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Radon in Northern Ireland: Indicative Atlas

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Radon in Northern Ireland: Indicative Atlas

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Abstract

A joint mapping method based on the results of radon measurements and geological information was used to estimate radon 'Affected Area' potential in Northern Ireland. The method allows variation of radon potential both between and within geological units and is based on measurements of radon in more than 23,000 homes.

This report presents information about elevated radon potential in Northern Ireland as an indicative map, based on the highest radon potential for each 1 km square of the Irish grid. The full definitive detail is published as a digital dataset for geographical information systems, which can be licensed. The estimated radon potential for an individual home can be obtained through the Public Health England radon website, www.ukradon.org.

The work was partially funded by the Northern Ireland Department of the Environment and was prepared jointly by Public Health England and the British Geological Survey.

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Maps with place names

Executive Summary

Radon has been recognised as a cause of lung cancer in humans for many years. Public Health England (PHE), and previously the Health Protection Agency and the National Radiological Protection Board, has advised that excessive exposures to radon should be reduced because of the risk of lung cancer. PHE advice* forms the basis of ongoing programmes of radon control.

Radon levels in individual buildings can only be assessed by measurement. To guide the implementation of PHE advice, it is essential to identify areas that are most affected by radon. This report presents an overview of the results of detailed mapping in Northern Ireland of radon potential, defined as the estimated percentage of homes in an area that are at or above the radon action level (200 Bq m^{-3}). The radon potential therefore corresponds to the probability that a home, that has not had a radon measurement, will have a long-term average radon concentration at or above the radon action level.

The joint mapping method is based on the results of measurements of radon in over 23,000 homes in Northern Ireland. The radon results are grouped first by geological boundaries and then by 1 km grid squares. The method allows variations in radon potential both between and within geological units to be mapped.

The resulting map, which defines areas with a 1% or greater probability of exceeding the action level (radon 'Affected Areas') in Northern Ireland, includes much more detail than could be shown in an atlas. The full detail is available as a dataset for geographical information systems. The estimated radon potential for an individual home can be obtained through the PHE radon website, www.ukradon.org. The atlas presented here is a simplified version of the map, so is indicative rather than definitive: that is, each 1 km grid square is coloured according to the highest radon potential found within it.

The new atlas, together with the underlying definitive digital information sources, will aid the identification of areas where homes have a 1% or greater probability of exceeding the action level and in which householders or others should make radon measurements. These resources may also be used by appropriate government authorities to identify localities in which new homes or other buildings should be constructed with precautions against radon.

This work was carried out jointly by PHE and the British Geological Survey. Some work was funded by the Northern Ireland Department of the Environment (DOENI).

* Health Protection Agency (2010). Limitation of Human Exposure to Radon. Chilton, HPA, RCE-15.

Contents

1 Introduction

Radon has been recognised as a cause of lung cancer in humans for many years (AGIR, 2009). Advice published in 2010 (HPA, 2010) recommended that the established UK radon action level of 200 Bq m^{-3} should be retained and that all areas should be classified according to the probability that a home in the locality will have an indoor radon concentration at or above the action level. Areas with probabilities in the range 1–10% and 10% or more are referred to as ‘intermediate’ and ‘higher’ radon probability areas, respectively. Together, these terms match the existing definition of radon ‘Affected Areas’. Public Health England advises that radon measurements should be made in homes in these areas. Areas with probabilities less than 1% are referred to as ‘lower’ radon probability areas.

To allow the UK radon programme to be implemented, it is useful to identify areas most affected by radon. PHE and the British Geological Survey (BGS) have published maps showing the estimated radon potential, or proportion of homes above the action level, by grid square in different parts of the UK (Miles et al, 2007, 2011; Green et al, 2009).

Indoor radon concentrations depend on a number of factors, including the geological characteristics of the ground underneath the home. This can be taken into account in maps of radon potential, but other factors, including the construction details and the living styles of the occupants, are responsible for a very wide variation of indoor radon concentrations found in homes built on ground with the same radon potential.

Earlier maps published separately by PHE and the BGS grouped house radon results either by grid square or by geological unit, before applying lognormal modelling (Miles, 1998). Both of these mapping methods ignore some part of the geographical variation in radon potential: grid square mapping ignores variation between geological units within grid squares, and geological mapping ignores variation within areas sharing combinations of geological characteristics. It was realised by PHE and the BGS that combining the two methods could give more accurate mapping than either separately. The two organisations cooperated to develop a joint geological/grid square mapping method. This atlas is the outcome of applying this method to radon mapping in Northern Ireland, and supersedes the previous atlas of radon potential in Northern Ireland (Green et al, 2009). The radon measurement data on which the mapping is based, summarised by administrative area and by divisions of the postcode system, is published elsewhere (Green et al, 2009; Hodgson et al, 2011).

2 Measurements

The results of radon measurements, made in homes and used in the maps presented here, are collated from the many different radon survey programmes carried out by PHE, many of them funded by the Northern Ireland Department of the Environment. These surveys were seldom representative of the housing stock of large areas or regions. Indeed, many were intentionally targeted to areas where higher levels were expected. The initial national survey (Wrixon et al, 1988) was the only one in which care was taken to obtain a population-weighted sample of homes throughout the UK. The results of this survey continue to provide the best estimates of the average exposure at both national and county level.

Measurements in all surveys are made with two passive integrating detectors in each dwelling – one in the main living area and one in a regularly used bedroom (Hardcastle et al, 1996). The detectors are placed for 3 months and the results combined to reflect typical occupancy patterns. Indoor radon levels are usually higher in cold weather, so the results reported to householders are normalised for typical seasonal variations in radon levels to allow the estimated annual radon concentration to be reported (Pinel et al, 1995; Wrixon et al, 1988). It has been shown (Miles, 1998) that the seasonal variations correspond to average outdoor temperature variations. To allow for the fact that weather patterns vary from year to year, the majority of annual average radon concentrations in houses used in the mapping reported here were calculated using corrections based on temperature. Where temperature data was missing, the annual average radon concentrations were calculated using seasonal corrections.

