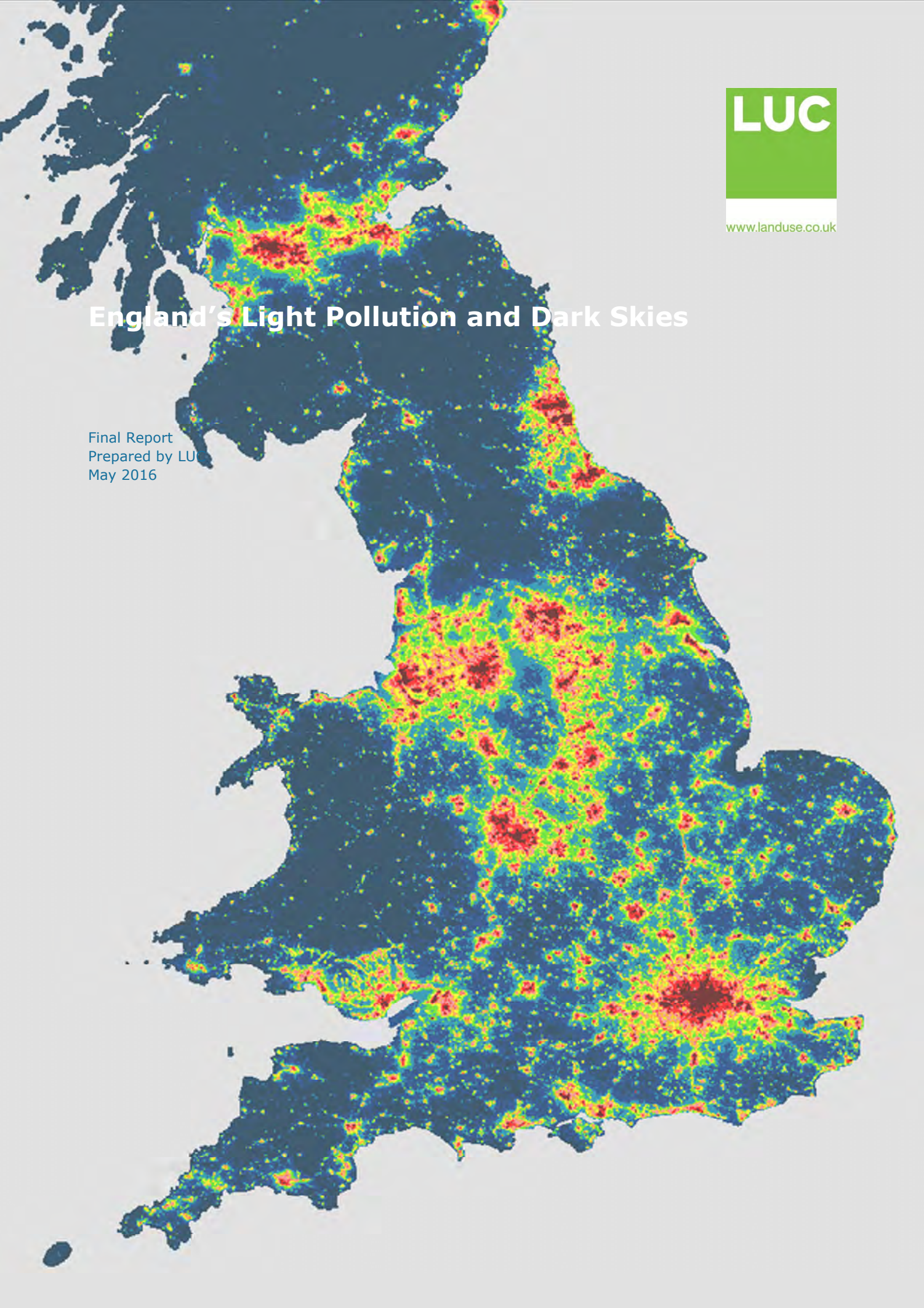

# England's Light Pollution and Dark Skies

Final Report
Prepared by LUC
May 2016

LUC
www.landuse.co.uk

**Project Title**: England's Light Pollution and Dark Skies

**Client**: Campaign to Protect Rural England

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www.landuse.co.uk

# England's Light Pollution and Dark Skies

Prepared by LUC
May 2016

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# Contents



## Tables

## Figures

# 1 Introduction

1.1 In December 2015, Campaign to Protect Rural England (CPRE) commissioned LUC to develop an up-to-date national map of England's light pollution. This mapping work will inform a wider CPRE campaign to tackle light pollution, whilst identifying dark skies and landscapes that need to be protected and improved. This new mapping work builds on previous work undertaken in 2003 to show the extent of light pollution in the UK in 1993 and 2000. The Night Blight! CPRE campaign launched in 2003.

1.2 The aims of this study are to:

- Create a **UK-wide light pollution map** using the latest available satellite data
- Test the potential to **investigate the change over time** using the new national map as the baseline.
- Produce **detailed light pollution maps** for the following geographical areas:
    - Regions
    - Counties
    - Districts
    - National Parks
    - Areas of Outstanding Natural Beauty (AONBs)
    - National Character Areas (NCAs)
- Produce **overview and detailed quantitative analysis** of the maps for each of these geographical areas in order to support the comparison of locations as well as the identification of the best and worst performers in terms of light pollution.
- A **report** summarising the approach to the mapping, headline statistics and the results of the quantitative analysis at the more detailed levels. The report is to be supported by case studies and graphics to feed into the wider CPRE campaign.
- Produce an **interactive light pollution map** to be hosted on the CPRE website to allow a range of users to access and explore the data and information created during this commission.

# 2 Creating a National Map

## Obtaining night light imagery from satellites

2.1 Since the 1960s, the U.S. Air Force has operated the Defense Meteorological Satellite Program (DMSP), a series of 18 polar-orbiting satellites that observe clouds and other weather variables in key wavelengths of infrared and visible light. Data from this satellite programme was used in 2003 to generate CPRE's maps of light pollution in England for the periods 1993 and 2003.

2.2 In October 2011, the United States National Oceanic and Atmospheric Administration (NOAA) launched the Suomi National Polar-orbiting Partnership or Suomi NPP. This sun-synchronous polar-orbiting satellite flies over any given point on the earth's surface twice each day at roughly 1:30 a.m. and 1:30 p.m (local solar time). The **Visible Infrared Imaging Radiometer Suite (VIIRS)** is one of the instruments on board this satellite and it captures visible and infrared imagery to monitor and measure processes including wildfires, ice motion, cloud cover, and land and sea surface temperature amongst other things.

2.3 The VIIRS sensor collects data in a number of channels including the **Day/Night Band (DNB).** The DNB sensor determines on-the-fly whether to use its low, medium or high gain mode to gather information on the amount of light emitted. By being able to alter the exposure time, if a pixel is very bright, a low gain mode on the sensor prevents the pixel from over-saturating. The opposite occurs if a pixel is dark.[1]

2.4 The VIIRS data offers significant benefits over the DMSP data such as:

- better spatial resolution (a cell size of 742m x 742m)
- no saturation on bright lights (urban areas were often saturated in DMSP datasets)

2.5 Using the DNB data collected by the Suomi-NPP satellite, we are able to **get a daily picture of every location at the same time every night (1:30am)**.

2.6 In 2012, NOAA published the first image of night time lights for the earth using the Suomi-NPP VIIRS DNB derived data. This first global image used data captured between April 18-26 2012 and October 11-23 2012 to generate a composite image of global night time light levels.

2.7 The algorithms and processes used to create the first 2012 image have been evolving and improving ever since. Since January 2014, it has been possible to download monthly composites that have been filtered to exclude data impacted by stray light, lightning, lunar illumination and cloud cover.

2.8 For the purposes of this study, data covering the period January 2014 to December 2015 (the latest available dataset at the time of undertaking this work) were downloaded for review and analysis. Each monthly dataset is supported by a second image which shows the number of cloud free nights used to make up the night light monthly average image.

2.9 It is worth noting that whilst the data captured by the Suomi-NPP DNB offers significant improvements over that of the DMSP data, the Suomi-NPP DNB lacks sensitivity at wavelengths shorter than 500 nm. Because of this, the blue-light emission peak of white LEDs is not detected. This means that the "blue blindness" of the VIIRS DNB could falsely suggest a reduction in light pollution in some towns and cities in the future, whereas the brightness of the sky as seen by human eyes may in fact increase. This is a known limitation of this data.

[1] http://earthobservatory.nasa.gov/Features/IntotheBlack/

## Selecting a baseline dataset and processing the data

2.10 For the purposes of selecting a baseline dataset to use in the creation of the national map, all of the datasets were brought into Geographic Information System (GIS) software – ESRI ArcMap. Each month was viewed alongside its cloud free composite data to establish the extent to which cloud cover was impacting the data. During months when there was a lot of cloud cover over the UK, the images were discounted.

2.11 After a thorough review, **September 2015** was selected as the best month in terms of low influence of cloud cover and has been used as the baseline dataset to create the national map.

2.12 Data has been georeferenced and clipped in GIS to the UK boundary with an additional 1km buffer around the coastline (so as to ensure the entire land area is covered by complete pixels). The data has been resampled to a 400m x 400m pixel size.

2.13 For the purposes of this report, it is not necessary to have a full understanding of the units of measurement of the dataset, merely that the lower the value, the lower the light pollution levels (and the darker the skies are likely to be) and the higher the values, the greater the levels of light pollution. The data values have been divided into nine colour bands ranging from dark blues (low brightness values) to dark reds (high brightness values) as shown in **Table 2.1** below.

**Table 2.1 Colour bandings and values**

| Colour band | Brightness values[2] (in nw/cm$^2$/sr) |
|---|---|
| Colour band 1 (Darkest) | <0.25 |
| Colour band 2 | 0.25-0.5 |
| Colour band 3 | 0.5-1 |
| Colour band 4 | 1-2 |
| Colour band 5 | 2-4 |
| Colour band 6 | 4-8 |
| Colour band 7 | 8-16 |
| Colour band 8 | 16-32 |
| Colour band 9 (Brightest) | >32 |

2.14 Further detail on the data source, units of measurement and how the data has been processed can be found in **Appendix 1**.

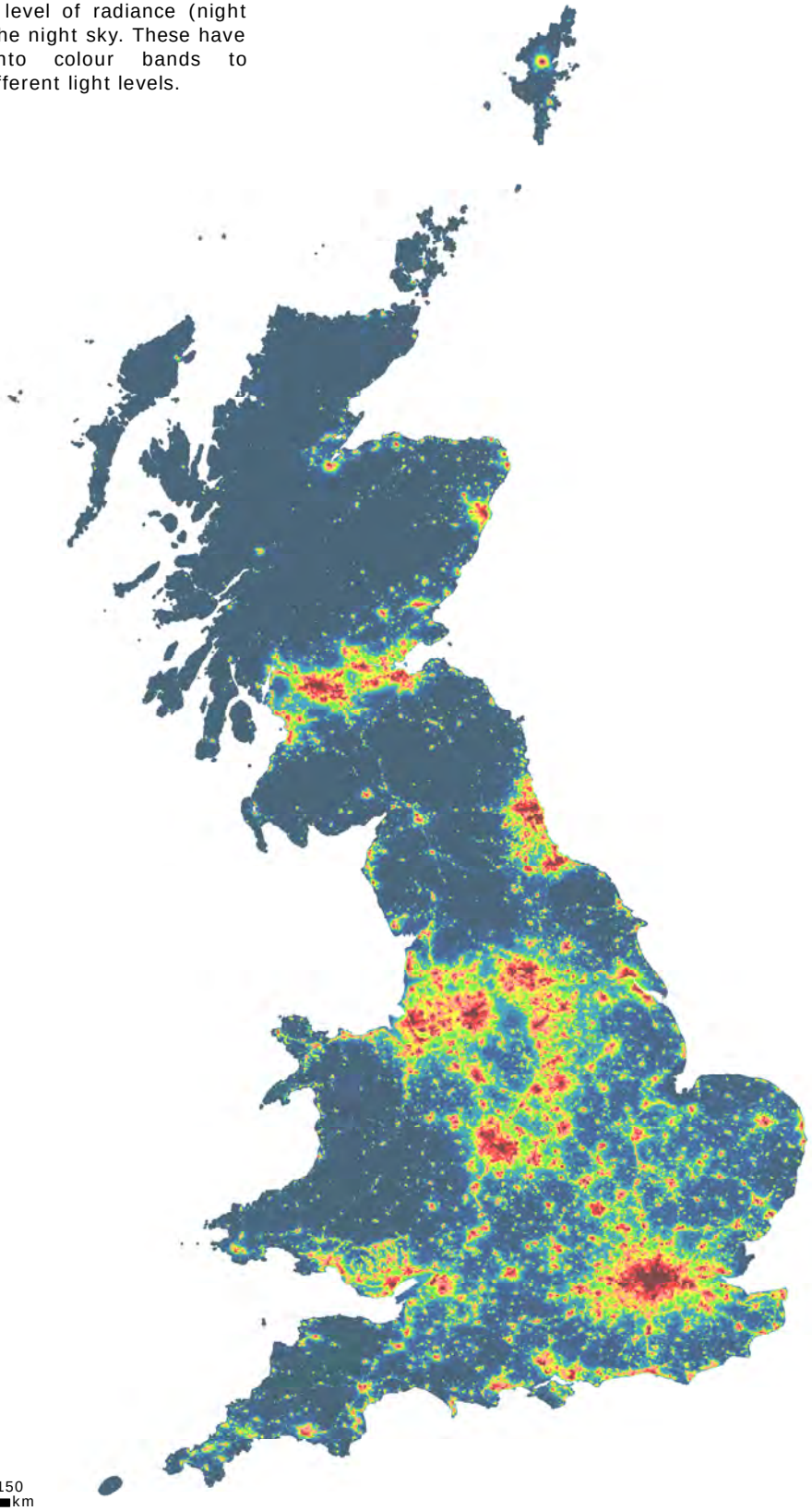
## The national map

2.15 **Figure 2.1** shows the resultant national map once the data has been classified into the nine colour bands. The map clearly identifies the main concentrations of night time lights, creating light pollution that spills up in to the night sky. Most notably, this is in, and around, towns and cities. In addition, the map identifies heavily lit transport infrastructure such as the M25 around London.

2.16 By contrast, the map also identifies areas where there is very little night time lighting – areas where the sky would be expected to be truly dark without the problems caused by light pollution.

[2] The raw data units for the data are nanowatts/cm$^2$/steradian (nw/cm$^2$/sr), and the values for September 2015 range from -0.185 to 1487.895. See Appendix 1 for more details.

Each pixel shows the level of radiance (night light) shining up into the night sky. These have been categorised into colour bands to distinguish between different light levels.



