sample size is increased. In other years the sample size is smaller to reduce the burden on farmers. There will therefore be lower confidence in the estimates for these years. Aggregating statistics to regional scale rather than a finer disaggregation will minimise this effect.

Future development of this indicator could consider estimating the area of low erosion risk crops on areas at high risk of soil erosion (e.g. certain soil types) to better quantify the beneficial effects that these crops may be having on soil maintenance.

AF16: Area of agricultural land losing soil organic carbon, by grade

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

AF17: Area of agricultural land converted to development, by grade

Introduction

Most of the English land area is in agricultural use. Converting agricultural land to development uses effectively takes soil out of productive use permanently. It therefore locks out certain areas from food production in the future and reduces the productive capacity of the land in response to climate change. As such the UK government have policy in place to protect agricultural land which is set out in the National Planning Policy Framework (NPPF) published in March 2012 (paragraph 112)[84].

The Agricultural Land Classification (ALC) system forms part of the planning system in England and Wales. It classifies agricultural land in five categories according to versatility and suitability for growing crops. The top three grades, Grade 1, 2 and 3a are referred to as 'Best and Most Versatile' land, and are warranted significant protection from development. For planning applications, specific consultations with Natural England are required under the Development Management Procedure Order in relation to best and most versatile agricultural land. These are for non-agricultural development proposals that are not consistent with an adopted local plan and involve the loss of twenty hectares or more of the best and most versatile land. The land protection policy is relevant to all planning applications, including those on smaller areas, but it is for the planning authority to decide how significant the agricultural land issues are, and the need for field information. Grade 4 and 5 are described as poor quality agricultural land and very poor quality agricultural land.

This indicator seeks to monitor the area of agricultural land converted to development, by ALC grade.

Methodology

A consistent methodology was used as in a previous report completed by the Environmental Change Institute on behalf of the Adaptation Sub Committee (ECI, 2013). This methodology identifies the change in the number of properties and their footprint area in England that are located on areas of agricultural, non-agricultural and urban land. For agricultural land, the results provide the property count and manmade area for Grades 1-5, where high grade agricultural land is Grade 1 and 2. Counts are provided for both residential and non-residential properties. The sources /datasets used in assessing this indicator are:

- ECI (2013) for figures for 2001, 2008 and 2011
- MasterMap 2016 address point data (for property counts) and topography layer (identifying ‘man made’ areas)
- Agricultural Land Classification (ALC) GIS data available from the online MAGIC database

[84] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/6077/2116950.pdf

The results provide details of the change in the number of properties and their footprint area, between 2001, 2008, 2011 and 2016, on land grade as classified by the ALC data from 1967-74. This gives an indication of the rate of development in recent years on land that has previously been used for agriculture.

Results

The property counts located in areas of agricultural, non-agricultural and urban land in England are shown in Table 34. Absolute counts differ markedly between 2011 and 2016 due to the use of a different OS product (AddressBase Plus) compared to the one used previously by ECI (2013). The dataset used by ESI was Address-Point, which has since been withdrawn. Nevertheless, looking at the percentage distribution of property locations in 2016 compared to previous years indicates that more properties are being built on agricultural land and fewer in urban areas (as defined by the ALC).

The areas of 'man made' land located in areas of agricultural, non-agricultural and urban land in England are shown in Table 35. Over the past 16 years, over 23 thousand hectares of high grade (grade 1 & 2) agricultural land has been converted to 'man made' land classifications (or 230 square kilometres).

Table 34. Total property counts in England, as identified by OS Address-Pont (2001 – 2011) and AddressBase Plus (2016) located in areas of agricultural (by grade), non-agricultural and urban land uses.

	2001		2008		2011		2016	
('000s of properties)	**Property count**	**% in grade**	**Property count**	**% in grade**	**Property count**	**% in grade**	**Property count**	**% in grade**
Grade 1	185	0.8%	203	0.9%	215	0.9%	636	1.3%
Grade 2	824	3.7%	901	3.9%	952	3.9%	2,886	5.9%
Grade 3	3,838	17.3%	4,150	17.8%	4,345	18.0%	12,264	25.0%
Grade 4	1,000	4.5%	1,071	4.6%	1,121	4.6%	3,340	6.8%
Grade 5	51	0.2%	53	0.2%	57	0.2%	267	0.5%
Non Agricultural	335	1.5%	369	1.6%	393	1.6%	1,165	2.4%
Urban	15,943	71.8%	16,581	71.0%	17,040	70.4%	28,548	58.1%
Total in high grade agricultural land (grade 1 & 2)	1,009	4.5%	1,104	4.7%	1,167	4.8%	3,523	7.2%
Total Property Count	22,209	100%	23,372	100%	24,202	100%	49,108	100%

Table 35. Total area (hectares) of 'man made' land in England, as identified in MasterMap 2016, 2011, 2008, 2001 located in areas of agricultural (by grade), non-agricultural and urban land uses.

	2001		2008		2011		2016	
	Area (ha)	% in grade	Area (ha)	% in grade	Area (ha)	% in grade	Area (ha)	% in grade
Grade 1	12,295	1.7%	13,031	1.7%	13,259	1.7%	16,833	1.9%
Grade 2	54,952	7.7%	59,248	7.8%	60,631	7.9%	73,880	8.4%
Grade 3	213,802	30.1%	234,812	31.0%	240,690	31.3%	287,690	32.7%
Grade 4	55,005	7.7%	60,602	8.0%	62,055	8.1%	76,457	8.7%
Grade 5	12,633	1.8%	6,445	0.9%	6,589	0.9%	10,257	1.2%
Non Agricultural	28,908	4.1%	30,994	4.1%	31,519	4.1%	38,663	4.4%
Urban	333,138	46.9%	351,208	46.4%	353,606	46.0%	376,060	42.7%
Total in high grade agri-land (grade 1 & 2)	67,247	9.5%	72,261	9.6%	73,891	9.6%	90,713	10.3%
Total Man-Made Land Area	710,733	100%	756,323	100%	768,349	100%	879,839	100%

As seen in Figure 58, the rate of development on Grade 1 to Grade 4 land over the past 16 years has been fairly consistent ranging from a 34-39% increase. Grade 5 agricultural land has seen an overall decrease of 20% due to a dramatic decrease between 2001 and 2016. The farmed area in England as reported in the Defra June Survey (2016) is approaching 9 million hectares. The area of man-made land within high grade agricultural land is therefore approximately 1% of the total farmed area.

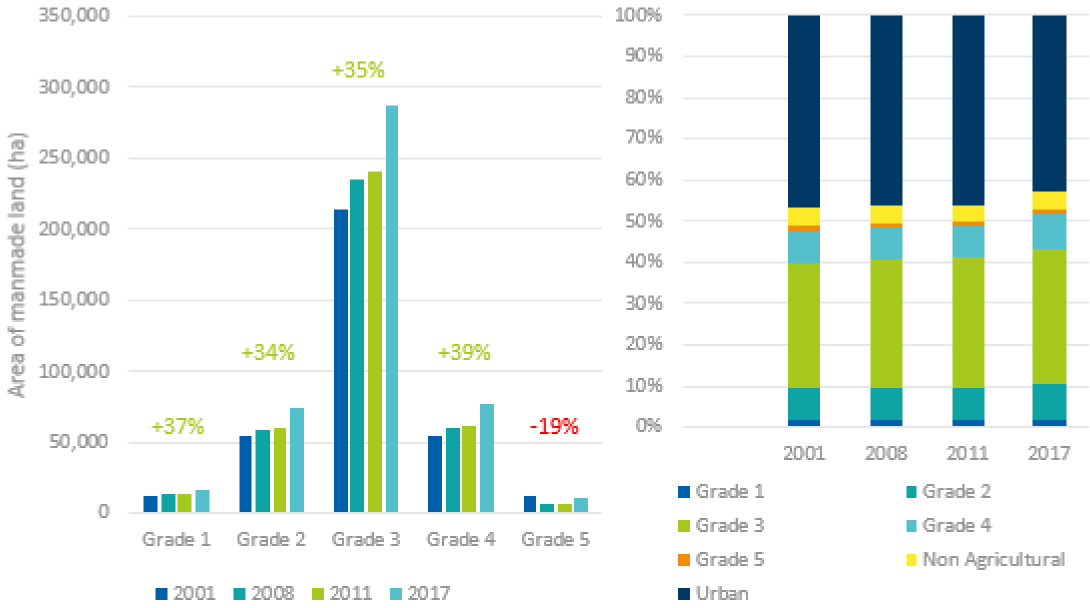


Figure 58. A) Change in area of 'man made' land in England located in areas of agricultural land, by grade. B) Proportion of the total area (hectares) of 'man made' land in England located in the various ALC grades (including non-agricultural and urban for completeness). Source: ADAS for ASC.

Development on agricultural land as a proportion of the total area (hectares) of 'man made' land in England located in areas of agricultural, non-agricultural and urban land use has also increased from 49% in 2001 to 53% in 2017 showing that a greater rate of development is occurring on agricultural land than on non-agricultural or urban land.

Robustness

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 manmade areas. The Ordnance Survey Address-Point data used by ESI (2013) for obtaining property counts per ALC grade could not be used in 2016 due to it being withdrawn. The replacement product used was AddressBase Plus[85], which adds 6 million more addresses to those contained in the basic AddressBase produce, plus a greater level of detail. It is therefore not directly comparable to previous years' results.

The Provisional ALC map is based on reconnaissance field surveys (1966 -1974) and contemporary climate data. It is only suitable for strategic purposes, is not sufficiently accurate for use in assessment of individual sites, and should not be used other than as general guidance. More recent work has produced a predictive map of 'likelihood of Best and Most Versatile (BMV) land' that does not break down area by grade, but identifies areas which are likely to have >60%,

[85] https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase-products.html

20-60% and <20% BMV land (Entec, 2010). This could not directly give an area measurement of the amount of BMV land at risk, but could for example identify the area of land having a 'high likelihood of BMV' being at risk. The use of this map could be considered in future iterations of this indicator.

AF18: Area of agricultural land under minimum/no tillage, by grade

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

AF19: Area of agricultural land covered by soil conservation measures

Introduction

Agriculture can lead to a range of soil related issues such as erosion, decline in organic matter and compaction all leading to reduced productivity of the soil. Whilst estimates of the area at risk of erosion vary by crop, typically, about 17% of arable soils in England and Wales show signs of erosion (Defra, 2011a; 2011b). Soil degradation can result from inappropriate farming practices, excessive use of irrigation, improper use of pesticides and fertilisers, use of heavy machinery and over grazing (Defra, 2009).

Farmers are required to meet certain criteria to meet EU standards of soil protection and to claim for basic farm payment (BPS) under Pillar 1 of the Common Agricultural Policy. The criteria is in the form of GAECs (Good Agricultural and Environmental Conditions) and SRM's (statutory management requirements), some requirements within these headings are legal and others are purely to encourage good practice and environmental protection in order for farmers to receive BPS payments. This is detailed in '*the guide to cross compliance in England 2016*' (Defra, 2016b), which covers a variety of farming activities. In many cases, these guidelines cover things that farm businesses should be doing anyway – under European and UK legislation. This document identifies the relevant legislation.

In addition to the BPS requirements for soil husbandry there are a number of soil conservation measures that farmers can take to protect and even improve the quality of the soil on their land. These soil conservation measures include; leaving crop residues on the soil surface and use of cover crops to prevent areas of land remaining bare for extended periods, especially over winter. This indicator aims to capture data on the level of uptake of soil conservation measures, recognising that there is limited data available to complete this assessment.

Methodology

There is no time series data available covering a holistic view of soil conservation measures as a whole. The most recent survey of soil cover (a key indication of risk from soil erosion) occurred in 2010 as part of the Defra Farming Practices Survey. There is no subsequent data to demonstrate whether soil cover has increased or decreased as a whole, although personal communication with experts in cover crops was used to give an indication of what the current situation is with regards cover crop area.

Results

One key aspect of soil conservation is minimising the area of bare soil present over winter. In the 2010 Defra Farming Practices Survey the area of land covered by different types of cropping, soil conservation measure or left bare was assessed. This showed that in 2010 there were 325,000ha of arable land (in England) left bare over winter (Figure 59). There were 81,000 ha of cover crops grown and 514,000 ha of land where crop residues or stubble were left over winter to protect the soil surface. Recent work by Natural England estimated that the area of cover crops (included in voluntary measures) had increased by about 25% to 2015. If applied to the Defra survey figure of 81,000 ha in 2010, this would mean that the current estimated area of cover crops is about 100,000 ha, demonstrating a trend for increased areas of cover.

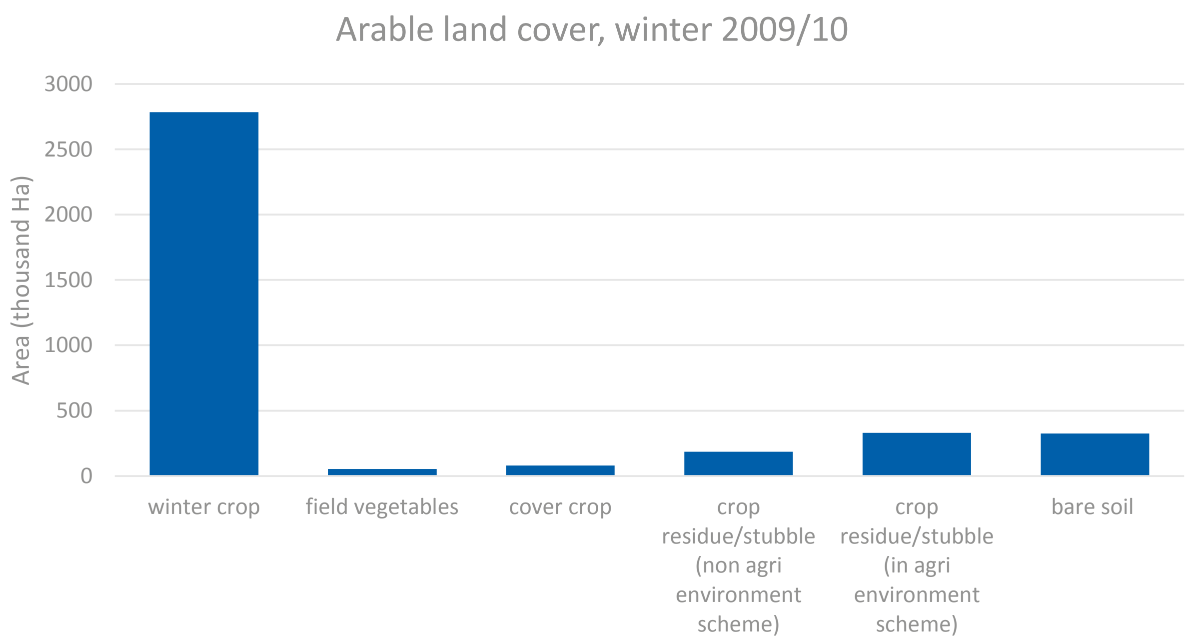


Figure 59. Arable land cover winter 2009/10. Defra farm practices survey 2010. Winter crops are arable crops including winter cereals, winter oilseed rape and winter beans. Field vegetables include brassicas, leeks and carrots that have growing seasons that extend into the winter months. Cover crops are planted specifically between the harvest of one crop and the planting of the next as a soil conservation measure – they are not harvested for any financial gain. Bare soil will often be areas of land that have been cultivated in the autumn in preparation for drilling of spring crops from March onwards. Source: ADAS for ASC.

Robustness

This indicator lacks a time series of data to monitor change. The baseline data is from a robust source the Defra survey which was sent to approximately 16,500 holdings with an overall response rate of 65% (Defra, 2010a). However, the lack of subsequent surveys means that current data is based on expert judgement. Including specific questions on soil conservation, particularly land cover, in subsequent farm practices surveys would assist in providing supporting data for this indicator.

AF20: Investment in research into soil conservation

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

AF21: Agricultural losses from soil erosion

Introduction

There is increasing concern that the way in which soils are used by agriculture can lead to their degradation, which gives rise to significant costs, both in monetary terms and in terms of losses to the essential ecosystem services that soils provide. Research by Graves et al. (2015) developed and used an approach to estimate the total economic costs of soil degradation in England and Wales. This research is relatively recent, but bases land cover on the Centre for Ecology and Hydrology (CEH) Land Cover Map 2000 (LCM2000). The CEH aim to release a new version of the LCM in 2017, therefore this method could be replicated using the new LCM if required.

Methods

Graves et al. (2015) estimated degradation costs (£) by type of degradation at the national scale for dominant combinations of land cover and soil, known as 'soilscapes'. They used an ecosystem services framework to assess how degradation affects the capacity of soils to support a range of 'final goods', distinguishing between on-site and off-site costs, and market and non-market effects. Six processes resulting in soil degradation were considered relevant for England and Wales and were included in the estimates. These processes are: soil erosion; soil compaction; soil organic matter loss; soil diffuse contamination; losses in soil biodiversity; and soil sealing. Please see the original source for details of the methodology and further results.

Results

The results of the research of Graves et al. (2015) for soil erosion, soil compaction and soil organic matter loss are summarised in tabular form below.

Soil erosion

Graves et al. (2015) estimated that 2.9 Mt of soil is lost to erosion in England and Wales each year. Most of this was associated with silts and sands on arable and horticultural areas. This equated to an annual cost of about £150 million, of which 27% are on-farm costs and 73% off-farm costs (Table 36).

Table 36. Estimated erosion and the cost of soil erosion for all soilscapes in England and Wales. Source: Graves et al. (2015).

Data category	Data description	Data value	Unit
Physical data			
Area at risk of soil loss	Total areas at risk	1,022,459	ha
	Total soil erosion	2,920,626	t a^{-1}
	Mean soil erosion	0.21	t ha^{-1} a^{-1}
Physical losses of soil nutrients and organic matter	Total N loss	18,026	t a^{-1}
	Total P loss	4,830	t a^{-1}
	Total K loss	38,280	t a^{-1}
	Total C loss	225,787	t a^{-1}
On-site costs			
Provisioning service	Crop productivity decrease	5,358	£'000
Stock value of lost nutrients	N loss in soil stock	11,176	£'000
	P loss in soil stock	3,284	£'000
	K loss in soil stock	19,906	£'000
	C loss in soil stock	151	£'000
Off-site costs			
Drinking water quality service	N removal in drinking water	2,024	£'000
	Sediment removal in drinking water	29,359	£'000
Environmental water quality service	N in rivers and lakes	1,894	£'000
	N in transitional waters	105	£'000
	P in freshwater lakes	4,436	£'000
Flood regulation service	Sediment removal in rivers and canals	9,818	£'000
	Sediment removal in urban drainage	55,000	£'000
Climate regulation service	GHG cost of soil C loss	5,517	£'000
Total costs			
	Total on-site cost	39,874	£'000
	Total off-site cost	108,153	£'000

Soil compaction

Graves et al. (2015) estimated that 3.9 million ha are liable to soil compaction in England and Wales, mainly on clay soils in wet areas. Total costs of compaction were estimated at £472 million per annum, of which 50% are on-farm costs and 50% off-farm costs (Table 37).

Table 37. Estimated soil compaction and the cost of soil compaction for all soilscapes in England and Wales. Source: Graves et al. (2015).