3 Radon Maps

The integrated geological/grid square method used here for mapping radon potential is based on the work of Miles and Appleton (2005). In the integrated method, each combination of geological characteristics (bedrock, superficial and other) is taken in turn, and the spatial variation of radon potential within the combination is mapped, treating it as if the combination was continuous over the land area.

3.1 Location of each home

In order to determine which geological unit a house lies on, it is necessary to know its location as accurately as possible. Ordnance Survey of Northern Ireland Pointer® provides a national grid reference that falls inside the permanent building structure of an address. Where several addresses are in one building (for example, a block of flats) the same coordinates are used for each address. It was possible to obtain Pointer® coordinates for over 90% of the dwellings in Northern Ireland with radon measurement results. For the remainder, coordinates were obtained from Royal Mail Postal Address Files®, which allocate coordinates according to the postcode of a dwelling. In the UK each postcode covers 16 dwellings on average, but in densely populated areas the number is higher and in sparsely populated areas it is lower. In most cases the grid reference allocated to a dwelling using the Postal Address Files® will be accurate to within a few hundred metres, but in sparsely populated areas the uncertainty may be greater.

3.2 Attribution of geological codes to measurement locations

Bedrock and superficial geological codes were attributed to each house location using the Geological Survey of Northern Ireland (GSNI) 1 : 10,000 DiGMap and 1 : 250,000 scale digital geological map data (Figure 1). Each different combination of geological characteristics may appear at the land surface in many discontinuous locations across the country. Geological mapping of the UK has been carried out over many years, during which time there have been changes in the nomenclature of mapped rock units. Consequently, the names of geological units sometimes change at map sheet boundaries. In order to facilitate the seamless 1 km interpolation of radon potential within major geological units, simplified bedrock and superficial geology classification systems were developed. These ensure continuity across map sheet boundaries and also group some geological units with similar characteristics. Grouping similar geological units ensures that there is a sufficient number of indoor radon measurements for intra-geological unit grid square mapping to be carried out over a greater proportion of the UK. There are 360 named 1 : 10,000 scale bedrock geological units in Northern Ireland and 44 bedrock units in the area with only 1 : 250,000 scale bedrock geology. These are grouped using a simplified bedrock classification comprising 69 units. At 1 : 250,000 scale there are 12 individually named superficial geological units and at 1 : 10,000 scale there are 27 superficial geological units. These were grouped into 13 types according to a simplified system based on permeability and generic type (Appleton et al, 2014). A total of 466 bedrock superficial geological combinations resulted from the simplified classification and these were used for the radon potential mapping.

3.3 Estimation of radon potential

Within each geological combination with more than 79 radon measurements, the variation of indoor radon concentrations was mapped using 1 km squares of the national grid. A radon potential was allocated to each 1 km grid square on the basis of the nearest 30 house radon measurement results to that square, or all of the results in the square if that was 30 or more. The geometric mean (GM) and the geometric standard deviation (GSD) of the results allocated to each square were calculated, and a lognormal model was used to estimate the proportion of the distribution above the action level. This parameter, equivalent to the radon potential, is the one shown in the maps. In cases where there were too few house radon results available for a bedrock superficial geological combination to allow the spatial variation to be mapped using the combined geology-grid square radon mapping method (Miles and Appleton, 2005), a number of different approaches were taken, dependent on the number of indoor radon measurements and their distribution (Appleton et al, 2014).

In order to improve the accuracy of the estimates of the radon potential, certain corrections were applied. It has been shown (Darby, 2003) that the measured GSD for any group of house radon measurement results, each made over 3 months, is higher than the GSD that would have been observed if the measurements had been made over several years in each house. The difference is caused by uncertainties in estimates of long-term average radon concentrations, both from extrapolating from 3 months to a year and from year-to-year variations in radon levels. It is possible to correct the measured GSD for this effect, using data from studies of the year-to-year variation in 3-month house radon measurement results. Such corrections always reduce the GSD, and therefore always reduce percentages above a threshold, if the GM of the area is below the threshold. This correction was applied in the mapping exercise reported here. Earlier mapping exercises in Northern Ireland did not take account of this factor.

There is also some random variation in the calculated values of the GSD. It has been shown (Miles and Appleton, 2000) that the use of Bayesian estimates of GSD gives less uncertain estimates of the proportion of homes above the action level, and does not bias the estimates in any way. The reduction of the uncertainty by the use of Bayesian statistics was significant but not very large. This correction was also applied in the mapping exercise reported here.

3.4 Presentation of results

The resulting map is highly detailed, with an implied precision of less than 1 m. In fact there is uncertainty in the location of the boundaries on geological maps and in the size and orientation of the footprint of the house from the point location. To reduce the possibility of advising householders that the risk of radon problems was small, when in fact it could be significant, a buffer was applied around each area. This buffer was applied in sequence from the highest to the lowest radon areas. The uncertainty in geological boundaries was assigned a value of 10 m in areas with 1 : 10,000 scale geological data and 250 m in areas with 1 : 250,000 scale data The uncertainty in building location was assigned a value of 25 m, giving a combined buffer width of 35 m or 275 m, respectively. Because of the difficulty in processing the highly detailed data, it was necessary to simplify the map, converting it to 25 m squares of the national grid, each attributed a uniform value of the highest radon potential within it. This buffering process is likely to lead to a slight overestimate of the area and number of homes in the higher bands of probability.