0 50 100 150 km

Night lights (NanoWatts / cm$^2$ / sr)

| | |
|---|---|
| >32 | Brightest |
| 16 - 32 | |
| 8 - 16 | |
| 4 - 8 | |
| 2 - 4 | Brighter |
| 1 - 2 | |
| 0.5 - 1 | |
| 0.25 - 0.5 | |
| < 0.25 | Darkest |

Map Scale @ A4: 1:5,700,000

# Great Britain Light Pollution and Dark Skies

Figure 2.1 National Map

Source: Earth Observation Group, NOAA National Geophysical Data Center

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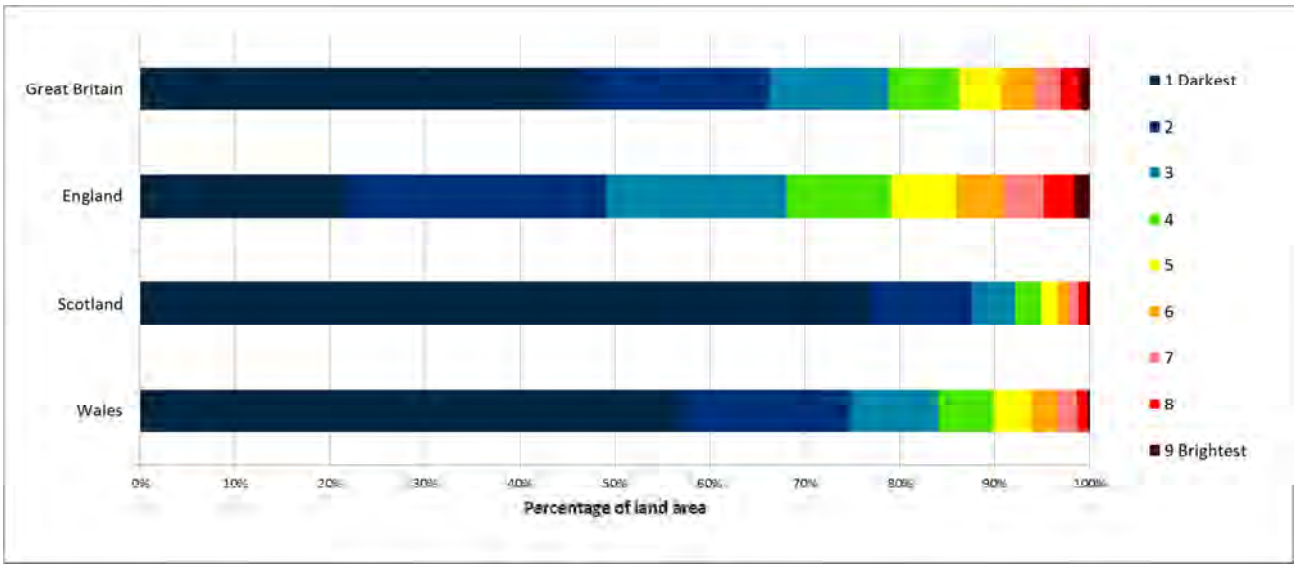
# 3 Headline findings

3.1 Using GIS (ESRI's Spatial Analyst extension), quantitative analysis has been undertaken to explore the data in more detail. This section presents the findings of the national and regional analysis.

## National findings

3.2 As the data have been divided into nine discrete bands, the following graph shows the breakdown of land coverage into these bands for England, Wales, Scotland and Great Britain overall.

**Figure 3.1 Percentage of land area in each colour band overall**




3.3 **Table 3.1 shows the percentage of land falling into each of the colour bands.**

**Table 3.1 Percentage of land falling into each colour band**

| Colour band | England | Wales | Scotland | GB |
|---|---|---|---|---|
| Colour band 1 (Darkest) | 21.73 | 56.82 | 76.77 | 46.16 |
| Colour band 2 | 27.31 | 17.95 | 10.74 | 20.05 |
| Colour band 3 | 19.04 | 9.29 | 4.63 | 12.60 |
| Colour band 4 | 11.02 | 5.85 | 2.74 | 7.36 |
| Colour band 5 | 6.81 | 3.79 | 1.72 | 4.57 |
| Colour band 6 | 4.98 | 2.87 | 1.20 | 3.33 |
| Colour band 7 | 4.29 | 2.13 | 1.02 | 2.83 |
| Colour band 8 | 3.23 | 1.04 | 0.85 | 2.11 |
| Colour band 9 (Brightest) | 1.59 | 0.25 | 0.32 | 0.98 |

3.4 **Table 3.2 shows the maximum and average (mean) brightness values for each country**. Based on the average (mean) brightness values for each country, Scotland is the darkest. Interestingly, the brightest value in the dataset is found in Scotland – at the Grangemouth Refinery, suggesting that this is a gas flare.

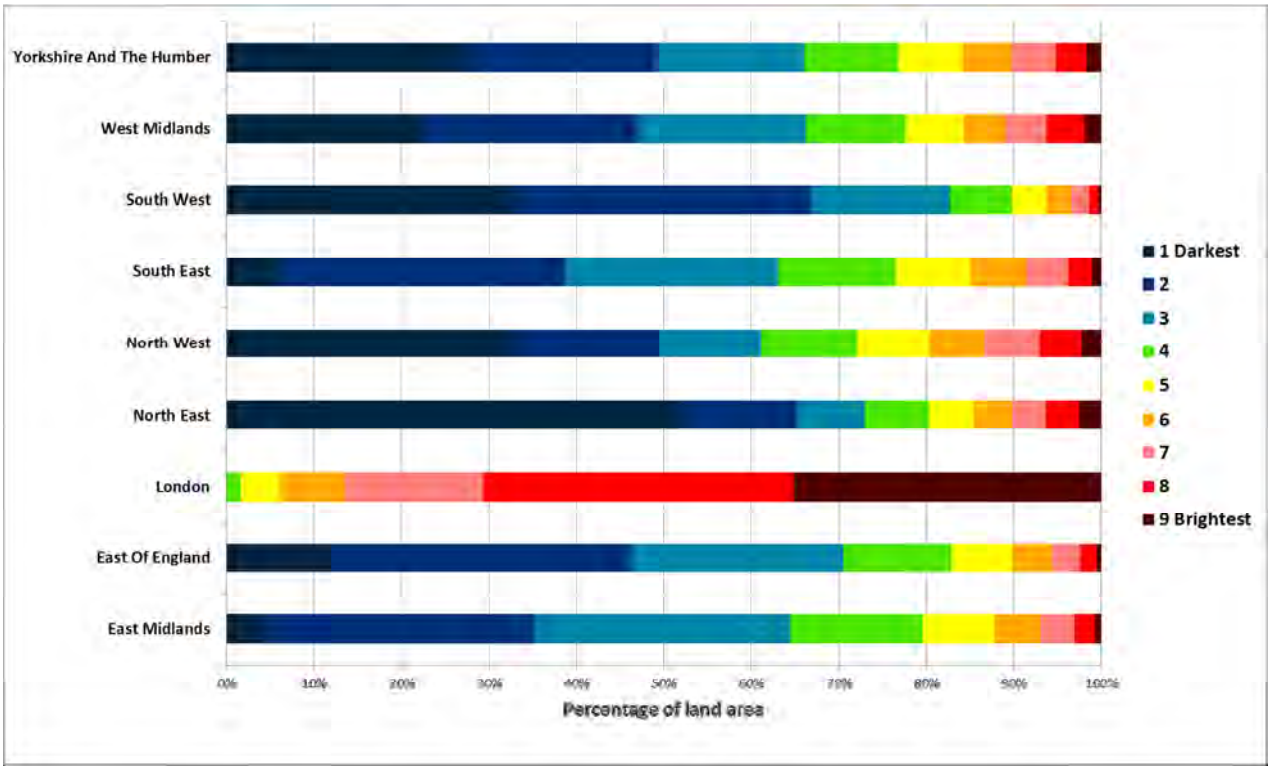
**Table 3.2 Comparison of average (mean) and maximum brightness values by country**

| Country | Maximum brightness value | Average brightness value (mean) |
|---|---|---|
| England | 887.93 | 2.92 |
| Scotland | 1556.84 | 0.79 |
| Wales | 160.69 | 1.15 |

## Regional findings

3.5 The nine regions in England have been analysed in GIS. **Figure 3.2** shows how the regions compare in terms of the percentage of land area in each of the colour bands.

**Figure 3.2 Percentage of land area in each colour band by region**




3.6 For each of the regions, the average (mean) brightness value has been calculated and **Table 3.3** below ranks the regions from darkest to brightest based on the average (mean) brightness values. Whilst average (mean) brightness values are a useful means of comparing different areas, it is also worth noting the maximum brightness values of each region to understand whether there are any particularly bright spots within the region.

**Table 3.3 Regions ranked by average (mean) brightness values**

| Region | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| South West | 1 | 1.25 | 81.74 |
| East Of England | 2 | 2.01 | 181.96 |
| East Midlands | 3 | 2.35 | 133.26 |
| South East | 4 | 2.75 | 584.98 |
| Yorkshire And The Humber | 5 | 3.16 | 887.93 |
| North East | 6 | 3.22 | 280.13 |
| West Midlands | 7 | 3.26 | 142.35 |
| North West | 8 | 3.86 | 209.26 |
| London | 9 | 30.53 | 571.54 |

3.7 Based on the average (mean) brightness values for each region, the South West is the darkest region in England. London is the brightest region, with an average (mean) brightness value of almost 10x the next brightest region, the North West.

**Table 3.4: Location of brightest pixels by region**

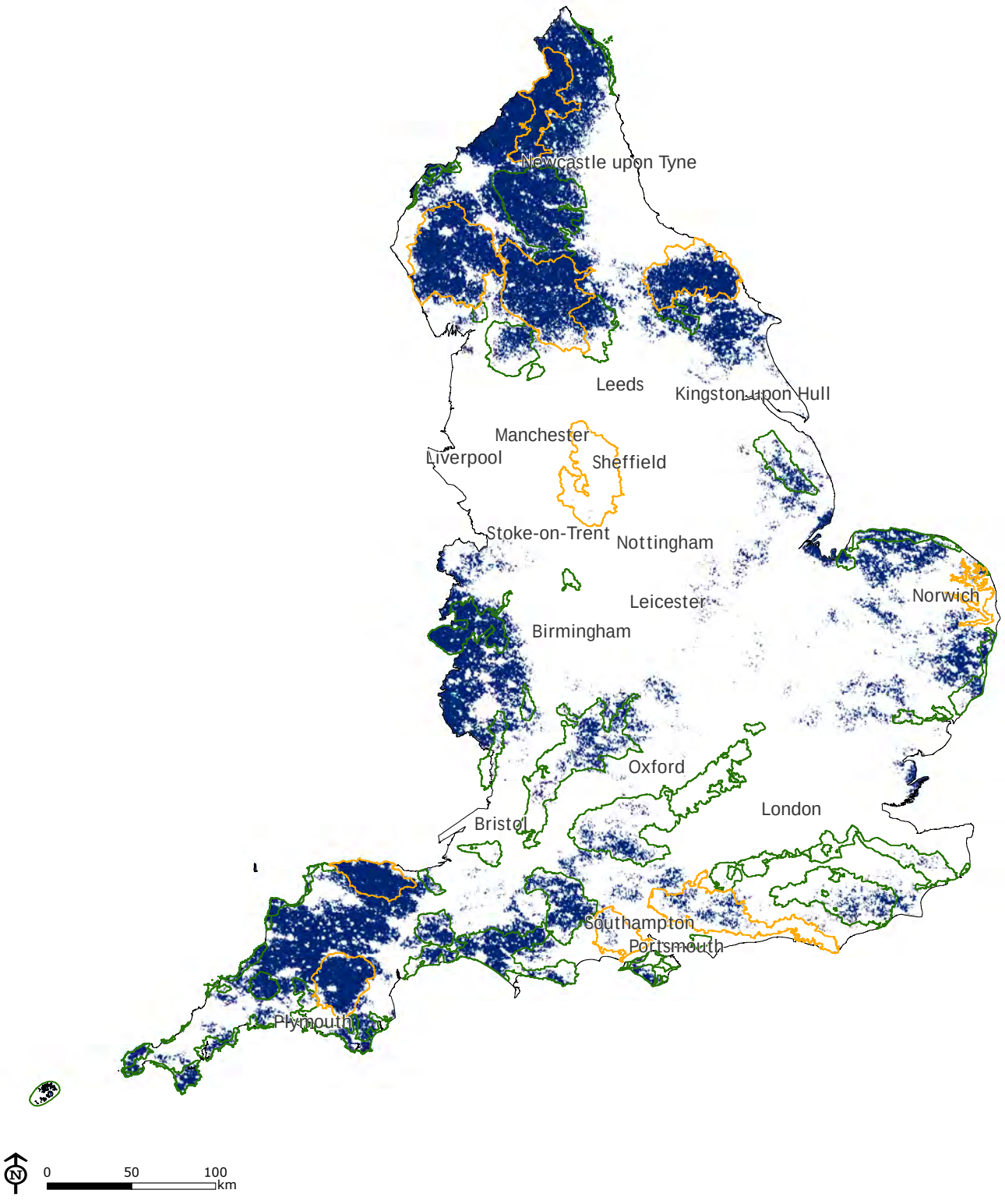
| Region | Maximum brightness value | Location of brightest pixels |
|---|---|---|
| South West | 81.74 | Area around Drake Circus and Guildhall, Plymouth Town Centre (postcode area PL1) |
| East Of England | 181.96 | Port of Felixstowe (just outside postcode area IP11) |
| East Midlands | 133.26 | Area around King Power Stadium, Leicester (postcode area LE2) |
| South East | 584.98 | Thanet Earth, Thanet (postcode area CT7) |
| Yorkshire And The Humber | 887.93 | Tata Steel, Rotherham (postcode area S62) |
| North East | 280.13 | Grainger Town, Newcastle upon Tyne (postcode area NE1) |
| West Midlands | 142.35 | Area around Birmingham New Street Station and New Street (postcode area B2) |
| North West | 209.26 | Area around Etihad Stadium and Ashton New Road, Beswick (postcode area M11) |
| London | 571.54 | Near Wembley Stadium (postcode area HA9) |

3.8 The highest radiance value in England is found in Yorkshire and the Humber and is associated with Tata Steel in Rotherham.

3.9 There are no locations in London within the two darkest colour bands and only a handful of locations (13 pixels) within the third darkest category. The highest brightness value in London is a pixel near Wembley Stadium. The darkest location in London can be found in Bromley where the largest continuous zone of colour band 4 (light green) in London is found in southern end of the borough.

3.10 The brightest value in the South East is associated with Thanet Earth, the UK's largest, most high-tech greenhouse complex in Thanet. Similarly, in Chichester, there are very high brightness values associated with greenhouses.

3.11 **Figure 3.3** shows the data for colour band 1 only (the darkest skies). Large swathes of the darkest skies are associated with protected landscapes, however there are some notable swathes that are outside protected landscapes.




