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Mapping Flood Disadvantage in Scotland 2015: Methodology Report

AGRICULTURE, ENVIRONMENT AND MARINE

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Mapping Flood Disadvantage in Scotland 2015: Methodology report

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Contents

Abbreviations

CEH	Centre for Ecology and Hydrology
IG	Intermediate Geography
NFRA	National Flood Risk Assessment
OS	Ordnance Survey
PLP	Property Level Protection
SD	Standard deviation
SEPA	Scottish Environment Protection Agency
SFDAD	Scottish Flood Defence Asset Database
SIMD	Scottish Indices of Multiple Deprivation

Glossary

Adaptive capacity	The ability of people to prepare for, respond to and recover after flooding, related mainly to their social and material situation.
Annual exceedance probability	Annual exceedance probability (AEP) describes the probability of a flood of a given magnitude occurring in any given year. AEP is the inverse of the flood return period. For example, 3.3% AEP refers to a return period of 1 in 30 years.
Data zones	Compact areas with around 500-1,000 residents that contain households with similar social characteristics used by the Scottish Government for reporting social statistics, for example the census. There are 6505 data zones in Scotland.
Defended flood extent	The area that has been identified as potentially exposed to flooding, where the underlying models have included consideration of formal flood prevention schemes (e.g. walls, embankments). Thus, defended flood extents cover smaller areas than undefended flood extents.
Direct indicator	An indicator that directly reflects the factor influencing social vulnerability to flooding, e.g. proportion of older people in the population
Exposure (enhanced)	One of the dimensions of vulnerability, which refers to the aspects of the physical environment (housing and presence of permeable surfaces), which accentuate or offset the severity of flood events.
Flood disadvantage	A situation where vulnerable neighbourhoods are exposed to flooding. In other words, disadvantage occurs where high social vulnerability to flooding spatially coincides with flood hazard-exposure represented by flood extents.
Flood extent	The predicted area of flooding from rivers, the sea or surface water based on the Scottish Environment Protection Agency Flood Maps.
Flood hazard-exposure	The degree to which people or other systems may come into contact with flooding. In this project flood hazard-exposure is estimated spatially as the proportion of residential addresses located within flood extents.
Flood return period	The average interval between floods of a given magnitude. It is a measure of the rarity of flood events - the longer the return period, the rarer the event.
Property level protection	Flood protection measures implemented for individual properties, which either keep the flood waters outside the property or minimize the damage if flood waters enter the building.
Proxy indicator	An indicator that provides an approximation of the factor influencing social vulnerability to flooding, e.g. the density of social networks is represented by proxy indicator of older people living on their own as they are likely to be the most socially isolated group.
Sensitivity	One of the dimensions of vulnerability, which reflects the personal characteristics, namely age and health status, that increase the likelihood that a flood event will have negative health and well-being impacts on people.
Social vulnerability to flooding	The varying degree to which people's health and well-being would be negatively affected by flooding (the higher the vulnerability, the greater the negative effect of flooding).
Standard deviation	A measure expressing by how much the scores in a group differ from the mean score for the group. Standard deviation is found by taking the square root of the variance – which is the spread of the scores within the group.
Standardisation	A statistical process of re-calculating values for variables or indicators measured using different scales in order to present them on a uniform scale.
Surface water flooding	Flooding that results from rainfall runoff flowing or ponding over the ground before it enters a natural (e.g. watercourse) or artificial (e.g. sewer) drainage system or when it cannot enter a drainage system (e.g. because the system is already full to capacity or the drainage inlets have a limited capacity) (JBA, 2014)

Undefended flood extent	The areas that may be affected by flooding if no flood defences were present, in other words assuming that all areas are undefended. In practice some areas identified as flood prone do have defences in place and thus have a lower chance of flooding than the data would suggest.
Z-score	A statistical measurement of a score's relationship to the mean (average value) in a group of scores. A Z-score of 0 means the score is the same as the mean (average value). A Z-score can be positive or negative, indicating whether it is above or below the mean and by how many standard deviations. Z-score standardisation represents the deviation of a raw score from its mean in standard deviation units.

1. About this report

The aim of this report is to describe the methods applied in developing the flood disadvantage dataset for Scotland 2015. It is intended for decision and policy makers and researchers wishing to understand, replicate and amend the social vulnerability to flooding and flood disadvantage assessment.

This document accompanies other deliverables of the 'Mapping Flood Disadvantage in Scotland 2015' project, including:

- The main report, presenting the key findings of the disadvantage assessment for Scotland and exploring the findings and their understanding in more detail through three case studies;
- Interactive maps of social vulnerability to flooding and flood disadvantage;
- The spatial dataset providing information on flood disadvantage with regard to different types of flooding and for various return periods, as well as the disaggregated underlying indicators used in the assessment;
- The dataset compiling the indicators and indices (in a spreadsheet format) accompanied by a short, user-friendly guide, directed at those who may not have a technical or statistical background;
- Recommendations report; and
- Research findings report summarising the headline messages.

This report has been compiled to enable either direct replication of the analysis or to support analysis for an amended set of indicators as new knowledge and data on social vulnerability emerges. The report discusses in an open manner the caveats and uncertainties associated with the data and methods used and suggests some actions to address them.

This report is organised into 8 sections:

- Section 2 explains the main principles of the approach to the assessment of flood disadvantage in Scotland. It outlines the conceptual framework applied and explains the area-based approach and its advantages and disadvantages.
- Section 3 discusses the spatial units used for the disadvantage assessment and introduces the datasets used as sources of information on factors affecting vulnerability.
- In section 4, the selection of the indicators of social vulnerability to flooding is described, followed by an explanation of the processing of the indicators.

- Section 5 focuses on the hazard-exposure element of the assessment. It presents the flood hazard data used and outlines how the number of households and people potentially exposed to flood risk was calculated.
- Section 6 describes how the indices were calculated and presented on maps.
- Section 7 briefly discusses other approaches that can be used to assess social vulnerability to flooding.
- Section 8 provides recommendations for future assessments of social vulnerability to flooding and flood disadvantage.

2. The approach to flood disadvantage assessment

2.1 The assessment framework

This assessment of flood disadvantage in Scotland builds on the methodology used in the assessment of social vulnerability to flooding (Lindley at el., 2011) and flood disadvantage in Scotland assessment (Lindley and O'Neill, 2013). The current assessment further develops the methods used in the original work in terms of the set of indicators used (the modifications to the set of indicators are described and justified in section 4 and Appendix 1 provides more details), but the main principles remain the same. However, due to different sets of indicators used, the outcomes of the 2013 assessment and this assessment are not directly comparable.