In some areas geological information includes a large number of small zones that are of a geological type that has been observed to have elevated radon potential. Since many of the individual zones are much less than a kilometre in width, the buffering process increases the size of these zones to a greater proportion than is the case for larger zones. These buffered zones are included in the radon potential dataset. This effect was also present in the radon atlases for England and Wales (Miles et al, 2007) and Scotland (Miles et al, 2011). In most cases, this will not affect the banding shown in the indicative maps but for some grid squares, containing perhaps only one or two of these small zones, the great majority of the grid squares will be of a lower classification than that shown in this atlas. The effect is illustrated hypothetically in Figure 2. Figure 2a shows unbuffered (grey shaded) and buffered areas of radon potential; Figure 2b shows the indicative levels for each 1 km grid square, based on the highest classification in the square.

The map plates show the major road network as well as larger settlements chosen to give a reasonable geographical spread across the maps regardless of population density. Superimposed on the maps are the administrative boundaries introduced on 1 April 2015. Council names are given wherever possible subject to the limitations of space, especially in urban areas. This atlas can also be viewed without place names on the maps, which may be helpful to clarify the result where it is obscured by a place name.

An overall map of Northern Ireland (Figure 3) precedes a map giving the key to the following five maps, each covering about 16,000 km^2 (Figure 4).

3.5 Application to workplaces

Although the radon data used in the production of this atlas comes from measurements in homes, the maps indicate the likely extent of the local radon hazard in all buildings. The information in this atlas is therefore relevant to employers in assessing workplace risks. Under the Health and Safety at Work Act (HSENI, 1978, 1998), the employer must, so far as is reasonably practicable, ensure the health and safety of employees and others who have access to their work environment. The Management of Health and Safety at Work Regulations (HSENI, 2000) require the assessment of health and safety risks.

Guidance on how to apply the maps contained in this atlas in assessing workplace radon is available from the Health and Safety Executive Northern Ireland (HSENI) website, www.hseni.gov.uk. This addresses a number of topics including using radon maps to determine the need for measurement in ground-floor and below-surface workplaces. The HSENI and local authorities are responsible for enforcing the regulations in various workplaces.

4 Conclusions

This atlas provides an overview of the probability of the radon level in any home in Northern Ireland being at or above the action level. It updates previous reports and complements the formal advice of PHE on the need to reduce long-term exposure to elevated radon levels. It will be of use and interest to individuals and organisations with a duty to assess, and where appropriate reduce, the radon exposure of the population, both in the home and in the workplace. It is expected that further updates, incorporating the latest available data, will be published at intervals.

5 Acknowledgements

The data used to construct the maps has been collated from many different radon surveys carried out over time by PHE, and previously by the HPA and NRPB. Many of the measurements were funded by the Northern Ireland Department of the Environment, by local government, by landlords and by individual householders.

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6 Glossary

Becquerel (symbol Bq)	Unit of the amount or activity of a radionuclide. Describes the rate at which transformations occur. 1 Bq = 1 transformation per second
Becquerel per cubic metre of air (symbol Bq m^{-3})	Amount of a radionuclide in each cubic metre of air. Often referred to as the activity concentration
Radon	A naturally occurring radioactive gas that is the major source of ionising radiation exposure. For more information see www.ukradon.org

Radon action level	Recommended limit for the activity concentration of radon in UK homes. Its value, expressed as the annual average radon gas concentration in the home, is 200 Bq m^{-3}
Radon Affected Areas	Parts of the country with a 1% probability or more of present or future homes being above the action level

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8 Figures and Maps

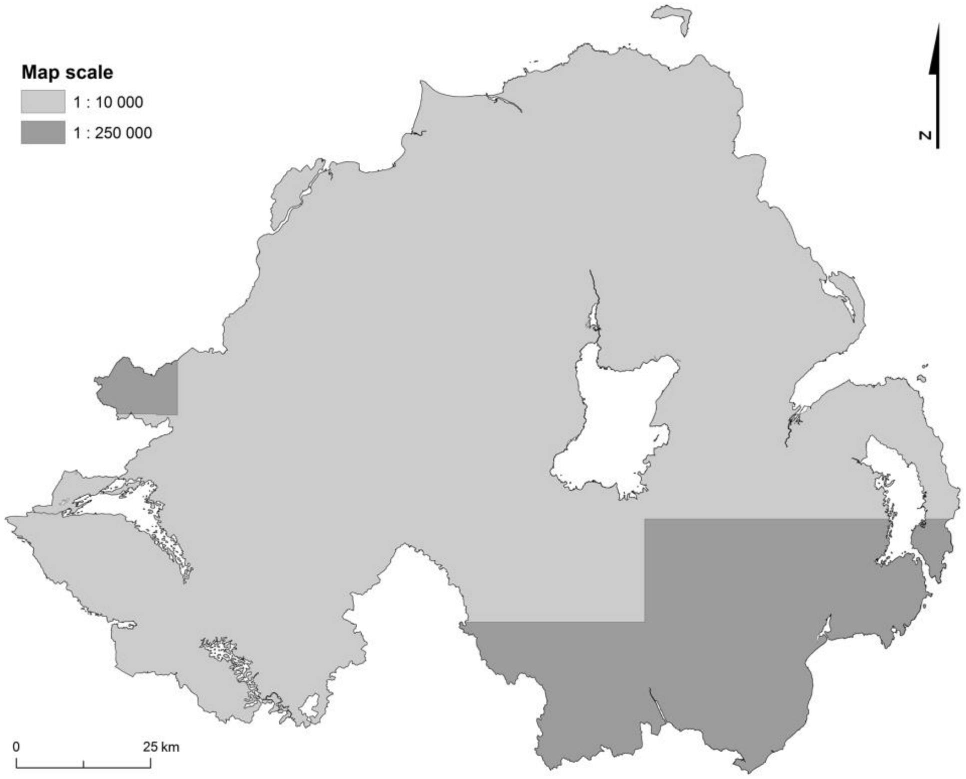

Figure 1: Scale of geological data used to produce the Northern Ireland radon map