National Parks

Areas of Outstanding Natural Beauty

Colour band 1 (darkest)

Map Scale @ A4: 1:3,500,000

**England's Light Pollution and Dark Skies**

Figure 3.3 Protected landscapes and the darkest skies

Source: Natural England, Earth Observation Group, NOAA National Geophysical Data Center

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CB:DM EB:Manson D LUCGLA Fig 3-3 6693-01_019_Band1_A4P 23/05/2016

# 4 Detailed analysis

4.1 The national dataset has been further examined in GIS to identify the areas within England where night time lights are potentially detracting from dark night skies. The dataset has been examined at the following geographical levels:

- County
- District
- Protected Landscapes (National Parks and Areas of Outstanding Natural Beauty)
- National Character Areas

4.2 This chapter provides an overview of the findings of this analysis.

## County

4.3 For the purposes of this analysis, the counties analysed are Ceremonial Counties. 41 Ceremonial Counties[3] in England have been examined in terms of their average (mean) and maximum brightness values. These Ceremonial County boundaries align well with the CPRE branches. **Counties have been assigned a rank according to the average (mean) brightness values and Table 4.1 shows them ranked from darkest to brightest.**

**Table 4.1 Counties ranked by average (mean) brightness values**

| County | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| Herefordshire | 1 | 0.51 | 55.67 |
| Northumberland | 2 | 0.60 | 54.27 |
| Cumbria | 3 | 0.65 | 103.29 |
| Cornwall | 4 | 0.71 | 26.28 |
| Rutland | 5 | 0.80 | 14.63 |
| Devon | 6 | 0.82 | 81.74 |
| Shropshire | 7 | 1.02 | 65.70 |
| Norfolk | 8 | 1.06 | 149.33 |
| Suffolk | 9 | 1.28 | 181.96 |
| North Yorkshire | 10 | 1.31 | 163.72 |
| Somerset | 11 | 1.33 | 71.48 |
| Wiltshire | 12 | 1.35 | 61.98 |
| Dorset | 13 | 1.39 | 77.81 |
| East Sussex | 14 | 1.50 | 80.85 |
| Lincolnshire | 15 | 1.55 | 180.07 |
| Isle of Wight | 16 | 1.55 | 62.45 |
| Gloucestershire | 17 | 1.71 | 68.94 |

[3] There are 48 Ceremonial Counties in England. Seven of these have been excluded from this analysis (Bristol, Merseyside, Greater Manchester, West Midlands, Tyne & Wear, Greater London, City of London)

| County | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| Oxfordshire | 18 | 1.82 | 60.10 |
| Cambridgeshire | 19 | 1.86 | 67.95 |
| Worcestershire | 20 | 2.10 | 55.14 |
| East Riding of Yorkshire | 21 | 2.20 | 206.39 |
| West Sussex | 22 | 2.23 | 469.90 |
| Hampshire | 23 | 2.35 | 143.42 |
| Northamptonshire | 24 | 2.41 | 84.72 |
| Warwickshire | 25 | 2.53 | 75.37 |
| Essex | 26 | 3.02 | 154.38 |
| Derbyshire | 27 | 3.17 | 113.21 |
| Leicestershire | 28 | 3.19 | 133.26 |
| Kent | 29 | 3.24 | 584.98 |
| Lancashire | 30 | 3.32 | 74.15 |
| Durham | 31 | 3.32 | 113.24 |
| Bedfordshire | 32 | 3.33 | 178.24 |
| Buckinghamshire | 33 | 3.43 | 79.14 |
| Staffordshire | 34 | 3.61 | 110.14 |
| Surrey | 35 | 3.70 | 136.03 |
| Hertfordshire | 36 | 3.96 | 99.22 |
| Nottinghamshire | 37 | 4.37 | 94.49 |
| Cheshire | 38 | 5.03 | 117.47 |
| Berkshire | 39 | 5.06 | 124.35 |
| South Yorkshire | 40 | 7.42 | 887.93 |
| West Yorkshire | 41 | 10.28 | 170.35 |

## Districts (including Unitary Authorities, London Boroughs and Metropolitan Boroughs)

**4.4** The 326 districts in England have been examined in terms of their average (mean) and maximum brightness values. This includes all districts that make up the counties reported on in the section above as well as all Unitary Authorities, Metropolitan Boroughs and London Boroughs. **Districts have been assigned a rank according to the average (mean) brightness values and Table 4.2 shows the darkest 20 districts ranked from darkest to brightest.**

**Table 4.2 Darkest 20 Districts based on average (mean) brightness values**

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| South West | Cornwall | Isles of Scilly | 1 | 0.14 | 1.27 |
| South West | Devon | West Devon | 2 | 0.28 | 12.39 |
| North West | Cumbria | Eden | 3 | 0.31 | 31.48 |
| Yorkshire and the | North Yorkshire | Ryedale | 4 | 0.31 | 15.64 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| Humber | | | | | |
| South West | Devon | Torridge | 5 | 0.33 | 18.54 |
| Yorkshire and the Humber | North Yorkshire | Richmondshire | 6 | 0.42 | 20.83 |
| South West | Somerset | West Somerset | 7 | 0.43 | 71.48 |
| North West | Cumbria | South Lakeland | 8 | 0.43 | 17.88 |
| Yorkshire and the Humber | North Yorkshire | Craven | 9 | 0.43 | 23.71 |
| South West | Devon | Mid Devon | 10 | 0.44 | 21.80 |
| South West | Dorset | West Dorset | 11 | 0.51 | 30.18 |
| West Midlands | Herefordshire | Herefordshire | 12 | 0.51 | 55.67 |
| South West | Gloucestershire | Cotswold | 13 | 0.56 | 20.65 |
| South West | Devon | South Hams | 14 | 0.57 | 22.28 |
| East of England | Norfolk | North Norfolk | 15 | 0.58 | 49.87 |
| South West | Dorset | North Dorset | 16 | 0.58 | 19.05 |
| North East | Northumberland | Northumberland | 17 | 0.61 | 54.27 |
| Yorkshire and the Humber | North Yorkshire | Hambleton | 18 | 0.62 | 30.00 |
| South West | Devon | North Devon | 19 | 0.62 | 43.79 |
| South East | East Sussex | Wealden District | 20 | 0.64 | 11.97 |

4.5 As can be seen from **Table 4.2**, half of the Districts in the top 20 (with lowest average (mean) brightness values) are in the South West. There are no Districts in the East Midlands or London on this list.

4.6 19 of the 20 brightest Districts are London Boroughs. Manchester is the only District outside of London that falls within the list of 20 brightest Districts. **Table 4.3 shows the brightest 20 Districts outside of London from brightest to 'darkest'.**

**Table 4.3 Brightest 20 Districts outside of London based on mean radiance values**

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| North West | Greater Manchester | Manchester | 313 | 40.89 | 209.26 |
| South East | Berkshire | Slough | 306 | 31.39 | 70.79 |
| North West | Merseyside | Liverpool | 304 | 29.55 | 152.30 |
| North East | Tyne & Wear | Sunderland | 303 | 28.85 | 184.15 |
| West Midlands | West Midlands | Sandwell | 301 | 27.43 | 84.79 |
| South East | West Sussex County | Crawley | 300 | 26.97 | 149.13 |
| North East | Tyne & Wear | South Tyneside | 299 | 26.84 | 107.41 |
| West Midlands | West Midlands | City of Wolverhampton | 297 | 26.61 | 117.11 |
| West | West Midlands | Birmingham | 296 | 26.21 | 142.35 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| Midlands | | | | | |
| Yorkshire and the Humber | East Riding of Yorkshire | City of Kingston upon Hull | 295 | 26.19 | 79.51 |
| East Midlands | Nottinghamshire | City of Nottingham | 294 | 25.89 | 94.49 |
| North East | North Yorkshire | Middlesbrough | 293 | 25.22 | 95.46 |
| East of England | Bedfordshire | Luton | 292 | 25.18 | 178.24 |
| North East | Tyne & Wear | Newcastle upon Tyne | 291 | 24.73 | 280.13 |
| East Midlands | Derbyshire | City of Derby | 289 | 24.32 | 113.21 |
| North West | Lancashire | Blackpool | 287 | 23.89 | 74.15 |
| North West | Greater Manchester | Trafford | 286 | 23.57 | 174.00 |
| South East | Hampshire | City of Portsmouth | 285 | 23.57 | 108.75 |
| West Midlands | Staffordshire | City of Stoke-on-Trent | 284 | 23.56 | 110.14 |
| South East | Berkshire | Reading | 283 | 23.53 | 124.35 |

4.7 **Figure 4.1** shows the average (mean) brightness values for all of the Districts in England and **Appendix 2** shows the complete list of results for Districts. They are divided into quintiles to highlight the darkest 20% through to brightest 20% (with approximately 65 districts in each category).

## Protected Landscapes

**4.8** As can be seen in **Figure 3.3**, some of the darkest skies in England are associated with Protected Landscapes. The 10 National Parks in England have been examined in terms of their average (mean) and maximum brightness values. **Table 4.4 shows the National Parks ranked from darkest to brightest.** Northumberland National Park is an International Dark Sky Park. Overall, 59% of all National Parks are in the darkest category.

**Table 4.4 National Parks ranked by average (mean) brightness values**

| National Park | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value | Percentage of National Park that is Band 1 (darkest category) |
|---|---|---|---|---|
| Northumberland National Park | 1 | 0.14 | 3.86 | 96% |
| Exmoor National Park | 2 | 0.19 | 6.03 | 92% |
| Yorkshire Dales National Park | 3 | 0.21 | 5.87 | 79% |
| Dartmoor National Park | 4 | 0.23 | 12.39 | 80% |
| Lake District National Park | 5 | 0.24 | 12.00 | 79% |

| National Park | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value | Percentage of National Park that is Band 1 (darkest category) |
|---|---|---|---|---|
| North York Moors National Park | 6 | 0.28 | 23.03 | 71% |
| New Forest National Park | 7 | 0.62 | 20.48 | 8% |
| South Downs National Park | 8 | 0.66 | 30.63 | 14% |
| Peak District National Park | 9 | 0.67 | 16.52 | 0% |
| The Broads National Park | 10 | 0.77 | 46.09 | 8% |

4.9 The 34 Areas of Outstanding Natural Beauty (AONBs) in England have been examined in terms of their average (mean) and maximum brightness values. **Table 4.5 shows the AONBs ranked from darkest to brightest**.

**Table 4.5 AONBs ranked by average (mean) brightness values**

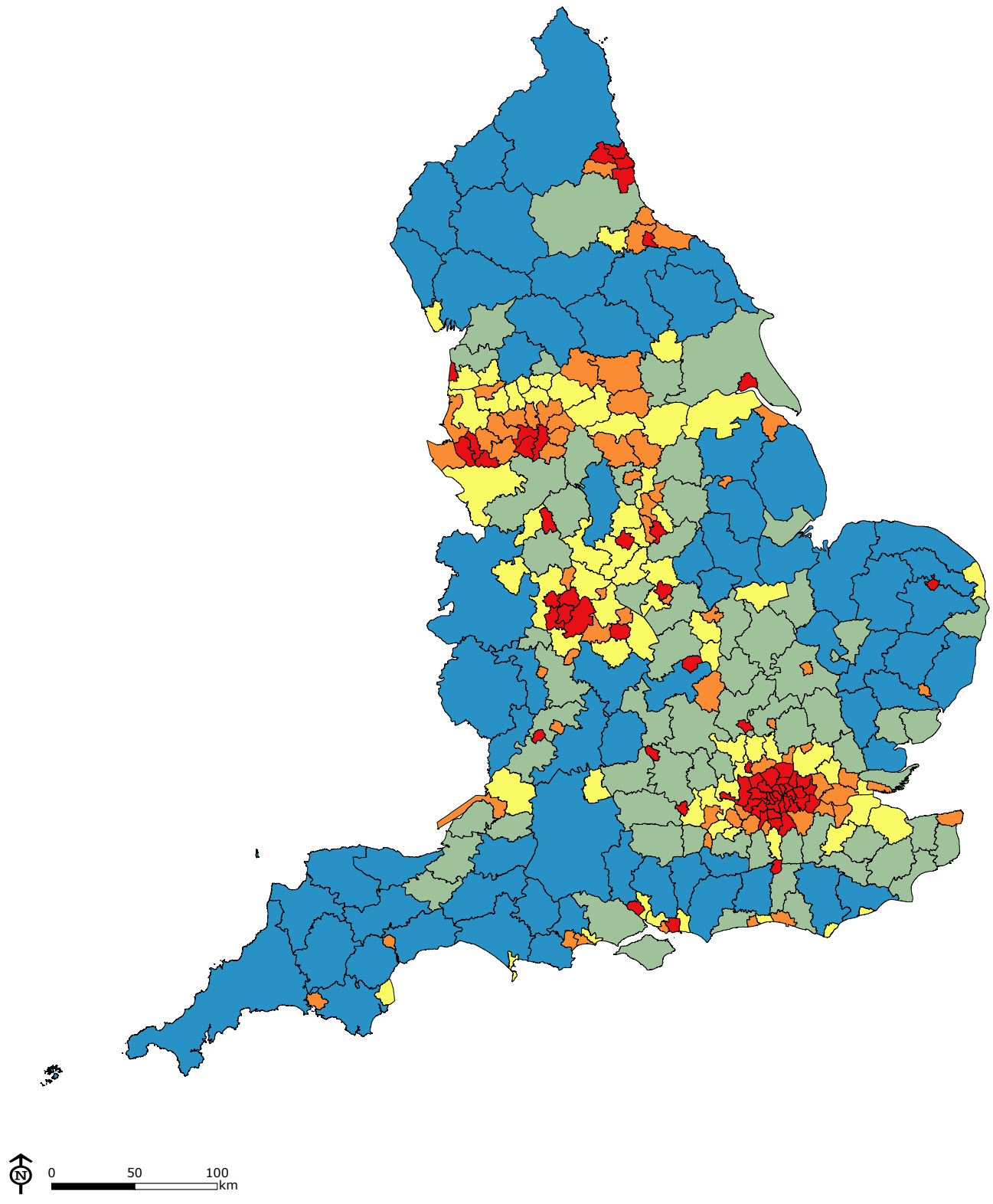
| AONB | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value | Percentage of AONB that is Band 1 (darkest category) |
|---|---|---|---|---|
| Isles Of Scilly AONB | 1 | 0.08 | 1.27 | 98% |
| North Pennines AONB | 2 | 0.19 | 10.52 | 86% |
| Shropshire Hills AONB | 3 | 0.20 | 4.56 | 86% |
| Howardian Hills AONB | 4 | 0.25 | 3.78 | 71% |
| Blackdown Hills AONB | 5 | 0.28 | 4.02 | 53% |
| Quantock Hills AONB | 6 | 0.30 | 2.00 | 37% |
| Cornwall AONB | 7 | 0.32 | 6.21 | 63% |
| Cranborne Chase & West Wiltshire Downs AONB | 8 | 0.33 | 11.85 | 52% |
| Solway Coast AONB | 9 | 0.33 | 5.75 | 54% |
| Lincolnshire Wolds AONB | 10 | 0.36 | 5.58 | 31% |
| Forest Of Bowland AONB | 11 | 0.40 | 5.99 | 32% |
| Nidderdale AONB | 12 | 0.41 | 25.73 | 48% |
| Norfolk Coast AONB | 13 | 0.41 | 38.12 | 52% |
| Northumberland Coast AONB | 14 | 0.42 | 8.92 | 63% |
| East Devon AONB | 15 | 0.42 | 5.72 | 42% |

| AONB | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value | Percentage of AONB that is Band 1 (darkest category) |
|---|---|---|---|---|
| Tamar Valley AONB | 16 | 0.44 | 10.59 | 34% |
| South Devon AONB | 17 | 0.45 | 10.71 | 44% |
| Dorset AONB | 18 | 0.45 | 32.56 | 57% |
| North Devon AONB | 19 | 0.45 | 7.68 | 51% |
| Dedham Vale AONB | 20 | 0.47 | 6.54 | 11% |
| Wye Valley AONB | 21 | 0.51 | 17.94 | 27% |
| Malvern Hills AONB | 22 | 0.55 | 10.41 | 29% |
| Arnside & Silverdale AONB | 23 | 0.56 | 6.59 | 18% |
| Cotswolds AONB | 24 | 0.56 | 19.91 | 24% |
| High Weald AONB | 25 | 0.59 | 22.86 | 15% |
| North Wessex Downs AONB | 26 | 0.60 | 34.02 | 15% |
| Mendip Hills AONB | 27 | 0.60 | 9.25 | 1% |
| Isle Of Wight AONB | 28 | 0.63 | 25.13 | 33% |
| Suffolk Coast & Heaths AONB | 29 | 1.18 | 181.71 | 33% |
| Chilterns AONB | 30 | 1.21 | 36.83 | 0% |
| Surrey Hills AONB | 31 | 1.26 | 28.27 | 0% |
| Chichester Harbour AONB | 32 | 1.30 | 11.94 | 0% |
| Kent Downs AONB | 33 | 1.37 | 84.20 | 3% |
| Cannock Chase AONB | 34 | 1.51 | 8.74 | 0% |

4.10 Of particular note is the high brightness value in Suffolk Coast & Heaths AONB. This value is associated with Felixstowe Port.

4.11 Overall, it is worth noting that even the 'brightest' protected landscapes are darker than the vast majority of districts. 40% of all AONBs are within the darkest category.

4.12 In England, 21.7% of all land is within the darkest category. Of this, 53% is in AONBs (26%) and National Parks (27%).