The assessment is carried out at the community or neighbourhood level, and therefore has a strong geographical dimension, i.e. it is strongly linked to particular locations. The assessment of vulnerability and disadvantage of neighbourhoods to flooding is based upon a conceptual framework (Lindley et al., 2011; Figure 1), whereby social vulnerability to flooding is a combination of:

- Sensitivity (influenced by a mix of personal factors, e.g. disability or age);
- Enhanced exposure (linked to environmental factors, e.g. elevation of housing, presence of green space); and,
- Adaptive capacity of communities, which is affected by social factors (e.g. levels of income, tenure or extent of social networks) and divided into:
    - The ability to prepare for flooding
    - The ability to respond to flooding during the flood event

- The ability to recover after flooding

In locations where social vulnerability is high but there is no likelihood of flooding, the negative impacts of flood events on health and well-being will not be realised. Therefore, flood disadvantage is realised only where vulnerable neighbourhoods are located within areas which may be affected by flooding (Figure 1). This means that the level of flood disadvantage reflects two components:

- The magnitude of social vulnerability to flooding, i.e. the combination of the personal, social and environmental factors that, in the event of flooding, would mean that the well-being of people in a given location would be negatively affected;
- The proportion of the vulnerable community that is likely to be exposed to flooding (i.e. the percentage of people living within an area with a particular likelihood of flooding).

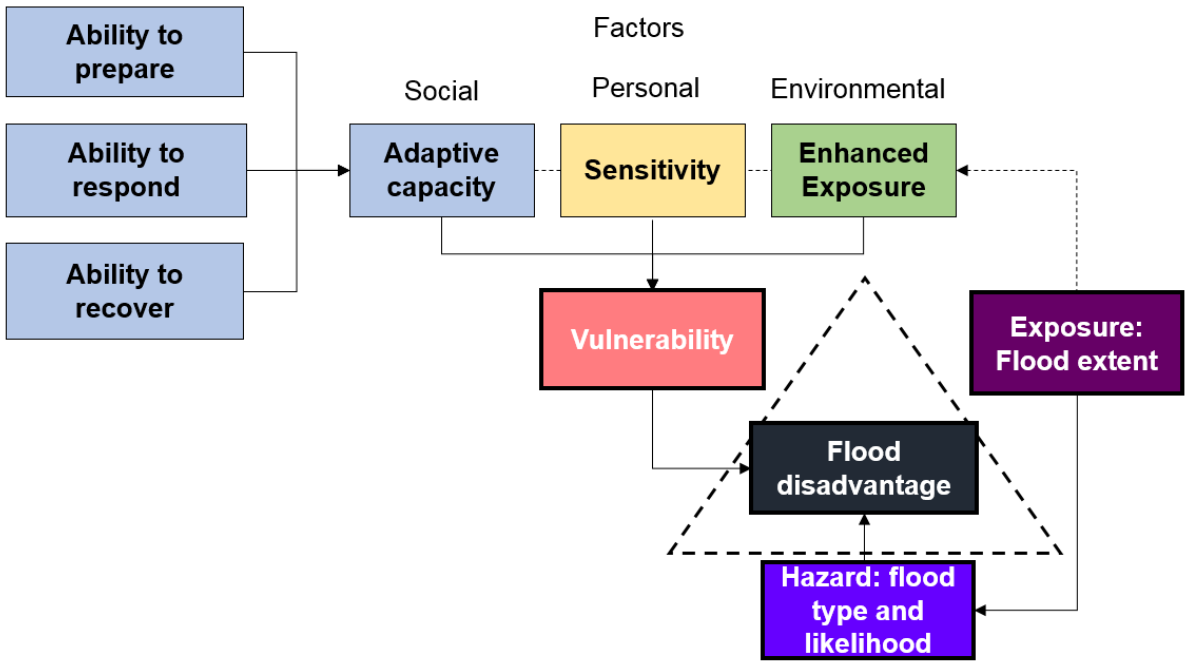


Figure 1. The framework of socio-spatial vulnerability and flood disadvantage (after Lindley et al., 2011; adapted for flood hazard).

Different flood types (coastal, river and surface water flooding) and probability of flooding (return periods), which also take into account the effects of climate change, are considered as varying the level of the potential hazard-exposure.

The main report explains the concepts of social vulnerability to flooding and flood disadvantage and the variety of factors influencing them in more detail.

2.2 Area-based approach

The assessment of social vulnerability to flooding and flood disadvantage uses an area-based approach, i.e. datasets were collected and analysed for distinct census units (see section 3) and the indicators are expressed in relation to the area (e.g. % of population in the area characterised by a certain feature; % of the spatial unit area characterised as urban).

Benefits of an area-based approach include:

- It minimises the issues of data protection and confidentiality as it enables the generalisation of personal, social and economic data for census units.
- It provides a broader picture that makes the outputs suitable for strategic planning. Therefore, it may be particularly useful to support decisions when preparing areas of known flood exposure prior to a flood event (e.g. through appropriate planning or neighbourhood design reducing exposure; through actions targeted at raising awareness of the risk of flooding and local authority's actions to reduce that risk across the community).
- It offers the opportunity to represent the results on maps. This may be used to highlight areas of high flood disadvantage (see case studies in the main report), guiding the efforts of local authorities and other local service providers to prioritise the areas for action. It may also ensure that the most effective preventative measures and responses to flooding by considering the characteristics of the community.
- Area-based mapping of vulnerability, instead of focusing on individuals, fits within the UK focus on populations in public health policies, rather than biology and behaviour of individuals, as is the case in the US, for example (Gordon, 2003).

The drawbacks of an area-based approach:

- It does not offer detailed information about the particular vulnerabilities of individual people and households (information which is available to public health services and social care departments of local authorities), and thus may not be sufficiently detailed to guide the action of emergency services in the event of flooding. This is reflected in previous research, where spatial vulnerability assessments were seen by emergency services as meaningful for prevention, planning, recovery and training, but having a limited role during the immediate response phase of a flood incident (Alexander et al., 2011).
- Low overall vulnerability at the census unit level may conceal the high vulnerability of a small number of individuals or households living in that area. Similarly, not all people living in an area classed as highly

disadvantaged in terms of flooding would necessarily be exposed to flooding or have high vulnerability.