Data category	Data description	Data value	Unit
Physical data			
Area at risk of compaction	Total areas at risk	3,858,670	ha
Physical losses of fertiliser	Fertiliser N loss	37,044	$t\ a^{-1}$
	Fertiliser P loss	979	$t\ a^{-1}$
	Fertiliser K loss	1,751	$t\ a^{-1}$
Added traction	Additional diesel use	41,611,147	$l\ a^{-1}$
On-site costs			
Provisioning service	Crop productivity and production loss	161,670	£'000
	N fertiliser loss	22,697	£'000
	P fertiliser loss	666	£'000
	K fertiliser loss	911	£'000
	Additional diesel use	17,477	£'000
Off-site costs			
Drinking water quality service	N in drinking water	2,166	£'000
Environmental water quality service	N in rivers and lakes	2,028	£'000
	N in transitional waters	112	£'000
	P in freshwater lakes	1,377	£'000
Flood regulation service	Flooding damage cost	168,000	£'000
Climate regulation service	GHG cost of N as N2O	73,627	£'000
	GHG cost of N as NH3	3,458	£'000
	GHG cost of increased N loss	9,446	£'000
	GHG cost of increased P loss	50	£'000
	GHG cost of increased K loss	45	£'000
	GHG cost of additional diesel	6,579	£'000
Total costs			
	Total on-site cost	203,691	£'000
	Total off-site cost	266,889	£'000

Soil organic matter loss

An estimated 5.3 Mt a^{-1} of carbon is lost from soil each year in England and Wales, much from clays and peats (Table 38). The annual cost of on-farm loss of organic C was estimated as £3.5 million per annum by Graves et al. (2015). The off-site costs are considerably greater.

Table 38. The estimated costs of loss of soil organic matter content in England and Wales. Source: Graves et al. (2015).

Data category	Data description	Data value	Unit
Physical data			
Physical losses of soil C	Soil C loss	5,260,886	t a^{-1}
On-site costs			
Provisioning service	Crop productivity cost of soil C loss	3,507	£'000
Off-site costs			
Climate regulation service	GHG cost of soil C loss	566,124	£'000

Robustness

Graves et al. (2015) estimates of total annual costs of soil degradation in England and Wales are considerably larger than those estimated in the Soil Strategy for England (Defra, 2009). They conclude that these higher estimates partly reflect a more comprehensive and integrated treatment of degradation costs, explicitly considering the spatially distributed vulnerability of soils to major types of degradation under given land uses, as well as a more complete assessment of the costs of degradation. This paper was the most recent estimate of costs of soil degradation that was found by the project team, however it uses an outdated map for land use categorisation (Land Cover Map 2000 – produced by CEH). It is possible that this exercise could be repeated using the soon to be released Land Cover Map 2015. The figures relate to England and Wales, not just England.

X3: Uplands, what are they used for?

Introduction

The uplands of the UK support a range of open, semi-natural habitats. Such habitats occur above the upper limits of agricultural enclosure, usually over 250–400 m altitude. Collectively they cover around one-third of the UK land surface (Reed et al., 2009). Upland areas provide many functions and ecosystem services (for example, supplying over 70% of the UK's drinking water (Heal, 2003)), and support important land-based industries such as hill farming, forestry, water industries, field sports and tourism.

Methodology

The Moorland Line was drawn as a means of establishing eligibility of farmers within the Less Favoured Area (LFA) for the Moorland (Livestock Extensification) Regulations 1995 (SI 1995/904)[86]. Moorland is defined in terms of the vegetation present, which must be predominantly semi-natural upland vegetation, or predominantly made up of rock outcrops and semi-natural vegetation, used primarily for rough grazing. Moorland includes both open moors

[86] https://www.gov.uk/guidance/hill-farming

and enclosed land on the margins of uplands. The Moorland Line encloses just over 40% of (LFA) land[86]. The moorland line, which is available from MAGIC (website provides authoritative geographic information about the natural environment from across government), and the different land cover classifications in the Corine land cover 2012 dataset for the UK[87] (CLC12) was used to assess the primary uses of upland areas.

Results

The total upland area inside the moorland line is estimated to be 7,732 km^2. The three main land use categories within the moorland line are peat bogs (34%), moors and heathland (32%) and Natural grassland (25%), shown in Table 39.

Table 39. Land use (from CLC12) within upland areas of England as defined by the moorland line.

Land use category	Area (km^2)	Proportion of total upland area within the moorland line
Moors and heathland	2497.7	32%
Pastures	166.9	2%
Natural grasslands	1960.1	25%
Peat bogs	2642.1	34%
Sparsely vegetated areas	315.6	4%
Other	5.5	< 1%
	7731.7	

Robustness

Corine Land Cover is a few years out of date and has a minimum mapping unit of 25ha, therefore only gives an indication of current land uses. It is recommended that the process is repeated with more recent and more spatially accurate land use datasets (classifying land according to these broad themes) when these become available. For example, CEH is working on the production of Land Cover Map 2015 (LCM2015), due for completion later in 2017[88].

[87] https://data.gov.uk/dataset/corine-land-cover-2012-for-the-uk-jersey-and-guernsey

[88] http://www.ceh.ac.uk/services/land-cover-map-2015

4.3 Prevalence of new and existing pests and diseases

AF22: Agricultural losses from pests/pathogens

Introduction

Pests and diseases can have significant effects on agricultural crops through reduced yield or total crop failure resulting in large economic impacts on farm. There are a range of factors that can influence both the severity and incidence of pest and disease prevalence, including climate change which will have an influence on the distribution and activity of certain pest and disease species. The UK Climate Change Risk Assessment (CCRA) report identified several pests and diseases that will potentially be affected by climatic changes, including;

- Root and stem base fungal diseases (e.g. take-all & eyespot) – forecast to increase
- Stem and leaf fungal pathogens (leaf blotch, net blotch, yellow rust, late blight, light leaf spot, phoma stem canker) – forecast to decrease although may have earlier onset
- Powdery mildew – increased risk
- Vector-borne viral disease (e.g. aphid borne Barley Yellow Dwarf Virus)

These pests and diseases all have the potential to impact on crop yields, although it is not always easy to determine yield impacts at a national scale as there are multiple factors influencing yields in any one year. This indicator aims to link changes in pest and disease incidence to agricultural losses. It focuses on wheat and oilseed rape as two of the affected crops covering large areas.

Methodology

It is difficult to quantify the actual yield losses at the national level that are due to pest or disease damage due to the complex interaction of a range of factors impacting yield. The yield responses in the AHDB recommended list trials (AHDB, 2017) for wheat and oilseed rape were plotted against the England national average wheat and oilseed rape yield to show where high disease pressure corresponded to poorer yields. Commentary based on Crop Monitor data (Crop monitor 2005-2014) and other sources of information on disease pressure, as well as AHDB harvest reports (AHDB, 2017) were then used to put these yields in context with what was happening in the wider picture (e.g. weather influences). Only sites in England with both treated and untreated data were used. The recommended lists can further be used to demonstrate percentage of infection by specific disease pressures including yellow rust and Septoria (wheat) and light leaf spot (OSR).

In most years the use of fungicides (or insecticides) is able to minimise the actual yield losses from disease (or pests), and therefore understanding the response to the fungicides and the disease pressure is probably a clearer indicator of climate risk than the actual yield loss to the disease. It should be noted that the availability of pesticide active substances is coming under increasing pressure due to changes in EU legislation aimed at protecting human health and the environment, and therefore there is the risk that there will be fewer active substances available for disease control in the future, which may further exacerbate any climate impacts. Although there are benefits to the use of pesticides, there have also been many problems associated with their use including impacting biodiversity and water quality highlighting the importance of evidence based legislation.

Figures were available for diseases including septoria, powdery mildew, eye spot, yellow & brown rust, light leaf spot and stem canker. Other diseases such as take all, leaf blotch, Barley Yellow Dwarf Virus (BYDV), net blotch and late blight are common in UK agriculture and can be affected by changing weather conditions although this data was not available within the Crop Monitoring archive data. Data from 2016 harvest has not yet been released on the Crop Monitoring site.

Winter wheat results

Figure 60 demonstrates the yield response to fungicide treated wheat crops (using AHDB fungicide response trial data) against England average yields for 2007 – 2015. 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. The yield responses were highest in 2012 and 2014. Across England average yields throughout 2012 were well below the average for the period 2007 – 2015 at 6.7 t/ha, the yield response from treated crops accounted for over half of the total average yield at 3.59t/ha; indicating disease may have been a contributing factor to poor yields. There were challenging weather conditions in 2012 (see AF5) that were considered to have influenced yield, but also resulted in disruptions to planned fungicide applications and therefore some of the reduction in yields in 2012 could be attributed to poor disease control. In 2014 although there was a large yield response to fungicides, it was possible to apply fungicides as planned and therefore yields were to a large extent protected despite high disease pressure, allowing crops to average over 8 t/ha.

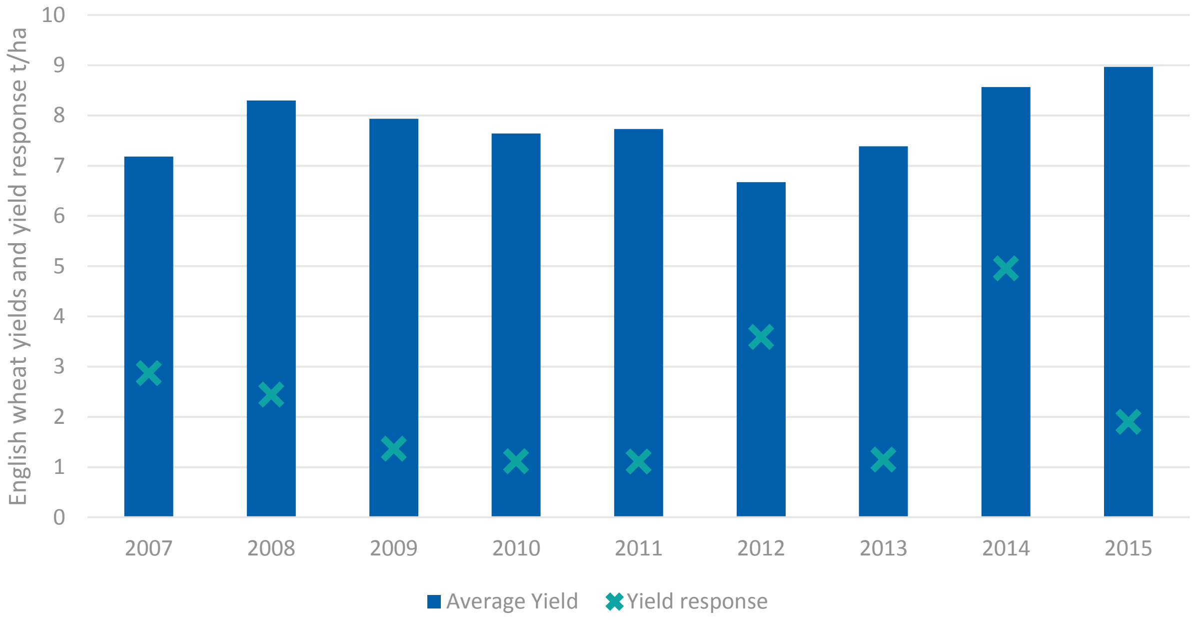


Figure 60. Relationship between average yields for England wheat crops and yield response to fungicides on HGCA trial crops. Source: ADAS for ASC.

AHDB recommended list trials (AHDB, 2017) includes data demonstrating the percentage of infection found on winter wheat crops from yellow rust and Septoria (Figure 61), this can be used to identify years with high rates of infection that may have reduced yield.

In both 2012 and 2014 there were high yield responses (over 3 t/ha) to fungicide treatment. In 2012 there was the highest reported incidence of yellow rust (reported as % infection on the top four leaves) and second highest recorded incidence of septoria, whilst in 2014 there was the highest recorded incidence of septoria and second highest recorded incidence of yellow rust (Figure 60). The lower yield response in 2013 (0.89t/ha yield difference) corresponded with lower incidence of both septoria and yellow rust.

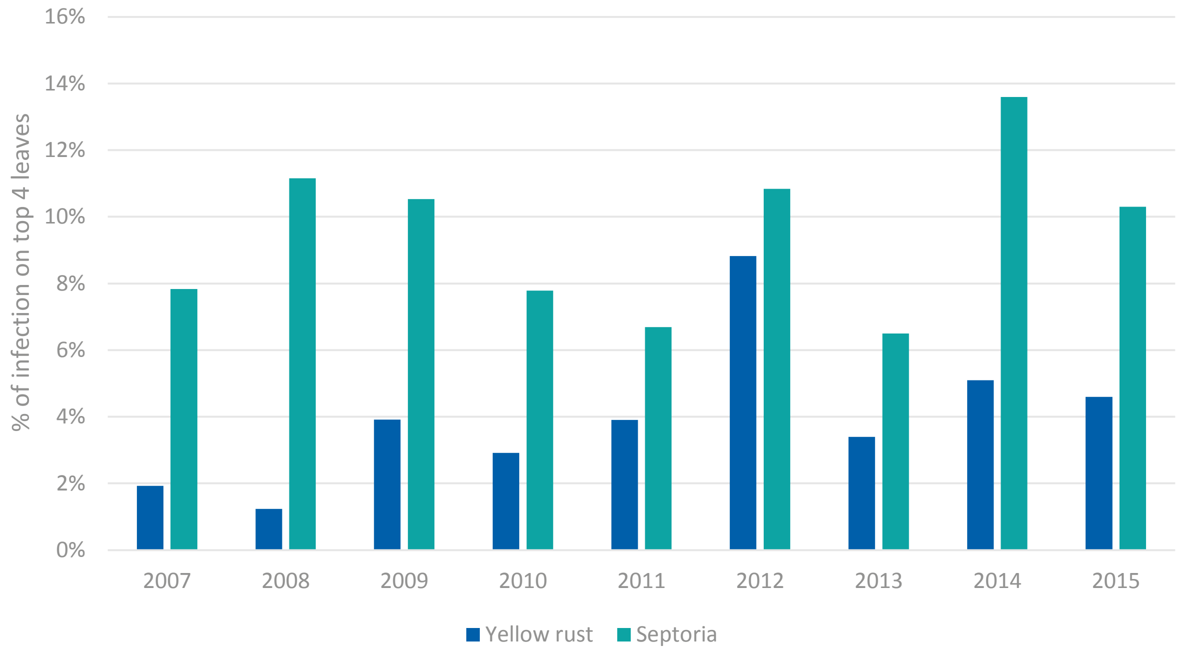


Figure 61 Percentage infection on top 4 leaves of winter wheat crops. HGCA recommended list harvest results

Winter Oilseed Rape Results

Figure 62 demonstrates the relationship between average yields of England oilseed rape crops (Defra, Crop production estimates) from 2007-2010. Data is presented for 2007 – 2010 as after this time AHDB Cereals & Oilseeds stopped monitoring the yields of untreated OSR crops, therefore yield response data was not available. Figure 5 shows the yield response plotted against English national average yield data.

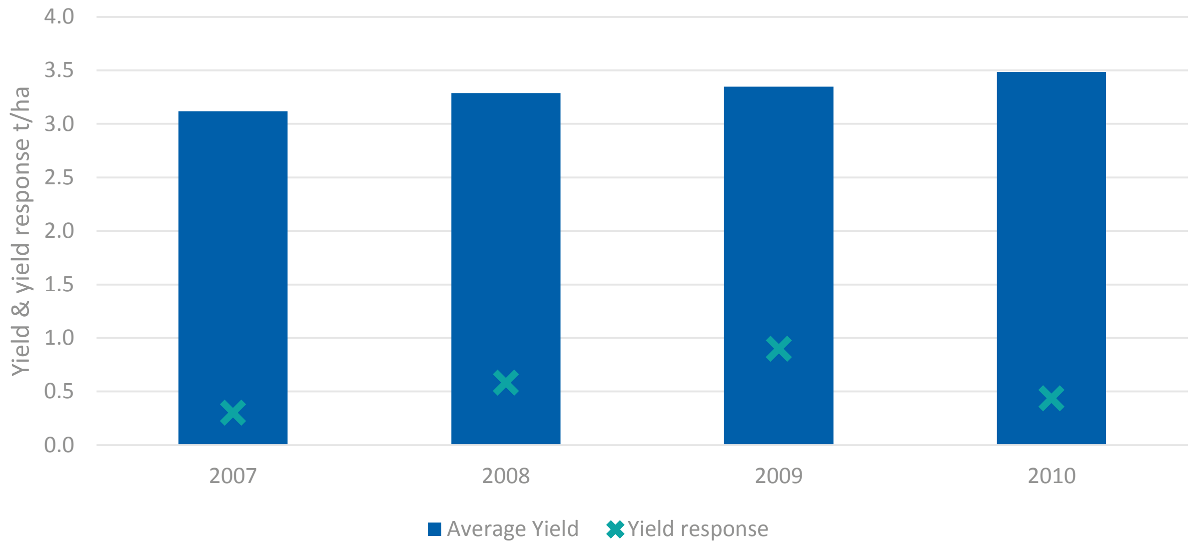


Figure 62 Relationship between average yields for England oilseed rape crops and yield response to fungicides on HGCA trial crops. Source: ADAS for ASC.

Yield results from Figure 62 can be compared to levels of infection of light leaf spot, this indicates the percentage infection on the top three leaves (Figure 63). Light leaf spot was the only disease in OSR that was consistently measured. The lower yielding years (2007), coincide with higher incidence of light leafspot, but also show low levels of disease response to fungicides as compared to the higher yielding year of 2009. Given that there are a number of other disease such as Phoma and Sclerotinia that affect OSR the lack of data on these means that it is difficult to draw clear conclusions from the available data.

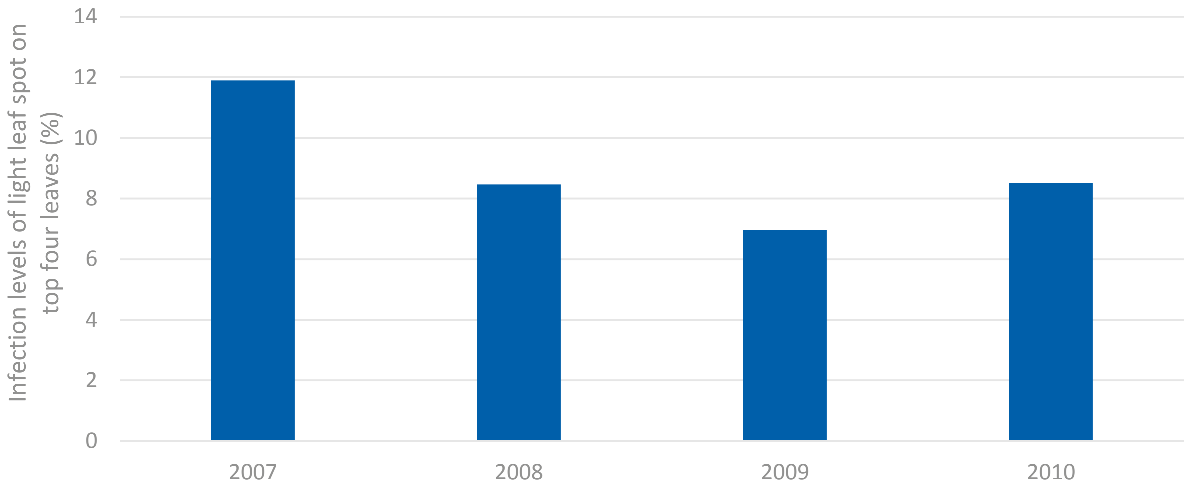


Figure 63. Percentage (%) infection on top 4 leaves due to light leaf spot on OSR. HGCA recommended list trials. Source: ADAS for ASC.

Robustness

The data on yields is available from Defra National Statistics and is based on a large sample size of UK farmers on an annual basis. The AHDB recommended list data is produced for a number of specific sites across the country using a standard protocol. Data on yield responses is anticipated to be available for wheat going forwards, although is no longer being collected for oilseed rape. There is no direct link between national yield data and yield responses therefore there is a need for expert judgement to take available evidence for those years to interpret whether there are links between yield reductions and disease pressure, or whether there are other influences affecting yield. This indicator should therefore be interpreted with caution.

AF23: Timber losses from pests/pathogens

Introduction

Climate change has and will continue to affect trees and woodlands, allowing the spread of new pests and pathogens. It is therefore important to monitor the impact of different pests and pathogens on our forests, two tree pathogens commonly found in England were investigated:

- *Dothistroma* needle blight
- *Phytophthora ramorum*

Forestry in the UK remains largely reliant on four coniferous species (Sitka spruce, Douglas fir, Scots pine and larch), although increasingly broadleaf species such as oak, beech, ash and cherry are grown commercially.