Districts

Average (mean) brightness values

- 0.14 - 1.28 (Darkest 20%)
- 1.29 - 3.04
- 3.05 - 7.20
- 7.21 - 16.35
- 16.36 - 127.78 (Brightest 20%)

Map Scale @ A4: 1:3,500,000

England's Light Pollution and Dark Skies

Figure 4.1 District mean values

Source: Earth Observation Group, NOAA National Geophysical Data Center

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 CB:DM EB:Manson D LUCGLA Fig 4-16693-01_017_Local_Auth_means_A4P 23/05/2016

## National Character Areas

4.13 The 159 National Character Areas (NCAs) in England have been examined in terms of their average (mean) and maximum brightness values. **Table 4.6 shows the darkest 20 NCAs ranked from darkest to brightest**. Full results for all 159 NCAs can be found in **Appendix 3**.

**Table 4.6 Darkest 20 NCAs based on average (mean) brightness values**

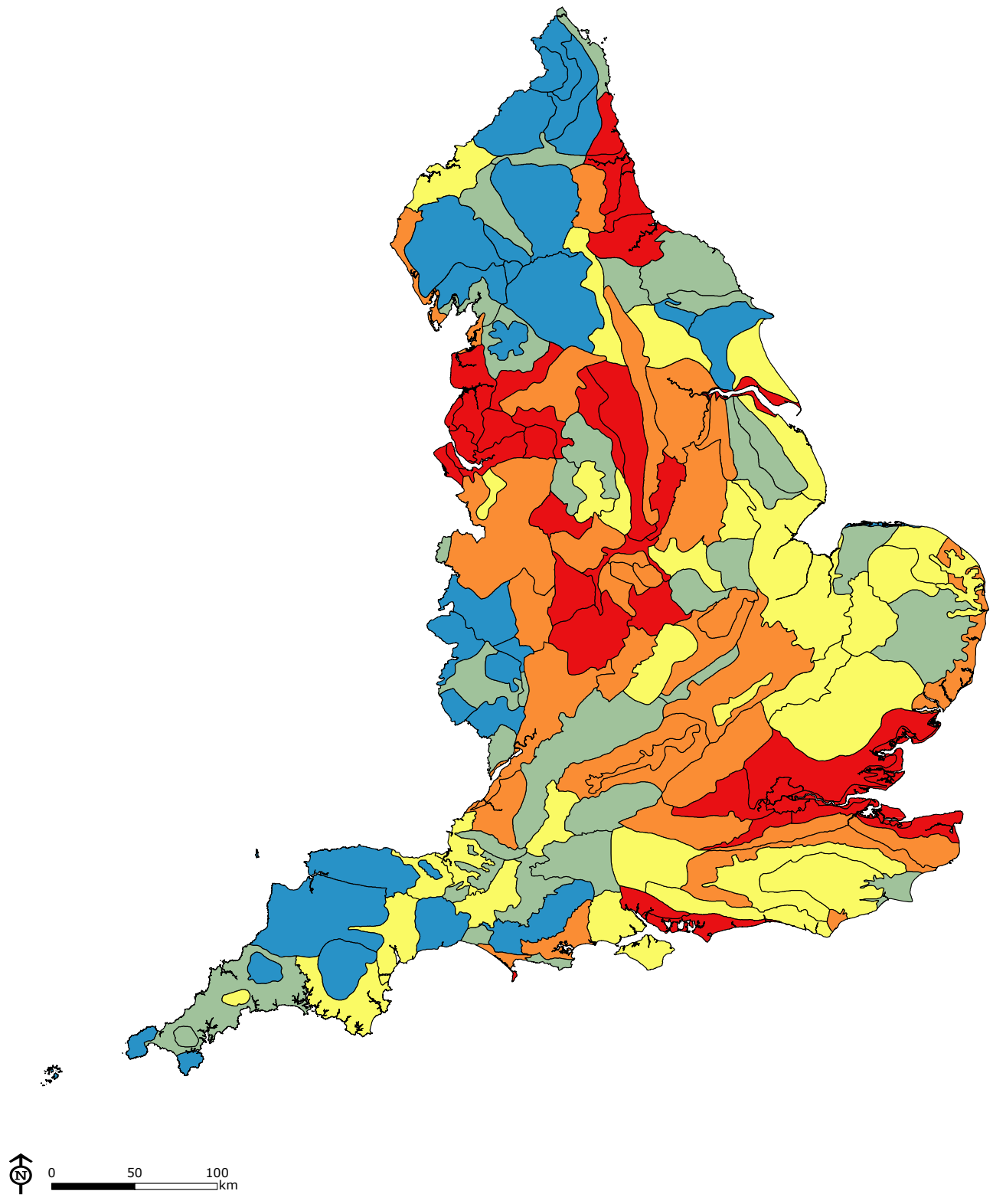
| NCA | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| NCA 159 - Lundy | 1 | 0.10 | 0.20 |
| NCA 4 - Cheviots | 2 | 0.12 | 0.44 |
| NCA 5 - Border Moors And Forests | 3 | 0.14 | 3.86 |
| NCA 158 - Isles Of Scilly | 4 | 0.15 | 1.27 |
| NCA 3 - Cheviot Fringe | 5 | 0.19 | 6.53 |
| NCA 98 - Clun And North West Herefordshire Hills | 6 | 0.20 | 6.14 |
| NCA 2 - Northumberland Sandstone Hills | 7 | 0.21 | 15.74 |
| NCA 10 - North Pennines | 8 | 0.21 | 11.60 |
| NCA 99 - Black Mountains And Golden Valley | 9 | 0.21 | 4.02 |
| NCA 18 - Howgill Fells | 10 | 0.21 | 3.73 |
| NCA 150 - Dartmoor | 11 | 0.22 | 12.39 |
| NCA 8 - Cumbria High Fells | 12 | 0.23 | 12.00 |
| NCA 153 - Bodmin Moor | 13 | 0.23 | 4.38 |
| NCA 34 - Bowland Fells | 14 | 0.26 | 2.33 |
| NCA 21 - Yorkshire Dales | 15 | 0.26 | 23.71 |
| NCA 77 - North Norfolk Coast | 16 | 0.26 | 4.19 |
| NCA 144 - Quantock Hills | 17 | 0.26 | 0.50 |
| NCA 17 - Orton Fells | 18 | 0.27 | 8.29 |
| NCA 157 - The Lizard | 19 | 0.29 | 4.33 |
| NCA 101 - Herefordshire Plateau | 20 | 0.30 | 10.61 |

4.14 **Table 4.7 shows the brightest 20 NCAs ranked from brightest to 'darkest'. Figure 4.2** shows the average (mean) values of each of the NCAs. They are divided into quintiles to highlight the darkest 20% through to brightest 20%.

**Table 4.7 Brightest 20 NCAs based on average (mean) brightness values**

| NCA | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| NCA 112 - Inner London | 159 | 52.14 | 284.62 |
| NCA 55 - Manchester Conurbation | 158 | 30.03 | 209.26 |
| NCA 58 - Merseyside Conurbation | 157 | 27.29 | 152.30 |
| NCA 14 - Tyne And Wear Lowlands | 156 | 18.17 | 280.13 |
| NCA 114 - Thames Basin Lowlands | 155 | 13.97 | 95.78 |
| NCA 115 - Thames Valley | 154 | 13.88 | 285.02 |
| NCA 54 - Manchester Pennine Fringe | 153 | 13.67 | 73.42 |
| NCA 60 - Mersey Valley | 152 | 13.62 | 117.47 |
| NCA 41 - Humber Estuary | 151 | 13.57 | 149.16 |
| NCA 38 - Nottinghamshire, Derbyshire And Yorkshire Coalfield | 150 | 12.94 | 887.93 |
| NCA 67 - Cannock Chase And Cank Wood | 149 | 12.79 | 88.26 |
| NCA 15 - Durham Magnesian Limestone Plateau | 148 | 11.06 | 184.15 |
| NCA 37 - Yorkshire Southern Pennine Fringe | 147 | 10.84 | 124.78 |
| NCA 56 - Lancashire Coal Measures | 146 | 10.20 | 115.22 |
| NCA 97 - Arden | 145 | 9.84 | 142.35 |
| NCA 111 - Northern Thames Basin | 144 | 9.69 | 571.54 |
| NCA 69 - Trent Valley Washlands | 143 | 9.19 | 113.21 |
| NCA 81 - Greater Thames | 142 | 8.79 | 138.32 |

| NCA | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| Estuary | | | |
| NCA 57 - Sefton Coast | 141 | 8.21 | 65.66 |
| NCA 113 - North Kent Plain | 140 | 8.18 | 584.98 |




National Character Areas

Average (mean) brightness values

- 0.10 - 0.52 (Darkest 20%)
- 0.53 - 1.06
- 1.07 - 2.00
- 2.01 - 4.96
- 4.97 - 52.14 (Brightest 20%)

Map Scale @ A4: 1:3,500,000

England's Light Pollution and Dark Skies

Figure 4.2 National Character Area average (mean) values

Source: Natural England, Earth Observation Group, NOAA National Geophysical Data Center

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CB:DM EB:Manson D LUCGLA Fig 4-2 6693-01_020_NCA_means_A4P 23/05/2016

# 5 Case studies

## Investigating change over time

5.1 The potential to investigate change over time through comparison of satellite images from different periods has been explored as part of this study. Now that it is possible to access monthly images from the NOAA website, the potential for comparisons does exist.

5.2 As the images are influenced by the number of cloud free nights that have been used to create the monthly composites, it is not possible to get two images that are captured under exactly the same climatic conditions. It is therefore reasonable to assume that the data may be influenced by this. So, whilst it is possible to explore the changes in values over time, this does need to be borne in mind.

5.3 Using the data acquired for September 2014, and processing it in the same way as the new national map, it is possible to compare the brightness values in sample locations for September 2014 and September 2015. When comparing the images in this section, it is important to bear in mind that some of the change may be due to the factors highlighted above.

### Ashington, Northumberland

5.4 In March 2015, Ashington Town Council in Northumberland started a programme of modernising street lighting by replacing nearly 17,000 lampposts and refitting all streetlights with new LED lights. The work will take approximately three years in total, and will result in about 29,000 lights being changed to LED. The LED lights are also manufactured and fitted to help reduce light pollution, ensuring footpaths and roads are well lit but avoiding an intrusion of light into people's homes and gardens.

5.5 **Figure 5.1** below shows the area 'before' (September 2014) and 'after' (September 2015). It does appear that the brightest locations in 2014 have become darker in 2015. Similarly, there are a number of pixels that have changed from colour band 8 to colour band 7 – effectively getting darker overall.

### Isle of Wight

5.6 In April 2013, the Isle of Wight street lighting improvement programme began enhancing or replacing the 12, 068 street lights across the island. The programme will take three years to complete and will lead to the conversion of the lights to LED. **Figure 5.2** shows the Isle of Wight in September 2014 and September 2015. There does appear to be an overall darkening effect.

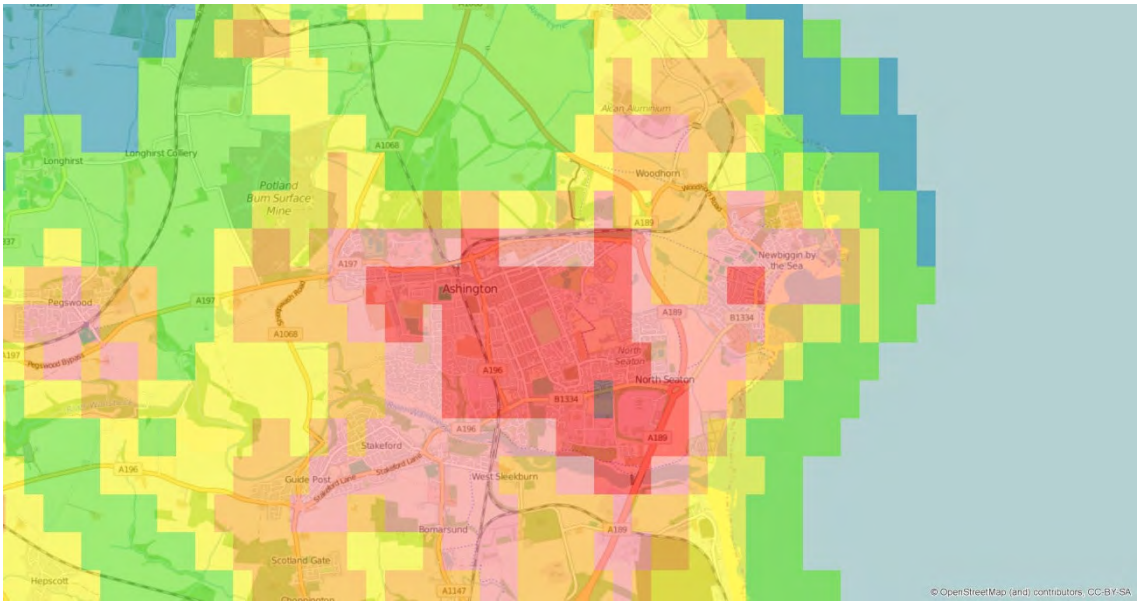
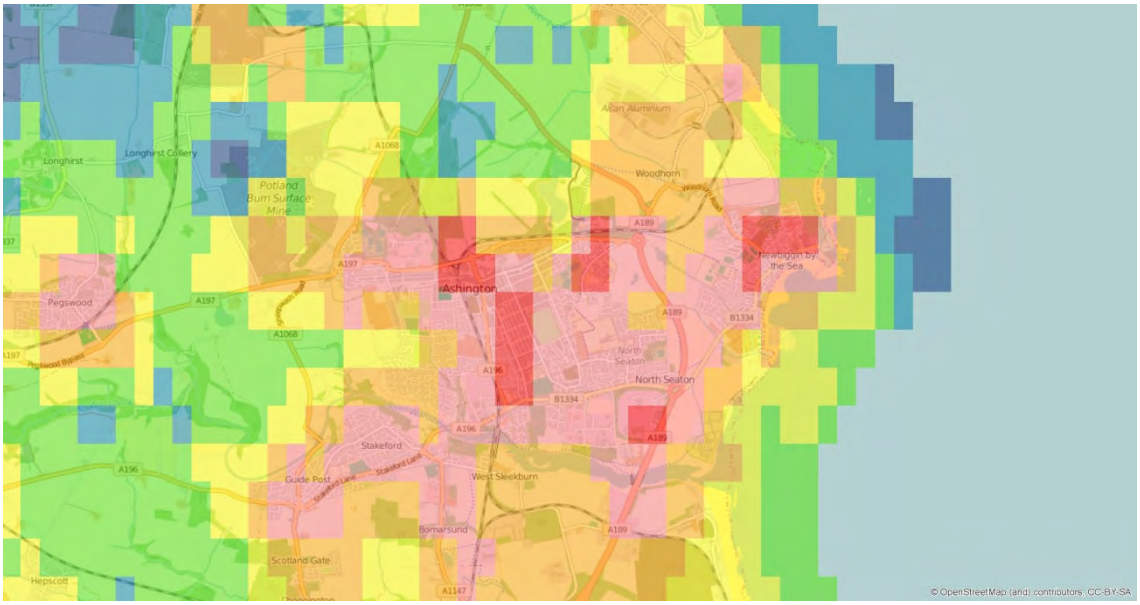