Due to these limitations, this dataset should be considered as an initial indication of areas affected by social vulnerability to flooding and flood disadvantage. One of its main uses has been identified as a tool to start cross-departmental and multi-stakeholder discussion about the appropriate responses to flood disadvantage (see the case study section in the main report). It is recommended that in the decision-making phase, local authorities and other end users supplement this area-based dataset with a more detailed (and up to date) knowledge pertaining to the specific aspects and levels of vulnerability and exposure to flood in a specific location.

3. Spatial units and datasets used

The data zones 2001 were applied as the spatial units in this assessment. Data zones are the small area geography used by the Scottish Government to make statistics available (NRS 2013). They are compact areas each of around 500-1,000 residents[1] that are nested within local authority boundaries, and contain households with similar social characteristics (SG ATOM Feed, 2014). There are 6505 data zones in Scotland (Figure 2)[2].

Data zones were chosen as the spatial unit for analysis because most data used in the vulnerability assessment is reported at that scale (for example: census 2011; SIMD; Scottish Neighbourhood Statistics data). If a finer scale was used (census Output Areas, for example), data for some of the indicators would not be available or would need to be derived from larger units. Using data zones has helped to limit the uncertainty associated with re-scaling the data from one type of territorial unit to another.

Further, for confidentiality issues, census data reported at fine-scale spatial units are subject to statistical disclosure control, e.g. record swapping; therefore, for the smaller units, the effects of trade-offs between the data utility and the risk of disclosing confidential information may be more pronounced. Data zones are large enough areas to allow statistics to be presented accurately without fear of disclosure and yet small enough that they can be used to represent communities.

[1] On the day of census 2011, the population for the 6,505 data zones in Scotland ranged from 0 – 8,703; 2.9% of data zones had a population of less than 500 and 2.0 percent had a population of 1,500 or more (NRS, 2013).

[2] The data zones were revised in November 2014 (they are referred to as data zones 2011). However, as the majority of the data used in this project was reported for the census 2001 data zones, those were used as spatial units for the assessment of social vulnerability to flooding and flood disadvantage.

One limitation of Data zones is their large variability in area (Figure 2), due to the units being defined based upon population numbers. The physical size of units (e.g. in rural areas) and/or their internal variability will mean that not all socially vulnerable places may be accurately identified. The variability in size also causes some challenges for the presentation and interpretation of the data. For example, results for the smallest data zones (those with high population density) are not legible when viewing the whole of Scotland and visually comparing areas with large differences in size is more difficult. A recommended approach to address the presentation of the maps is to display them in an online portal allowing the users to view the data at a preferred scale[3].

An alternative approach would have been to use abstract spatial units that are uniform in size, such as $1km^2$ grid cells which were used in the National Flood Risk Assessment (SEPA, 2011). Whilst this would have been justified in a situation where a large proportion of data was not reported for any specific spatial unit (e.g. NFRA is reporting on issues such as location of infrastructure), in the context of the data relating to population, the census-derived units were seen as the best option. Further, they are recognised by local authorities as they are used in resource allocation and planning services (NRS, 2013).

The data zones were initially developed based on census 2001 data. For the consistency of reporting, ONS has used the same data zones to report census 2011 findings. Between 2001 and 2011 there was little change in the population of most data zones. However, some data zones experienced greater change (769 data zones increasing by 20% or more and 147 data zones decreasing by 20 % or more; NRS, 2013). The changes in the distribution of the population, in particular associated with urban regeneration and demolition of housing estates in Edinburgh and Glasgow resulted in five data zones not having any population associated with them in 2011.[4] For these data zones the census data was not reported and so they were excluded from the analysis and are presented as blank on maps.

[3] See for example http://www.climatejust.org.uk/map

[4] S01002296 (Edinburgh City); S01003031, S01003319, S01003505, S01003548 (Glasgow City).

Local authority	DZs	Local authority	DZs
Aberdeen City	267	Highland	292
Aberdeenshire	301	Inverclyde	110
Angus	142	Midlothian	112
Argyll and Bute	122	Moray	116
City of Edinburgh	548	North Ayrshire	179
Clackmannanshire	64	North Lanarkshire	418
Comhairle nan Eilean Siar	36	Orkney Islands	27
Dumfries and Galloway	193	Perth and Kinross	175
Dundee City	179	Renfrewshire	214
East Ayrshire	154	Scottish Borders	130
East Dunbartonshire	127	Shetland Islands	30
East Lothian	120	South Ayrshire	147
East Renfrewshire	120	South Lanarkshire	398
Falkirk	197	Stirling	110
Fife	453	West Dunbartonshire	118
Glasgow City	690	West Lothian	211