Methodology

For *Dothistroma* needle blight initial baseline data was provided by a 2006 GB wide survey on the public forest estate (PFE), (Forestry Commission, 2012). There have been no systematic surveys in private forests in GB. In England, no further assessments of the distribution of the disease have been made on the PFE.

Phytophthora ramorum incidence is monitored by the Forestry commission on their outbreak map. With annual results shown in different colours (see Figure 64).

Results

***Dothistroma* needle blight** of pine, until recently known as red band needle blight, has infected pine trees across Britain. It inhibits their growth reducing timber yield, and in some cases eventually kills the infected tree. The main symptom is a loss of the trees' needles (defoliation). Outbreaks of *Dothistroma* needle blight recently occurred in the South West, Central and Eastern England. In 2006, 70 per cent of the Corsican pine stands inspected in Britain had the disease, and it is estimated that 44 per cent of these infected stands had crown infection levels greater than 30 per cent (Forestry Commission, 2006). A total of 86 pine (*Pinus*) species, 5 spruce (*Picea*) species, European larch (*Larix decidua*) and Douglas fir (*Pseudotsuga menziesii*) have been reported as hosts of the disease (the majority are listed in Watt et al., 2009). In Britain the main species currently affected are Corsican pine (*Pinus nigra* ssp. *laricio*), lodge pole pine (*Pinus contorta* var. *latifolia*), and Scots pine (*Pinus sylvestris*). The total planted areas of these species in Britain are shown below and represent some 15% of the GB woodland resource (Table 40).

Table 40: The total planted areas of scots pine, lodgepole pine and Corsican pine.

	England	Wales	Scotland	GB
Scots pine (000 ha)	82	5	140	227
Lodgepole pine (000 ha)	7	6	122	135
Corsican pine (000 ha)	41	3	2	46
Total (000 ha)	**130**	**14**	**264**	**408**

In 2006, a GB wide survey on the public forest estate (PFE) found the disease to be present within 70% of Corsican pine stands younger than 30 years (Forestry Commission, 2012). However, in 2009, an assessment of the intensity of the disease in infected stands (>1ha) was undertaken. 85% of stands had less than 50% viable needles remaining and ca.90% of stands showed some mortality, although the majority of these (ca. 70%) had less than 5% tree death (Forestry Commission Website).

Phytophthora ramorum is a fungus-like pathogen which causes extensive damage and mortality to a wide range of trees and other plants. It is sometimes referred to in Britain as 'Larch tree disease' because larch trees are particularly susceptible, and large numbers have been affected. Few trees in the UK were affected until 2009, when *P. ramorum* was found infecting and killing large numbers of Japanese larch trees in South West England.

The UK has been divided into three risk zones, with Zone 1 being at greatest risk from *P. ramorum* infection, and Zone 3 being at least risk, these risk zones are set out on the Forestry Commission website[89]. The Forestry Commission monitors areas where there is or has been confirmed or presumed infection in larch trees through their outbreak map (Figure 64). The coloured dots on the map indicate sites where *P. ramorum* has been confirmed or presumed, and statutory plant health notices (SPHNs) have been issued. Statutory Plant Health Notices, requiring the felling of infected trees, are issued by the Forestry Commission/Forest Service to prevent the spread of pests and diseases. No data on levels of felling was provided.

[89] http://www.forestry.gov.uk/pdf/Pramorum_risk_zones_Oct11.pdf/$FILE/Pramorum_risk_zones_Oct11.pdf

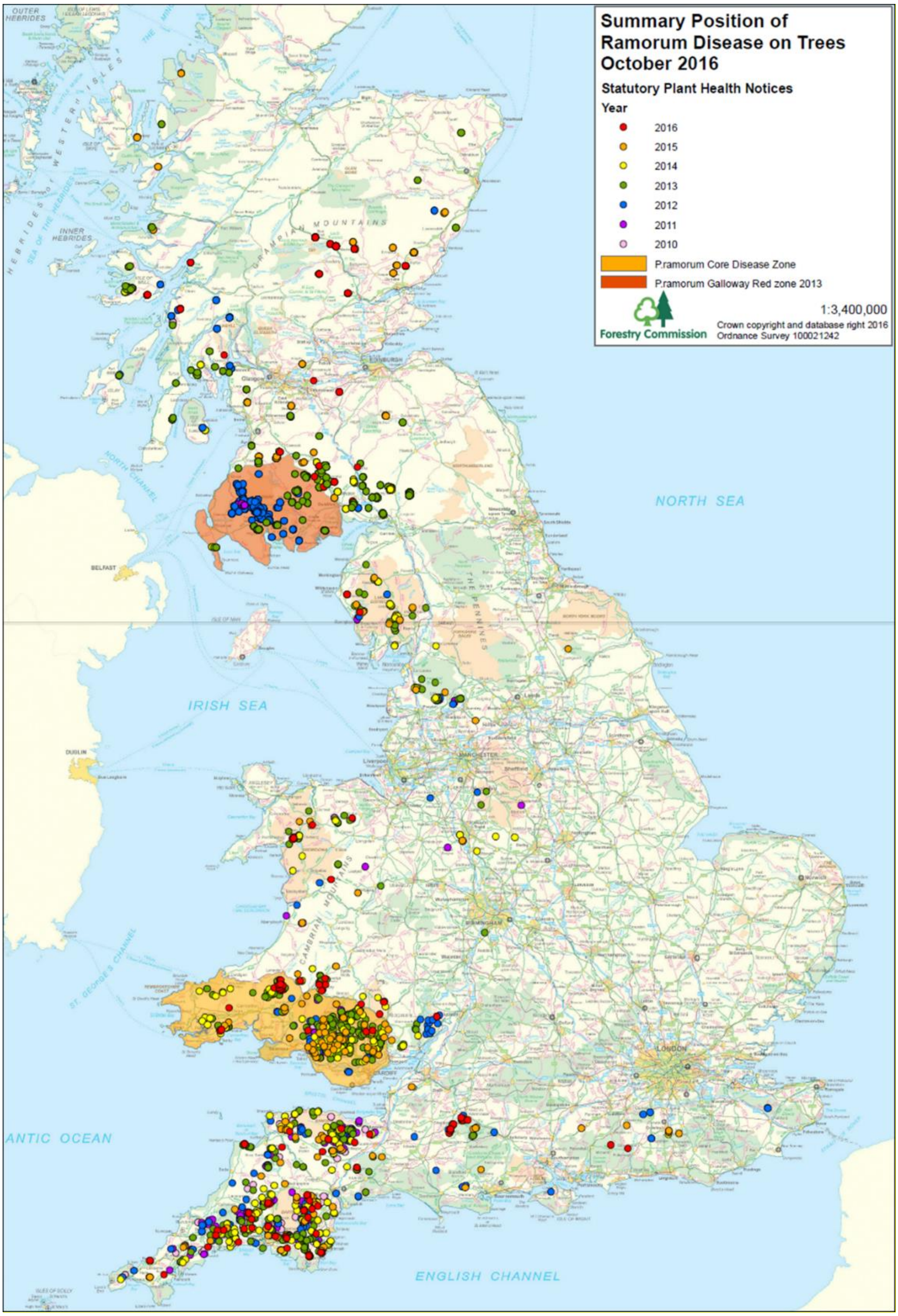


Figure 64. Confirmed or presumed infection in larch trees through their outbreak map (Source: Forestry Commission – outbreak map[90])

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[90] https://forestry.gov.uk/pdf/OMTOutbreakMapOct2016.pdf/$FILE/OMTOutbreakMapOct2016.pdf

5 Natural environment

5.1 Ecological condition of wetland habitats (bogs, fen, marsh)

NE8: Area of blanket bog SSSI with consents in place that allow burning

Introduction

This indicator assesses blanket bog Sites of Special Scientific Interest (SSSI):

- A blanket bog is an extensive mostly flat peat bog formed in cool regions with high rainfall or humidity. Great Britain has about 10-15% of the total global area of blanket bog, making it one of the most important international locations for this habitat[91].
- A site of special scientific interest (SSSI) is a designated area, protected by law[92] to conserve its wildlife or geology. There are certain things land managers can't do on SSSI land without Natural England's (NE) consent, which depends on the terms included in the specific SSSI.

Blanket bog SSSIs require consents in place before the burning of heather and grass can occur. Such consents may be provided by NE. Burning is widely used as a tool in the management of a range of moorland vegetation types including upland peatlands, principally: to create new growth for livestock grazing; to increase the diversity of the age and structure of heather for game management.

Methodology

Data to support this indicator was requested from Natural England (NE). Natural England provided data separately for two different European protected area designations (Natura sites) which largely overlap with Sites of Special Scientific Interest (SSSI) namely, Special Areas of Conservation (SAC), and Special Protection Area (SPA). Natural England also provided an approximation for SSSIs that are not Natura (SAC/ SPA) Sites.

Results

Natural & SSSI burning consents covered 110,700 ha in 2015 (Table 41).

[91] https://www.buglife.org.uk/advice-and-publications/advice-on-managing-bap-habitats/blanket-bog#sthash.WhLbbhKs.dpuf
[92] The Conservation of Habitats and Species Regulations 2010 http://www.legislation.gov.uk/uksi/2010/490/contents/made

Table 41. Area of nature & SSSI with NE burning consents by 'designation' in 2015

Designation of protected area	Area with consents in place that allow burning (hectares)
Special Areas of Conservation	95,000
Special Protection Area	13,700
Non Natura SSSI	2,000
Total Natura & SSSI burning consents	**110,700**

There are 7 Special Areas of Conservation (SACs) in Northern England with burning consents which are all designated for blanket bog, namely; Mires, Kielder-Butterburn; Ingleborough Complex; Moor House - Upper Teesdale; North Pennine Moors; North York Moors; Simonside Hills; South Pennine. Grouse moors were identified as the only places with consent to burn blanket bog habitat in English SACs Moors. These 7 sites represent 98% of the SAC burning consents. From data provided by the EA on peat depth, habitats & burning consents, the maximum area of deep peat with rotational burning consents within SAC protected areas is ~95,000 ha.

If Special Protection Areas (SPAs) are included, then the total will increase by 13,700 ha through the inclusion of the Bowland fells SPA.

Natural England note that on SSSIs that are not Natura Sites there is a small area (~2,000 ha), of consents, however detailed consenting data held focuses on Natura sites, and detailed statistics on non Natura SSSI sites is not available.

Robustness

Burning consents will continue to be provided by NE, and NE will continue to capture data on agreed consents. A change in area with consents over time should be possible to assess in the future through the use of this methodology.

NE9: Area of deep peat covered by catchment-scale restoration programmes

Introduction

There are nearly 1.7 million hectares of deep peat soils in Britain, the great majority of which are bogs (Forestry Commission, 2000). Deep peat soils are defined as soil with a surface peat layer of at least 50 cm depth. The International Union for the Conservation of Nature (IUCN) Commission of Inquiry on Peatlands highlighted in 2011 that around 80% of UK peatlands have been damaged in some form (ICUN, 2011). This degradation is predominantly due to past drainage, fire, afforestation and / or grazing. The UK's deep peatlands are rare habitats of global importance and form a major part of Britain's terrestrial carbon sink, provided these habitats are well managed.

Restoration techniques have been developed and successfully used across the UK[93]. Restoration programmes are generally deployed at a catchment level as excessive drainage is seen as one of the key issues. Restoring damaged peat lands can help mitigate climate change by reducing carbon loss from these systems, whilst creating healthy peatlands that can absorb and lock up carbon dioxide from the atmosphere[93].

Methodology

Data to support this indicator was requested from the Environment Agency (EA). The EA hold information on delivering favourable condition at protected site level e.g. The South Pennines, but not at a catchment level as requested in this indicator. Some of this information may be available online from various sources. There are a large number of individual datasets relating to the restoration of deep peat from a variety of partner organisations including Moorland Partnerships, AoNBs, National Parks, National Trust, Water companies, Natural England Environmental Stewardship. However the data needed to support this indicator are currently piecemeal and difficult to collate and summarise. There should be consolidated data coming out as part of the Department for Business, Energy & Industrial Strategy's Wetland Supplement research project being published this summer/ autumn on areas of peat covered by restoration projects (Defra, pers. comm.).

Results

In a previous report completed by the Environmental Change Institute on behalf of the Adaptation Sub-Committee (ASC) it was found that nearly one-third (1,010 km^2) of upland peat was identified as having a management plan in place that could return protected sites to favourable condition[94]. This represents just over 28% of the total area of upland peat. However, no-recent update was available to modify the original data used.

NE10: Annual greenhouse gas emissions/carbon losses from degraded peatlands

Introduction

Natural England estimates that in their current state English peatlands are responsible for the emission of ~3 million tonnes of CO_2 equivalents a year. However, this report also points out a number of limitations to this assessment including:

- The calculation of the net emission factors is based upon adding up CO_2 equivalent fluxes of the GHGs CO_2, CH_4, N_2O, and Dissolved Organic Carbon (DOC) and, in some cases, Particulate Organic Carbon (POC). It is extremely rare that all of these components are

[93] http://www.iucn-uk-peatlandprogramme.org/publications/demonstrating-success/uk-peatland-restoration-demonstrating-success
[94] Environmental Change Institute et al. (2013) for the Adaptation Sub-Committee.

measured at any one site and hence the calculations carry a large caveat in extrapolating data across sites with different climatic conditions and management regimes.

- The calculations are based upon knowledge of the processes involved rather than on direct measurement. Most studies have been for individual years or short runs of years, and there are almost no studies that can demonstrate changes over longer (decadal) time periods.
- None of the emission factors are based upon whole life cycle analysis, e.g. they don't include emissions due to on-site fuel use during drainage or tree harvesting, etc.

Results

BEIS funded research to implement the IPCC wetland supplement will publish this summer and will set out annual emissions and removals from peat, with a time series based on best available data and latest science to derive tier 2 emission factors – therefore no indicator has been calculated.

NE11: Colour levels (hazen) in raw water for drinking water supplies

Introduction

Upland areas make up 30% of the land area of Great Britain, but supply over 70% of potable water (Watts et al., 2001). A major perceived problem in water sources from upland areas is water colour. Water appears coloured after passing through peat, a major soil type in upland areas (see indicator NE36).

Water colour is considered a major problem for water companies because deterioration in water colour could lead to breaches of European Union drinking water standards. Although coloured water is not considered to be a direct health risk, it may be linked to increased use of water treatment products such as chlorine, which can interact with DOC to produce trihalomethane. Both chlorine and trihalomethane are a concern in terms of human health (Malliarou et al., 2005).

Water companies must comply with the EC maximum colour standard for treated water considered to be equivalent to 20 Hazen (Watts et al., 2001).

Methodology

Water companies monitor the amount of colour in drinking water supplies before it reaches a treatment works ('raw' water). Four water companies, operating in regions with upland peat, were contacted with a request for data on water colour. Two companies, Northumbrian Water and United Utilities, monitoring water in the North East and North West of England, responded providing monitoring data on water colour for a total of 15 sites. The time series for this indicator was set between 2009 and 2016 as complete data sets were available for each site, throughout this period.

Generally, the higher values of colour occur in the autumn although sudden peaks can occur at any time. The monitoring frequency also varies between sites – for some sites data is recorded daily, other sites it is weekly and others are every two weeks. Annual mean values were used for each of the sites to remove the effect of seasonal variations. From the annual mean values for each site, an overall mean was calculated along with the rate of change (slope of increase / decrease). The rate of change was displayed as a percentage change per year calculated by dividing the slope by the mean across all 8 years. A negative value indicates a decreasing trend and a positive value indicates an increasing trend. The rate of change displayed both as a slope and as a percentage change per year (from the mean) was split into five classifications namely; rapid positive change (>2% decrease in colour levels (hazen) per year), positive change (1-2% decrease per year), little change (<1% increase or decrease each year), negative change (1-2% increase per year) and rapid negative change (>2% increase per year).

Results

A summary of colour levels (hazen) across all 15 sites can be seen in Table 42. The average change across all sites was a 1.5% increase (negative change) in colour levels per year.

- Five of the sites show a positive (decreasing) trend in colour levels (hazen) (ranging from 1.2% to 2.9% decrease each year). Three of these sites showed a 'rapid positive change', and two showed a 'positive change'.
- Ten of the sites show a negative (increasing) trend in colour levels (hazen) (ranging from 0.5% to 7.2% increase each year). Seven of these sites showed a 'rapid negative change', two showed a 'negative change' and two showed 'little change'.

Table 42. Summary of colour data across 15 sites – rate of change is calculated based on the slope of the trend line across the time series.

Site	Annual mean values for colour levels (hazen)								Mean	Rate of change / slope	Rate %/yr
	2009	2010	2011	2012	2013	2014	2015	2016			
Alston raw reservoir	6	7	9	6	9	6	5	5	7	-0.29	-4.3%
Arnfield	69	80	74	86	60	80	76	95	77	1.82	2.3%
Ashworth Moor wtw	52	59	40	43	56	47	52	63	52	0.81	1.6%
Buckton castle inlet	65	72	65	68	67	82	87	102	76	4.60	6.0%
Clough bottom wtw	53	56	54	66	52	56	59	66	58	1.20	2.1%
Cowpe wtw	20	22	22	29	25	23	25	31	25	1.05	4.2%
Geltsdale new river intake	45	68	93	71	58	65	78	75	69	1.94	2.8%
Lostock franklaw landgen	48	40	57	57	45	56	73	74	56	4.03	7.2%
Broken Scar	93	88	97	116	82	131	136	145	111	8.00	7.2%
Fontburn	265	228	256	293	175	245	253	234	244	-2.91	-1.2%
Gunnerton	78	85	86	95	62	73	83	74	79	-1.29	-1.6%
Horsley	88	91	121	121	90	105	100	101	102	0.70	0.7%
Lartington	122	111	125	131	91	99	113	107	112	-2.58	-2.3%
Lumley	87	78	80	123	97	82	74	63	86	-2.48	-2.9%
Wear Valley	148	122	144	169	153	170	150	128	148	0.78	0.5%

Classification of rate of change:					
	Rapid positive change		Little change		Rapid negative change
	Positive change				Negative change

With two thirds of the sites showing an increase, this data indicates that there is a general trend towards increasing levels of colour in water in these catchments. However, with such a small sample no overall assumptions can be made.

Robustness

These data sets show good levels of robustness with the potential to get future data sets in subsequent years. A larger sample which includes data from additional water treatment sites, in different regions would constitute a more comprehensive indicator.

NE12: Dissolved Organic Carbon concentrations in upland water bodies

Introduction

The long term monitoring of upland water bodies provides important insight into the biogeochemical and ecological processes that govern natural ecosystems, their condition, and their response to anthropogenically imposed change (Evans et al., 2010).

Concentrations of Dissolved Organic Carbon (DOC) in freshwater rivers and lakes in the UK have increased during the last 15 years, there are a number of potential explanations for this rise including the destabilisation of peatland soils through climate change (Evans et al., 2010), changes in atmospheric deposition chemistry, nitrogen deposition or changes in land use (Monteith et al., 2007).

Methodology

The Upland Water Monitoring Network (UWMN) have ongoing monitoring of DOC at 11 lakes (quarterly) and 12 streams (monthly). Most monitoring started in 1988, with a few sites added in the early 1990s. Two of the sites have only begun to be monitored relatively recently and were therefore not included in this analysis. DOC data (to the end of 2015) for the 21 sites in the network with long-term records were included in this analysis. These sites are located across the UK – 5 in England, 4 in wales, 8 in Scotland and 4 in Northern Ireland, shown in Figure 65.