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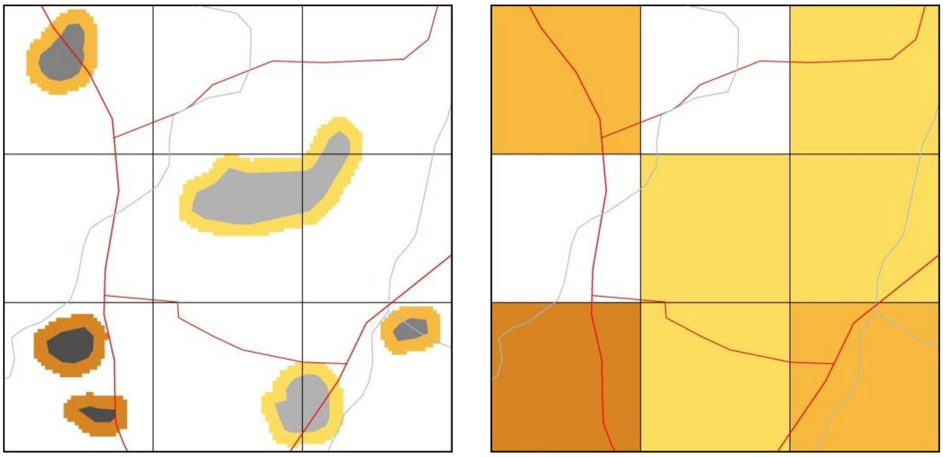

(a) (b)

Figure 2: If 1 km grid squares on the definitive radon map contain more than one percentage band as shown in the three-by-three 1 km grid (a), they are shown on the indicative map presented in this atlas entirely coloured as the highest percentage band within the square (b)

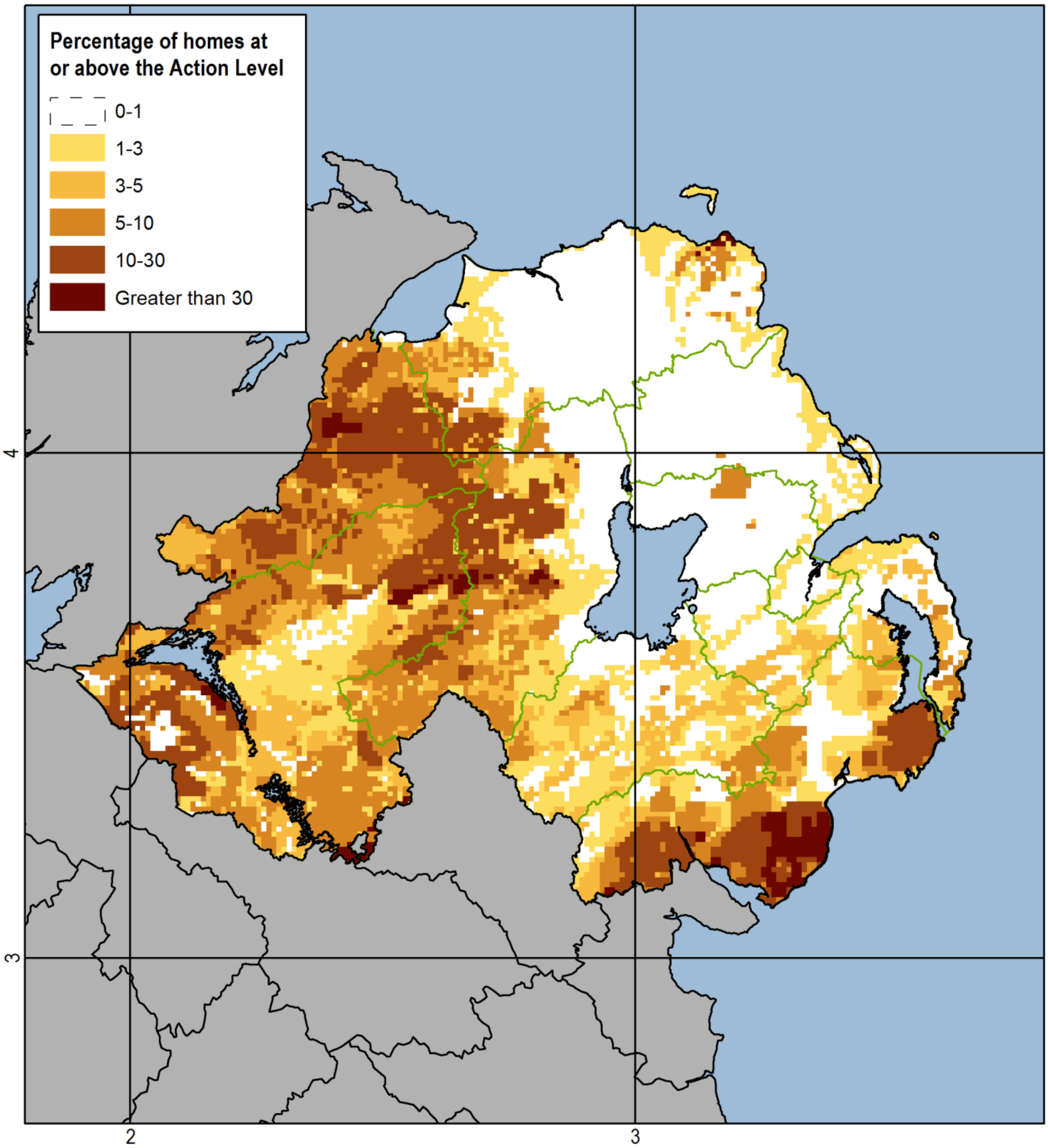

Figure 3: Overall map of radon Affected Areas in Northern Ireland (the axis numbers are the 100 km coordinates of the Irish grid)