Excluding 5 data zones with no population recorded in 2011

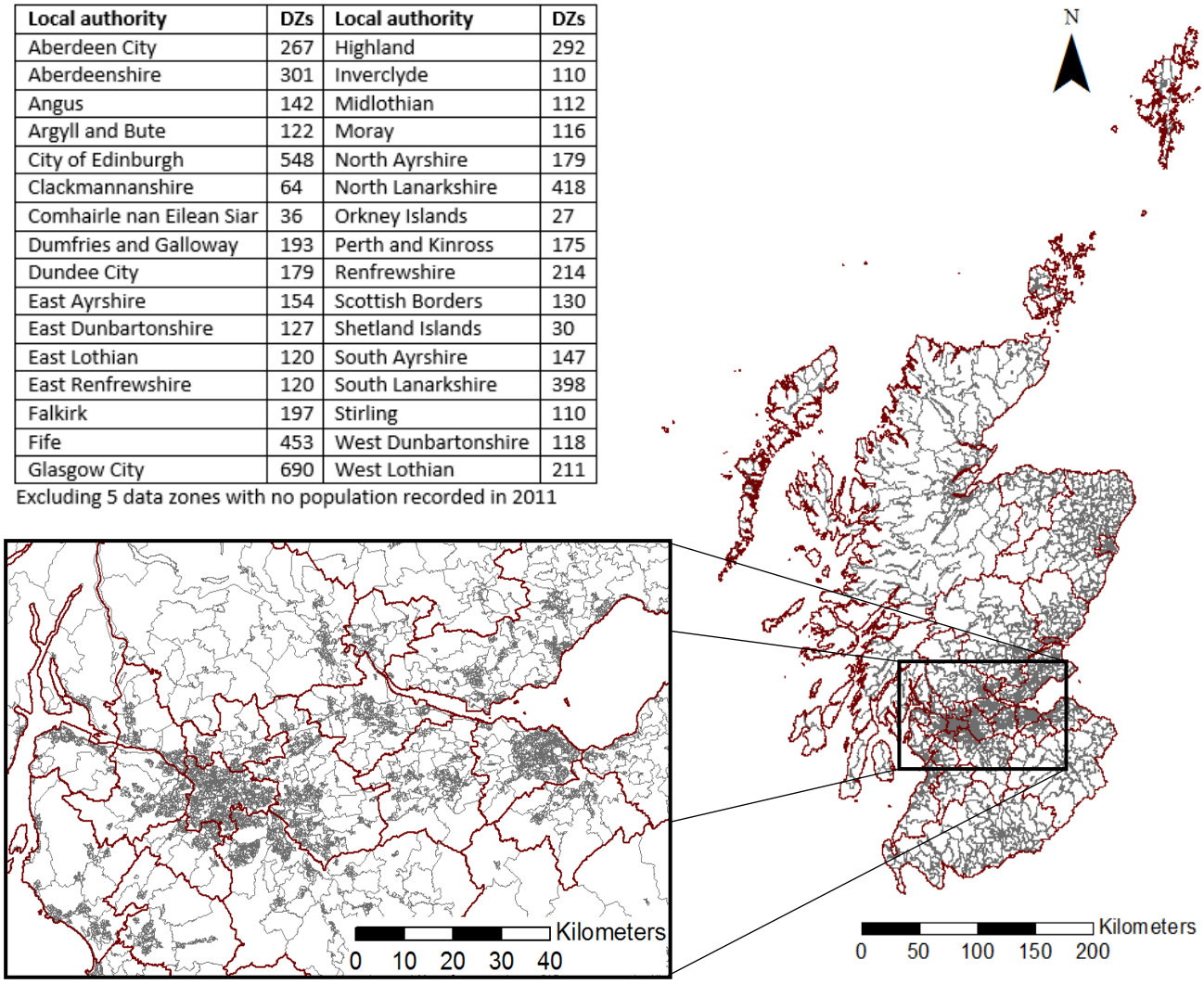


Figure 2. Data zones in Scotland. Ordnance Survey data © Crown Copyright and database right 2015

In addition, the analysis of the OS Addressbase 2015 has indicated that further changes in the distribution of population meant that five data zones (including two of those identified as having no population in 2011) were recorded as having no residential addresses associated with them in 2015[5]. This means that these data zones had zero residential addresses at risk of flooding and therefore were treated as not exposed to flooding and feature on the flood disadvantage maps as blank. The issue of an absence of population affects only 8 out of 6505 data zones, which is around 0.1% of the total number of data zones.

Data sources used to collate the information on the personal, social and environmental factors affecting social vulnerability to flooding are listed in

[5] S01002031 (Edinburgh City), S01003463, S01003533, S01003319 and S01003505 (Glasgow City; the last two data zones were also recorded as not having any residential population in census 2011).

Table 1. The flood extents (Flood Hazard Maps) obtained from SEPA and used to assess the flood disadvantage are listed in section 5.

Table 1. Data sources used in the assessment of social vulnerability to flooding

Dataset	Date	Source
Scottish census	2011	http://www.scotlandscensus.gov.uk/
Scottish census	2001	Scottish Government
Land Cover Map 2007	2007	Centre for Ecology and Hydrology (Morton et al., 2011)
Postcode Point Data	2014	Ordnance Survey
OS Addressbase	2015	Ordnance Survey
OS MasterMap Integrated Transport Network	2015	Ordnance Survey
Scottish Charity Register	2015	OSCR - Scottish Charity Regulator, http://www.oscr.org.uk/charities
Flood Warning Target Areas	2014	SEPA
Historic Flood Data	2014	SEPA
Flood Hazard Maps	2015 (version 1.1 released in March 2015)	SEPA
Scottish Neighbourhood Statistics	varied	http://www.sns.gov.uk/

4. Indicators of social vulnerability to flooding

4.1 Selecting the indicators

The factors affecting social vulnerability to flooding are represented by either direct or proxy indicators. A total of 34 indicators were used in the assessment (Table 2).

Table 2. Indicators used in the assessment of social vulnerability to flooding. For sources and more information see Appendix 1.

Domain	Indicator	Dimension of vulnerability				
		Sensitivity	Ability to prepare	Ability to respond	Ability to recover	Enhanced exposure
Age	% people under 5 years old	y				
	% people over 75 years old	y				
Health	% people whose day-to-day activities are limited	y				
	% households with at least one person with long term limiting illness	y				
Income	% people in routine or semi-routine occupations		y	y	y	
	% of long term unemployed people		y	y	y	
	% households with dependent children and no adults in employment		y	y	y	
	Number of Income Support claimants		y	y	y	
	Number of Job Seeker Allowance claimants		y	y	y	
	Number of Pension Credit claimants		y	y	y	
	Number of families receiving tax credits		y	y	y	
Information use	% people with <1 year residency in the UK		y	y	y	
	% people who do not speak English well		y	y	y	
Insurance	% new addresses located in flood risk areas		y	y	y	
	Number of historic flood events		y	y	y	
Local knowledge	% addresses in Flood Warning Target Areas		y	y		
	% new residents (< 1 year) arriving from outside the local area		y	y		
Tenure	% social rented households		y			
	% private rented households		y			
Mobility	% of Incapacity Benefit/Severe Disablement Allowance claimants			y	y	
	% people living in medical and care establishments			y	y	
	% households with no car or van			y	y	
Social networks	% children of primary school age			y	y	
	Number of voluntary organisations focused on local community			y	y	
	% single pensioner households			y	y	
Physical access	% people working further than 30km from home			y		
	Road density			y		
Crime	Number of domestic breakings			y		
Access to health services	Travel time to GP surgery (private transport)				y	
	Travel time to GP surgery (public transport)				y	
Housing characteristics	% households with the lowest floor level: ground floor					y
	% households with the lowest floor level: basement or semi-basement					y
	% caravans or other mobile or temporary structures					y
Physical environment	% urban land cover					y

The initial list of indicators was the one used as a basis for the first flood disadvantage assessment for Scotland (Lindley and O'Neill, 2013). This initial set of indicators was critically reviewed, taking into consideration the following:

- The strength of existing evidence supporting them (see the main report and Appendix 1).
- Feedback from stakeholders, mainly within the ClimateJust project[6], but also Scottish local authorities within the case studies carried out for this project and National Flood Forum.
- Consultation with the project's steering group, including representatives from the Scottish Government, SEPA, local authorities, and Joseph Rowntree Foundation.