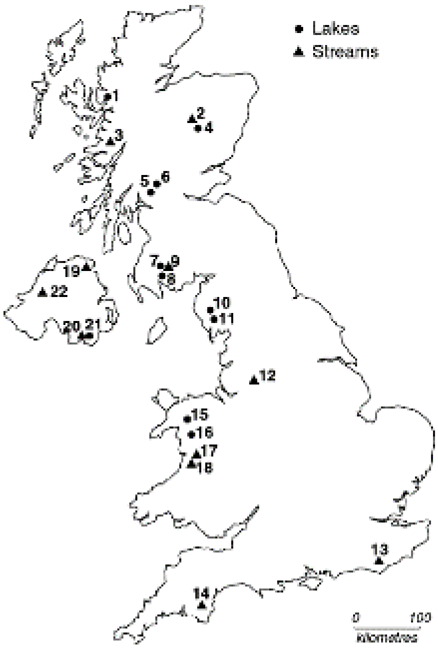

Figure 65. Location of the 22 monitoring sites (numbers corresponding to the names in table X). Source: Evans et al. (2010).

For all sites, the mean annual concentrations were plotted for each site between 1991 and 2015. These figures were then used to assess the rate of change in DOC levels at each of the sites. Rate of change was displayed as a percentage change per year rather than the absolute change. This is because some sites (peatlands) are intrinsically high-DOC, whereas others (e.g. high mountain lakes) are intrinsically low-DOC – so a 0.1 mg/l/yr increase at somewhere like Lochnagar or Scoat Tarn is actually a much bigger change than it might appear (because these sites have a low baseline level of DOC). The method used was to calculate 'change' as %/yr relative to the first 5 years of the series. This will enable the method to be replicated in future years. The rate of change displayed as a percentage change per year was split into five classifications namely; rapid positive change (>2% decrease in DOC per year), positive change (1-2% decrease per year), little change (<1% increase or decrease each year), negative change (1-2% increase per year) and rapid negative change (>2% increase per year).

Results

DOC has increased at all sites and by an average of 3.0% per year (ranging between 0.6% in Beagh's Burn and 6.7% in Lochnager). The average rate of increase in the English sites is slightly higher than the UK average across all sites at 3.7% per year. Over 70% of the sites were classified as a 'rapid negative change' - increasing at a rate of over 2% a year (Table 43).

Table 43. Rate of change in DOC levels across 21 sites (site no. 1 was not included in the analysis as this site is no longer being monitored).

	Site	Sample rate	Site type	Country	Mean (1991-2015)	STDEV	Slope	Mean (1991-1995)	Slope %/yr
2	Allt a'Mharcaidh	Monthly	Stream	Scotland	3.10	1.01	0.073	2.1	3.4%
3	Allt na Coire nan Con	Monthly	Stream	Scotland	5.73	1.37	0.156	3.8	4.1%
4	Lochnagar	Quarterly	Lake	Scotland	1.81	0.78	0.068	1.0	6.7%
5	Loch Chon	Quarterly	Lake	Scotland	4.90	1.25	0.127	3.3	3.9%
6	Loch Tinker	Quarterly	Lake	Scotland	6.10	1.15	0.085	4.7	1.8%
7	Round Loch of Glenhead	Quarterly	Lake	Scotland	4.02	0.84	0.067	3.0	2.2%
8	Loch Grannoch	Quarterly	Lake	Scotland	6.33	1.84	0.208	3.9	5.3%
9	Dargall Lane Burn	Monthly	Stream	Scotland	2.28	0.66	0.052	1.6	3.2%
10	Scoat Tarn	Quarterly	Lake	England	1.53	0.55	0.044	0.9	4.7%
11	Burnmoor Tarn	Quarterly	Lake	England	2.90	0.68	0.052	2.1	2.4%
12	River Etherow	Monthly	Stream	England	8.72	2.78	0.241	4.9	4.9%
13	Old Lodge	Monthly	Stream	England	7.90	3.22	0.249	4.8	5.2%
14	Narrator Brook	Monthly	Stream	England	1.73	0.39	0.017	1.5	1.2%
15	Llyn Llagi	Quarterly	Lake	Wales	3.12	0.53	0.052	2.4	2.2%
16	Llyn Cwm Mynach	Monthly	Stream	Wales	2.85	0.83	0.041	2.6	1.6%
17	Afon Hafren	Monthly	Stream	Wales	2.63	0.68	0.065	1.8	3.6%
18	Afon Gwy	Monthly	Stream	Wales	2.50	0.42	0.026	2.0	1.3%
19	Beagh's Burn	Monthly	Stream	NI	13.34	3.24	0.068	10.6	0.6%
20	Bencrom River	Monthly	Stream	NI	5.20	1.87	0.084	4.0	2.1%
21	Blue Lough	Quarterly	Lake	NI	4.60	1.18	0.077	3.3	2.4%
22	Coneyglen Burn	Monthly	Stream	NI	10.06	2.98	0.078	7.3	1.1%

Classification of rate of change:

	Rapid positive change		Little change		Rapid negative change
	Positive change				Negative change

The indicator shows a consistent increase in DOC across all assessed locations.

Robustness

These 22 sites which are regularly monitored by the UWMN provide the most comprehensive data available on concentrations of DOC in the UK, however, they still only constitute a sample and therefore may not provide a holistic picture. This data set is robust and it is anticipated that monitoring will continue into the future, enabling further updates of this indicator.

5.2 Ecological condition of rivers, lakes, estuaries and coastal waters

NE27: Number of catchments with partnerships in place

Introduction

A catchment is a geographic area defined naturally by surface water hydrology. Working at the catchment level, a catchment partnership is a group that works with key stakeholders to agree and deliver the strategic priorities for the catchment and to support the Environment Agency in developing an appropriate River Basin Management Plan, as required under the Water Framework Directive.

DEFRA have set out a policy framework to encourage the wider adoption of an integrated catchment based approach to improving the quality of our water environment. The catchment based approach aims to establish a catchment partnership in each of England's 83 catchments and the 6 that cross border with Wales. The partnerships drive cost-effective practical delivery of initiatives on the ground, resulting in multiple benefits including improvements to water quality, enhanced biodiversity, reduced flood risk, resilience to climate change and greater community engagement with their local river.

Methodology

For the past three years (2014, 2015 and 2016) the Environment Agency have published a list and map of catchment partnerships in operation as part of the catchment based approach on the Defra website[95]. The boundaries for whole catchments are based on those used in the River Basin Management Plan 2009 to 2015. Some of these catchments have been subdivided leading to partnerships acting at a 'sub-catchment' scale. This document includes a list and map of catchment partnerships in operation including details of who is operating at whole or sub catchment scale.

Results

In 2016 there were 82 whole catchment partnerships across England (including those that cross the border into Wales). These now cover the whole of England as can be seen in Figure 66. As there are only three years of data there is not enough information to discuss a trend in the number of sub catchments (Table 44).

Table 44. The number of catchment and sub catchment partnerships in place.

Year	2013-14	2014-15	2015-16
No. of whole catchments	78	82	82
No. of sub catchments	27	23	24
Total	**105**	**105**	**106**

[95] https://www.gov.uk/government/publications/catchment-partnerships-in-operation-list-and-map

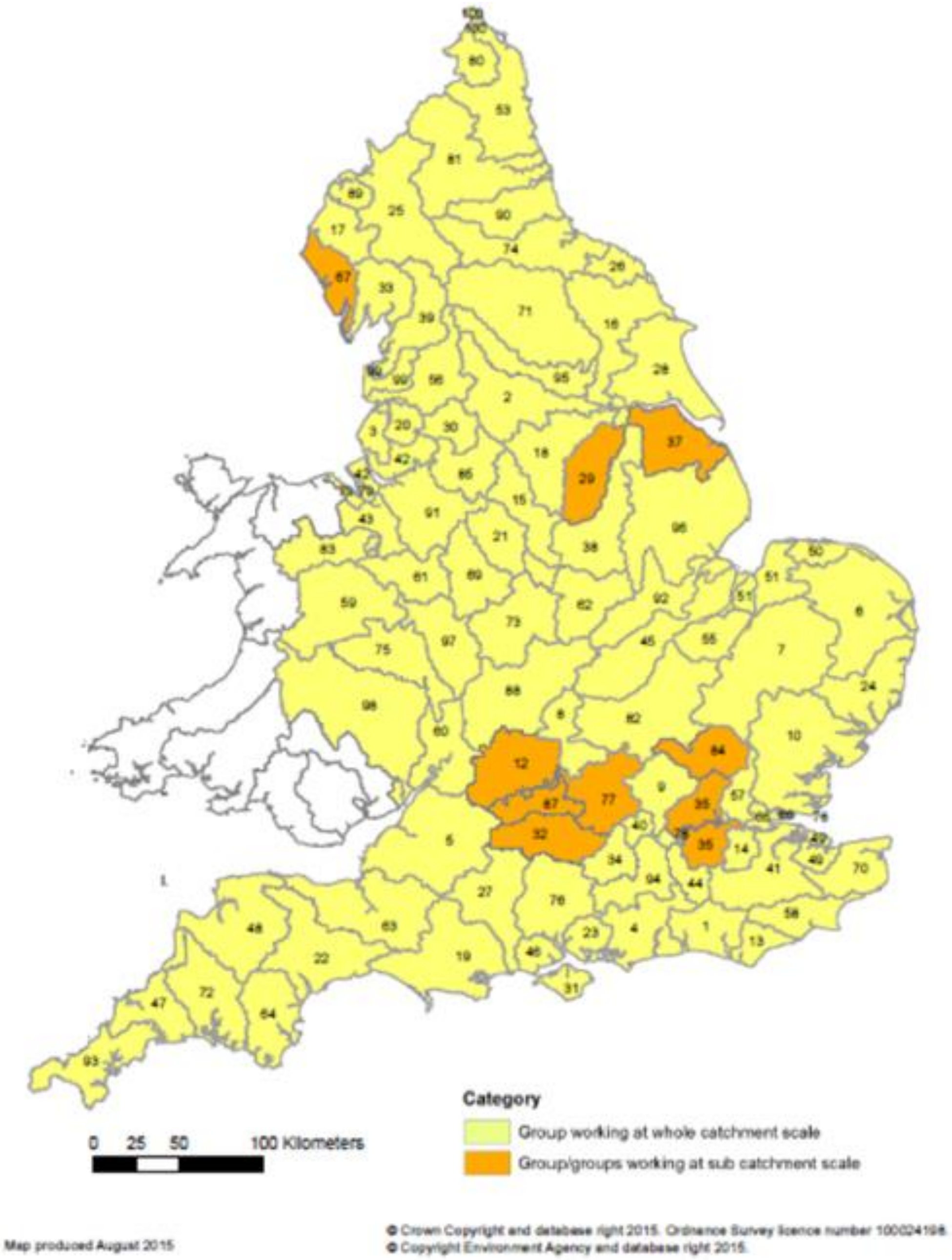

Figure 66. Catchment Partnerships in operation (August 2016). Source: Environment Agency.

Robustness

The data included in this indicator is from a reliable source (Environment Agency). However, at present the time series is insufficiently long to be able to identify trends. It is anticipated that this data will be collected in the future, and therefore that the indicator will be updateable in the future.

NE28: Number of low river flow (Q95) incidents

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

5.3 Ecological condition of marine environment

NE30: Proportion of Marine Protected Areas (SACs/SPAs/SSSIs/MCZs) in unfavourable condition

Introduction

Marine Protected Areas (MPAs) are one of the tools that help to protect the marine environment, whilst also enabling its sustainable use, with the aim of ensuring that it is in a healthy (a.k.a. favourable) condition. In the UK, MPAs are set up primarily for the conservation of marine biodiversity and to protect species and habitats of international or national importance. The main designations of MPAs in the UK are Special Areas of Conservation (SAC), Special Protection Areas (SPA), Sites of Special Scientific Interest (SSSI), Ramsar sites and Marine Conservation Zones (MCZ). The UK also has voluntary MPAs such as Voluntary Marine Conservation Areas (VMCAs) and Voluntary Marine Nature Reserves (VMNRs). JNCC responsible for Marine Protected Areas outside of the 12 nautical mile zone, NE responsible for within 12 miles.

Methodology

ADAS contacted various groups in JNCC, and Natural England requesting information. This indicator requires data on; a) the total area of MPAs in England and, b) the area of these MPAs in unfavourable condition.

Results

The area of marine protected sites in territorial waters (up to the 12 nautical mile limit of NE responsibilities) increased by more 273 percent between 2010 and 2015 to a total area of 1.1 million hectares[96]. This represents 21% of England's cumulative inland waters (Figure 67).

96 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/492530/1__Protected_Sites_2015_Final.pdf

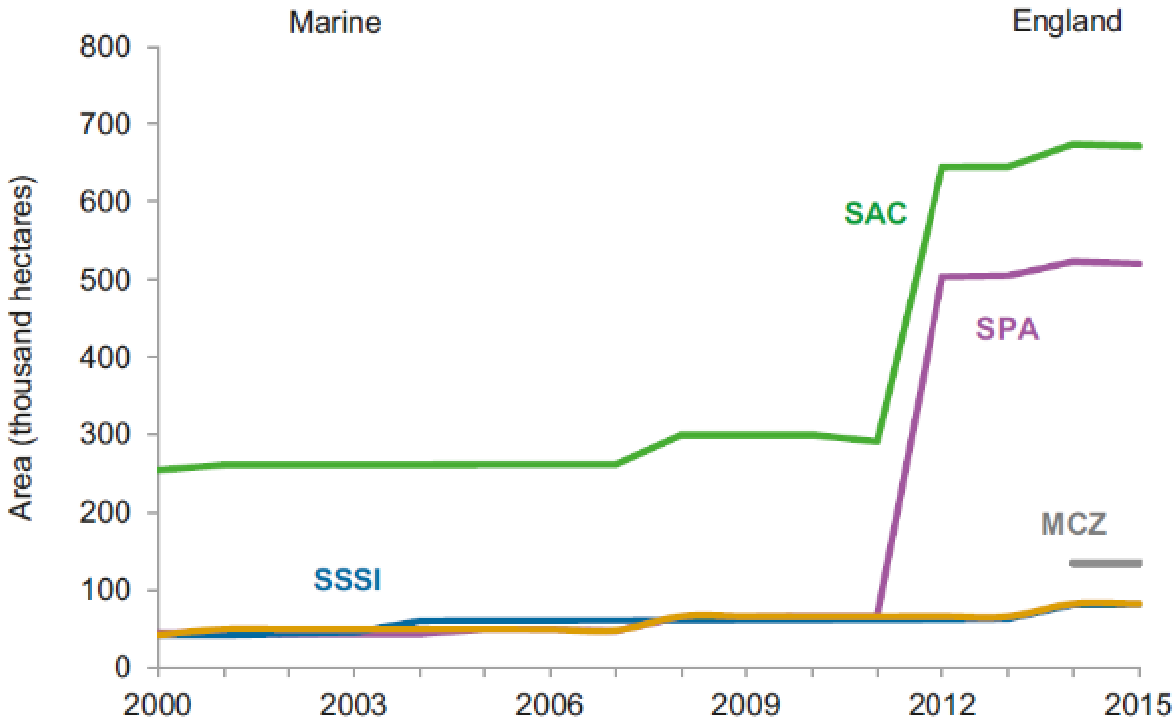

Figure 67: Extent of marine protected sites by designation. Area was assessed in April each year. Source: Natural England.

Most of these areas have been designated in the last 5 years as SAC or SPA. Although some of these sites may have had an initial vulnerability assessment conducted which would have been used to set this general management approach to maintenance or restoration, full condition assessments will not have been conducted on these sites to date and these are not expected to be completed for a number of years. Therefore no data is currently available regarding the condition of these designated sites.

The offshore SPAs and SACs (outside of the 12 nautical mile zone) were also designated recently and although there is information relating to these site's designation, there is no data yet available relating to their condition.

Monitoring data is available for SSSIs which have held their designation for a longer period. However, SSSI's only represent around 60,000 hectares of marine protected sites - a small percentage of the total marine protected area and would not inform a useful indicator.

5.4 Extent of priority habitats

NE35: Change in area of heathland

Introduction

There are 56 habitats recognised as being of 'principle importance' for the conservation of biological diversity in England. Of these habitats three types are heathland, which together represent 16% of the total area of priority habitats in England. Heaths are wide open landscapes dominated by plants such as heathers, gorse and heathland grasses. Heathland vegetation occurs widely on mineral soils and thin peats (<0.5m deep) throughout the uplands and moorlands of the UK.

Heathland is predominantly found in the north of England, and to a lesser extent in the South West (Figure 68). There are three Priority habitats comprising heathland vegetation:

- Lowland heathland - described as a broadly open landscape on impoverished, acidic mineral and shallow peat soil, which is characterised by the presence of plants such as heathers and dwarf gorses covering least 25% of the surface area. The most significant areas for lowland heathland include the counties of Hampshire, Cornwall, Dorset, Surrey, Devon, Staffordshire, Suffolk and Norfolk.
- Upland Heathland – comprises a similar set of species and attributes to Lowland Heathland but is situated below the alpine or montane zone (at about 600–750m) and usually above the upper edge of enclosed agricultural land (generally at around 250–400m). Upland heathland is characterised by the presence of dwarf shrubs covering at least 25% of the surface area.
- Mountain heaths and willow scrub - This habitat occurs in the montane zone above the natural tree-line. It encompasses a diverse range of near-natural vegetation. These are found mostly above 600m in altitude. The full extent of mountain heaths and willow scrub has not been fully surveyed.

The area of heathland and in particular lowland heathland has diminished post-1945, mainly due to the expansion of agriculture, urbanisation and afforestation. The UK has an important proportion (about 20%) of the international total of this habitat (BAP UK, 2010).

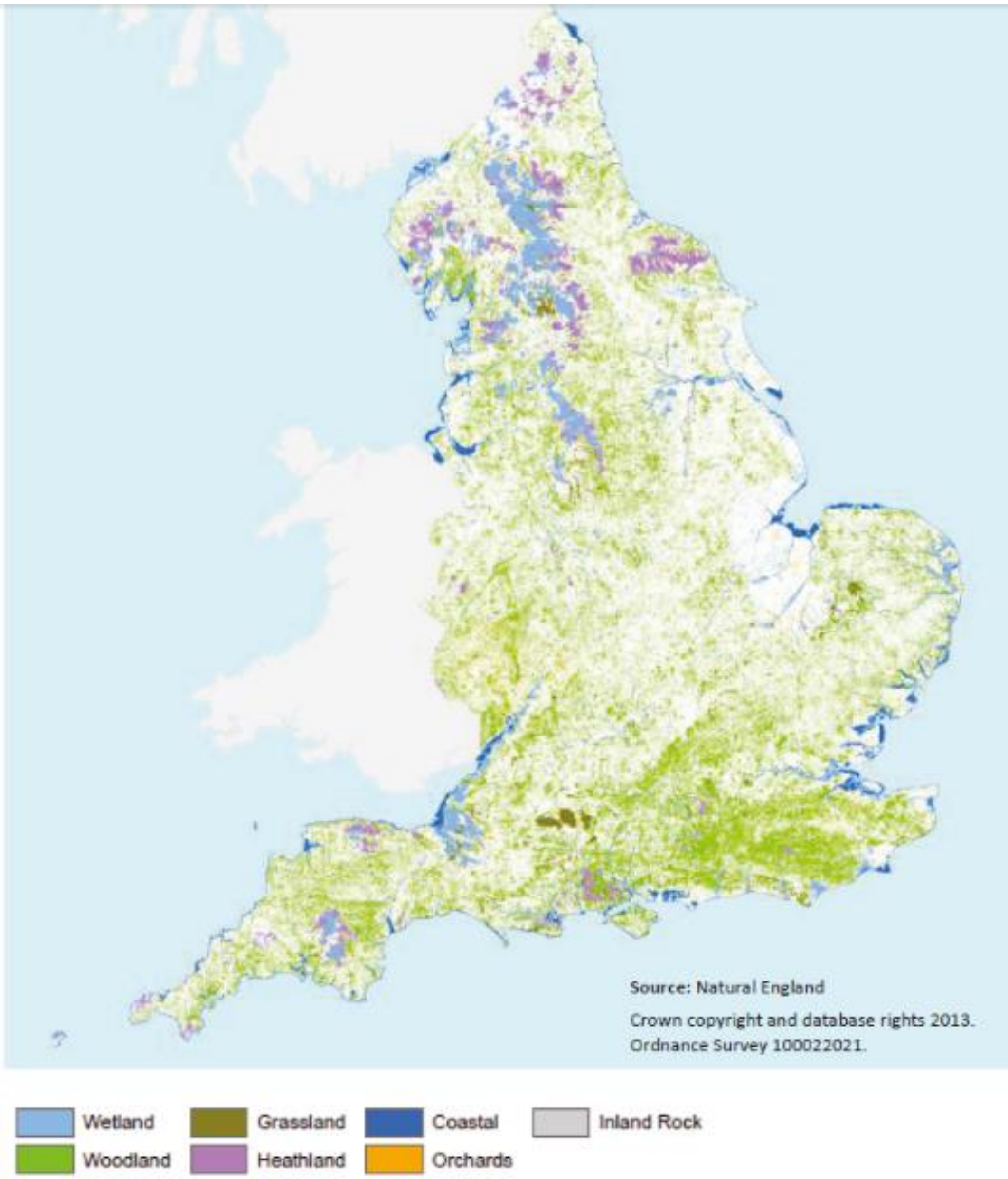

Figure 68: Distribution of habitat type across England. Source: Natural England.