**Figure 5.1 Comparison between Ashington 2014 and 2015**



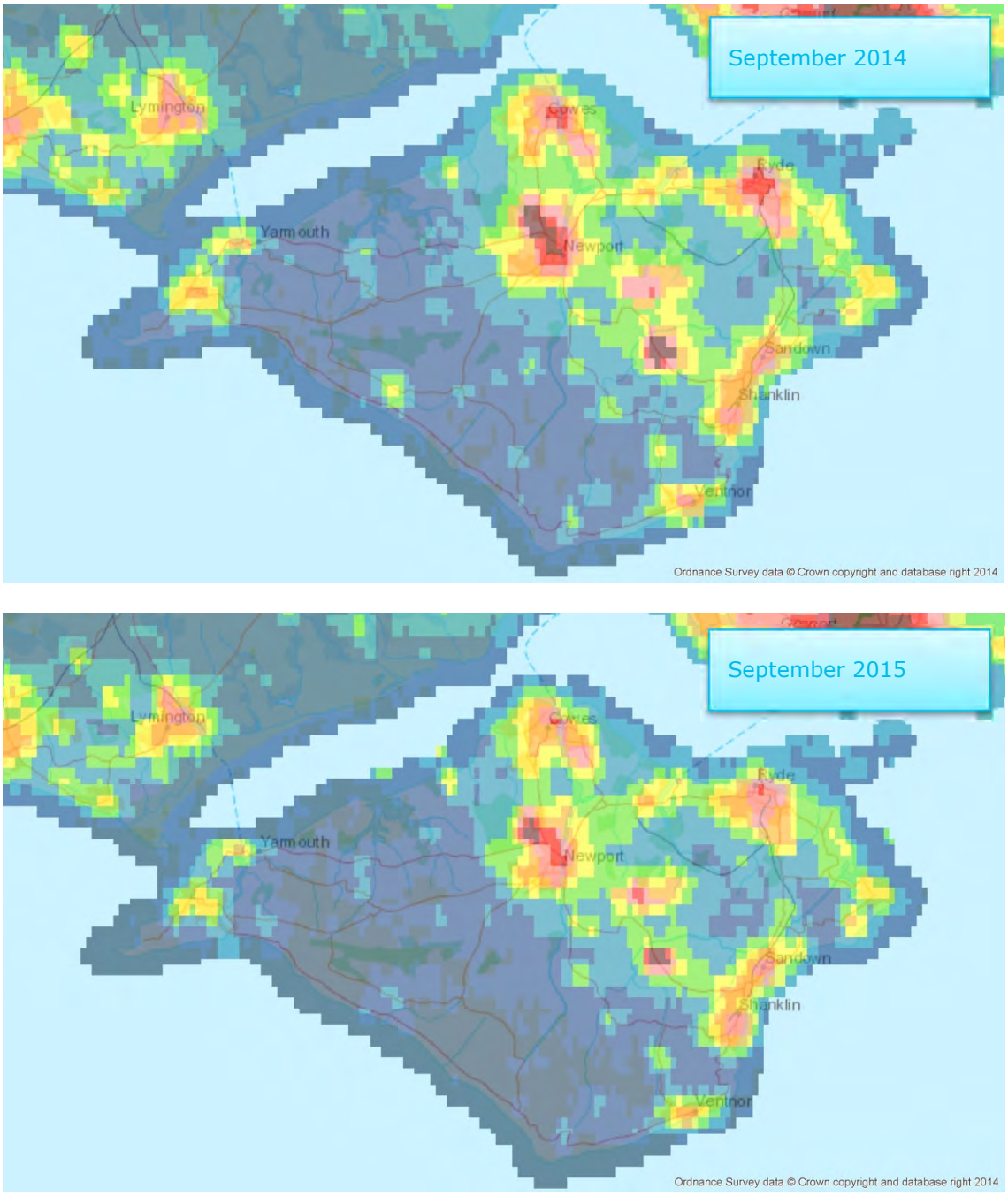



**Figure 5.2 Comparison between Isle of Wight 2014 and 2015**

# 6 Supporting tools and information

6.1 As part of this study, an online web map has been developed to provide users access to the underlying data. The web map can be accessed **here**.

6.2 By selecting the area of interest on the web map, users can download a PDF map showing summary data for that area. PDF maps are available for the following boundaries:

- National map
- Regions
- Counties
- Districts
- Protected Landscapes (National Parks and AONBs)
- National Character Areas

6.3 Furthermore, users can zoom to their area of interest (using zoom and pan tools or selecting their postcode sector) and print a map of their area.

## Potential uses for the updated light pollution maps

6.4 The experience of dark night skies is an important cultural service, contributing to the aesthetic and spiritual values placed on our landscapes. Such 'ecosystem services' are being given an increasingly high profile in land use planning and policy development. Information on dark skies and light pollution can therefore provide an important layer in the baseline evidence to inform a range of place based studies and help inform future change/ management requirements.

### Landscape and Seascape Character Assessments (LCA and SCA)

6.5 Updated light pollution maps can help define areas of dark skies and more 'remote character' and contribute to the process of characterisation. Dark skies can be a particularly valued characteristic of the seascape and views from the coast.

6.6 In the application of these studies for example landscape sensitivity, light pollution mapping can help indicate those areas more sensitive to development/change (i.e. those that might currently be free from light pollution) and or highlight where mitigation of the impact of lighting is required.

### Environmental Impact Assessment (EIA)

6.7 Data on the current levels of light pollution can provide the baseline against which to measure potential change introduced by new lighting associated with new developments and/or land uses, and help inform appropriate mitigation, for example as part of the Landscape and Visual impact Assessment (LVIA).

### Understanding the setting of valued assets

6.8 Settings studies are just one application where light pollution maps may have value, notably where the experience of an asset is dependent on the quality of its surrounding dark night skies. Light pollution maps can provide evidence to support this and to show how change/development may affect this experience.

### Cultural services

6.9 As noted ecosystem services are being given an increasingly high profile in land use planning. Light pollution mapping could therefore help inform policies in a range of documents for example Local plan policies, Designated Landscape Management Plans etc.

### Dark sky status applications

6.10 These new maps will be a useful supporting tool for areas who are looking to apply for dark Sky Status.

# Appendix 1 Detailed Methodology

## Using satellite data to map light pollution

### Pre-2012: Defense Meteorological Satellite Program (DMSP)

Since the 1960s, the U.S. Air Force has operated the Defense Meteorological Satellite Program (DMSP), a series of 18 polar-orbiting satellites that observe clouds and other weather variables in key wavelengths of infrared and visible light. Since 1972, the DMSP satellites have included the Operational Linescan System (OLS), an instrument which detects moonlight reflected upwards from clouds in order to measure the extent of cloud cover over different parts of the Earth's surface at night. An additional property of this instrument was that it could also detect lights from cities and towns, fires, gas flares and other heavily lit objects when there is no cloud cover.

Scientists from the US National Oceanographic and Atmospheric Administration (NOAA) developed ways of using this instrument to measure the total brightness of artificial night time lights within small areas of the Earth's surface.

Data from this satellite programme was used in 2003 to generate CPRE's maps of light pollution in England for the periods 1993 and 2003. The DMSP data and products have some shortcomings – namely:

- coarse spatial resolution (the 1993 and 2003 light pollution maps had a resolution of 1km x 1km)
- saturation of bright lights
- lack of in-flight calibration
- lack of spectral channels suitable for discriminating thermal sources of lighting
- lack of low light imaging spectral bands suitable for discriminating lighting types[4].

### Post-2012: Suomi National Polar Orbiting Partnership (Suomi NPP)

The Suomi National Polar-orbiting Partnership or Suomi NPP is a weather satellite operated by the United States National Oceanic and Atmospheric Administration (NOAA). Launched in October 2011, the polar-orbiting satellite flies over any given point on Earth's surface twice each day at roughly 1:30 a.m. and 1:30 p.m (local solar time). Suomi NPP orbits 824 kilometres (512 miles) above the surface as it circles the planet 14 times a day. Data is sent once per orbit to a ground station in Svalbard, Norway, and continuously to local direct broadcast users around the world. The mission is managed by NASA with operational support from NOAA and its Joint Polar Satellite System, which manages the satellite's ground system[5].

There are five instruments on the Suomi NPP satellite:[6]

- The Advanced Technology Microwave Sounder (ATMS), a microwave radiometer, which models temperature and moisture for weather forecasting purposes.
- The **Visible Infrared Imaging Radiometer Suite (VIIRS)** captures visible and infrared imagery to monitor and measure processes including wildfires, ice motion, cloud cover, and land and sea surface temperature amongst other things.
- The Cross-track Infrared Sounder (CrIS), which measures temperature, atmospheric moisture and pressure for weather forecasting.

[4] Why VIIRS data are superior to DMSP for mapping nighttime lights, Christopher D. Elvidge, Kimberly Baugh, Mikhail Zhizhin, Feng Chi Hsu, 2013
[5] http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=79803
[6] http://npp.gsfc.nasa.gov/instruments.html

- The Ozone Mapping and Profiler Suite (OMPS) collects data that is used to track the health of the ozone layer.
- The Clouds and the Earth's Radiant Energy System (CERES) monitors the amount of energy entering and exiting the atmosphere.

Of the above sensors, the important one for this study is the VIIRS instrument which is described in more detail in the next section. The VIIRS collects low light imaging data and has several improvements over the OLS' capabilities.

### Visible Infrared Imaging Radiometer Suite (VIIRS)

VIIRS is a scanning radiometer that collects visible and infrared imagery and radiometric measurements of the land, atmosphere, cryosphere, and oceans. VIIRS data is used to measure cloud and aerosol properties, ocean colour, sea and land surface temperature, ice motion and temperature, fires, and Earth's albedo.[7]

The sensor collects data in a number of channels including:

- 5 High resolution imagery channels (I-bands)
- 16 Moderate resolution channels (M-bands)
- **Day/Night Band (DNB)**

It is the last of these that is of interest for this study – the Day/Night Band.

One of the major differences between the Suomi-NPP data and the DMSP-OLS derived data is the ground footprint. The Suomi-NPP VIIRS pixel footprint is 742m at nadir - the point on the surface of the earth directly below the satellite instrument.

VIIRS produces an image by repeatedly scanning a scene and resolving it as millions of pixels. The DNB sensor determines on-the-fly whether to use its low, medium or high gain mode to gather information on the amount of light emitted. If a pixel is very bright a low gain mode on the sensor prevents the pixel from over-saturating, by altering the exposure time. The opposite occurs if a pixel is dark.[8]

In 2012, NOAA published the first image of night time lights for the earth using the Suomi-NPP VIIRS DNB derived data. This first global product used data captured between April 18-26 2012 and October 11-23 2012 to generate a composite image using cloud free images.

### What can be measured?

Whilst astronauts are able to take photos of the earth at night with a very high spatial resolution, a number of which have been widely publicised, they are limited to the orbit of the International Space Station which only passes over the same point every two or three days at variable times. Using the DNB data collected by the Suomi-NPP satellite, **a daily picture is generated for every location at the same time every night (1:30am)**.

The VIIRS DNB sensor collects data in the spectral range of 500–900 nanometres (nm).

The radiance units are measured in nanowatts/cm2*sr where sr is steradians. A steradian is a section of a sphere where the surface area is equal to the radius of the full sphere. It represents the surface area required by a detector to detect the full radiant flux (energy) at any given distance.

For example, if 1cm$^2$ on the ground was emitting 1 nanowatt of radiant flux and the recording device was 1 meter away, it would require a surface area of 1 square meter in order to collect all of the energy from that nanowatt.

[7] http://www.nsof.class.noaa.gov/saa/products/search?datatype_family=VIIRS
[8] http://earthobservatory.nasa.gov/Features/IntotheBlack/

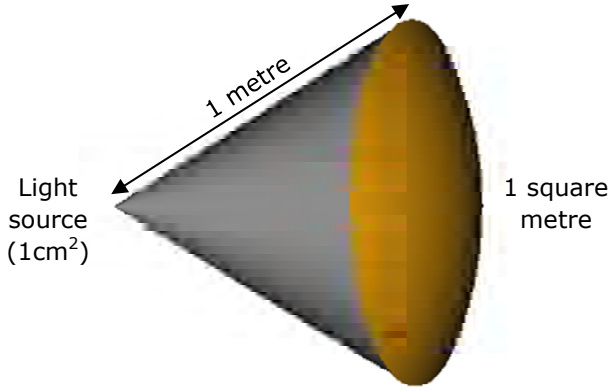



**Figure A.6.1 Illustration of a steradian**

As a further example, if 1cm$^2$ on the ground was emitting 235 nanowatts of radiant flux and the recording device was 824km above the surface of the Earth (as the satellite is in this study), it would require a detector that is 824 km$^2$ in order to fully absorb all 235 nanowatts. Since this satellite does not have detectors anywhere near that size, it instead measures the light that is detected by its detector and multiplies the size of that into the 824km$^2$ to get the measurement of radiance.

The reason for this is that the intensity of light falls off with the inverse-square of distance – the intensity of the light is proportional to the square of the distance between the emitter and the detector. For example; a detector at 2km from the light source would detect a quarter of the light one at 1km would. Just detecting the light falling on the detector would take into account both the intensity of the light being detected, and its distance from the detector. Calculating the radiance removes the distance variable.

LUC and CPRE have continually monitored the availability of satellite imagery to create an updated map of night time lights for the UK for a number of years. Through dialogue with scientists at NOAA (Chris Elvidge and Kim Baugh in particular), it was established that the data being produced by the Suomi-NPP VIIRS DNB offered the opportunity for a significant advancement in the mapping of night time lights in the UK over the original 1993 and 2000 maps.

It is worth noting that whilst the data captured by the Suomi-NPP DNB offers significant improvements over that of the DMSP data, the Suomi-NPP DNB lacks sensitivity at wavelengths shorter than 500 nm. Because of this, the blue-light emission peak of white LEDs is not detected. This means that the "blue blindness" of the VIIRS DNB could falsely suggest a reduction in light pollution in some towns and cities in the future, whereas the brightness of the sky as seen by human eyes may in fact increase. This is a known limitation of this data.

In the future it would be useful to undertake further analysis comparing Sky Quality Meter (SQM) readings which are taken from the ground to the information that is being picked up by the satellite to better understand the impact of LED lighting that is not visible to the satellite. We will also monitor advances in technology that will enable this end of the spectral range to be explored in future.

## Obtaining data to create a new national map

The algorithms and processes used to create the first 2012 image have been evolving and improving ever since. The Earth Observations Group (EOG) at NOAA produces a Version 1 suite of monthly average radiance composite images using night time data from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB). Since January 2014, it has been possible to download monthly composites that have been filtered to exclude data impacted by stray light, lightning, lunar illumination and cloud cover.

These Version 1 composites span the globe and are produced in 15 arc second geographic grids as geotiff files. The globe is split into a set of 6 tiles (for storage, handling and processing purposes). Each tile includes two images:

- Average DNB radiance values, and
- Number of cloud free observations used to make the average.

The data are composited monthly, but there are areas of the globe where it is impossible to get good quality data coverages for some months of the year. Reasons for this include:

- Cloud cover (particularly in the tropics)
- Solar illuminations (particularly in areas near the poles in summer months).

There are two versions of each dataset which are created using different configurations. The first excludes any data impacted by stray light. The second includes these data if the radiance values have undergone the stray light correction procedure. The latter of these (stray light corrected) has more coverage towards the poles, and it is this set of data that has been selected for this study.

Data were downloaded from the website here:
http://ngdc.noaa.gov/eog/viirs/download_monthly.html

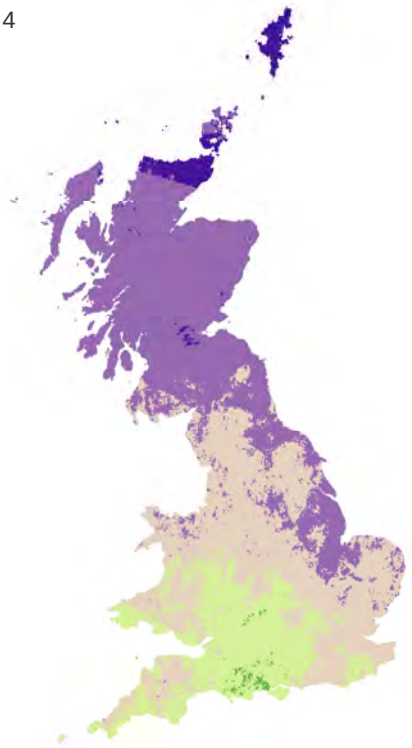
The datasets are very large and the downloading and extraction (from compressed file formats) is time consuming. For the purposes of this study, data covering the period January 2014 to December 2015 (the latest available dataset) at the time of undertaking this work were downloaded for review and analysis.