The project team made changes to the original set of indicators, in collaboration with the Steering Group, due to the following reasons:

- Low level of confidence in some of the indicators, as suggested by the feedback offered by the local authorities and other intended users consulted within the ClimateJust project[7]. For example, the indicator: 'percentage of people not providing unpaid care', was used previously as a proxy for the quality of social networks. However, it was seen by the stakeholders as difficult to understand and ambiguous: whilst the process of providing care helps to extend social networks for those being cared for, carers themselves may be socially isolated or in poor health (ClimateJust).
- Presence of additional data specific for Scotland. For example, the Scottish Charity Register was used as a source of data on the location of voluntary organisations with a specific interest in the local community, which is being used as a proxy for local networks.
- Emergence of more relevant data. For example, whilst in the original assessment of social vulnerability to climate change (Lindley et al., 2011), percentage of people born outside the UK was used as a proxy for the ability of people to speak English, census 2011 collected data on actual English language proficiency, which more accurately reflects the ability to use information related to flooding.
- Specificity of Scotland in comparison to England and the rest of the UK. For example, in the climate disadvantage assessment for England, the proportion of all pensioner households was used as one of the proxies for low income households. However, in Scotland, the proportion of

[6] www.climatejust.org.uk

[7] The indicators listed on ClimateJust portal are given confidence flags based on the strength of evidence and user feedback gained in the development of the portal.

pensioners in low income is lower than in any of the other regions of the UK and pensioners are much less likely to be living in low-income households than non-pensioners[8]. Thus, this indicator was not considered to be relevant as a proxy for low-income households.

- Unintentional overlap between like indicators (in relation to income). The redundant indicators, i.e. those likely to represent the same aspect of vulnerability as other indicators, were removed based on the results of a correlation analysis (see Appendix 2).

At the same time, it was not possible to update some of the indicators. Census 2011 did not collect data on the lowest floor level of the household which is needed to estimate the enhanced exposure index. Therefore, the data for 2001 has been used, which may not be accurate for areas that have had significant turnover of housing stock, i.e. areas of urban regeneration (see also section 3 in relation to data zones with zero population). This emphasises the importance of local authorities treating this dataset as indicative of the flood disadvantage in their area and using more detailed, locally available information to assess the disadvantage with higher accuracy.

The final set of indicators used in the vulnerability assessment is provided in table 2, which shows how the different indicators have been grouped into thematic domains, and how they fit under different dimensions of vulnerability. Appendix 1 provides more detail about the datasets used, the processing involved in developing the indicators, and the modifications made since the first flood disadvantage assessment (Lindley and O'Neill, 2013).

The association of different domains with the dimensions of vulnerability is open to debate. For example, it could be argued that tenure does not only affect the ability to prepare (due to the limited power of tenants to make changes to the property they live in), but also affects the ability to recover, as evidence suggests that recovery is often hindered by the additional stress of dealing with frequently uncooperative landlords in the aftermath of flooding. As a result, tenants may suffer from more pronounced and lasting intangible impacts associated with physical and mental health than owner occupiers (Walker, 2006; Whittle et al., 2010). However, whilst the ability to prepare is similar for majority of the tenants, their recovery-phase situation can vary depending on the landlord's actions, thus it is more difficult to generalise.

The association of thematic domains with different dimensions of vulnerability was based on the existing evidence. As new evidence and data emerges, the balance of how different indicators contribute to different dimensions of vulnerability may shift. In addition, different locations, both within the UK and overseas, may have their specific circumstances affecting how the indicators and domains correspond with the ability to prepare, respond and recover.

[8] Older people in low-income households, The Poverty Site http://www.poverty.org.uk/s64/index.shtml

The set of indicators presented in table 3 aimed to achieve a balance between the availability of data, consideration of stakeholders' expertise and opinions and evidence available from published research. Also, in some cases, trade-offs had to be made between the spatial accuracy of the data and its topical relevance. For example, the indicator used previously for the domain 'crime' was the SIMD 2004 Crime index, combining information on recorded instances of various types of crime (see also Appendix 1). Out of these types of crime, only domestic housebreakings bear relevance: fear of looting is a common reaction in the event of flooding (Bonkiewicz and Ruback, 2012), which may mean that people are hesitant to leave their homes. Further, with regard to property level protection (PLP) measures that would need to be in place when the resident was out of the home (e.g. flood barriers), some people may be concerned that these measures make it obvious that the occupiers are away and thus could make the houses more prone to burglary (Douglas, et al., 2010). Consequently, in this assessment, only 'domestic break-ins per 10,000 households' was used; however, this data was only available for the level of intermediate geography (IG; census data units that contain between 2,500 and 6,000 household residents, one level up in the spatial hierarchy from data zones), which meant that all data zones within a given intermediate geography unit were assigned the number of domestic breakings for this unit, whilst there may have been substantial spatial variation among the data zones.

Similarly, the number of charities specifically focused on working within local communities or neighbourhoods was recorded, based on their postcodes, for IG units. This was done using the logic that it is unlikely that charitable organisations' activities would be limited to the small unit of a data zone. The number of charities found for IG unit was applied to the data zones contained within the IG unit, assuming an equal coverage by the charities' activities within that area. However, the data underpinning the majority of the indicators are available at the data zone level, thus the generalisations made for the remaining indicators are unlikely to have a significant bearing for the overall assessment of social vulnerability to flooding.

The indicator that is subject to particular limitations relates to insurance availability, which estimates the proportion of properties built after 1st January 2009 in flood risk areas as potentially uninsurable. This is based on the exemption of such properties from the commitment to provide insurance under the Statement of Principles between the Association of British Insurers (ABI) and the Scottish Government (2008) in order to discourage the development of properties on flood plains. The caveats associated with this indicator are as follows:

- The 1 in 200 years + climate change flood maps were considered, whilst the ABI Statement of Principles is largely based on the 1 in 75 years return period. This means that the flood extents that were used for the

analysis here may overestimate the number of residential properties with potentially limited access to flood insurance.