Heathland is a priority habitat for a number of reasons:

- It provides a vital habitat for many species that are not found in other habitats.
- It is valuable in the provision of ecosystem services such as carbon sequestration, climate regulation and the mitigation of flood risk (due to the slowing and absorption of water).

Methodology

Two separate methods were used to calculate the total area of heathland in England:

Method 1

Areas were taken from a report by Natural England from 2015 entitled 'Biodiversity 2020: A Strategy for England's Wildlife & Ecosystem' (DEFRA, 2015). An area was provided in hectares for each of the three types of heathland; lowland heathland, upland heathland and mountain heaths & willow scrub.

The Biodiversity Strategy report figures do not include Fragmented Heaths, which are small isolated patches of heathland. Natural England supplied the figure for Fragmented Heaths.

Method 2

Areas were extracted from Natural England's Priority Habitats' Inventory (PHI) England - version 2.1[97] (2015) – a more up to date data was requested but was not available. This is a spatial dataset that describes the geographic extent and location of Natural Environment and Rural Communities Act (2006) Section 41 habitats of principal importance including both lowland & upland heathland. Values were extracted in km^2 but converted to hectares.

Note: A revised Natural England's Priority Habitat Inventory (PHI) was implemented from November 2014 in order to update the inventory with new information. For consistency the 2015 figures have been produced using the original PHI. However, the baseline may be adjusted in future to better reflect the new information.

Results

Based on the two methods used estimates for English heathland area range from 284,000 ha for just lowland and upland heathland to 306,000ha for all heathland types including an estimate for fragmented heathland (Table 45). There is currently no time series of data so it is not possible to record changes in area, but if subsequent estimates of total area a made using similar approaches these can be compared to this baseline figure.

Table 45: Area of priority heathland in England

Heathland type	Method 1 (ha)	Method 2 (ha)	Difference
Lowland heathland	56,800	56,400	0.7%
Upland heathland	236,900	227,600	3.9%
Mountain heaths and willow scrub	6,200	-	
Fragmented heath	6,000*	-	
Total Heathland	**306,000**	**284,000**	**7.2%**

*Natural England supplied the figure of 6000 hectares for Fragmented Heaths.

Robustness

This indicator provides a current snapshot and not a time series.

97 https://data.gov.uk/dataset/priority-habitat-inventory-england2

A revised Natural England's Priority Habitat Inventory (PHI) was implemented from November 2014 in order to update the inventory with new information. The baseline may need to be adjusted in future to better reflect the new information to reflect the updated inventory.

NE36: Change in area of bog or fen

Introduction

Bogs and fens are both types of wetland commonly found in England. Bogs are wetlands that support vegetation that is usually peat-forming and which receive mineral nutrients principally from precipitation rather than ground water while a fen is a type of wetland fed by ground water and runoff. There are 56 habitats recognised as being of 'principle importance' for the conservation of biological diversity in England. Four of these fall within the category of bog or fen, namely; blanket bog; lowland fens; lowland raised bog; upland flushes, fens and swamps. A description of each of these priority habitats is provided in the UK Biodiversity Action Plan (Maddock et al., 2008). The total area of priority habitats in England is estimated to be approximately 1.9 million hectares[98]. These four habitats combined represent 17% of the total area of priority habitat in England.

Methodology

Two separate methods were used to calculate the total area of bog or fen in England:

Method 1

Areas were taken from a report by Natural England from 2015 entitled 'Biodiversity 2020: A Strategy for England's Wildlife & Ecosystem' (DEFRA, 2015). An area was provided in hectares for each of the four types of wetland that fall within the category of bog or fen, namely; blanket bog; lowland fens; lowland raised bog; upland flushes, fens and swamps.

Method 2

Areas were extracted from Natural England's Priority Habitats' Inventory (PHI) England - version 2.1[99] (2015). This is a spatial dataset that describes the geographic extent and location of Natural Environment and Rural Communities Act (2006) Section 41 habitats of principal importance including blanket bog (BBOG), lowland fens (LFENS) and upland flushes, fens & swamps (UFFSW). Values were extracted in km^2 but converted to hectares.

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98 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/492531/2a__priority_habitats2a_2015_Final.pdf

99 https://data.gov.uk/dataset/priority-habitat-inventory-england2

Note: A change in area can only be calculated when a consistent method is used over a certain time period. Currently this indicator only measures the total area of bog or fen – but over time this method can be used to monitor a change in area.

Results

Estimates for the area of bog and fen in England in 2015 range from 261,000 ha to 323,000 ha (Table 46). There is no time series data to compare to, but if similar assessment are completed in the future using this approach this can form a baseline for comparison.

Table 46: Area of priority bog or fen in England

	Method 1	**Method 2**	**Difference**
Bog or fen type	**Total (ha)**	**Total (ha)**	**%**
Blanket bog	280,000	231,000	18
Lowland fens	22,000	20,300	9
Lowland raised bog	10,000	-	
Upland flushes, fens and swamps	11,000	10,000	7
Total bog and fen	**323,000**	**261,300**	**19**

Robustness

This indicator provides a current snapshot and not a time series.

A revised Natural England's Priority Habitat Inventory (PHI) was implemented from November 2014 in order to update the inventory with new information. The baseline may need to be adjusted in future to better reflect the new information to reflect the updated inventory.

NE37: Change in area of coastal habitats

Introduction

UK coastal habitats are a priority for nature conservation. This is partly due to the variety of specialised species associated with them, but also because of their naturalness, fragility, scarcity and intrinsic appeal[100]. Accordingly, there are seventeen coastal habitat types listed under Annex I of the EU Habitats Directive and six coastal priority habitats listed under the UK Biodiversity Action Plan[98] namely; coastal sand dunes, coastal vegetated shingle, maritime cliff and slope, mudflats, saline lagoons and saltmarsh.

Methodology

To calculate the total area of coastal habitats in England, areas were taken from a report by Natural England from 2015 entitled 'Biodiversity 2020: A Strategy for England's Wildlife &

[100] http://jncc.defra.gov.uk/page-1429

Ecosystem' (DEFRA, 2015). An area was provided in hectares for each of the five types of coastal habitat, namely; coastal sand dunes, coastal vegetated shingle, maritime cliff and slope, mudflats, saline lagoons and saltmarsh.

Note: A change in area can only be calculated when a consistent method is used over a certain time period. Currently this indicator only measures the total area of bog or fen – but over time this method can be used to monitor a change in area.

Results

Based on the Biodiversity 2020 report (Defra, 2015) the combined area of coastal habitat in England in 2015 was approximately 130,000 ha (Table 47 and Figure 69) or roughly 7% of the total area of priority habitat in England. There is no time series data to compare to, but if similar assessment are completed in the future using this approach this can form a baseline for comparison.

Table 47: Area of priority coastal habitat in England

Coastal Habitat	Total (ha)
Coastal sand dunes	10,500
Coastal vegetated shingle	4,100
Maritime cliff and slope	11,500
Mudflats	78,000
Saline lagoons	1,400
Saltmarsh	24,500
Total	**130,000**

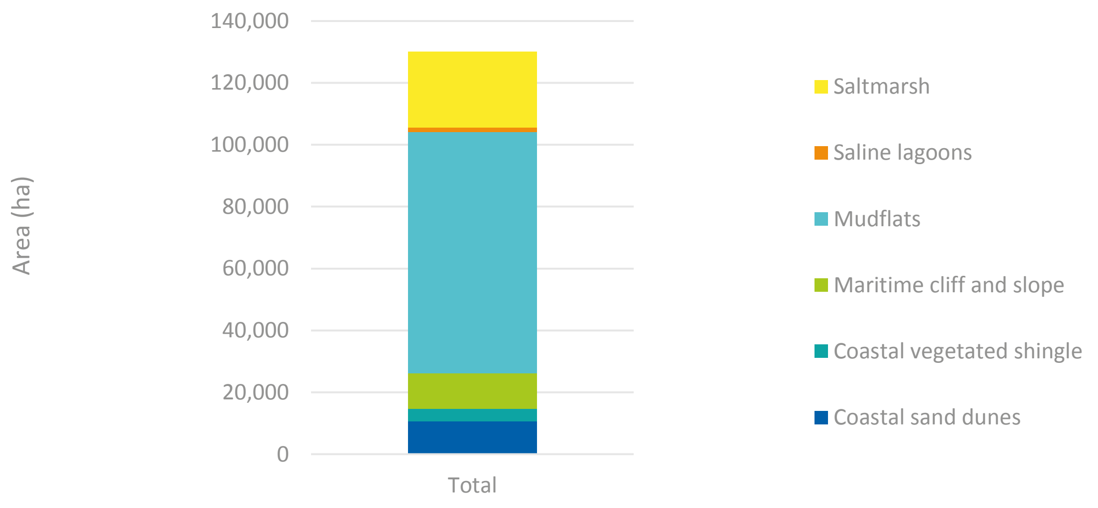

Figure 69. Area of priority coastal habitat in England. Source: ADAS for ASC.

NE38: Area of priority habitat created in order to meet BD2020 Outcome 1B

Introduction

This indicator is in reference to a Defra Strategy document entitled 'Biodiversity 2020: A strategy for England's wildlife and ecosystem services'[101], which sets out a biodiversity strategy for England *"to halt overall biodiversity loss, support healthy well-functioning ecosystems and establish coherent ecological networks, with more and better places for nature for the benefit of wildlife and people".* This strategy includes a set of high-level outcomes to show what achieving this overarching objective by 2020 will mean in practice.

Outcome 1 encompasses the measures that are put in place so that biodiversity is maintained and enhanced, further degradation is halted and where possible, restoration is underway. The outcome is subdivided into four specific outcomes 1A, 1B, 1C, 1D. Outcome 1B is the establishment of more, bigger and less fragmented areas for wildlife, with no net loss of priority habitat and an increase in the overall extent of priority habitats by at least 200,000 ha.

The aim is for the government and it agencies in England to work towards more, better, bigger and joined sites for nature. Such ecological networks are considered to be an effective means to conserve ecosystems and wildlife in environments, such as England, that have become fragmented by human activities. This indicator can be used to evaluate government progress in meeting Outcome 1B of England's biodiversity strategy.

Methodology

Information was requested from DEFRA, Natural England & Wildlife Trusts on current progress towards the government target to increase priority habitats by at least 200,000 ha by 2020.

Results

As of 31 March, 2016, a total of 114,798 ha of new priority habitat had been created through a number of mechanisms as a contribution to Biodiversity 2020 Outcome 1b. This represents 57% of the 200,000 ha target by 2020. As demonstrated in Figure 70, this is slightly ahead of target if we assume a linear increase to 2020.

[101] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69446/pb13583-biodiversity-strategy-2020-111111.pdf

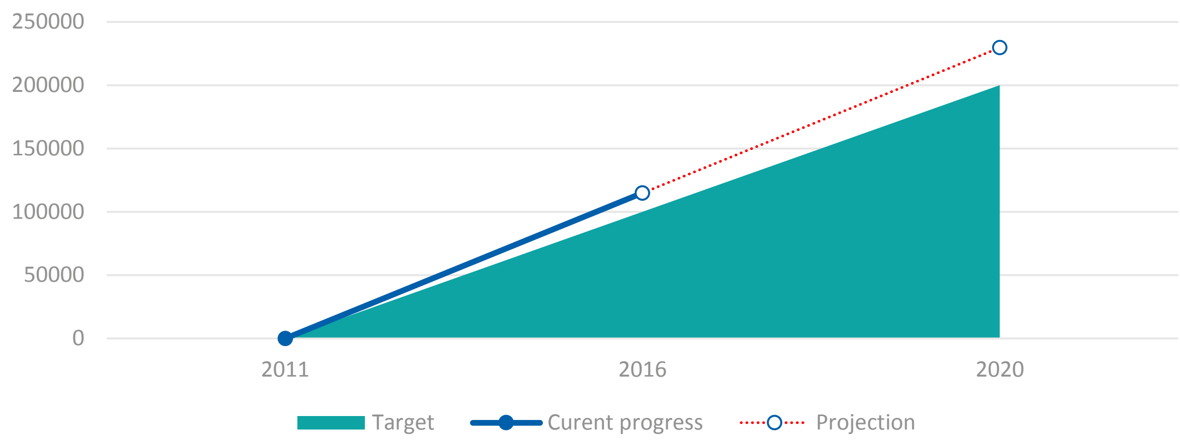

Figure 70. Area of new priority habitat created

The delivery mechanisms contributing to Biodiversity 2020 Outcome 1B and the extent of their contribution is set out in Figure 71. Environmental stewardship creation & restoration together make up 55% of the total. Environmental Stewardship (ES) is a land management scheme run across England. The habitat creation initiatives run by the Forestry Commission at 25% also represents an important mechanism for the creation of priority habitat.

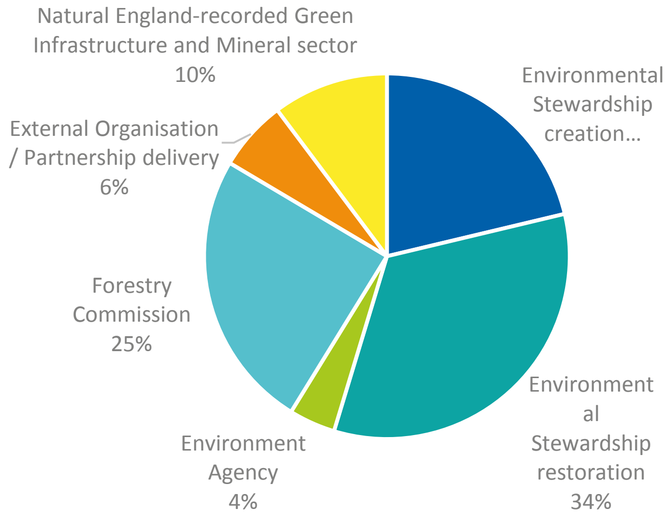

Figure 71. Mechanisms contributing to Biodiversity 2020 Outcome 1B. Source: ADAS for ASC.

Robustness

The figures used in this indicator are held by Natural England and are updated regularly using a consistent methodology – and are available on request. Updated figures for priority habitat creation under the Biodiversity 2020 outcomes will be available from Natural England in April 2017.

5.5 Coherence of ecological networks

NE41: Area covered by 'landscape-scale' conservation initiatives

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

NE42: Habitat connectivity in the wider countryside

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

6 Business

6.1 Business impacts from severe weather

BUS5: Proportion/number of businesses at risk of flooding taking up property-level flood protection measures

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

6.2 Water demand by industry

BUS12: Water abstraction and consumption of public water supply by industry

Introduction

Climate forecasts for higher temperatures and reduced rainfall in the summer increases the risk of stress on already scarce water resources when they are needed the most[102]. Records of water abstraction licences are held in the National Abstraction Licensing Database (NALD). The responsible data holder is the Environment Agency (and Natural Resources Wales). This dataset is not currently available as open data as some of the information is considered confidential. The Department for Environment, Food & Rural Affairs (DEFRA) provide summary information from the NALD on their website in the form of water abstraction tables. Data on the number of licenses held and estimates of average abstraction in millions of cubic metres are presented for non-tidal waters (groundwater and non-tidal surface waters) and tidal waters, and by category.

Methodology

Data was extracted from DEFRA's water abstraction tables (last updated 3 February 2016). The table used was entitled 'estimated abstractions from all sources except tidal by purpose and Environment Agency/NRW charge region: 2000 – 2014'. The version excluding tidal was selected as this indicator only considers fresh water use. The abstraction figures for 'other industry' for England were extracted from these tables (Table 48). This includes water abstracted by industry – but does not include water abstracted for the purpose of electricity generation.

Results

In 2014, estimated abstractions for the purposes of 'other industry' made up just under 9% of the total estimated abstractions from all sources (except tidal) in England. No specific definition of what is included under 'other industry' was found, however, it is thought to incorporate all other industry apart from the 'electricity supply industry'.

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102 http://ukclimateprojections.metoffice.gov.uk/21684

Table 48: Estimated abstractions from all sources 'except tidal' for other industry in England: 2000 – 2014.

Estimated abstractions from all sources 'except tidal' for other industry in England: 2000 – 2014. Units: million cubic metres								
Year	2000	2001	2002	2003	2004	2005	2006	2007
Abstraction	1357	1028	1082	1513	1462	1371	1174	819
Year	2008	2009	2010	2011	2012	2013	2014	
Abstraction	958	1061	762	618	983	726	848	

In 2014, water abstraction by industry from freshwater sources was 848 million cubic meters (Table 48). This is a 37% decrease from other industry abstractions in 2000 (1,357 million cubic meters), shown in Figure 72. This decreasing trend corresponds to an annual decrease of over 44 million cubic metres. There could be a number of possible drivers for this including the closure of water intensive industries, improved water efficiency or changes to the abstraction licencing – but any further analysis would be purely speculative in the absence of a more detailed breakdown by 'use description'.

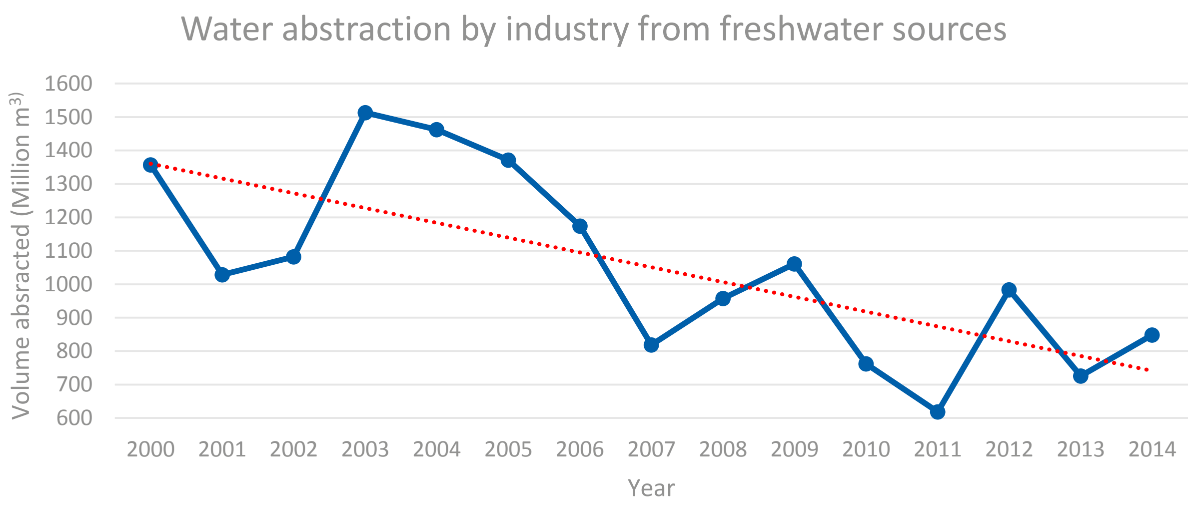

Figure 72: Estimated abstractions from all sources except tidal for industry in England for 'other industry': 2000 – 2014. Source: DEFRA ENV15 - Water abstraction tables (last updated 3 February 2016). Source: ADAS for ASC.