## Review of the data to identify a baseline dataset

For the purposes of selecting a baseline dataset to use in the creation of the national map, all of the datasets were brought into Geographic Information System (GIS) software – ESRI ArcMap. Each month was viewed alongside its cloud free composite data to establish the extent to which cloud cover was impacting the data.

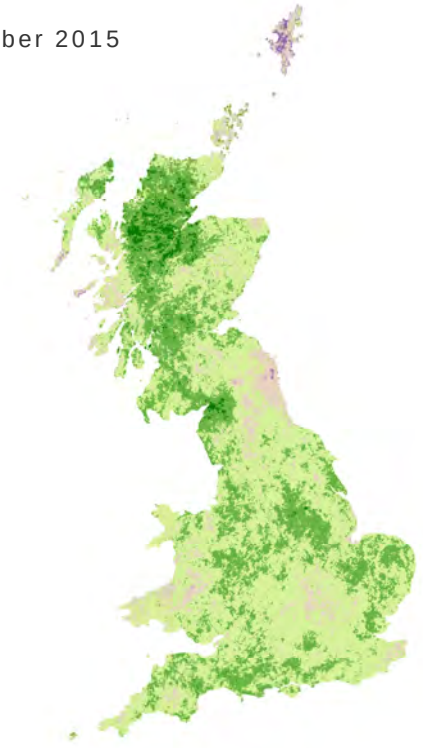
It was noticeable that the effect of solar illumination was significantly reducing the quality of information for the UK in the summer months. Examples of data that were dismissed as being of too poor quality for this study are shown in the top two boxes in **Figure A.2.**

July 2014



July 2015

September 2015



October 2015

Cloud free days

- 0
- 1 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21+

Map Scale @ A4: 1:12,500,000

England's Light Pollution and Dark Skies

Figure A.2 Cloud free data

Source: Earth Observation Group, NOAA National Geophysical Data Center

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CPRE Campaign to Protect Rural England
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CB:DM EB:Manson D LUCGLA Fig A-2 6693-01_018_Cloud_free_data_A4P 23/05/2016

Other months were dismissed due to the extent of cloud cover affecting one or more parts of the country. After a thorough review, **September 2015** was selected as the best month in terms of low influence of cloud cover, and has been used as the baseline dataset to create the national map. The bottom two boxes in **Figure A.3** show the better quality (in terms of cloud free days) data obtained in September and October 2015.

## Processing the data

Data covering the UK is available as part of a larger tile covering 120 degrees of latitude (75N/060W) and reaching south to the equator. Bringing the data into GIS, the raw data has a geographic projection of WGS84[9] and the coordinates are latitude and longitude.

Data has been clipped in GIS to the UK boundary with an additional 1km buffer around the coastline (so as to ensure the entire land area is covered by complete pixels).

The pixel size of the original dataset was 15 arc seconds and was projected in WGS84. This projection distorts the shape of land areas the further they are from the equator, so Great Britain becomes more distorted the further north the pixels are. The southernmost pixel was 300m by 460m, and the northernmost 225m by 469m.

In order to make the data display properly within the web map it was necessary to project it to WGS 1984 Web Mercator. This involved resampling the pixels from 15 arc seconds to 400m x 400m cells – a value chosen as it falls between the minimum and maximum pixels size within the original data.

## Creating a national classification

The range of data (brightness) values was reviewed in both ArcGIS and in Excel in order to identify the best method of classifying the data into discreet bands for the purposes of analysis as well as visual display.

The range of data values differs on a monthly basis, but for September 2015, the values (once clipped to the UK boundary) ranged from -0.286 to 1556.843 nw/cm2/sr. [10]

Although a number of automated classification methods were tested in GIS, the final method of classification was a manual classification. Colours have been assigned to each of the bands ranging from dark blues (low brightness values) to dark reds (high brightness values) as shown in **Table A.1**.

**Table A.1 Colour bandings and values**

| Band | Values in nw/cm$^2$/sr |
|---|---|
| Colour band 1 (Darkest) | <0.25 |
| Colour band 2 | 0.25-0.5 |
| Colour band 3 | 0.5-1 |
| Colour band 4 | 1-2 |
| Colour band 5 | 2-4 |

[9] WGS84 is the reference coordinate system used by GPS.
[10] Negative numbers exist in the dataset due to the overall global calibration of the dataset.

| Band | Values in nw/cm$^2$/sr |
|---|---|
| Colour band 6 | 4-8 |
| Colour band 7 | 8-16 |
| Colour band 8 | 16-32 |
| Colour band 9 (Brightest) | >32 |