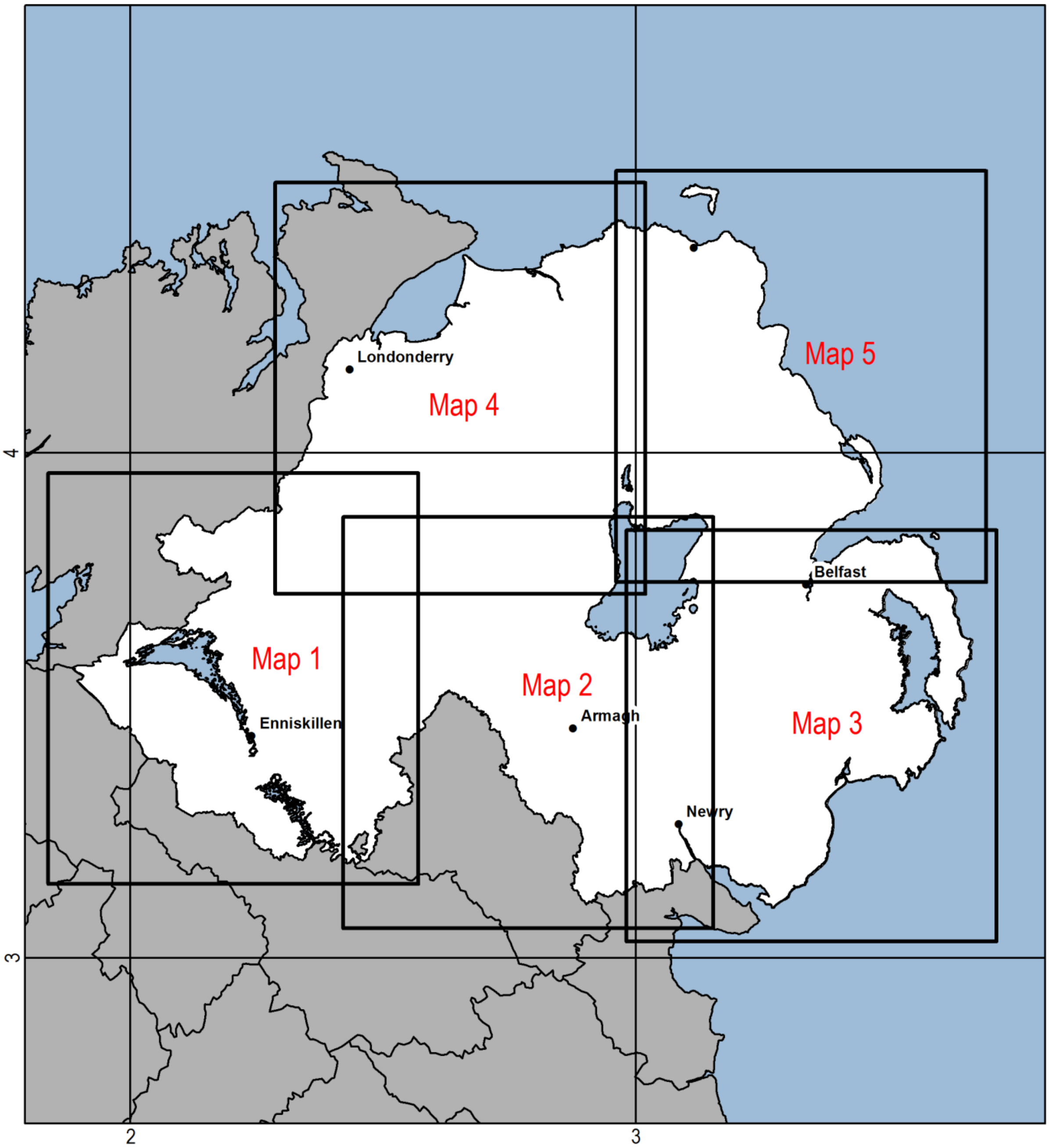

Figure 4: Key to larger scale maps of radon Affected Areas in Northern Ireland (the axis numbers are the 100 km coordinates of the Irish grid)