Robustness

This dataset was updated in February 2016, but only includes data between 2000 and 2014. This dataset is updated regularly and should incorporate more recent data as it becomes available.

BUS15: Number of businesses affected by Hands off Flow conditions

Introduction

Water can be abstracted in England from groundwater, surface water, or tidal water, subject to the appropriate abstraction licence, which details what is permitted, such as how much water is allowed to be abstracted and at what times. Records of water abstraction licences are held in the

National Abstraction Licensing Database (NALD). The responsible data holder in England is the Environment Agency.

Water abstraction from groundwater sources, surface water sources and tidal water sources are split into three sizes of abstraction[103]:

- Small size of abstraction - the licence allows a maximum of 100 m^3 to be abstracted daily, within the permitted period, from the permitted source.
- Medium size of abstraction - the licence allows a maximum of 2,499 m^3 to be abstracted daily, within the permitted period, from the permitted source.
- Large size of abstraction - the licence allows abstraction over 2,500 m^3 daily, within the permitted period, from the permitted source.

In addition to the permitted abstraction limits, some licences are subject to Hands off Flow (HOF) conditions. This means the temporary cessation of abstractions when the source flow or level falls below a particular threshold. There are three types of cessation condition that can be applied to a licence, the level of the source (CES-LEV), the groundwater level of the source (CES-GWL) and the source flow (CES-FLOW),

This indicator assesses the number of licences (and thus an indication of the number of businesses) that are affected by HOF conditions in England, as well as the total maximum annual authorised quantity that can be abstracted under the licences (m3), subject to HOF.

Methodology

Two datasets were obtained from the Environment Agency, one with information on abstraction licences and the authorised maximum annual and daily quantity (m^3) permitted, the second with details on those licences subject to HOF conditions.

A total of 17,907 individual abstraction licences with authorised quantities were provided by the EA for England and Wales, based on current data stored on EA systems in February 2017 for all records. These licences were split out to provide England only regions which resulted in 17,466 licences. The licences primary description for abstraction use were associated with either agriculture, water supply, industrial, commercial and public services, amenity, environmental and production of energy.

Using Excel, lookup tables were created between the two spreadsheets to identify which licences were subject to HOF for the three types (CES-LEV, CES-GWL and CES-FLOW), the English region the licence was permitted in, and the maximum annual and daily quantities permitted in normal conditions.

[103] http://apps.environment-agency.gov.uk/wiyby/151261.aspx

Results

A total of 17,466 abstraction licences in England were included in the dataset, of which 13,214 abstraction licences had no HOF conditions linked to them, whilst the other 4,252 abstraction licences were permitted, subject to HOF conditions. Of these, 3,211 were subject to HOF linked to source flow, 939 were linked to source level, and 102 were linked to groundwater source level, shown in Figure 73.

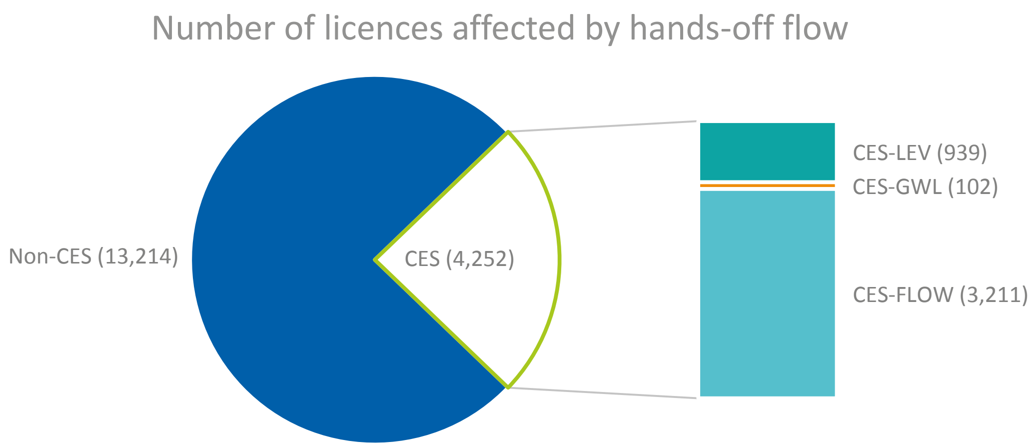

Figure 73. Number of licences in England which are subject to cessation or HOF conditions, due to either source level (CES-LEV), source flow (CES-FLOW) or groundwater source level (CES-GWL). Source: ADAS for ASC.

It is not clear whether these abstraction licences cover all businesses, or whether all licences assessed were for business use (as opposed to e.g. residential use). Nevertheless, it suggests that approximately a quarter of businesses in England, which abstract water, are subject to HOF.

The proportion of abstraction licences subject to HOF varies between regions, with the Thames region exhibiting the lowest proportion (12%) and the Anglian region exhibiting the greatest proportion (33%), shown in Figure 74.

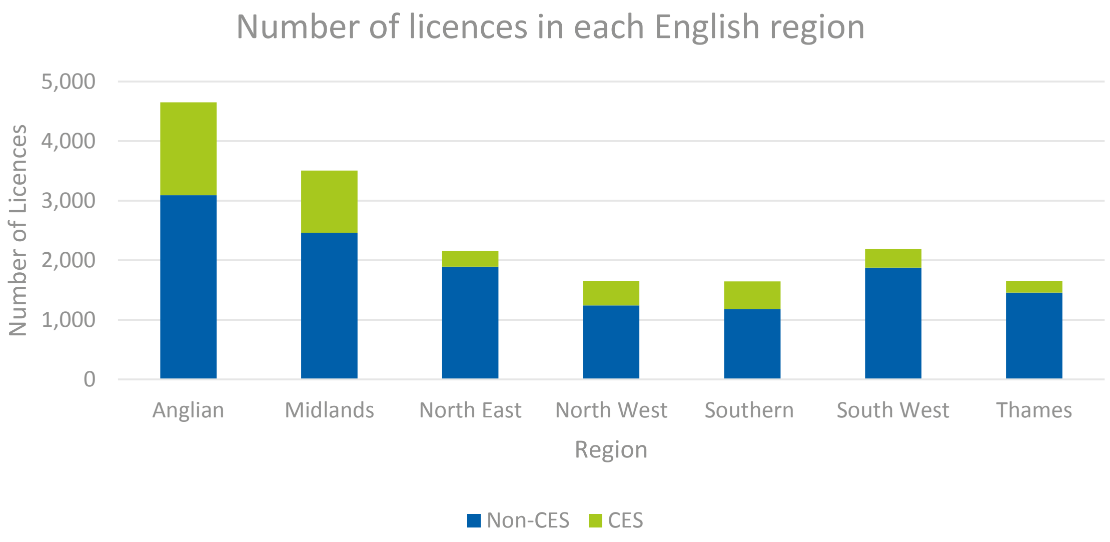

Figure 74. Number of licences in each English region, showing the split between those with normal abstraction conditions, and those subject to cessation (CES) or hands off flow (HOF). Source: ADAS for ASC.

The total maximum annual quantity permitted for abstraction varies by region, from 4.6 billion m^3 in the South West, 5.9 billion m^3 in Thames, 6.9 billion m^3 in Anglian, 7.0 billion m^3 in North West, 7.8 billion m^3 in North East, 7.9 billion m^3 in Midlands to 8.6 billion m^3 in the Southern region. Figure 75 shows the split by region, of the maximum annual quantity approved for abstraction for licences subject to, and not subject to HOF. In the southern region, despite 28% of abstraction licences being subject to HOF, only 5%, (0.4 billion m^3) of the total annual quantity permitted for abstraction is affected by HOF.

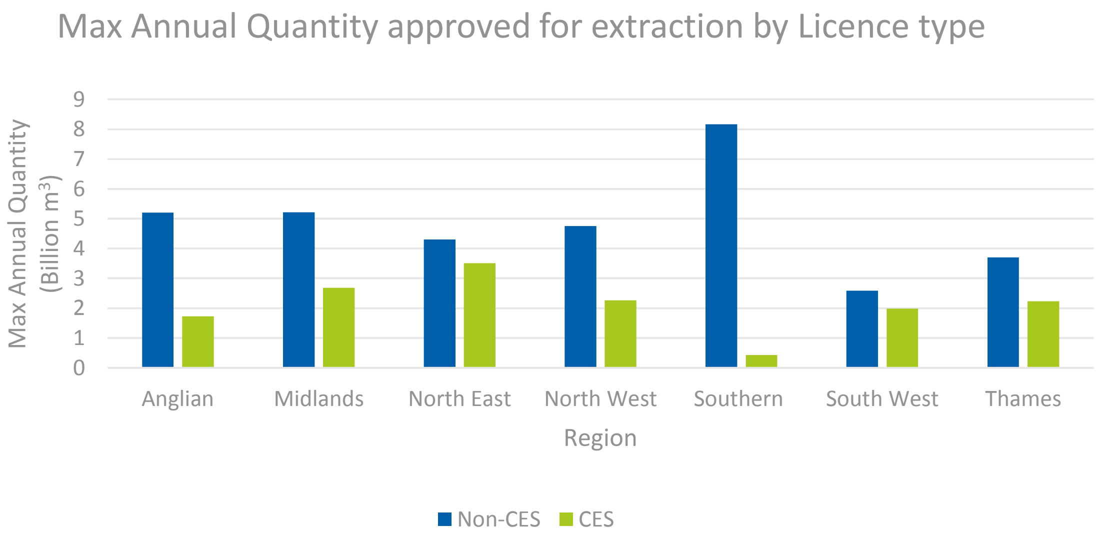

Figure 75. Maximum annual quantity (billion m^3) by region approved for abstraction under current licences, split by those licences subject to, and not subject to cessation (CES) or hands off flow (HOF). Source: ADAS for ASC.

Robustness

The Environment Agency hold good records on abstraction licences and permitted quantities authorised for extraction. The data is not open access, but can be obtained at specific request to the EA and with an appropriate licence. The indicator cannot provide a direct indication to the number of businesses affected by HOF, but gives a good indication of those that are, for uses outlined above.

The dataset provided by the EA was subject to the following information warning and caveats:

- Information provided is based on that available at the time of preparation (24 February 2017). Timing of licence renewals and updates to the dataset may mean at any one point in time not all current live licences are listed. For all licences in the data set details of the current version are given.
- Where the same water abstraction licence number was listed multiple times it means the licence authorises abstraction from multiple points and/or for multiple purposes.
- Maximum annual quantity does not take into account any aggregate quantity conditions which may restrict abstraction.

BUS16: Uptake of water efficiency measures by water-intensive industries

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

6.3 Business opportunities from climate change

BUS18: Number of patents registered by UK companies for adaptation technologies and products each year

Indicator not updated due to relevant data not being identified, or datasets not being available or accessible within the timescales of the project.

X1: Number of wine producing vineyards

Introduction

According to the Organisation of Vine and Wine (2016) Statistical Report on World Vitiviniculture, the global area under vines, was estimated at 7.5 million hectares in 2015. Since 2000, the world's total vineyard surface area has been decreasing, mainly due to the reduction in area of European vineyards.

It is expected that changes in global climate will impact some wine producing regions with direct and, sometimes, quite severe implications for both vineyard management and wineries (Mozell and Thach, 2014). The projected shift in mean temperatures is expected to move premium grape growing regions out of areas currently devoted to that activity and simultaneously cause a shift in current grape variety cultivation. For example, model projections indicate that viticulture suitability will decline in many traditional wine-producing regions (e.g. the Bordeaux and Rhône valley regions in France and Tuscany in Italy) by 2050, and increase in more northern regions in North America and Europe (Hannah et al., 2013).

Shifts in global and regional climate may, therefore, create more favourable growing conditions for vineyards in areas that were not previously deemed as favourable, such as England. This indicator shows how the number of wine producing vineyards, and hectares in production has changed in England and Wales. It should be noted that economic influences will also impact on the expansion or contraction of the industry.

Methodology

Data was available from UK vineyards statistics (May 2016) for the period 1994 – 2015 on the English Wine Producers Website[104], whilst the FSA had production data available for the period from 2004-2015. The UK vineyard stats for 2013 -2015 were incomplete and therefore for this period the FSA statistics were used to complete the data set. For earlier years the FSA & UK Vineyards Statistics were consistent with one another.

Data was also provided directly by the Food Standards Agency for 2004 to 2015. Figures for 2004 to 2012 support the data provided by UK Vineyards Stats (May 2016) summary table. Whilst the 2013-2015 data was used on its own to replace the incomplete UK Vineyards Stats (May 2016) data for those years.

Total time series of data used for analysis was 1994 to 2015. The data provided by both sources was originally sourced through annual harvest and production declarations provided to the Food Standards Agency from commercial vineyards.

Results

For the 2015 wine year there were 502 commercial vineyards (comprising 133 wine producers) in England and Wales, with an estimated 1,839 hectares in production, shown in Figure 76. In addition, there were 87 vineyards which were classified as hobby vineyards as their production was not sold or recorded and around 49 abandoned vineyards.

The majority of commercial vineyard plantings were situated in South East England with approximately 1186 hectares under vine in Kent, East and West Sussex, Surrey, Hampshire, and the Isle of Wight. There were approximately 235 hectares in the South West (Cornwall, Devon, Dorset, Somerset Wiltshire and Gloucestershire).

The number of active vineyards in England and Wales went through a period of decline between 1994 and 2002/3, decreasing by 23% from a peak of 435 vineyards in 1994 to a low of 333 vineyards in 2002/3. However, the area (ha) of production remained relatively stable during this

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

period, ranging between 733 and 842 ha a year, indicating consolidation of smaller businesses into larger ones, rather than any change in production.

Since 2003, the number of vineyards have typically increased year on year, reaching 502 vineyards in 2015. The hectares in production has more than doubled in the last decade from 756 ha in 2003 to 1,839 ha in 2015. There is no indication in the data sets 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.

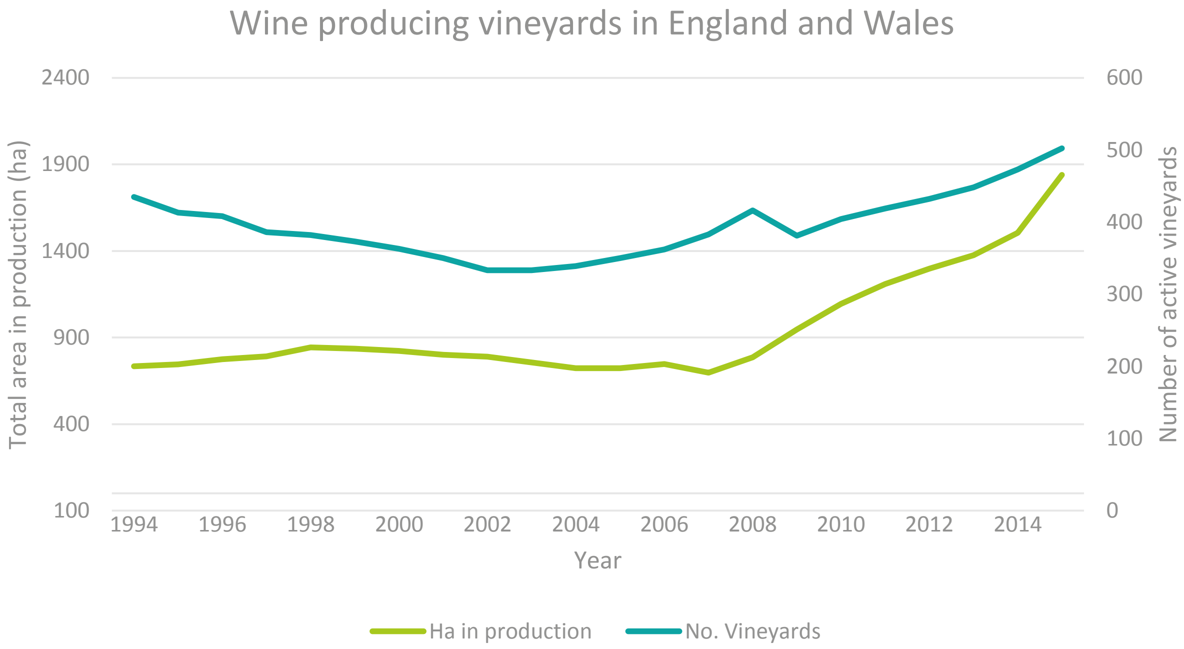

Figure 76. Number of wine producing vineyards and hectares in production in England and Wales from 1994 to 2015. Source: ADAS for ASC.

Robustness

The data provided by the Food Standards Agency is fairly robust and provides a good indicator of change over time. The original source of data comes from annual declarations on a survey from commercial vineyard growers, therefore 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 allowing for future updates of the data set.

X4: Rates of inspection and enforcement of basic payment schemes

The basic payment scheme (BPS) is the biggest rural grant and payment scheme in the European Union and is designed to help the farming industry meet a range of environmental and food safety criteria whilst maintaining an economically viable business. It replaced the Single Payment Scheme in 2015. Farmers apply once a year, normally in May, with payments released from December. The scheme applies to the holding and is aimed at farmers who meet the Rural

Payments Agencies requirements which are passed down through EU legislation. The claimant must produce, rear or grow agricultural products for a farming purpose to qualify and prove themselves as an 'active farmer'. In addition claimants must farm a minimum of 5 hectares of land. During 2015, there were approximately 87,000 UK claimants for BPS (NFU, 2016).

Greening payments are incorporated into the BPS, which encompasses areas such as crop diversification (the 3 crop rule), permanent grassland and ecological focus areas. In order for farmers to gain BPS payments they must demonstrate compliance to all required standards. To monitor compliance, inspections are carried out by the RPA and the Animal and Plant Health Agency (APHA) on 1% of claimants for BPS, 1% of claimants for rural development agreements and 1% of claimants who keep farmed animals every year. Inspections consist of either a visit on farm in person or through aerial and satellite images and photography, advanced notice does not need to be provided. Farmers chosen for inspection must allow the inspector (and anyone with them) to check their land, animals, storage facilities and farm records. If the inspection finds that the rules aren't being followed, there may be reductions and penalties applied to the BPS payment. In addition the RPA will also inspect to make sure cross compliance rules are being followed and can enforce penalties for non-compliance.

Farmers are inspected against set criteria, there are numerous requirements that must be met but are encompassed under the two titles; Good Agricultural and Environmental Conditions (GAEC) and statutory management requirements (SMR). Although these requirements are either a simple pass or fail, if a farm receives a fail it will result in a deduction of BPS. Deductions largely depend on the extent of the failure, if multiple failures are found or a failure is severe it could result in a complete loss of BPS payment to the farmer.

This indicator assesses the rates of inspection and enforcement of basic payment schemes.

Methodology

In order to gain figures to assess this indicator a request for information was put into the information rights team accessed through the government website. The request for information was to identify cross compliance inspection statistics and the resulting reductions in BPS payments. Information was provided from 2006 – 2015 on how many failures were found to the relevant criteria (SMR/GAEC) and the resulting penalties imposed. The data does not specifically identify the number of inspections undertaken.

Results

Inspection rates

No detailed data was provided as part of the freedom of information request on the number of claimants and the number of inspections on claimants that take place on an annual basis. Annual inspections should take place on 1% of claimants for BPS, 1% of claimants for rural development agreements and 1% of claimants who keep farmed animals every year on UK farms (Defra, 2016a), and therefore there should be data available to demonstrate that these targets have been met. Following the 1% inspection statistics this would mean a minimum of 870 farms were inspected per category.