# Appendix 2 Full results of district-level analysis

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| South West | Cornwall | Isles of Scilly | 1 | 0.14 | 1.27 |
| South West | Devon | West Devon | 2 | 0.28 | 12.39 |
| North West | Cumbria | Eden | 3 | 0.31 | 31.48 |
| Yorkshire and the Humber | North Yorkshire | Ryedale | 4 | 0.31 | 15.64 |
| South West | Devon | Torridge | 5 | 0.33 | 18.54 |
| Yorkshire and the Humber | North Yorkshire | Richmondshire | 6 | 0.42 | 20.83 |
| South West | Somerset | West Somerset | 7 | 0.43 | 71.48 |
| North West | Cumbria | South Lakeland | 8 | 0.43 | 17.88 |
| Yorkshire and the Humber | North Yorkshire | Craven | 9 | 0.43 | 23.71 |
| South West | Devon | Mid Devon | 10 | 0.44 | 21.80 |
| South West | Dorset | West Dorset | 11 | 0.51 | 30.18 |
| West Midlands | Herefordshire | Herefordshire | 12 | 0.51 | 55.67 |
| South West | Gloucestershire | Cotswold | 13 | 0.56 | 20.65 |
| South West | Devon | South Hams | 14 | 0.57 | 22.28 |
| East of England | Norfolk | North Norfolk | 15 | 0.58 | 49.87 |
| South West | Dorset | North Dorset | 16 | 0.58 | 19.05 |
| North East | Northumberland | Northumberland | 17 | 0.61 | 54.27 |
| Yorkshire and the Humber | North Yorkshire | Hambleton | 18 | 0.62 | 30.00 |
| South West | Devon | North Devon | 19 | 0.62 | 43.79 |
| South East | East Sussex | Wealden | 20 | 0.64 | 11.97 |
| East of England | Norfolk | Breckland | 21 | 0.66 | 21.62 |
| North West | Cumbria | Allerdale | 22 | 0.67 | 50.24 |
| West Midlands | Shropshire | Shropshire | 23 | 0.68 | 37.11 |
| South East | East Sussex | Rother | 24 | 0.69 | 25.81 |
| South West | Cornwall | Cornwall | 25 | 0.72 | 26.28 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| East of England | Suffolk | Mid Suffolk | 26 | 0.73 | 35.39 |
| East Midlands | Lincolnshire | East Lindsey | 27 | 0.76 | 78.50 |
| South West | Devon | East Devon | 28 | 0.77 | 40.41 |
| East Midlands | Rutland | Rutland | 29 | 0.80 | 14.63 |
| South East | Hampshire | East Hampshire | 30 | 0.81 | 17.73 |
| West Midlands | Worcestershire | Malvern Hills | 31 | 0.82 | 17.07 |
| East of England | Essex | Maldon | 32 | 0.82 | 20.65 |
| East Midlands | Leicestershire | Melton | 33 | 0.84 | 27.05 |
| East Midlands | Lincolnshire | West Lindsey | 34 | 0.86 | 36.23 |
| Yorkshire and the Humber | North Yorkshire | Scarborough | 35 | 0.87 | 51.89 |
| South West | Dorset | Purbeck | 36 | 0.88 | 31.41 |
| South West | Gloucestershire | Forest of Dean | 37 | 0.88 | 26.19 |
| East of England | Suffolk | Babergh | 38 | 0.90 | 97.74 |
| East of England | Norfolk | King's Lynn and West Norfolk | 39 | 0.90 | 48.97 |
| South West | Devon | Teignbridge | 40 | 0.91 | 30.87 |
| South East | Hampshire | Winchester | 41 | 0.91 | 33.45 |
| East Midlands | Derbyshire | Derbyshire Dales | 42 | 0.91 | 23.95 |
| North West | Cumbria | Copeland | 43 | 0.93 | 80.83 |
| East of England | Norfolk | South Norfolk | 44 | 0.94 | 31.71 |
| North West | Cumbria | Carlisle | 45 | 0.94 | 47.69 |
| West Midlands | Warwickshire | Stratford-on-Avon | 46 | 0.95 | 36.22 |
| Yorkshire and the Humber | North Yorkshire | Harrogate | 47 | 0.96 | 48.25 |
| South West | Wiltshire | Wiltshire | 48 | 0.97 | 58.63 |
| South West | Dorset | East Dorset | 49 | 0.98 | 17.17 |
| East of England | Cambridgeshire | East Cambridgeshire | 50 | 1.00 | 19.96 |
| North West | Lancashire | Ribble Valley | 51 | 1.00 | 33.73 |
| East of England | Essex | Braintree | 52 | 1.05 | 30.01 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| South West | Somerset | South Somerset | 53 | 1.06 | 37.51 |
| East of England | Suffolk | St. Edmundsbury | 54 | 1.07 | 40.10 |
| South West | Somerset | Mendip | 55 | 1.09 | 20.64 |
| East Midlands | Lincolnshire | South Kesteven | 56 | 1.11 | 35.46 |
| South East | Oxfordshire | West Oxfordshire | 57 | 1.12 | 49.95 |
| East Midlands | Lincolnshire | North Kesteven | 58 | 1.15 | 28.22 |
| East Midlands | Lincolnshire | South Holland | 59 | 1.15 | 32.01 |
| East of England | Norfolk | Broadland | 60 | 1.17 | 36.92 |
| South East | West Sussex | Horsham | 61 | 1.17 | 33.26 |
| South East | Hampshire | Test Valley | 62 | 1.17 | 42.41 |
| South East | Surrey | Waverley | 63 | 1.21 | 22.46 |
| East of England | Suffolk | Suffolk Coastal | 64 | 1.22 | 181.96 |
| South East | West Sussex | Chichester | 65 | 1.27 | 469.90 |
| East Midlands | Northamptonshire | South Northamptonshire | 66 | 1.28 | 70.20 |
| East Midlands | Leicestershire | Harborough | 67 | 1.29 | 70.14 |
| South East | Kent | Ashford | 68 | 1.29 | 53.25 |
| South East | East Sussex | Lewes | 69 | 1.30 | 38.32 |
| West Midlands | Staffordshire | Staffordshire Moorlands | 70 | 1.30 | 22.02 |
| East Midlands | Northamptonshire | East Northamptonshire | 71 | 1.32 | 55.13 |
| South East | Kent | Tunbridge Wells | 72 | 1.36 | 30.36 |
| South West | Gloucestershire | Stroud | 73 | 1.37 | 37.58 |
| East of England | Cambridgeshire | South Cambridgeshire | 74 | 1.40 | 67.95 |
| East of England | Suffolk | Waveney | 75 | 1.40 | 46.75 |
| Yorkshire and the Humber | East Riding of Yorkshire | East Riding of Yorkshire | 76 | 1.42 | 206.39 |
| East Midlands | Lincolnshire | Boston | 77 | 1.44 | 28.08 |
| South West | Somerset | Taunton Deane | 78 | 1.44 | 35.94 |
| South East | Buckinghamshire | Aylesbury Vale | 79 | 1.44 | 54.70 |
| North West | Lancashire | Lancaster | 80 | 1.45 | 65.27 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| East of England | Cambridgeshire | Fenland | 81 | 1.46 | 39.65 |
| East Midlands | Derbyshire | High Peak | 82 | 1.48 | 31.71 |
| West Midlands | Worcestershire | Wychavon | 83 | 1.49 | 36.45 |
| South East | Hampshire | Basingstoke and Deane | 84 | 1.50 | 87.49 |
| East Midlands | Northamptonshire | Daventry | 85 | 1.53 | 84.72 |
| East of England | Hertfordshire | East Hertfordshire | 86 | 1.53 | 35.80 |
| East of England | Essex | Uttlesford | 87 | 1.54 | 154.38 |
| South East | Isle of Wight | Isle of Wight | 88 | 1.55 | 62.45 |
| South East | Oxfordshire | South Oxfordshire | 89 | 1.57 | 58.05 |
| East of England | Essex | Rochford | 90 | 1.59 | 40.78 |
| South West | Somerset | Sedgemoor | 91 | 1.61 | 49.22 |
| East of England | Cambridgeshire | Huntingdonshire | 92 | 1.61 | 32.79 |
| South East | Hampshire | New Forest | 93 | 1.62 | 98.86 |
| South West | Gloucestershire | Tewkesbury | 94 | 1.65 | 38.07 |
| South East | Oxfordshire | Vale of White Horse | 95 | 1.68 | 34.09 |
| South East | West Sussex | Mid Sussex | 96 | 1.68 | 19.35 |
| East of England | Essex | Tendring | 97 | 1.71 | 70.84 |
| East of England | Hertfordshire | North Hertfordshire | 98 | 1.74 | 40.79 |
| South East | Kent | Shepway | 99 | 1.77 | 69.28 |
| South East | Berkshire | West Berkshire | 100 | 1.83 | 55.37 |
| South East | Kent | Sevenoaks | 101 | 1.90 | 24.06 |
| South West | Somerset | Bath and North East Somerset | 102 | 1.91 | 36.03 |
| South East | Oxfordshire | Cherwell | 103 | 1.91 | 54.07 |
| South East | Buckinghamshire | Chiltern | 104 | 2.02 | 19.79 |
| West Midlands | Staffordshire | Stafford | 105 | 2.04 | 52.79 |
| South East | Kent | Dover | 106 | 2.05 | 84.20 |
| South East | Surrey | Tandridge | 107 | 2.06 | 28.27 |
| North East | Durham | County Durham | 108 | 2.08 | 69.89 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| South East | Hampshire | Hart | 109 | 2.09 | 37.95 |
| East Midlands | Nottinghamshire | Newark and Sherwood | 110 | 2.10 | 50.03 |
| East of England | Suffolk | Forest Heath | 111 | 2.14 | 48.20 |
| South East | Kent | Canterbury | 112 | 2.19 | 34.71 |
| North West | Lancashire | Wyre | 113 | 2.24 | 40.65 |
| South East | Surrey | Mole Valley | 114 | 2.25 | 65.92 |
| North West | Lancashire | Pendle | 115 | 2.26 | 25.51 |
| South East | Kent | Maidstone | 116 | 2.28 | 47.99 |
| East of England | Essex | Colchester | 117 | 2.30 | 53.17 |
| West Midlands | Worcestershire | Wyre Forest | 118 | 2.33 | 36.02 |
| South East | West Sussex | Arun | 119 | 2.34 | 35.84 |
| Yorkshire and the Humber | North Yorkshire | Selby | 120 | 2.37 | 98.13 |
| East of England | Bedfordshire | Bedford | 121 | 2.42 | 54.78 |
| East of England | Essex | Chelmsford | 122 | 2.43 | 66.79 |
| East Midlands | Nottinghamshire | Bassetlaw | 123 | 2.50 | 48.64 |
| East Midlands | Nottinghamshire | Rushcliffe | 124 | 2.56 | 48.98 |
| East of England | Bedfordshire | Central Bedfordshire | 125 | 2.63 | 48.97 |
| East Midlands | Derbyshire | North East Derbyshire | 126 | 2.78 | 32.25 |
| South East | Buckinghamshire | Wycombe | 127 | 2.83 | 64.32 |
| South East | Surrey | Guildford | 128 | 2.89 | 46.88 |
| North West | Cheshire | Cheshire East | 129 | 2.89 | 70.27 |
| East Midlands | Leicestershire | Hinckley and Bosworth | 130 | 2.92 | 87.10 |
| South West | Somerset | North Somerset | 131 | 3.04 | 58.41 |
| South West | Devon | Torbay | 132 | 3.04 | 20.78 |
| East Midlands | Northamptonshire | Kettering | 133 | 3.05 | 51.01 |
| West Midlands | Staffordshire | South Staffordshire | 134 | 3.08 | 39.14 |
| West Midlands | Staffordshire | East Staffordshire | 135 | 3.09 | 97.89 |
| East Midlands | Derbyshire | South Derbyshire | 136 | 3.11 | 49.15 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| South East | Kent | Swale | 137 | 3.19 | 118.79 |
| North West | Lancashire | Rossendale | 138 | 3.20 | 24.81 |
| West Midlands | Warwickshire | Warwick | 139 | 3.21 | 73.53 |
| East of England | Essex | Epping Forest | 140 | 3.31 | 49.57 |
| West Midlands | Warwickshire | Rugby | 141 | 3.32 | 71.09 |
| West Midlands | Staffordshire | Lichfield | 142 | 3.33 | 84.82 |
| East Midlands | Derbyshire | Amber Valley | 143 | 3.37 | 47.04 |
| Yorkshire and the Humber | Lincolnshire | North Lincolnshire | 144 | 3.46 | 180.07 |
| East of England | Norfolk | Great Yarmouth | 145 | 3.51 | 47.80 |
| East Midlands | Northamptonshire | Wellingborough | 146 | 3.52 | 38.13 |
| South West | Gloucestershire | South Gloucestershire | 147 | 3.56 | 68.94 |
| East of England | Essex | Brentwood | 148 | 3.57 | 34.13 |
| North West | Lancashire | West Lancashire | 149 | 3.64 | 40.55 |
| West Midlands | Worcestershire | Bromsgrove | 150 | 3.72 | 29.78 |
| East of England | Hertfordshire | Dacorum | 151 | 3.82 | 75.75 |
| East Midlands | Leicestershire | Charnwood | 152 | 3.82 | 48.92 |
| North West | Lancashire | Fylde | 153 | 4.16 | 48.64 |
| South West | Dorset | Christchurch | 154 | 4.16 | 26.27 |
| South East | Surrey | Surrey Heath | 155 | 4.32 | 42.43 |
| South East | Kent | Tonbridge and Malling | 156 | 4.34 | 54.86 |
| North West | Lancashire | Burnley | 157 | 4.38 | 42.72 |
| North West | Lancashire | Chorley | 158 | 4.43 | 57.77 |
| West Midlands | Staffordshire | Newcastle-under-Lyme | 159 | 4.57 | 57.13 |
| East of England | Cambridgeshire | City of Peterborough | 160 | 4.60 | 56.00 |
| Yorkshire and the Humber | North Yorkshire | York | 161 | 4.61 | 70.45 |
| Yorkshire and the Humber | West Yorkshire | Calderdale | 162 | 4.63 | 81.92 |
| East Midlands | Leicestershire | North West Leicestershire | 163 | 4.63 | 84.71 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| East Midlands | Derbyshire | Bolsover | 164 | 4.76 | 54.18 |
| West Midlands | Shropshire | Telford and Wrekin | 165 | 4.83 | 65.70 |
| West Midlands | Warwickshire | North Warwickshire | 166 | 4.91 | 75.37 |
| North West | Cheshire | Cheshire West and Chester | 167 | 5.05 | 117.47 |
| East Midlands | Nottinghamshire | Gedling | 168 | 5.06 | 38.31 |
| North West | Cumbria | Barrow-in-Furness | 169 | 5.07 | 103.29 |
| South East | Hampshire | Fareham | 170 | 5.13 | 33.45 |
| North West | Lancashire | Blackburn with Darwen | 171 | 5.30 | 49.70 |
| East Midlands | Leicestershire | Blaby | 172 | 5.38 | 55.94 |
| North East | Durham | Darlington | 173 | 5.40 | 62.43 |
| South East | East Sussex | Eastbourne | 174 | 5.45 | 29.43 |
| South East | Hampshire | Havant | 175 | 5.53 | 34.51 |
| East of England | Essex | Castle Point | 176 | 5.57 | 35.60 |
| South East | Surrey | Woking | 177 | 5.62 | 75.97 |
| South East | Surrey | Reigate and Banstead | 178 | 5.65 | 49.26 |
| South East | Hampshire | Eastleigh | 179 | 5.70 | 33.90 |
| South East | Berkshire | Windsor and Maidenhead | 180 | 5.84 | 57.38 |
| South East | Berkshire | Wokingham | 181 | 5.93 | 91.43 |
| Yorkshire and the Humber | South Yorkshire | Barnsley | 182 | 5.94 | 74.27 |
| East of England | Hertfordshire | St. Albans | 183 | 5.99 | 55.21 |
| South East | West Sussex | Adur | 184 | 6.00 | 39.74 |
| East of England | Hertfordshire | Welwyn Hatfield | 185 | 6.07 | 99.22 |
| South West | Dorset | Weymouth and Portland | 186 | 6.39 | 44.09 |
| East of England | Hertfordshire | Three Rivers | 187 | 6.51 | 27.08 |
| Yorkshire and the Humber | South Yorkshire | Doncaster | 188 | 6.56 | 107.71 |
| South East | Buckinghamshire | South Bucks | 189 | 6.56 | 43.51 |
| South East | East Sussex | Hastings | 190 | 6.70 | 21.40 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| East Midlands | Derbyshire | Erewash | 191 | 6.78 | 31.23 |
| South West | Wiltshire | Swindon | 192 | 6.78 | 61.98 |
| North West | Lancashire | Hyndburn | 193 | 6.90 | 42.87 |
| North West | Lancashire | Preston | 194 | 7.05 | 71.46 |
| Yorkshire and the Humber | West Yorkshire | Kirklees | 195 | 7.15 | 98.91 |
| South East | Kent | Medway | 196 | 7.20 | 80.06 |
| West Midlands | Warwickshire | Nuneaton and Bedworth | 197 | 7.21 | 52.87 |
| East Midlands | Northamptonshire | Corby | 198 | 7.36 | 53.89 |
| East Midlands | Leicestershire | Oadby and Wigston | 199 | 7.70 | 23.28 |
| Yorkshire and the Humber | Lincolnshire | North East Lincolnshire | 200 | 7.80 | 104.00 |
| South East | Surrey | Elmbridge | 201 | 7.89 | 75.97 |
| South East | Kent | Gravesham | 202 | 7.94 | 92.61 |
| West Midlands | Worcestershire | Redditch | 203 | 8.01 | 46.62 |
| East of England | Hertfordshire | Hertsmere | 204 | 8.02 | 62.10 |
| South East | Surrey | Runnymede | 205 | 8.09 | 44.52 |
| South East | Berkshire | Bracknell Forest | 206 | 8.33 | 82.10 |
| South East | Surrey | Epsom and Ewell | 207 | 8.35 | 27.36 |
| North West | Lancashire | South Ribble | 208 | 8.36 | 50.71 |
| East of England | Hertfordshire | Broxbourne | 209 | 8.45 | 75.33 |
| Yorkshire and the Humber | South Yorkshire | Rotherham | 210 | 8.75 | 887.93 |
| West Midlands | Staffordshire | Cannock Chase | 211 | 8.81 | 57.40 |
| North West | Greater Manchester | Wigan | 212 | 8.92 | 49.42 |
| South East | Hampshire | Gosport | 213 | 8.98 | 26.34 |
| South East | West Sussex | Worthing | 214 | 9.06 | 34.96 |
| Yorkshire and the Humber | South Yorkshire | Sheffield | 215 | 9.07 | 108.85 |
| North West | Merseyside | Wirral | 216 | 9.32 | 77.76 |
| South East | Buckinghamshire | Milton Keynes | 217 | 9.34 | 79.14 |
| South West | Gloucestershire | Cheltenham | 218 | 9.45 | 46.44 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| North East | Durham | Hartlepool | 219 | 9.54 | 86.02 |
| East of England | Essex | Basildon | 220 | 9.67 | 83.62 |
| North East | North Yorkshire | Redcar and Cleveland | 221 | 9.82 | 163.72 |
| North West | Greater Manchester | Rochdale | 222 | 9.87 | 73.42 |
| North East | Tyne & Wear | Gateshead | 223 | 9.91 | 101.97 |
| Yorkshire and the Humber | West Yorkshire | Bradford | 224 | 9.96 | 124.78 |
| South West | Bristol | City of Bristol | 225 | 10.10 | 76.92 |
| North West | Greater Manchester | Oldham | 226 | 10.22 | 62.93 |
| North West | Greater Manchester | Bury | 227 | 10.42 | 68.64 |
| East Midlands | Nottinghamshire | Ashfield | 228 | 10.53 | 50.83 |
| East Midlands | Derbyshire | Chesterfield | 229 | 10.69 | 78.49 |
| East Midlands | Nottinghamshire | Mansfield | 230 | 10.90 | 71.42 |
| North West | Merseyside | Sefton | 231 | 11.01 | 138.56 |
| London | Greater London Authority | Bromley | 232 | 11.28 | 61.12 |
| North West | Greater Manchester | Bolton | 233 | 11.44 | 115.22 |
| South East | East Sussex | The City of Brighton and Hove | 234 | 11.45 | 80.85 |
| East Midlands | Nottinghamshire | Broxtowe | 235 | 11.50 | 50.67 |
| North West | Merseyside | St. Helens | 236 | 11.77 | 79.40 |
| North West | Cheshire | Warrington | 237 | 12.07 | 79.43 |
| West Midlands | West Midlands | Solihull | 238 | 12.15 | 133.77 |
| South West | Dorset | Bournemouth | 239 | 12.16 | 77.81 |
| East of England | Essex | Harlow | 240 | 12.50 | 57.05 |
| South East | Kent | Thanet | 241 | 12.59 | 584.98 |
| East of England | Essex | Southend-on-Sea | 242 | 12.60 | 59.41 |
| South West | Devon | Exeter | 243 | 13.23 | 55.70 |
| North East | Durham | Stockton-on-Tees | 244 | 13.27 | 113.24 |
| East Midlands | Lincolnshire | Lincoln | 245 | 13.32 | 49.18 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| South West | Devon | City of Plymouth | 246 | 13.33 | 81.74 |
| Yorkshire and the Humber | West Yorkshire | Wakefield | 247 | 13.35 | 117.67 |
| East of England | Cambridgeshire | Cambridge | 248 | 13.40 | 37.14 |
| South East | Hampshire | Rushmoor | 249 | 13.72 | 60.54 |
| South East | Surrey | Spelthorne | 250 | 13.74 | 136.03 |
| South West | Dorset | Poole | 251 | 14.28 | 73.37 |
| West Midlands | Staffordshire | Tamworth | 252 | 14.36 | 66.10 |
| Yorkshire and the Humber | West Yorkshire | Leeds | 253 | 14.63 | 170.35 |
| London | Greater London Authority | Havering | 254 | 14.67 | 107.08 |
| North West | Greater Manchester | Tameside | 255 | 14.77 | 59.33 |
| East of England | Suffolk | Ipswich | 256 | 14.79 | 76.44 |
| West Midlands | Worcestershire | Worcester | 257 | 15.21 | 55.14 |
| East of England | Hertfordshire | Stevenage | 258 | 15.31 | 69.37 |
| North West | Greater Manchester | Stockport | 259 | 15.41 | 76.32 |
| South East | Kent | Dartford | 260 | 16.04 | 85.32 |
| East of England | Essex | Thurrock | 261 | 16.35 | 137.41 |
| East Midlands | Northamptonshire | Northampton | 262 | 16.48 | 83.80 |
| South West | Gloucestershire | Gloucester | 263 | 17.03 | 52.65 |
| North West | Greater Manchester | Salford | 264 | 17.12 | 97.12 |
| East of England | Hertfordshire | Watford | 265 | 17.25 | 75.33 |
| West Midlands | West Midlands | Dudley | 266 | 17.26 | 62.81 |
| South East | Oxfordshire | Oxford | 267 | 17.33 | 60.10 |
| West Midlands | West Midlands | Coventry | 268 | 17.54 | 88.48 |
| North West | Cheshire | Halton | 269 | 17.92 | 81.12 |
| North West | Merseyside | Knowsley | 270 | 18.52 | 96.39 |
| London | Greater London Authority | Croydon | 271 | 19.84 | 91.58 |
| London | Greater London Authority | Kingston upon Thames | 272 | 20.37 | 74.11 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| North East | Tyne & Wear | North Tyneside | 273 | 20.42 | 84.11 |
| London | Greater London Authority | Barnet | 274 | 20.61 | 74.43 |
| London | Greater London Authority | Sutton | 275 | 20.62 | 95.78 |
| London | Greater London Authority | Harrow | 276 | 20.63 | 51.60 |
| South East | Hampshire | City of Southampton | 277 | 20.73 | 143.42 |
| London | Greater London Authority | Richmond upon Thames | 278 | 20.73 | 285.02 |
| London | Greater London Authority | Enfield | 279 | 21.66 | 94.13 |
| West Midlands | West Midlands | Walsall | 280 | 21.70 | 88.26 |
| East of England | Norfolk | Norwich | 281 | 21.94 | 149.33 |
| East Midlands | Leicestershire | City of Leicester | 282 | 21.97 | 133.26 |
| South East | Berkshire | Reading | 283 | 23.53 | 124.35 |
| West Midlands | Staffordshire | City of Stoke-on-Trent | 284 | 23.56 | 110.14 |
| South East | Hampshire | City of Portsmouth | 285 | 23.57 | 108.75 |
| North West | Greater Manchester | Trafford | 286 | 23.57 | 174.00 |
| North West | Lancashire | Blackpool | 287 | 23.89 | 74.15 |
| London | Greater London Authority | Bexley | 288 | 23.97 | 71.24 |
| East Midlands | Derbyshire | City of Derby | 289 | 24.32 | 113.21 |
| London | Greater London Authority | Redbridge | 290 | 24.43 | 67.44 |
| North East | Tyne & Wear | Newcastle upon Tyne | 291 | 24.73 | 280.13 |
| East of England | Bedfordshire | Luton | 292 | 25.18 | 178.24 |
| North East | North Yorkshire | Middlesbrough | 293 | 25.22 | 95.46 |
| East Midlands | Nottinghamshire | City of Nottingham | 294 | 25.89 | 94.49 |
| Yorkshire and the Humber | East Riding of Yorkshire | City of Kingston upon Hull | 295 | 26.19 | 79.51 |
| West Midlands | West Midlands | Birmingham | 296 | 26.21 | 142.35 |
| West Midlands | West Midlands | City of Wolverhampton | 297 | 26.61 | 117.11 |
| London | Greater London Authority | Merton | 298 | 26.78 | 65.49 |
| North East | Tyne & Wear | South Tyneside | 299 | 26.84 | 107.41 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| South East | West Sussex | Crawley | 300 | 26.97 | 149.13 |
| West Midlands | West Midlands | Sandwell | 301 | 27.43 | 84.79 |
| London | Greater London Authority | Hillingdon | 302 | 27.74 | 160.37 |
| North East | Tyne & Wear | Sunderland | 303 | 28.85 | 184.15 |
| North West | Merseyside | Liverpool | 304 | 29.55 | 152.30 |
| London | Greater London Authority | Hounslow | 305 | 29.72 | 210.12 |
| South East | Berkshire | Slough | 306 | 31.39 | 70.79 |
| London | Greater London Authority | Waltham Forest | 307 | 32.20 | 101.51 |
| London | Greater London Authority | Ealing | 308 | 35.39 | 100.08 |
| London | Greater London Authority | Barking and Dagenham | 309 | 35.88 | 103.47 |
| London | Greater London Authority | Lewisham | 310 | 36.13 | 83.18 |
| London | Greater London Authority | Haringey | 311 | 38.69 | 87.52 |
| London | Greater London Authority | Greenwich | 312 | 38.95 | 105.53 |
| North West | Greater Manchester | Manchester | 313 | 40.89 | 209.26 |
| London | Greater London Authority | Wandsworth | 314 | 43.73 | 110.57 |
| London | Greater London Authority | Camden | 315 | 49.50 | 127.20 |
| London | Greater London Authority | Kensington and Chelsea | 316 | 55.58 | 95.36 |
| London | Greater London Authority | Brent | 317 | 55.97 | 571.54 |
| London | Greater London Authority | Southwark | 318 | 56.19 | 180.57 |
| London | Greater London Authority | Hammersmith and Fulham | 319 | 56.78 | 141.05 |
| London | Greater London Authority | Lambeth | 320 | 57.72 | 127.09 |
| London | Greater London Authority | Newham | 321 | 58.14 | 284.62 |
| London | Greater London Authority | Islington | 322 | 68.72 | 127.81 |
| London | Greater London Authority | Hackney | 323 | 68.72 | 126.33 |
| London | Greater London Authority | City of Westminster | 324 | 73.35 | 189.02 |

| Region | Ceremonial County | District | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|---|---|
| London | Greater London Authority | Tower Hamlets | 325 | 82.07 | 224.37 |
| London | Greater London Authority | City of London | 326 | 127.78 | 180.57 |