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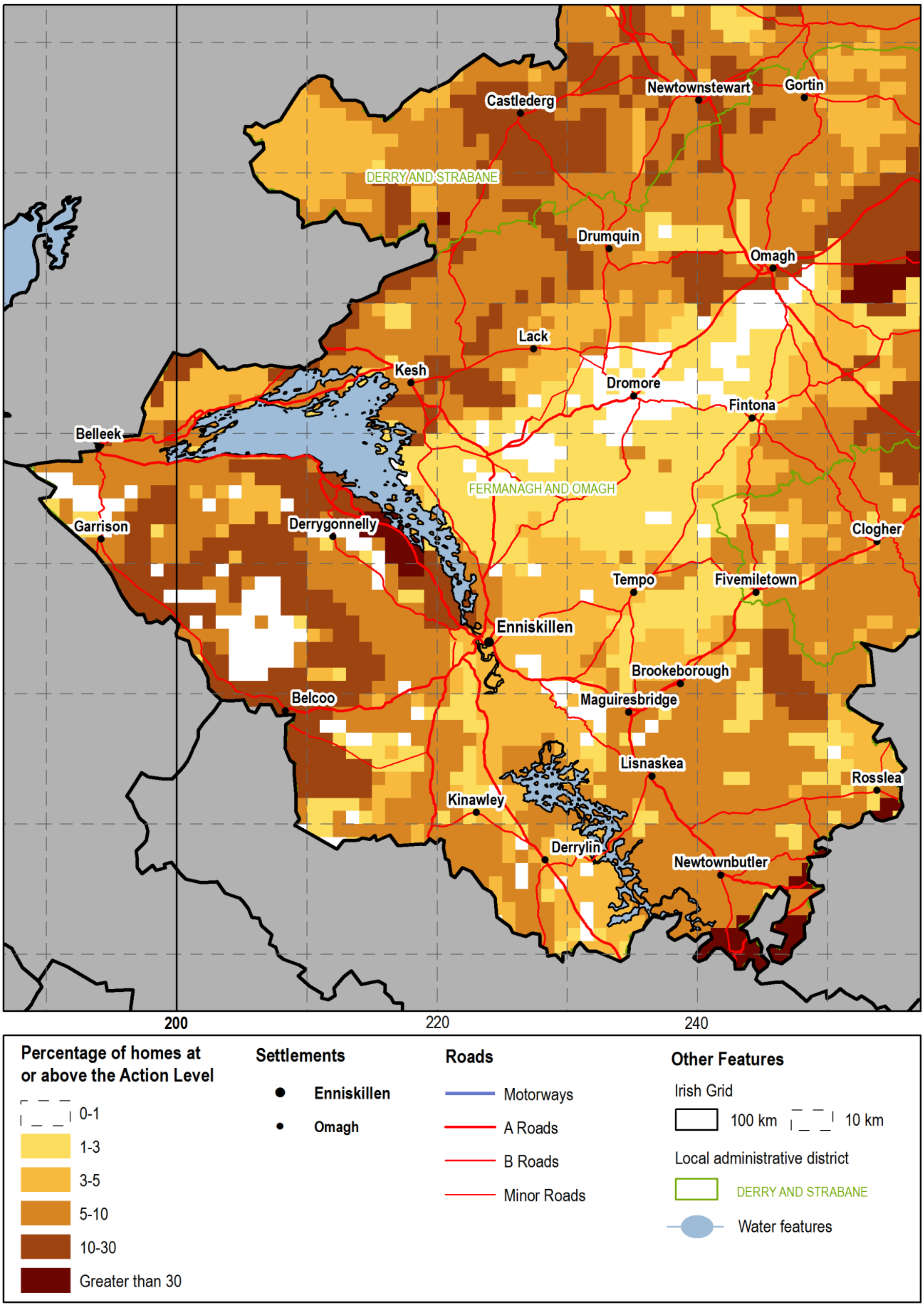
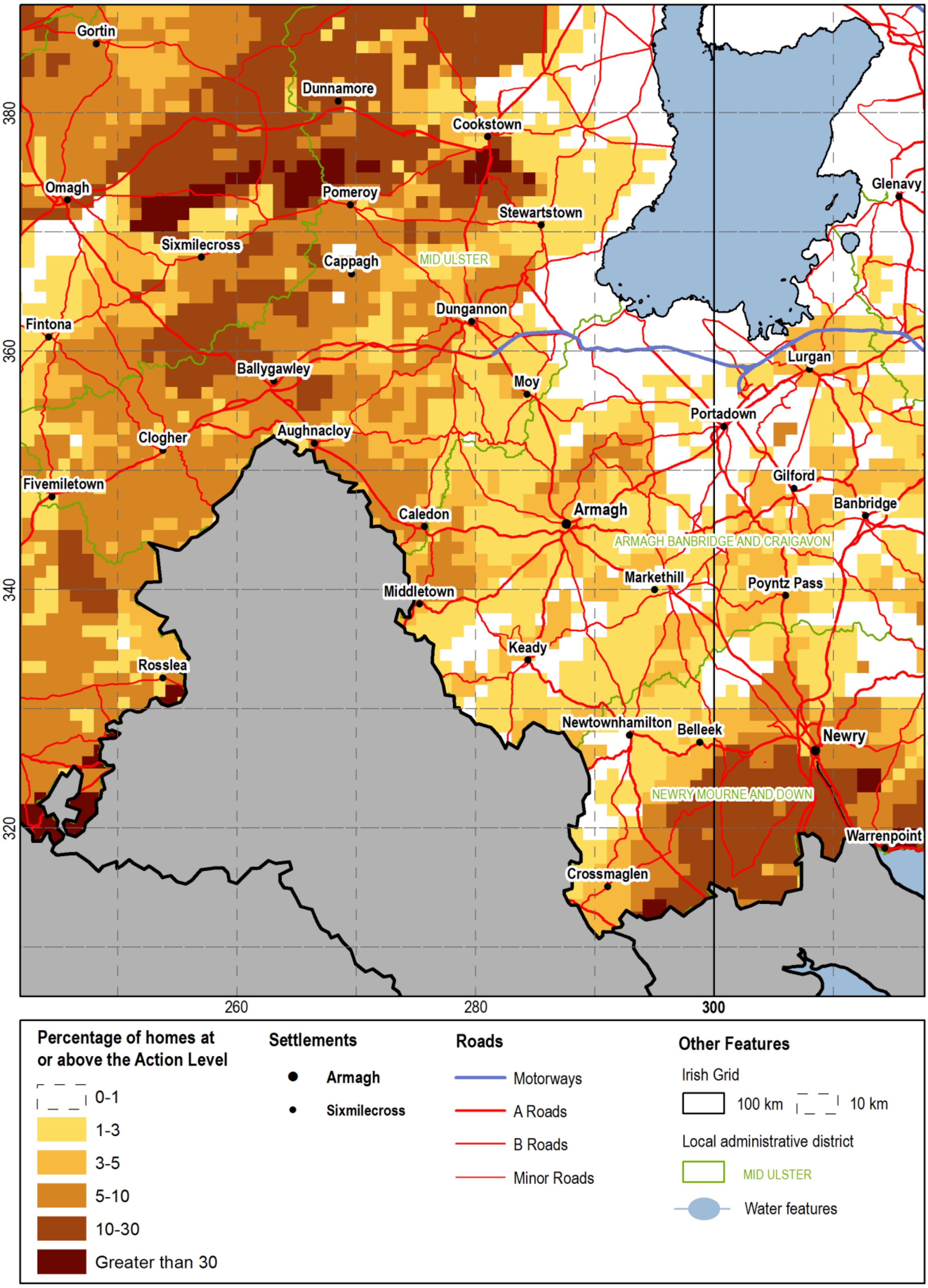
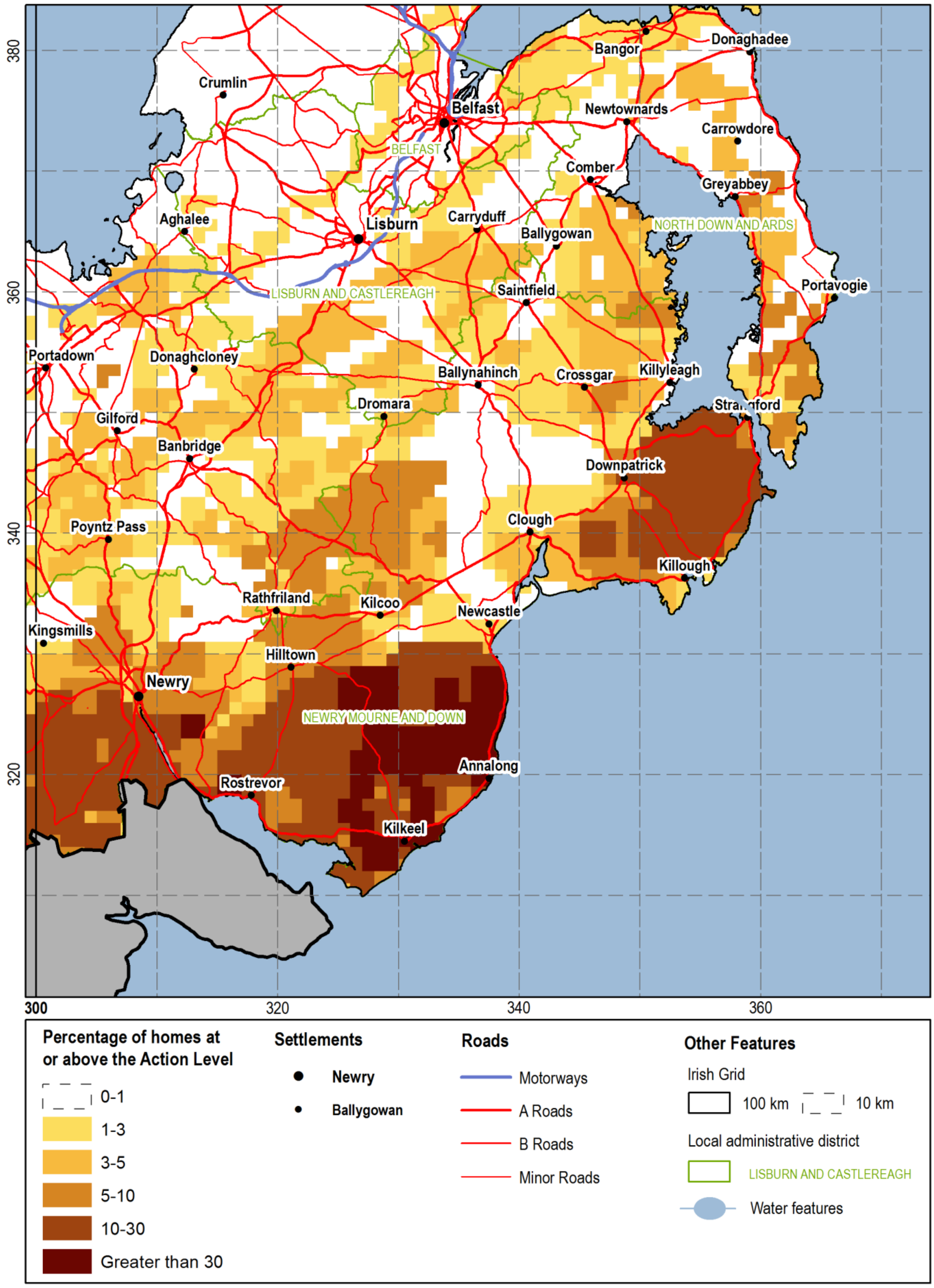