The data provided by the RPA in response to our freedom of information request does not contain details of the total number of inspections nor the number of UK BPS entrants for each year, although a UK report by NFU (2016), estimated that there were approximately 87,000 UK BPS entrants for 2015. The number of inspections are instead broken down by number of cross compliance inspections for each of the separate requirements that must be met under both the GAEC's and the SMRs. When an inspector visits a farm they will conduct inspections on one or more GAECs and SMRs depending upon which apply to the specific holding(s). Inspectors take a risk based approach to setting the scope of their inspections and they will use any necessary information from the Environment Agency, the Forestry Commission, Natural England, and Veterinary Medicines Directorate to guide the process. This leads to the some GAEC's and the SMRs being inspected more often than others (Figure 77).

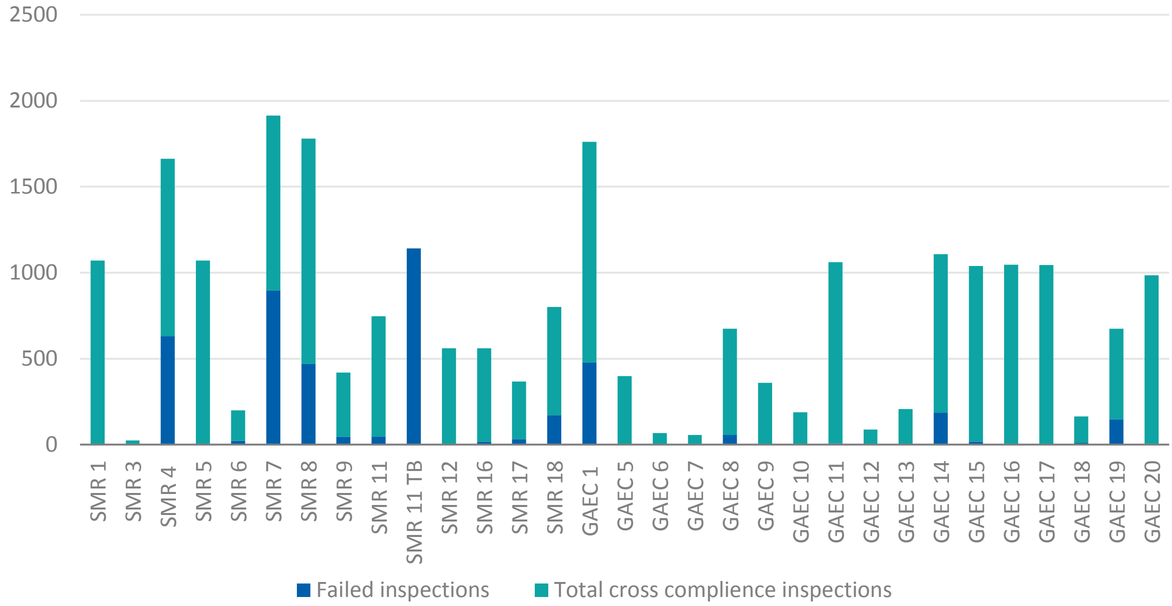

Figure 77: Total number of cross compliance inspections in 2014 including proportion of inspections failed by GAEC and the SMR. SMR11 TB relates to an inspection focus on targeting of Tuberculosis compliance in that year (Source: Rural Payments Agency (RPA), freedom of information request). Source: ADAS for ASC.

Claimants won't always receive advance warming of visits. Claimants who do not allow an inspector onto their land, or do not co-operate will automatically lose all their BPS payments. Depending on which GAEC's and SMRs apply to their holding, claimants may be inspected by one or more control authority e.g. Rural Payments Agency and the Animal and Plant Health Agency (https://www.gov.uk/guidance/guide-to-cross-compliance-in-england-2016/inspections).

Failures

There are a variety of reasons why farmers may fail their inspections. The most frequent reason for failures were under SMR 7 – Cattle Identification and registration. However, other common failures were more relevant to climate adaptation such as SMR4 Nitrate Vulnerable Zones, GAEC 1 – Soil protection review and GAEC 14 – Protection of hedgerows and watercourses. Both SMR 4 and GAEC 1 have shown increased rates of failure over the five years from 2010-2014, with GAEC 14 also showing modest increases in failures. SMR 4 failures occurred on an estimated 20-25% of inspected farms in 2013 and 2014.

Rural Payments Agency (2017) data demonstrates the top re-occurring cross compliance failures and can be seen in Figure 78. Data does not include 2015 due to the change of requirement names of SMRs and GAECs during the change from SPS to BPS, details of specific SMRs and GAECS mentioned are as follows:

- SMR 4 – Nitrate vulnerable zones
- SMR 7 – Cattle identification and registration
- SMR 11 – Food and feed law
- GAEC 1 – Soil protection review
- GAEC 14 – Protection of hedgerows and watercourses

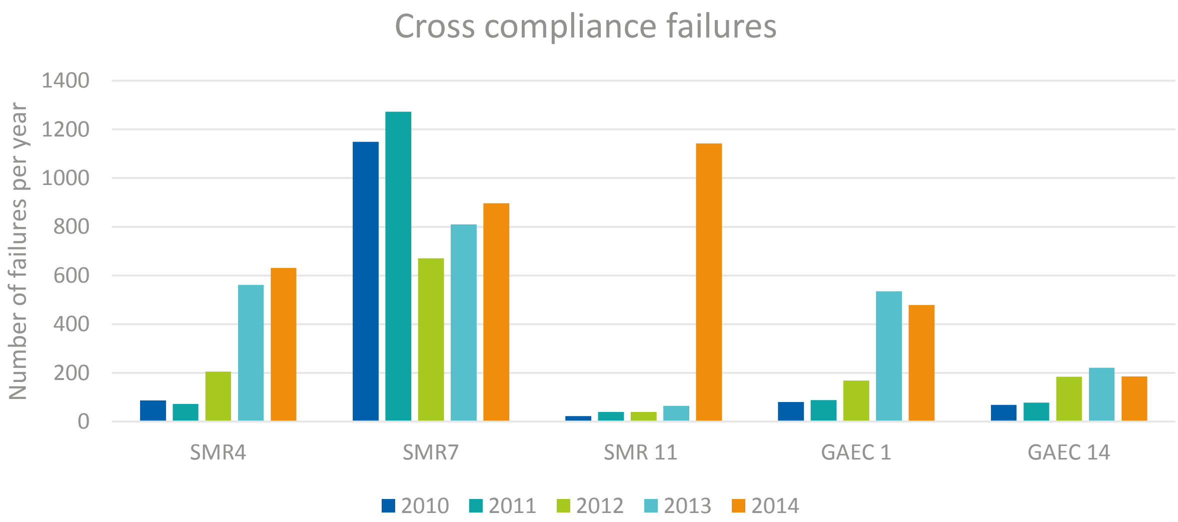

Figure 78. Number of cross compliance failures found by cause, 2010 - 2014 – Rural Payments Agency (RPA), freedom of information request. Source: ADAS for ASC.

Cattle identification SMR 7 failures were the main cause of failures in all years except for 2014, where SMR 11 (food and feed law) recorded high numbers of failures (SMR 11 TB), shown in Figure 77 and 78. This is linked to a targeting of Tuberculosis (TB) compliance in that year. Of those failures that relate more directly to climate change risk and adaptation it must be noted that in recent years Nitrate vulnerable zones SMR 4 and Soil protection reviews GAEC1 have shown an increasing number of failures, although it is unclear whether this is because more holdings have been inspected, or whether a higher proportion of inspected holdings are failing. SMR 4 increased from 205 failures in 2012 to 562 in 2013, with GAEC 1 demonstrating a similar pattern of increase with 169 failures in 2012 to 535 failures in 2013. GAEC 14, although not demonstrating high numbers of failures has consistently appeared throughout 2014 – 2010, the most common failure here can be pointed due to the farmer cultivating or applying fertilisers or pesticides in protection zones or around hedgerows and watercourses.

2015 failures

It is difficult to compare the 2015 failures with previous years, due to a number of the cross compliance standards changing from SPS to BPS. Throughout 2015 the food and feed law (Specifically TB requirements), Cattle identification and registration and Nitrogen vulnerable zones remained the highest failures. GAEC 1 which had previously shown an increase in failures for 2014 and 2013 reduced from 478 failures in 2014 to just 215 in 2015.

Deductions

Deductions for all failures can be seen in Figure 79. It is difficult to compare the 2015 failures with previous years, due to a number of the cross compliance standards changing from SPS to BPS, although figures show that the number of failures in 2015 came to a total of 3,788. There was an increase (of unknown quantity) in the number of inspections in 2015 (NFU, 2017), due to the high number of failures for SMR 4 (Nitrate Vulnerable Zones) and SMR 7 (Cattle ID) in 2014. Despite an increase in the number of inspections in 2015 compared to 2014 there was a decrease in the number of failures (4,395 failures in 2014). Figure two demonstrates the % deduction from a farm's total BPS payment as a result of failures, farms can fail on multiple requirements and each % deduction is based on the individual failure. As a result farms that have failed on multiple requirements have multiple deductions and have been counted more than once. If a farm receives a warning letter, no deduction is made.

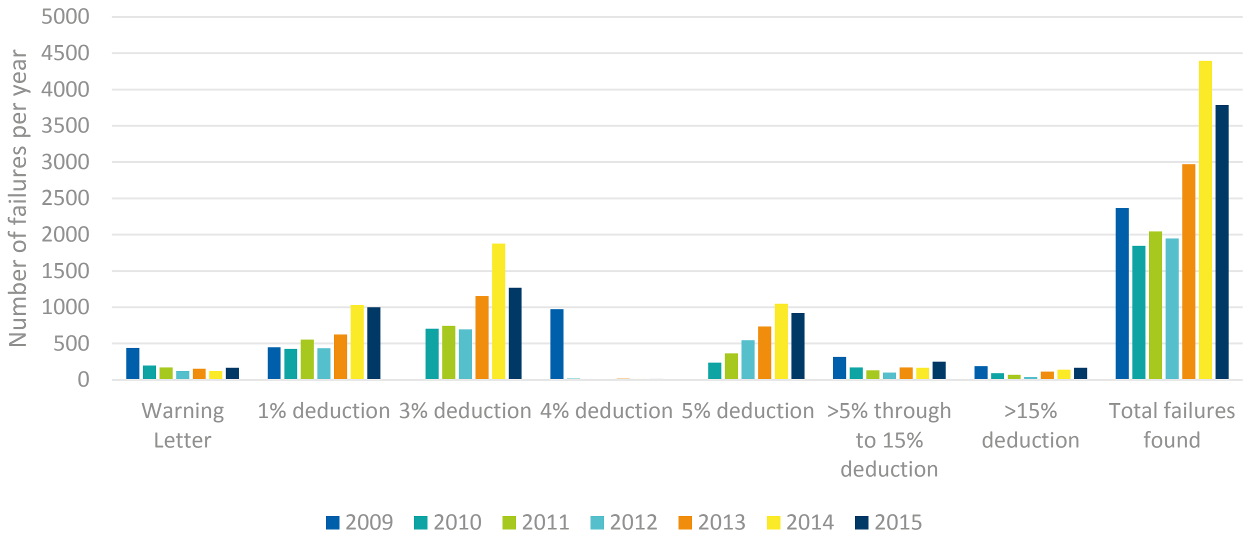

Figure 79. Cross compliance inspection statistics and reductions in BPS payments – Rural Payments Agency (RPA), freedom of information request. Deduction represents the percentage by which the farms BPS payment was reduced.

Robustness

This data set does not give a clear indicator of good practice, it just shows the number of farms inspected that fail to meet certain criteria. The fact that the main reason for failure revolves around cattle identification rather than the criteria linked to soil protection or nitrate vulnerable zones mean that total trends in deductions or failures are difficult to interpret. The change in the SPS to the BPS in 2015, mean that there is not a consistent data set or set of requirements to compare against across all years. Future data sets should align with the 2015 data. Without knowing the total number of inspections made it is unclear whether increases or decreases in failures relate to changes in practice or changes in sample size.

X5: Average lengths of farmer tenancies

Introduction

Large areas of farm land in England are managed by tenants under tenancy agreements, and the duration of the tenancy can potentially impact on planning timescales and investment in actions that may have long term sustainability benefits for a farm. For example on short term tenancies it may not be cost beneficial to take actions to improve the organic matter content of the soil as it can take many years to see the benefits of these actions.

Those agricultural tenancies agreed before 1 September 1995 are known as 1986 Act tenancies, or Full Agricultural Tenancies (FAT). Generally, tenancies granted under the 1986 Act have lifetime security of tenure. A Farm Business Tenancy (FBT) is a lease for land which is farmed for the purposes of trade or business and on which agriculture takes place agreed after the introduction of the Agricultural Tenancies Act 1995.

FBTs encompass both short term (less than 1 year rentals) and longer term tenancies. The short term rentals tend to be used by specialist growers renting land for specific crops (e.g. potatoes or field vegetables). It is part of the specialist grower's farm business plan to just rent land on an annual basis to allow them to have extended rotations (time between potato crops etc.) without needing to own or long term lease the whole acreage needed to maintain the rotation. Other farmers have tenancy agreements that rent farms or parts of farms to them for a set period of time, usually a number of years and they complete the whole of the rotation on that land.

Currently the average length of Farm Business Tenancies (FBT) in England and Wales is less than 4 years, but the Tenant Farmers Association (TFA) has launched a campaign to increase the average lengths of term on Farm Business Tenancies (FBT) to 10 years or more.

Methodology

This indicator will focus on the average length of new Farm Business Tenancies (FBT). The Central Association of Agricultural Valuers (CAAV) is a specialist professional body representing, qualifying and briefing over 2800 members practising in a diverse range of agricultural and rural work throughout England, Wales, Scotland and Northern Ireland. For the past 39 years the CAAV have been capturing data on changes in occupation from their members as part of their Agricultural Land Occupation Survey (CAAV, 2015). This survey collects information in on several types of land occupation:

- New Farm Business Tenancies
- New contract farming agreements
- The position where an existing Agricultural Holdings Act tenancy has come to an end
- AHA tenancy successions

The top level data collated from the CAAV Agricultural Land Occupation Survey includes;

- The average length of new FBTs granted between 2002 and 2015.
- The total number of new farm business tenancies, subdivided by the length of tenancy from 2009 to 2015 (including a figure on the proportion of new FBTs which have a term of one year or less).
- The average term length of FBTs which have a term greater than one year.

Results

The average length for new FBTs in 2015 was 3.83 years, which is within the range of the average lengths over the previous 10 years and slightly above the overall average of 3.77 years (Table 49). This includes all lettings, from seasonal lets of bare land to long term lettings of fully equipped holdings. It is generally the case that larger, and better equipped units let for longer terms.

Table 49. Analysis of term lengths of new FBTs 2009 - 2015

Length	Year						
	2009	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*
Life	0	0	0	0	0	0	0
40+ years	2	1	2	2	1	0	2
30-39 years	2	6	2	0	2	0	1
25-29 years	7	4	3	10	2	2	7
20-24 years	9	11	10	18	5	4	10
15-19 years	16	18	21	24	12	19	19
10-14 years	56	51	44	48	38	30	30
>5 and <10 years	34	30	44	126	46	49	33
5 years	103	131	146	184	168	112	102
>2 and <5 years	137	132	134	192	154	107	105
2 years	118	110	115	168	174	119	158
>1 and <2 years	9	25	8	12	3	3	2
1 year	309	291	258	256	322	215	217
Annual periodic	26	48	58	48	63	18	8
<1 year	11	6	23	51	26	13	18
Total (no. of new FBT's)	839	864	868	1139	1016	691	712
Average length (all new FBT)	**3.8**	**3.75**	**3.89**	**4.12**	**3.17**	**3.53**	**3.83**
% 1 year or less	41%	40%	39%	31%	40%	36%	34%
Average length (FBT >1 year)	-	-	**5.44**	**5.54**	**4.65**	**4.93**	**5.31**

Source: CAAV (2015) Agricultural Land Occupation Surveys

In the period 2009 to 2015, between 31% and 40% of new FBTs each year had a term length of one year or less. If the FBT's with a term length of one year or less were removed from the data, to exclude those farmers with renting land for just a single crop, the average length goes up to 5.31 years in 2015. It should be noted that in 2014 and 2015, there was a reduction in the number of 1 year tenancies, compared to the number taken out between 2009 and 2013.

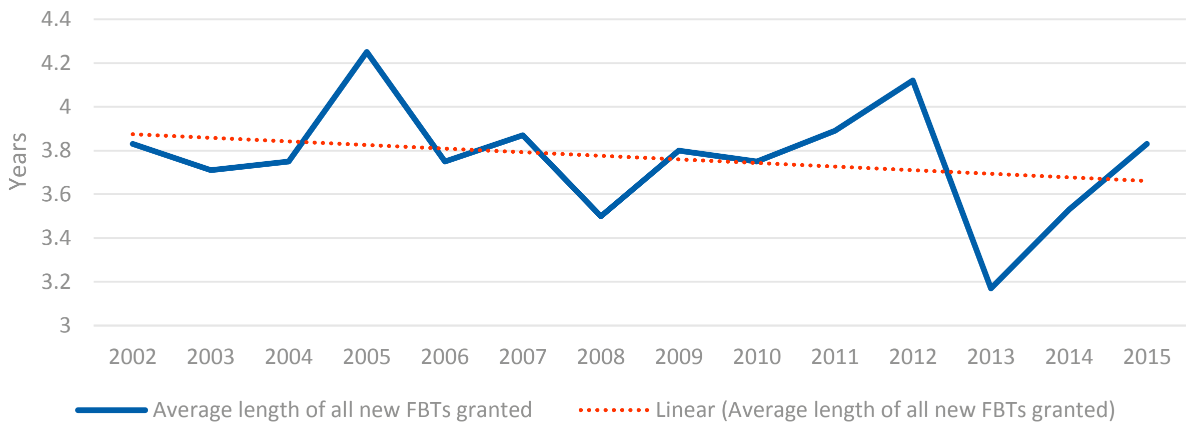

Figure 80. Average length of new FBTs granted. Source: ADAS for ASC.

In 2013 the average length for new FBTs was particularly low, thus pulling the trend line down (Figure 80). CAAV have attributed some of the changes we see in the data to the impact of changes to subsidy schemes. In particular, in years when there are changes to entitlements, this can have an impact on how long landowners are prepared to let their land for. In 2013, for instance, at the time when people were making decisions about letting there was concern about how entitlements would be dealt with when the Basic Payment Scheme (BPS) was introduced in 2015. It was widely thought then that entitlements in England would be re-allocated, although in fact they were allowed to rollover in the end. A decrease was noted in average term lengths that year in particular.

However changes to subsidy schemes may not be the only cause of variability. The low number of tenancies agreed in 2013 might have been affected by the unusual weather in 2012 that resulted in a wet autumn and failure to plant planned winter crops. This meant that there was an increased area of spring crops planted. There is the possibility that this unusual cropping pattern resulted in some changes to land rentals. Those farmers able to plant spring crops may have rented land from others who were not, increasing the number of short term rentals. Or where land was not planted at all farmers with appropriate tenancy agreements may have extracted themselves early to avoid the cost of renting land that remained fallow all year.

If the data point for 2013 is removed, for the reasons set out above, there is very little change in the average length of new FBTs granted between 2002 and 2015 (Figure 81).