- The information on the lowest level of dwelling was not available for the purposes of this analysis; therefore, it was not possible to separate houses and flats at/below ground level from those that are on higher floors and may not be affected by flooding. This means that an unknown proportion of these residential properties would never be affected by flooding (however, their residents may still be affected – e.g. all people living in an apartment block would experience some inconvenience if the ground floor was flooded). It is recommended that in future assessments, the Scottish Property Dataset is used to help identify the number of properties located at or below the ground level.
- Coastal and surface water is often readily managed to enable appropriate development.
- These figures do not take into account any resilience or resistance measures to mitigate flood damage that may be present (which under the Statement of Principles is required for properties built from 2009 onwards in areas exposed to flooding). Therefore, if there are PLP measures in place the exposure levels may be lower than indicated here.
- Many of the developments might have been subject to detailed flood risk assessments that demonstrate development as being appropriate to planning policy.
- There is also some uncertainty on the property dataset used, i.e. the column ‘start date’ may not be appropriate to identify new development.

Therefore, given the limitations of the method highlighted here, the outputs are best used to aid strategic planning to identify areas of concern; more detailed investigations into the nature of vulnerability are advised, to be carried out based on locally available, area-specific data, if possible, to guide specific decisions on targeting resources.

4.2 Standardising the indicators

In order to add all of the indicators together, they were standardised, which means presenting them on a uniform scale. This was done to avoid ‘comparing apples and pears’, as the indicators are expressed in different units (e.g. number/percentage of people; number/percentage of households; percentage of the area). Z-score standardisation was used, which means that all standardised indicators have a mean (average) value of zero and standard deviation value of one. For the standardised indicators, values above the mean for all data zones in Scotland are positive, and values below the mean for all the data zones in Scotland are negative. The further the original values are from the mean for all data zones, the more extreme the positive and negative values of z-scores.

5. Indicators of flood hazard-exposure

The Flood Risk Management (Scotland) Act 2009 (FRM Act) requires the publication of High (10-year return period), Medium (200-year return period) and Low (1000-year return period) probability flood hazard information. SEPA published new national Flood Maps for these scenarios for coastal, river (fluvial) and surface water flooding (incorporating rainfall and sewer model outputs) in 2013. The Flood Maps were based on the consistent application of modelling methodologies across Scotland.

The SEPA flood hazard maps were developed for a suite of flood scenarios ranging from high probability to low probability events and considering climate change. In addition, they considered ‘defended’ and ‘undefended’ scenarios. A ‘defended’ scenario is where the underlying models specifically consider formal flood protection schemes (e.g. walls, embankments). This information is taken from the Scottish Flood Defence Asset Database (SFDAD) which is the best source of information on defence structures. However, the SFDAD is incomplete and the information varies in quality across Scotland. Furthermore, certain necessary assumptions are applied in the application of defence data, appropriate to the strategic nature of the models. Consequently, the defended runs do not provide a precise, explicit assessment of flooding at each defence location. Threfore, a specific assessment of a particular defence structure is likely to indicate a more accurate reflection of the flood pattern and protection offered.

An ‘undefended’ scenario is one that does not explicitly consider formal flood protection structures. Both scenarios will include implicit reference to other structures (e.g. road embankments) where they are components of the underlying Digital Terrain Model (DTM).

Coastal, river, and surface water flooding were all considered separately in this assessment, in addition to flooding from any of these sources. This study uses the SEPA v1.1 Flood Maps, which were updated and made publicly available in March 2015. The mapping of flooding is a dynamic process and the Flood Maps are subject to change as input data, methodologies and techniques are developed. Thus, the Flood Maps are subject to continual improvement and the study represents the current knowledge on flood hazard as of March 2015. It may not account for more recent changes or fully reflect flood hazard in certain locations (e.g. Forres and Elgin).

In consultation with the Steering Group, three return periods were selected for each source of flooding to provide a range of outcomes of the probability of flooding (Table 4). The return periods covered 1 in 25 or 1 in 30 years (4% or 3.3% annual probability); and 1:200 years likelihood of flooding, together with a low scenario which incorporates consideration of future climate change

projections. For surface water flooding, the depth of 0.1 metres was considered, since even shallow water can cause significant damages and repair costs, thus making it difficult for people to recover after flooding (Kazmierczak and Cavan, 2011). The defended extents were used to include the presence of flood defences.

Analysis of the Flood Maps (v1.1) revealed some inconsistencies between the extents for different return periods, for example, in some areas, the 1 in 200 year extents did not incorporate all of the 1 in 25 year extents, as would be expected (the lower the probability of flooding, the greater its magnitude and the larger the area affected). Table 5 presents the number of data zones affected by these inconsistencies. Given the inherent uncertainty in flood modelling (i.e. resulting from simplifications necessary to reflect highly complex natural processes) there are areas of the country where the methods work more effectively than others. In these other areas (e.g. for very small, urban watercourses at lower return period scenarios) there is therefore relatively lower confidence in the outputs. For the statutory scenarios, SEPA sought to make amendments in areas of lower confidence prior to publication. However, further work is required to address some of the intermediate return periods not published but used in other areas of flood risk management (e.g. 30, 50, 100-year return periods). Thus there may remain locations where there are inconsistencies between the published return periods and those other scenarios.

SEPA is considering these inconsistencies in the improvement plan for the Flood Maps so that anomalies and inconsistencies between scenarios will be addressed and overall confidence improved with more focussed modelling assessments. In this assessment, we considered return periods for a given type of flooding seperately to avoid making assumptions, for which of the return periods the flood extents were more accurate. The ‘any type of flooding, 1 in 200 years incuding the impacts of climate change’ flood extent accounts to some extent for the inconsiencies by combining all flood extents (all types of flooding, all return periods).

Table 4: Flood hazard maps used in the project (SEPA, version 1.1, March 2015)

Type of flooding	Return period	Defended scenario	AEP[9]	Incorporation of climate change projections	Code used in tables and figures
Coastal	25-year	Yes	4%	-	C25
	200-year	Yes	0.5%	-	C200
	200-year climate change	No	0.5% (in 2080)	A precautionary approach which considered the worst case scenario was adopted. UKCP09 projections of sea level rise (high emissions, 95th percentile confidence limit for the year 2080) were used to account for sea level rise to 2080.	C200+cc
River	30-year	Yes	3.3%	-	R30
	200-year	Yes	0.5%	-	R200
	200-year climate change	No	0.5% (in 2080)	Estimates of future flood flows apply the UKCP09 2080s high emissions scenario, 67th percentile. Regional uplift factors for main river basin areas were applied (see Kay et al., 2011).	R200+cc
Surface water*	30-year	No	3.3%	-	S30
	200-year	No	0.5%	-	S200
	200-year climate change	No	0.5% (in 2080)	A national increase of 20% rainfall was applied to account for climate change. This is in line with Defra (2006) guidance.	S200+cc
Any flooding	200-year: climate change	No	All flood extents combined	See C200+cc, R200+cc, S200+cc	Any