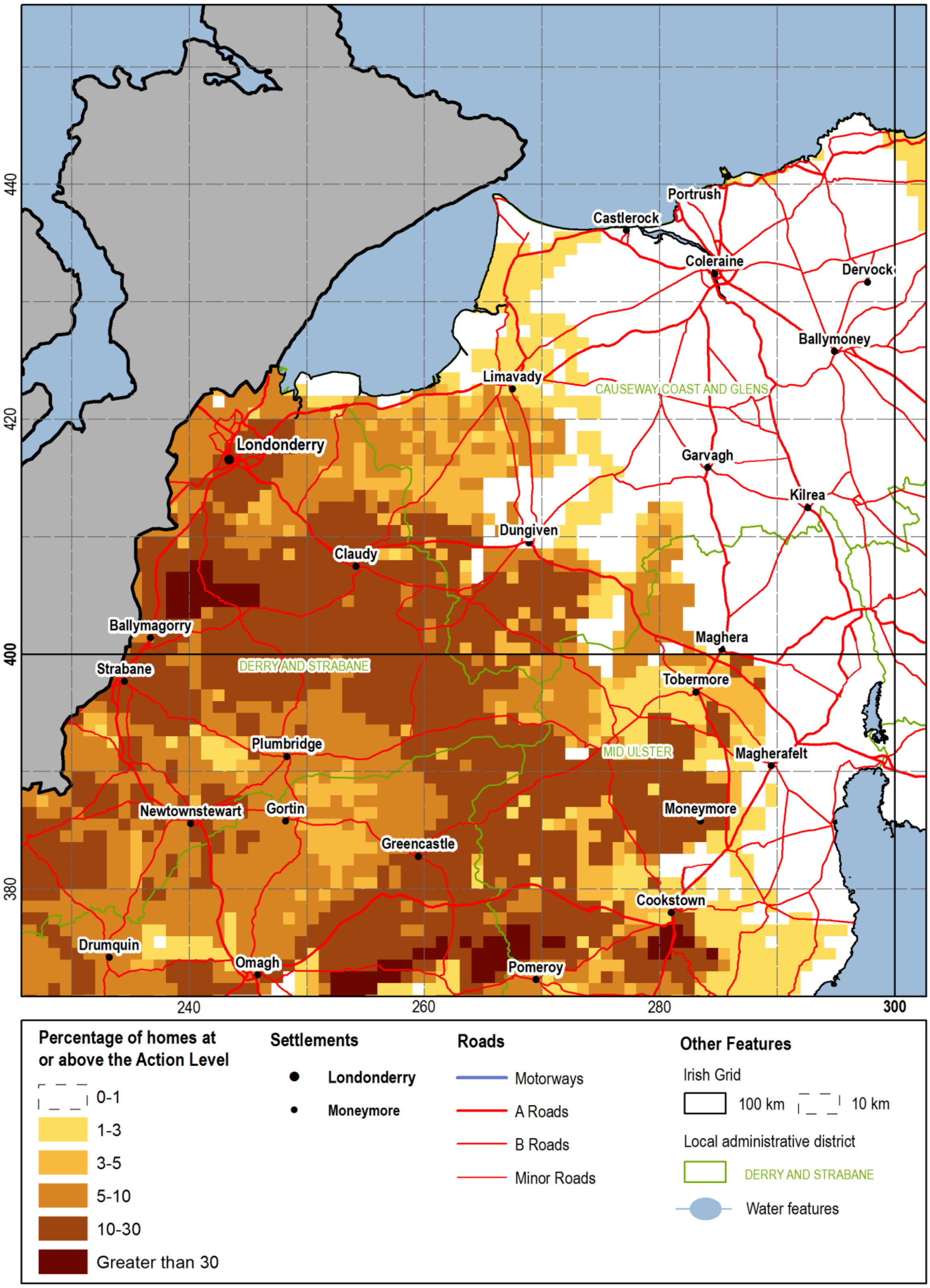
Map 1: South-western Northern Ireland (the axis numbers are the coordinates of the Irish grid)