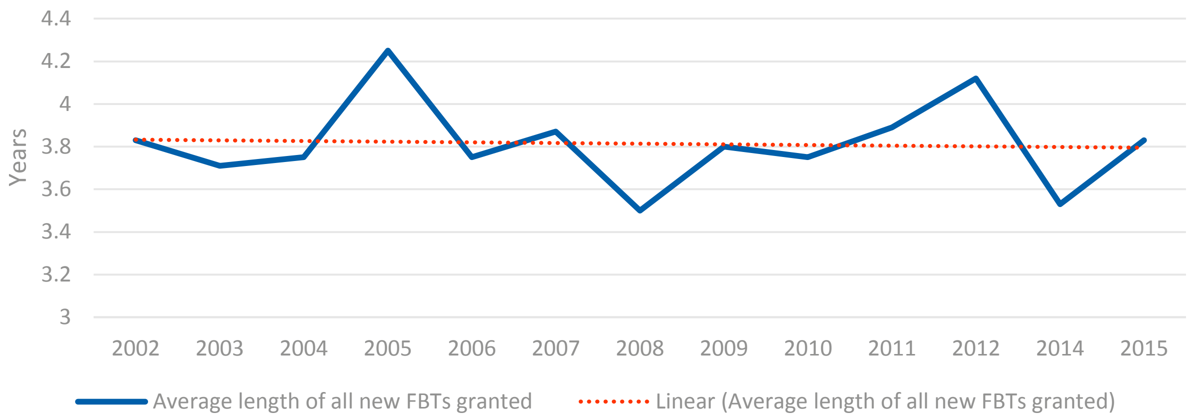

Figure 81. Average length of new FBTs granted (not including 2013). Source: ADAS for ASC.

References

Abrahamson V and Raine R (2009) Health and social care responses to the Department of Health Heatwave Plan. J Public Health. 2009 Dec; 31 (4):478-89. https://academic.oup.com/jpubhealth/article/31/4/478/1496128/Health-and-social-care-responses-to-the-Department

AHDB (2017) Winter Wheat & OSR recommended lists & harvest reports. https://cereals.ahdb.org.uk/varieties/ahdb-recommended-lists.aspx

Air Quality Expert Group (2012) Fine Particulate Matter (PM2.5) in the United Kingdom. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69635/pb13837-aqeg-fine-particle-matter-20121220.pdf

Association of British Insurers (2016) Responding to Major Floods, November 2016. https://www.abi.org.uk/~/media/Files/Documents/Publications/Public/2015/Property/Responding%20to%20Major%20Floods.pdf

Bailey RJ and Spackman E (1996) A model for estimating soil moisture changes as an aid to irrigation scheduling and crop water use studies. I. Operational details and description. *Soil Use and Management* 12: 122-128.

Bayer Crop Science (2016) BYDV. http://www.bayercropscience.co.uk/our-products/seed-treatment/redigo-deter/bydv/

Boyson C and Taylor S (2014) The National Heatwave Plan – A Brief Evaluation of Issues for Frontline Health Staff. PLOS Currents Disasters. 2014. Edition 1. doi: 0.1371/currents.dis.aa63b5ff4cdaf47f1dc6bf44921afe93. http://currents.plos.org/disasters/article/the-national-heatwave-plan-a-brief-evaluation-of-issues-for-frontline-health-staff/

British Lung Foundation (2016) The battle for breath – the impact of lung disease in the UK. https://www.blf.org.uk/what-we-do/our-research/the-battle-for-breath-2016

Byers A, Hall JW and Amezaga JM (2014) Electricity generation and cooling water use: UK pathways to 2050, Global Environmental Change, Volume 25, March 2014, Pages 16-30, ISSN 0959-3780. http://dx.doi.org/10.1016/j.gloenvcha.2014.01.005.

CAAV (2015) Agricultural Land Occupation Surveys. http://www.caav.org.uk/

Cancer Research UK (2014) Trends in awareness and behaviour relating to UV and sun protection: 2003-2013. Cancer Research UK. http://www.cancerresearchuk.org/sites/default/files/sun_protection_trends_-_cruk.pdf

Clarke J et al. (2009) Pesticide availability for cereals and oilseeds following revision of directive 91/414/EEC; effects of losses and new research priorities. https://cereals.ahdb.org.uk/media/268257/rr70.pdf

Comber A, Proctor C and Anthony SA (2007) Combined pycnophylactic-dasymetric method for disaggregating spatial data: the example of agricultural land use. [ed.] A. C. Winstanley. Proceedings of the Geographical Information Science Research UK Conference. s.l. : GISRUK, 2007, pp. 445-450.

Committee on Climate Change (2015) Reducing emissions and preparing for climate change: 2015 Progress Report to Parliament. https://www.theccc.org.uk/publication/reducing-emissions-and-preparing-for-climate-change-2015-progress-report-to-parliament/

Cook P, Short CA, Fair A, Lomas K and Noakes C (2013) Robust Hospitals in a Changing Climate - the DeDeRHECC project, 2013, Digital or Visual Products.

Crop monitor (2005-2014) winter oilseed rape: Yield losses 2005-2014 https://secure.fera.defra.gov.uk/cropmonitor/cmsReport.cfm?id=30

DairyCo (2011) Farmer Water Survey report. https://dairy.ahdb.org.uk/resources-library/research-development/environment/dairyco-water-report-2011/#.WJMb-lNBrIU

Defra (2009) Safeguarding Our Soils: A Strategy for England. Department for Environment, Food and Rural Affairs, London.

Defra (2010a) Defra Farm practices survey 2010 – ENGLAND. http://www.fao.org/fileadmin/templates/ess/ess_test_folder/World_Census_Agriculture/Country_info_2010/Reports/Reports_2/UK_ENG_REPc_2010.pdf

Defra (2010b) Water usage in agriculture and horticulture, results from the farm business survey 2009/2010 and the irrigation survey 2010. http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/statistics/files/defra-stats-foodfarm-farmmanage-fbs-waterusage20110609.pdf

Defra (2011a) Safeguarding our Soils - A Strategy for England. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69261/pb13297-soil-strategy-090910.pdf

Defra (2011b) The total costs of soil degradation in England and Wales - SP1606. http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=16992&FromSearch=Y&Publisher=1&SearchText=sp1606&SortString=ProjectCode&SortOrder=Asc&Paging=10#

Defra (2011c) Water Usage in Agriculture and Horticulture: Results from the Farm Business Survey 2009/10 and the Irrigation Survey 2010.

Defra (2012a) Distribution input and supply pipe leakage: 1992/93 to 2010/11

Defra (2012b) Developing a joint approach to improving flood awareness and safety at caravan and camping sites in England and Wales. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69495/pb13712-flood-camp-sites.pdf

Defra (2012c) Flood Rescue National Enhancement Project: Flood Rescue Concept of Operations. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/269390/pb13676-frco.pdf

Defra (2013) Update on Implementation of the Daily Air Quality Index. https://uk-air.defra.gov.uk/assets/documents/reports/cat14/1304251155_Update_on_Implementation_of_the_DAQI_April_2013_Final.pdf

Defra (2016a) Structure of the agricultural industry in England and the UK at June https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june

Defra (2016b) The guide to cross compliance in England 2017. https://assets.publishing.service.gov.uk/media/5684e7dbe5274a0367000002/Guide_to_cross_compliance_2016_-_v_1.0.pdf

Entec (2010) Application of Best and Most Versatile Land Policy by Planning Authorities. Defra Project SP1501, Final Report.

Environment Agency (2011) Incidents and their classification: the Common Incident Classification Scheme (CICS). http://www.fwr.org/WQreg/Appendices/Common_incident_classification_system_04_01.pdf

Environment Agency (2015) Drought response: our framework for England.

Environment Agency (2016a) Dataset Documentation: Flood Map for Planning (Rivers and Sea) Areas benefiting from defences. https://data.gov.uk/dataset/flood-map-for-planning-rivers-and-sea-areas-benefiting-from-defences

Environment Agency (2016b) Dataset Documentation: Flood Map for Planning (Rivers and Sea) Flood Zone 3. https://data.gov.uk/dataset/flood-map-for-planning-rivers-and-sea-flood-zone-3

Evans CD, Cooper DM, Monteith DT, Helliwell RC, Moldan F, Hall J and Cosby BJ (2010). Linking monitoring and modelling: can long-term datasets be used more effectively as a basis for large-scale prediction?. Biogeochemistry, 101(1-3), 211-227.

Forestry Commission (2012) Dothistroma needle blight: GB Strategy. https://www.forestry.gov.uk/pdf/DNBStrategy11-04-2012.pdf/$FILE/DNBStrategy11-04-2012.pdf

Gill SE, Handley JF, Ennos AR, Pauleit S, Theuray N and Lindley SJ (2008). Characterising the urban environment of UK cities and towns: a template for landscape planning. *Landscape and Urban Planning* 87, 210-222.

Giridharan R, Lomas KJ, Short A and Fair AJ (2013) Performance of hospital spaces in summer: A case study of a 'Nucleus'-type hospital in the UK Midlands. Journal of Energy and Buildings Vol 66 pp315-328.

Glaves DJ, Morecroft M, Fitzgibbon C, Owen M, Phillips S and Leppitt P (2013) The effects of managed burning on upland peatland biodiversity, carbon and water. Natural England evidence review NEER004. Peterborough, UK.

Graves AR, Morris J, Deeks LK, Rickson RJ, Kibblewhite MG, Harris JA, Farewell TS and Truckle I (2015) The total costs of soil degradation in England and Wales. *Ecological Economics,* 119, 399–413.

Greater London Authority (2008) Living Roofs and Walls, Technical Report: Supporting London Plan Policy. http://www.london.gov.uk/sites/default/files/living-roofs.pdf

Gupta R, Walker G, Lewis A, Barnfield L, Gregg M and Neven L (2016) Care provision fit for a future climate. https://www.jrf.org.uk/report/care-provision-fit-future-climate

Hannah L et al*.* (2013) Climate change, wine, and conservation. http://www.pnas.org/content/110/17/6907.full.pdf

Heal MR, Heaviside C, Doherty RM, Vieno M, Stevenson DS and Vardoulakis S (2013) Health burdens of surface ozone in the UK for a range of future scenarios. *Environment International.* 61, 36-44*.*

Heal W (2003) Introduction, context, and seminar conclusions - Managing Upland Catchments: Priorities for Water and Habitat Conservation, Joint Nature Conservation Committee, Durham (2003)

Heatwave plan for England (2016) Heatwave Plan for England. https://www.gov.uk/government/publications/heatwave-plan-for-england

Highways England (2017) Highways England Climate Adaptation Risk Assessment Progress Update – 2016. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/596812/climate-adrep-highways-england.pdf

HM Government (2016) National Flood Resilience Review. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/551137/national-flood-resilience-review.pdf

HR Wallingford (2015) Update analysis of the number of properties located in areas at risk of flooding and coastal erosion in England. https://www.theccc.org.uk/publication/hr-wallingford-2015-for-the-asc-update-analysis-of-the-number-of-properties-located-in-areas-at-risk-of-flooding-and-coastal-erosion-in-england/

ICUN (2011) IUCN UK Commission of Inquiry on Peatlands. Edinburgh, IUCN UK Peatland Programme.

IPCC (2014) The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). https://ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_All_Topics.pdf

JNCC and Defra (on behalf of the Four Countries' Biodiversity Group) (2012) UK Post-2010 Biodiversity Framework. July 2012. http://jncc.defra.gov.uk/page-6189

Keay CA, Jones RJA, Procter C, Chapman V, Barrie I, Nias I, Smith S and Astbury S (2013) SP1104 the Impact of climate change on the capability of land for agriculture as defined by the Agricultural Land Classification, DEFRA 138pp.

Knox JW, Daccache A, Weatherhead EK, Groves S and Hulin A (2013) Assessment of the impacts of climate change and changes in land use on future water requirement and availability for farming, and opportunities for adaptation. Final Report Defra (FFG1129), Cranfield University. http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=17341

Kovats RS and Osborn D (2016) UK Climate Change Risk Assessment Evidence Report: Chapter 5, People and the Built Environment. Contributing authors: Humphrey, K., Thompson, D., Johns. D., Ayres, J., Bates, P., Baylis, M., Bell, S., Church, A., Curtis, S., Davies, M., Depledge, M., Houston, D., Vardoulakis, S., Reynard, N., Watson, J., Mavrogianni, A., Shrubsole, C., Taylor, J., and Whitman, G. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.

Kowalski M, Lynn S, Waylen C and Bujnowicz A (2011) Freshwater use in the UK: agriculture sector: A sub-sectoral analysis of the use of licensed freshwater resources by agriculture in the United Kingdom. WRAP Report. http://www.wrap.org.uk/sites/files/wrap/PAD101-201%20-%20Agricultural%20sector%20water%20report%20-%20FINAL%20APPROVED%20for%20publication%20-%2012,03,12_0.pdf

Lomas KJ, Giridharan R, Short CA and Fair AJ (2012) Resilience of 'Nightingale' hospital wards in a changing climate. Journal of Building Services Engineering Research and Technology Vol 33 (1) pp 81-103.

Maddock, A. (2008). UK Biodiversity Action Plan; Priority Habitat Descriptions. UK Biodiversity Action Plan, 94pp. http://jncc.defra.gov.uk/PDF/UKBAP_PriorityHabitatDesc-Rev2011.pdf

Malliarou, E., Collins, C., Graham, N., & Nieuwenhuijsen, M. J. (2005). Haloacetic acids in drinking water in the United Kingdom. Water Research, 39(12), 2722-2730. http://www.sciencedirect.com/science/article/pii/S0043135405002241

Manley G (1953) The mean temperature of Central England, 1698 to 1952. Q.J.R. Meteorol. Soc., Vol 79, pp 242-261.

Manley G (1974) Central England Temperatures: monthly means 1659 to 1973. Q.J.R. Meteorol. Soc., Vol 100, pp 389-405.

Medlock J and Leach S (2015) Effect of climate change on vector-borne disease risk in the UK, The Lancet Infectious Diseases, Volume 15, Issue 6, June 2015, Pages 721-730, ISSN 1473-3099, http://dx.doi.org/10.1016/S1473-3099(15)70091-5

Met office (2013) Met office drought report

Milojevic A, Kovats S, Leonardi G, Murray V, Nye M and Wilkinson P (2014) Population displacement after the 2007 floods in Kingston upon Hull, England. Journal of Flood Risk Management.

Montazami A and Nicol F (2013) Overheating in schools: comparing existing and new guidelines, Building Research & Information, 41:3, 317-329.

Monteith DT et al. (2007). Dissolved organic carbon trends resulting from changes in atmospheric deposition chemistry. Nature, 450(7169), 537-540. http://www.nature.com/nature/journal/v450/n7169/abs/nature06316.html

Morgan RPC (1992) Soil conservation in the UK, Soil use and management. Volume 8, number 4. http://onlinelibrary.wiley.com/doi/10.1111/j.1475-2743.1992.tb00917.x/epdf?r3_referer=wol&tracking_action=preview_click&show_checkout=1&purchase_referrer=www.google.co.uk&purchase_site_license=LICENSE_DENIED

Mozell MR and Tharch L (2014) The impact of climate change on the global wine industry: Challenges & solutions. Wine Economics and Policy, Volume 3, Issue 2, 81–89.

Murphy JM et al. (2009) UK climate projections science report: climate change projections. http://ukclimateprojections.metoffice.gov.uk/media.jsp?mediaid=87893&filetype=pdf

National Flood Forum (2016) National Flood Forum Bulletin, December 2016. http://www.nationalfloodforum.org.uk/wp-content/uploads/Dec-2016_Flooding-One-Year-On.pdf

National Flood Forum (undated) Building the Charlton Flood Group – Worcestershire http://nationalfloodforum.org.uk/wp-content/uploads/Charlton-Flood-Group.pdf

Natural England (2010) England’s peatlands: carbon storage and greenhouse gases. Natural England Report NE257.

Network Rail (2017) Weather Resilience and Climate Change Adaptation Strategy 2017-2019. https://safety.networkrail.co.uk/wp-content/uploads/2017/02/NR-WRCCA-Strategy-2017-2019.pdf

NFU (2013) NFU Briefing, Soil Protection review reminder.

NFU (2016) NFU Information and analysis. BPS 2015 – analysis of cross compliance breaches.

Organisation of Vine and Wine (2016) OIV Statistical Report on World Vitiviniculture. http://www.oiv.int/public/medias/5029/world-vitiviniculture-situation-2016.pdf

Parker DE and Horton EB (2005) Uncertainties in the Central England Temperature series since 1878 and some changes to the maximum and minimum series. International J.Climatology, Vol 25, pp 1173-1188.

Parker DE, Legg TP and Folland CK (1992) A new daily Central England Temperature Series, 1772-1991. Int. J. Clim., Vol 12, pp 317-342.

Patterson G and Anderson R (2000) Forests and peatland habitats: guideline note. Guideline Note-Forestry Commission.

Penning-Rowsell E et al. (2014) Flood and coastal erosion risk management: a manual for economic appraisal. Routledge.

Potato Council (undated) Irrigation and Water Use: Best practice guide for potatoes. https://potatoes.ahdb.org.uk/sites/default/files/publication_upload/Irrigation%20for%20potatoes_0.pdf (Accessed 30/03/2017).

Public Health England (2015) Heatwave plan for England. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/429384/Heatwave_Main_Plan_2015.pdf

Reed MS et al. (2009) The future of the uplands, Land Use Policy, Volume 26, Supplement 1, Pages S204-S216, ISSN 0264-8377, http://dx.doi.org/10.1016/j.landusepol.2009.09.013. http://www.sciencedirect.com/science/article/pii/S0264837709001380)

Rural Payments Agency (2017) Cross compliance inspection statistics. http://webarchive.nationalarchives.gov.uk/20140305104944/http:/rpa.defra.gov.uk/rpa/index.nsf/UIMenu/9B27CED347D543A58025721B003EC086?Opendocument (Accessed 10 February 2017).

Short CA, Giridharan R and Lomas KJ (2015) A medium-rise 1970s maternity hospital in the east of England: Resilience and adaptation to climate change. Building Serv. Eng. Res. Technol, 1-28.

Short CA, Lomas KJ, Giridharan R and Fair AJ (2012) Building resilience to overheating into 1960's UK hospital buildings within the constraint of the national carbon reduction target: Adaptive strategies. Building and Environment 55, 73-95.

Short CA, Noakes CJ, Gilkeson CA and Fair A (2014) Functional recovery of a resilient hospital type. Buildings Research and Information.

Silgram M, Hatley D and Gooday R (2007) IRRIGUIDE: a decision support tool for drainage estimation and irrigation scheduling. Proceedings of the 6th Biennial Conference of the European Federation of IT in Agriculture (EFITA) World Congress on Computing in Agriculture (WCCA) 2007 joint conference "Environmental and rural sustainability". Glasgow, UK, 2-5 July 2007.

Singh SP and Singh P (2015) Effect of temperature and light on the growth of algae species: A review. Renewable and Sustainable Energy Reviews, Volume 50, 431–444

TCPA (2016) Planning for the Climate Challenge? Understanding the Performance of English Local Plans, Town and Country Planning Association. November 2016. https://www.tcpa.org.uk/Handlers/Download.ashx?IDMF=7d92ec4c-09f7-4b21-9d22-b1aad77fd062

The UK Biodiversity Action Plan (2010) UK Biodiversity Action Plan. http://jncc.defra.gov.uk/default.aspx?page=5155

UKCP (2009) UK Climate Projections Version 2 (2009). http://ukclimateprojections.metoffice.gov.uk/media.jsp?mediaid=87894&filetype=pdf

Vardoulakis S and Heaviside C [eds.] (2012) *Health Effects of Climate Change in the UK 2012 – Current evidence, public health recommendations and research gaps.* Health Protection Agency. Centre for Radiation, Chemical and Environmental Hazards, UK. ISBN: 978-0-85951-723-2.

Waite et al. (2017) The English national cohort study of flooding and health: cross-sectional analysis of mental health outcomes at year one. BMC public health, 17(1), 129.

Watts CD, Naden PS, Machell J and Banks J (2001) Long term variation in water colour from Yorkshire catchments. Science of the Total Environment, 278(1), 57-72. http://www.sciencedirect.com/science/article/pii/S0048969700008883

Yallop AR, Thacker J and Clutterbuck B (2012) Burning on Deep Peat and Bog habitat in England. http://www.energyroyd.org.uk/wp-content/uploads/2013/02/Cranfieldburningonbog-V3.pdf