*Depth 0.1m, incorporating rainfall and sewer model outputs

[9] Annual Exceedance Probability (AEP) - chance of being exceeded in any given year

Table 5. Number of data zones affected by the inconsistencies in flood risk maps

Type of flooding	Type of inconsistency	Number of data zones affected
Coastal	1:25 extent larger than 1:200	16
River	1:30 extent larger than 1:200	45
	1:30 extent larger than 1:200+cc	38
	1:200 extent larger than 1:200+cc	80
Surface water flooding	1:30 extent larger than 1:200	12
	1:30 extent larger than 1:200+cc	31
	1:200 extent larger than 1:200+cc	46

The index of flood hazard-exposure represents the percentage of residential addresses exposed to flooding in each data zone. Calculating the percentage of residential addresses within the flood extents presents a more accurate account of the proportion of the population exposed than simply using the percentage of the data zone area exposed to flooding, because the extent of flooding may include unpopulated areas. Furthermore, whilst Flood Maps are of a strategic nature and not appropriate for property level assessment, they are intended for use at a community level, and therefore, presenting our findings at the data zone level is more appropriate.

Residential addresses were obtained from Ordnance Survey AddressBase, supplied by the Scottish Government (version: 11 April 2015). OS AddressBase classifies each address into residential or commercial (Figure 3). Only residential addresses were considered in this assessment, and therefore, as previously noted, it is different to the NFRA, which also considers flood risk to commercial properties.

Processing conducted in ArcGIS v10.2 included Select by Location to calculate the number of residential properties within each flood extent, and a Spatial Join to summarise the information by data zone. Table 6 shows the number and percentage of residential addresses at risk from all types of flooding and extents for the whole of Scotland.

Figure 3. AddressBase over OS MasterMap Topography Layer (OS, 2015)

Table 6: Percentage of residential addresses exposed to flooding in Scotland (total number of residential addresses: 2475709*)

Flood type and risk level	Percentage of residential address points exposed to flooding
C25	0.38
C200	0.45
C200+cc	1.24
R30	1.00
R200	1.87
R200+cc	2.88
S30	0.33
S200	0.61
S200+cc	0.73
All coastal	1.24
All river	2.97
All surface water	0.74
Any type of flooding at 1:200+cc	4.37

* It should be noted that an additional 1465 address points were located outside of the Data zone extents. These properties have not been considered in this assessment. It is likely that they are mobile properties such as boats, but this level of information was not available in OS AddressBase (only AddressBase Plus or Premium products).

The percentage of residential address points within each flood extent, and all extents combined (any flooding) was calculated for each data zone. For each of the extents separately, and for all data zones (containing residential addresses, see section 3) the percentage of address points potentially exposed to flooding was standardised to develop the hazard-exposure indicator (see Figure 1).

The standardised percentage of residential addresses within all extents combined (thus residential properties exposed to any flooding) has been used to calculate the main flood disadvantage index.

6. Calculating and classifying the indices

Calculating the index of social vulnerability to flooding from standardised indicators involved the following five steps (summarised Figure 4):

- Indicators were grouped into 14 domains pertaining to themes such as health, income, social networks or housing characteristics (see Table 2).
- The standardised indicators (z-scores) were equally weighted within domains. This was done to avoid over-representing the domains with a larger number of indicators. For example, if there were 3 indicators within a domain, each of them had a weighting of 0.33; if there were 2 indicators, each of them had a weighting of 0.5. The weightings of the indicators are included in Appendix 1.
- The weighted indicators were added together to develop the dimensions of sensitivity, exposure, and ability to prepare, respond and recover.
- The dimensions of sensitivity, exposure, and ability to prepare, respond and recover were standardised and summed to form the vulnerability index.
- The vulnerability index was then standardised.

The index of disadvantage was then calculated by adding the standardised vulnerability index to the standardised hazard exposure index (Figure 4). The final step was the standardisation of the disadvantage index.