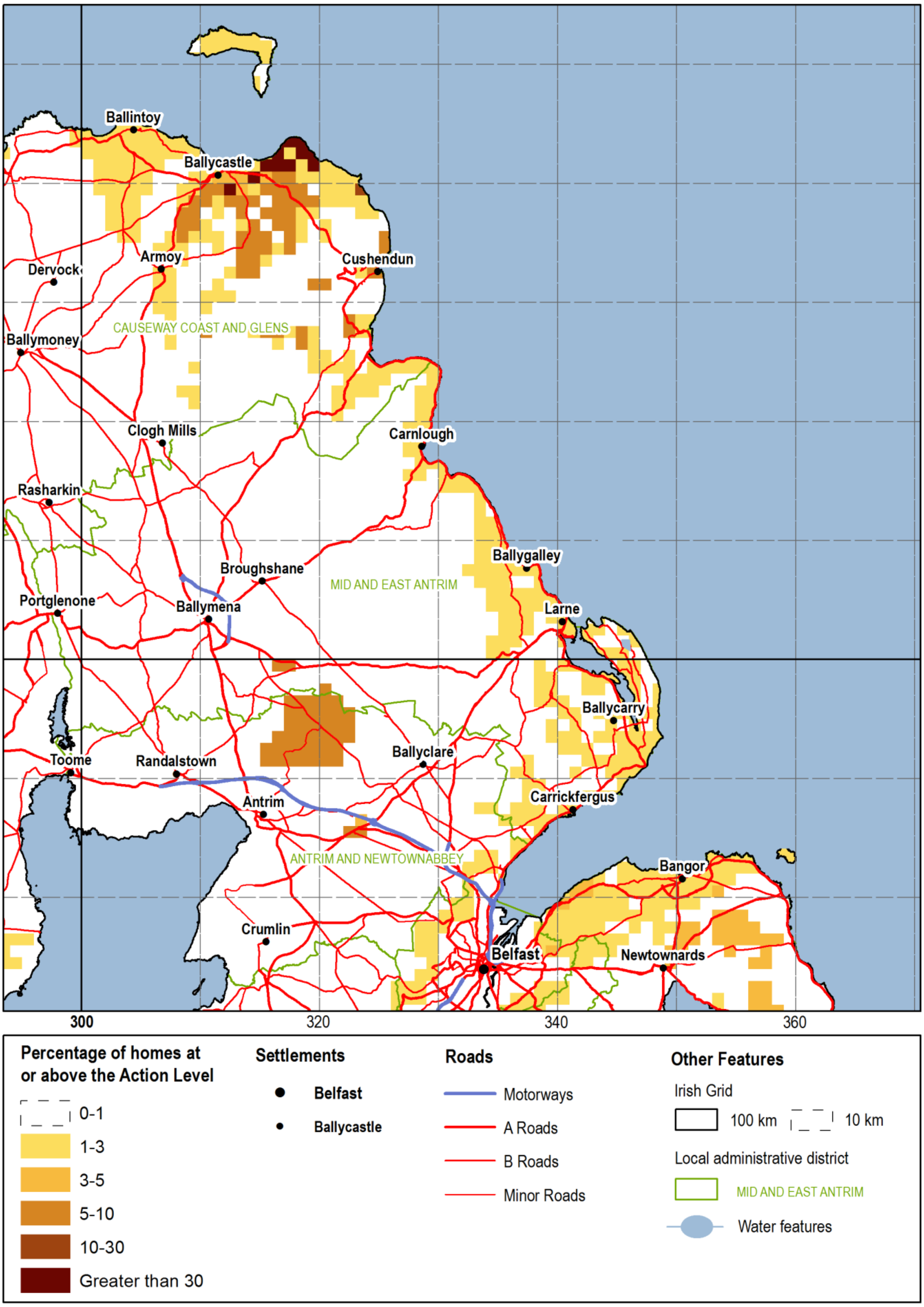
Map 2: Southern Northern Ireland (the axis numbers are the coordinates of the Irish grid)



Map 3: South-eastern Northern Ireland (the axis numbers are the coordinates of the Irish grid)



Map 4: North-western Northern Ireland (the axis numbers are the coordinates of the Irish grid)



Map 5: North-eastern Northern Ireland (the axis numbers are the coordinates of the Irish grid)