# Appendix 3 Full results of NCA-level analysis

| National Character Area | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| NCA 159 - Lundy | 1 | 0.10 | 0.20 |
| NCA 4 - Cheviots | 2 | 0.12 | 0.44 |
| NCA 5 - Border Moors And Forests | 3 | 0.14 | 3.86 |
| NCA 158 - Isles Of Scilly | 4 | 0.15 | 1.27 |
| NCA 3 - Cheviot Fringe | 5 | 0.19 | 6.53 |
| NCA 98 - Clun And North West Herefordshire Hills | 6 | 0.20 | 6.14 |
| NCA 2 - Northumberland Sandstone Hills | 7 | 0.21 | 15.74 |
| NCA 10 - North Pennines | 8 | 0.21 | 11.60 |
| NCA 99 - Black Mountains And Golden Valley | 9 | 0.21 | 4.02 |
| NCA 18 - Howgill Fells | 10 | 0.21 | 3.73 |
| NCA 150 - Dartmoor | 11 | 0.22 | 12.39 |
| NCA 8 - Cumbria High Fells | 12 | 0.23 | 12.00 |
| NCA 153 - Bodmin Moor | 13 | 0.23 | 4.38 |
| NCA 34 - Bowland Fells | 14 | 0.26 | 2.33 |
| NCA 21 - Yorkshire Dales | 15 | 0.26 | 23.71 |
| NCA 77 - North Norfolk Coast | 16 | 0.26 | 4.19 |
| NCA 144 - Quantock Hills | 17 | 0.26 | 0.50 |
| NCA 17 - Orton Fells | 18 | 0.27 | 8.29 |
| NCA 157 - The Lizard | 19 | 0.29 | 4.33 |
| NCA 101 - Herefordshire Plateau | 20 | 0.30 | 10.61 |
| NCA 65 - Shropshire Hills | 21 | 0.31 | 19.73 |
| NCA 149 - The Culm | 22 | 0.33 | 18.54 |
| NCA 29 - Howardian Hills | 23 | 0.34 | 15.64 |
| NCA 102 - Teme Valley | 24 | 0.36 | 12.13 |
| NCA 156 - West Penwith | 25 | 0.40 | 8.44 |
| NCA 104 - South Herefordshire And Over Severn | 26 | 0.44 | 17.94 |
| NCA 134 - Dorset Downs And Cranborne Chase | 27 | 0.44 | 30.18 |

| National Character Area | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| NCA 145 - Exmoor | 28 | 0.45 | 43.79 |
| NCA 147 - Blackdowns | 29 | 0.47 | 17.16 |
| NCA 19 - South Cumbria Low Fells | 30 | 0.50 | 17.88 |
| NCA 12 - Mid Northumberland | 31 | 0.51 | 21.76 |
| NCA 27 - Yorkshire Wolds | 32 | 0.52 | 17.56 |
| NCA 139 - Marshwood And Powerstock Vales | 33 | 0.52 | 13.46 |
| NCA 136 - South Purbeck | 34 | 0.53 | 12.02 |
| NCA 9 - Eden Valley | 35 | 0.53 | 31.48 |
| NCA 76 - North West Norfolk | 36 | 0.56 | 48.97 |
| NCA 133 - Blackmoor Vale And The Vale Of Wardour | 37 | 0.56 | 22.52 |
| NCA 83 - South Norfolk And High Suffolk Claylands | 38 | 0.56 | 20.03 |
| NCA 123 - Romney Marshes | 39 | 0.59 | 20.72 |
| NCA 43 - Lincolnshire Wolds | 40 | 0.60 | 26.60 |
| NCA 103 - Malvern Hills | 41 | 0.65 | 13.98 |
| NCA 1 - North Northumberland Coastal Plain | 42 | 0.66 | 18.29 |
| NCA 116 - Berkshire And Marlborough Downs | 43 | 0.66 | 34.02 |
| NCA 25 - North Yorkshire Moors And Cleveland Hills | 44 | 0.70 | 51.89 |
| NCA 93 - High Leicestershire | 45 | 0.73 | 19.17 |
| NCA 44 - Central Lincolnshire Vale | 46 | 0.75 | 20.16 |
| NCA 20 - Morecambe Bay Limestones | 47 | 0.76 | 15.75 |
| NCA 107 - Cotswolds | 48 | 0.78 | 36.03 |
| NCA 143 - Mid Somerset Hills | 49 | 0.80 | 20.64 |
| NCA 100 - Herefordshire Lowlands | 50 | 0.81 | 55.67 |
| NCA 152 - Cornish Killas | 51 | 0.84 | 26.28 |
| NCA 24 - Vale Of Mowbray | 52 | 0.85 | 30.00 |
| NCA 75 - Kesteven Uplands | 53 | 0.86 | 26.28 |
| NCA 11 - Tyne Gap And Hadrian'S Wall | 54 | 0.86 | 37.80 |
| NCA 33 - Bowland Fringe And Pendle Hill | 55 | 0.88 | 43.22 |
| NCA 26 - Vale Of Pickering | 56 | 0.89 | 25.07 |

| National Character Area | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| NCA 53 - South West Peak | 57 | 0.92 | 29.69 |
| NCA 91 - Yardley-Whittlewood Ridge | 58 | 0.93 | 13.01 |
| NCA 155 - Carnmenellis | 59 | 0.95 | 19.18 |
| NCA 132 - Salisbury Plain And West Wiltshire Downs | 60 | 0.96 | 58.63 |
| NCA 51 - Dark Peak | 61 | 1.02 | 16.95 |
| NCA 63 - Oswestry Uplands | 62 | 1.06 | 27.54 |
| NCA 105 - Forest Of Dean And Lower Wye | 63 | 1.06 | 26.19 |
| NCA 141 - Mendip Hills | 64 | 1.06 | 20.51 |
| NCA 52 - White Peak | 65 | 1.07 | 31.71 |
| NCA 122 - High Weald | 66 | 1.09 | 60.98 |
| NCA 140 - Yeovil Scarplands | 67 | 1.10 | 37.51 |
| NCA 130 - Hampshire Downs | 68 | 1.11 | 87.49 |
| NCA 85 - Breckland | 69 | 1.12 | 48.20 |
| NCA 6 - Solway Basin | 70 | 1.12 | 47.69 |
| NCA 84 - Mid Norfolk | 71 | 1.12 | 103.81 |
| NCA 46 - The Fens | 72 | 1.16 | 47.35 |
| NCA 22 - Pennine Dales Fringe | 73 | 1.20 | 48.25 |
| NCA 47 - Southern Lincolnshire Edge | 74 | 1.24 | 49.18 |
| NCA 74 - Leicestershire And Nottinghamshire Wolds | 75 | 1.26 | 29.49 |
| NCA 62 - Cheshire Sandstone Ridge | 76 | 1.30 | 8.63 |
| NCA 80 - The Broads | 77 | 1.32 | 149.33 |
| NCA 154 - Hensbarrow | 78 | 1.48 | 20.98 |
| NCA 131 - New Forest | 79 | 1.48 | 87.84 |
| NCA 78 - Central North Norfolk | 80 | 1.54 | 103.81 |
| NCA 127 - Isle Of Wight | 81 | 1.54 | 62.45 |
| NCA 95 - Northamptonshire Uplands | 82 | 1.54 | 84.72 |
| NCA 86 - South Suffolk And North Essex Clayland | 83 | 1.57 | 154.38 |
| NCA 87 - East Anglian Chalk | 84 | 1.58 | 40.79 |
| NCA 148 - Devon Redlands | 85 | 1.64 | 55.70 |

| National Character Area | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| NCA 125 - South Downs | 86 | 1.67 | 80.85 |
| NCA 117 - Avon Vale | 87 | 1.69 | 27.58 |
| NCA 50 - Derbyshire Peak Fringe And Lower Derwent | 88 | 1.70 | 30.27 |
| NCA 121 - Low Weald | 89 | 1.71 | 149.13 |
| NCA 28 - Vale Of York | 90 | 1.75 | 70.45 |
| NCA 151 - South Devon | 91 | 1.78 | 81.74 |
| NCA 40 - Holderness | 92 | 1.79 | 76.27 |
| NCA 146 - Vale Of Taunton And Quantock Fringes | 93 | 1.79 | 71.48 |
| NCA 142 - Somerset Levels And Moors | 94 | 1.91 | 49.22 |
| NCA 42 - Lincolnshire Coast And Marshes | 95 | 1.95 | 78.50 |
| NCA 90 - Bedfordshire Greensand Ridge | 96 | 2.00 | 24.62 |
| NCA 138 - Weymouth Lowlands | 97 | 2.00 | 44.09 |
| NCA 79 - North East Norfolk And Flegg | 98 | 2.05 | 49.87 |
| NCA 16 - Durham Coalfield Pennine Fringe | 99 | 2.24 | 39.04 |
| NCA 82 - Suffolk Coast And Heaths | 100 | 2.26 | 181.96 |
| NCA 72 - Mease/Sence Lowlands | 101 | 2.26 | 87.10 |
| NCA 108 - Upper Thames Clay Vales | 102 | 2.27 | 57.92 |
| NCA 120 - Wealden Greensand | 103 | 2.34 | 69.28 |
| NCA 48 - Trent And Belvoir Vales | 104 | 2.35 | 94.49 |
| NCA 96 - Dunsmore And Feldon | 105 | 2.40 | 73.53 |
| NCA 68 - Needwood And South Derbyshire Claylands | 106 | 2.48 | 94.78 |
| NCA 61 - Shropshire, Cheshire And Staffordshire Plain | 107 | 2.52 | 176.79 |
| NCA 92 - Rockingham Forest | 108 | 2.61 | 53.89 |
| NCA 106 - Severn And Avon Vales | 109 | 2.64 | 76.92 |
| NCA 36 - Southern Pennines | 110 | 2.70 | 62.02 |
| NCA 119 - North Downs | 111 | 2.72 | 84.20 |
| NCA 124 - Pevensey Levels | 112 | 3.06 | 29.43 |
| NCA 39 - Humberhead Levels | 113 | 3.17 | 206.39 |
| NCA 7 - West Cumbria Coastal Plain | 114 | 3.24 | 103.29 |

| National Character Area | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| NCA 45 - Northern Lincolnshire Edge With Coversands | 115 | 3.27 | 180.07 |
| NCA 88 - Bedfordshire And Cambridgeshire Claylands | 116 | 3.34 | 79.14 |
| NCA 110 - Chilterns | 117 | 3.41 | 178.24 |
| NCA 89 - Northamptonshire Vales | 118 | 3.50 | 83.80 |
| NCA 135 - Dorset Heaths | 119 | 3.60 | 77.81 |
| NCA 129 - Thames Basin Heaths | 120 | 3.80 | 75.97 |
| NCA 71 - Leicestershire And South Derbyshire Coalfield | 121 | 3.98 | 77.00 |
| NCA 70 - Melbourne Parklands | 122 | 4.09 | 78.36 |
| NCA 66 - Mid Severn Sandstone Plateau | 123 | 4.09 | 117.11 |
| NCA 109 - Midvale Ridge | 124 | 4.11 | 61.98 |
| NCA 30 - Southern Magnesian Limestone | 125 | 4.18 | 71.17 |
| NCA 118 - Bristol, Avon Valleys And Ridges | 126 | 4.60 | 64.84 |
| NCA 31 - Morecambe Coast And Lune Estuary | 127 | 4.85 | 65.27 |
| NCA 73 - Charnwood | 128 | 4.96 | 84.71 |
| NCA 94 - Leicestershire Vales | 129 | 5.06 | 133.26 |
| NCA 32 - Lancashire And Amounderness Plain | 130 | 5.41 | 74.15 |
| NCA 128 - South Hampshire Lowlands | 131 | 5.42 | 143.42 |
| NCA 35 - Lancashire Valleys | 132 | 5.47 | 57.77 |
| NCA 13 - South East Northumberland Coastal Plain | 133 | 5.99 | 79.81 |
| NCA 59 - Wirral | 134 | 6.17 | 37.12 |
| NCA 49 - Sherwood | 135 | 6.51 | 94.49 |
| NCA 137 - Isle Of Porland | 136 | 6.62 | 25.52 |
| NCA 64 - Potteries And Churnet Valley | 137 | 7.05 | 110.14 |
| NCA 126 - South Coast Plain | 138 | 7.36 | 469.90 |
| NCA 23 - Tees Lowlands | 139 | 7.61 | 163.72 |
| NCA 113 - North Kent Plain | 140 | 8.18 | 584.98 |
| NCA 57 - Sefton Coast | 141 | 8.21 | 65.66 |
| NCA 81 - Greater Thames Estuary | 142 | 8.79 | 138.32 |
| NCA 69 - Trent Valley Washlands | 143 | 9.19 | 113.21 |

| National Character Area | Rank of average brightness value (mean) | Average brightness value (mean) | Maximum brightness value |
|---|---|---|---|
| NCA 111 - Northern Thames Basin | 144 | 9.69 | 571.54 |
| NCA 97 - Arden | 145 | 9.84 | 142.35 |
| NCA 56 - Lancashire Coal Measures | 146 | 10.20 | 115.22 |
| NCA 37 - Yorkshire Southern Pennine Fringe | 147 | 10.84 | 124.78 |
| NCA 15 - Durham Magnesian Limestone Plateau | 148 | 11.06 | 184.15 |
| NCA 67 - Cannock Chase And Cank Wood | 149 | 12.79 | 88.26 |
| NCA 38 - Nottinghamshire, Derbyshire And Yorkshire Coalfield | 150 | 12.94 | 887.93 |
| NCA 41 - Humber Estuary | 151 | 13.57 | 149.16 |
| NCA 60 - Mersey Valley | 152 | 13.62 | 117.47 |
| NCA 54 - Manchester Pennine Fringe | 153 | 13.67 | 73.42 |
| NCA 115 - Thames Valley | 154 | 13.88 | 285.02 |
| NCA 114 - Thames Basin Lowlands | 155 | 13.97 | 95.78 |
| NCA 14 - Tyne And Wear Lowlands | 156 | 18.17 | 280.13 |
| NCA 58 - Merseyside Conurbation | 157 | 27.29 | 152.30 |
| NCA 55 - Manchester Conurbation | 158 | 30.03 | 209.26 |
| NCA 112 - Inner London | 159 | 52.14 | 284.62 |