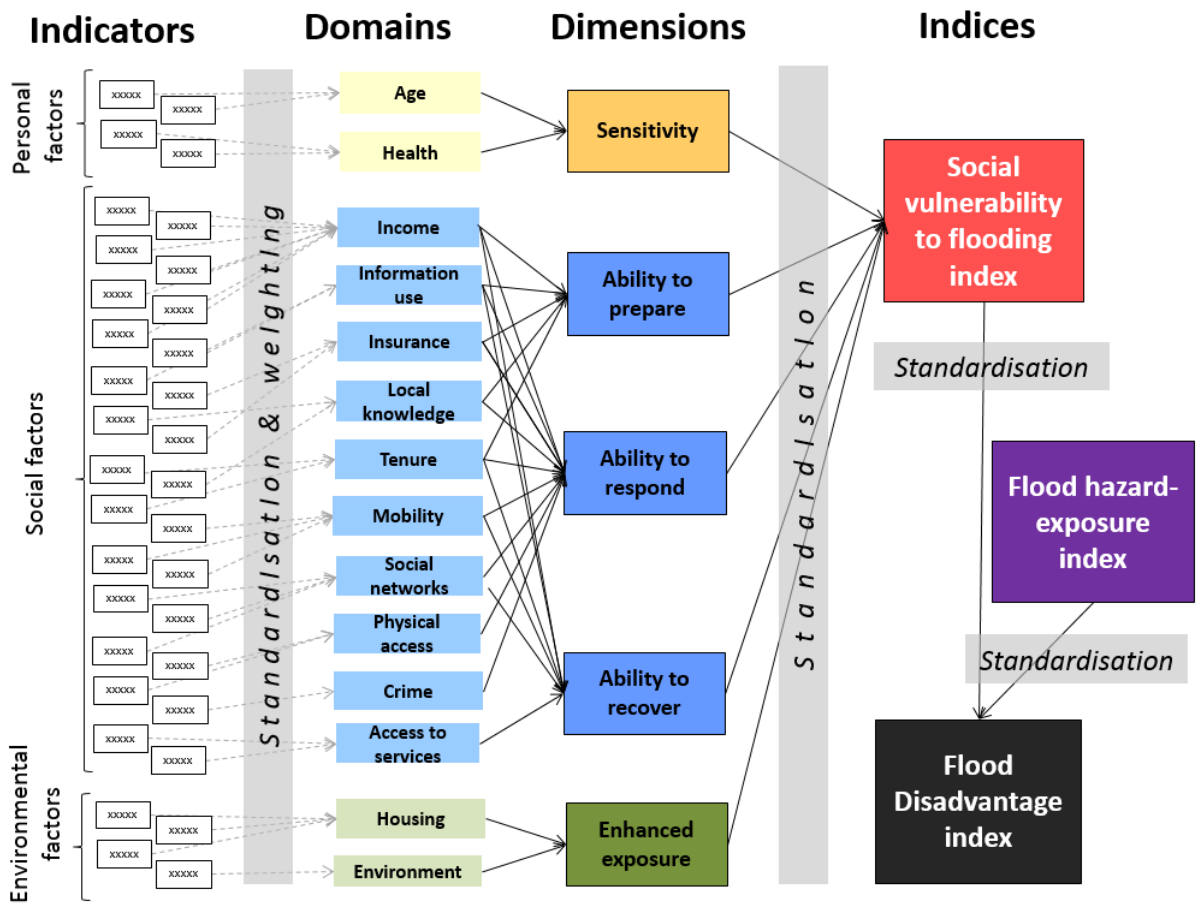


Figure 4. A schematic diagram showing the process of developing the indices of social vulnerability to flooding and flood disadvantage

This approach to assessing social vulnerability to flooding is based on equal weightings of the domains. This was discussed with the Steering Group and the case study local authorities. It has been recognised, based on the consultations with stakeholders within the ClimateJust project that it is next to impossible to achieve a consensus on the weighting of domains when involving stakeholders from different sectors or various local authority departments.

Therefore, in addition to the indices developed within this project, the users of the flood disadvantage dataset are encouraged to develop their own weightings if replicating the method. In the future, we recommend development of an online tool which would allow the users to freely select the indicators they see as suitable to their vulnerability assessment and enter the weights that are relevant to their locality or area of work.

The final outputs of the assessment of social vulnerability to flooding and flood disadvantage are maps, developed for Scotland as a whole as well as for the individual local authorities. The standardised indices of social vulnerability to flooding and flood disadvantage are classified using standard deviation (SD)

value, which, for standardised indices, equals 1. The average values of social vulnerability to flooding and flood disadvantage are understood as those that concentrate within -/+0.5 SD from the mean (average) value. The larger the positive or negative value of the index, the further the values are from the mean value. The classes are summarised in Table 7.

Table 7. Classes of social vulnerability to flooding and flood disadvantage

Value of the standardised index	Level of vulnerability / disadvantage
≥ 2.5	Acute
1.5 – 2.5	Extremely high
0.5 – 1.5	Relatively high
-0.5 – 0.5	Average
-1.5 – -0.5	Relatively low
-2.5 – -1.5	Extremely low
≤ -2.5	Slight

The method of classification based on SD was chosen in order to allow comparisons to the 'average' Scottish neighbourhood. The purpose of the assessment carried out for the entire country was to enable identification of the extreme and acute levels of vulnerability and disadvantage as locations where further investigation should be targeted, followed by action. The classification based on SD was also used in the NFRA (SEPA, 2011) to identify different levels of social vulnerability.

Whilst the classification based on SD allows identification of the areas with values far removed from the Scottish mean, this method may be less useful for users in local authorities, in particular in locations with little variation in vulnerability and disadvantage (e.g. where most of the neighbourhoods are close to average, or only range from relatively low to relatively high). The datasets containing the indicators (the simple spreadsheet and the spatial dataset) allow the end users in local authorities to apply their own classification. For example they could base them on quantiles, natural breaks or equal intervals to classify the data in a manner that would allow the identification of differences between data zones in terms of their vulnerability or disadvantage at the local level. In addition, the average values are provided in the simple spreadsheet with the data, not only for Scotland but also for each individual local authority.

7. Alternative vulnerability assessment methods

To date, no methodological ‘best practice’ has been established for the assessment and mapping of social vulnerability to flooding and to climate-related events more broadly (Preston et al., 2011). Whilst the underlying causes of social vulnerability to extreme weather events (such as age, health or living conditions) are well-recognised, the selection of indicators, methods of combining them and spatial representation may vary considerably. They depend on how vulnerability is defined; whether the assessment pertains only to people vulnerable in a crisis, or whether it also takes into account the vulnerability affecting the ability to prepare for or recover after the flood event.

Whilst spatial mapping of the vulnerability of people to extreme weather events has been the subject of multiple studies in North America, fewer such studies have been undertaken to date in the UK context (Kazmierczak and Cavan, 2011; Haynes et al., 2008; Lindley et al., 2006; Tapsell et al., 2002).

The Social Flood Vulnerability Index (SFVI) developed by Tapsell et al. (2002) is still being used in assessments of vulnerability. It uses three social characteristics and four financial deprivation indices:

- Social Characteristics:
    - Long Term Sick
    - Lone Parents
    - Elderly (over 75 years old)
- Financial Indices:
    - Unemployment
    - Overcrowding
    - Non-car ownership
    - Non-home ownership.

Therefore, SFVI when compared to the assessment described here, focuses mainly on the themes of age, health and income (although non-car ownership also relates to mobility and non-home ownership reflects the vulnerability of tenants). SFVI has been used as one of the indices in NFRA assessment (SEPA, 2011), contributing to the receptor group ‘health’. This well-recognised approach helps to identify some socially vulnerable areas. However, the assessment of social vulnerability to flooding used here goes further and attempts to represent a number of other issues through relevant indicators, from the ability to use the information provided to the qualities of the physical

environment that enable targeting of measures before, during and after flood events. Other advantages of the approach used here over SFVI can be seen, firstly, in the dissagregation of the final index into the dimensions of vulnerability and secondly, in the combination of vulnerability and flood hazard-exposure into a disadvantage index.

As well as the selection of the indicators, the method of combining them together is also open to debate. Some studies – similar to the assessment carried out here - add different weighted or unweighted indicators together, resulting in one overall index (e.g. Tapsell et al., 2002; Cutter et al., 2000; Chakraborty et al., 2005; Haynes et al., 2008; Wu et al., 2002); others use factor analysis or similar data reduction methods to organise the indicators (Clark et al., 1998; Cutter et al., 2003; Kazmierczak and Cavan, 2011). In particular, Principal Component Analysis (PCA) can be helpful as a means of identifying key underlying components which help to explain a larger dataset. The basic assumption made by PCA is that a few underlying components or factors within the data can be used to explain complex relationships between the whole dataset. These factors can then be mapped and combined into an index (e.g. Cutter et al., 2003).

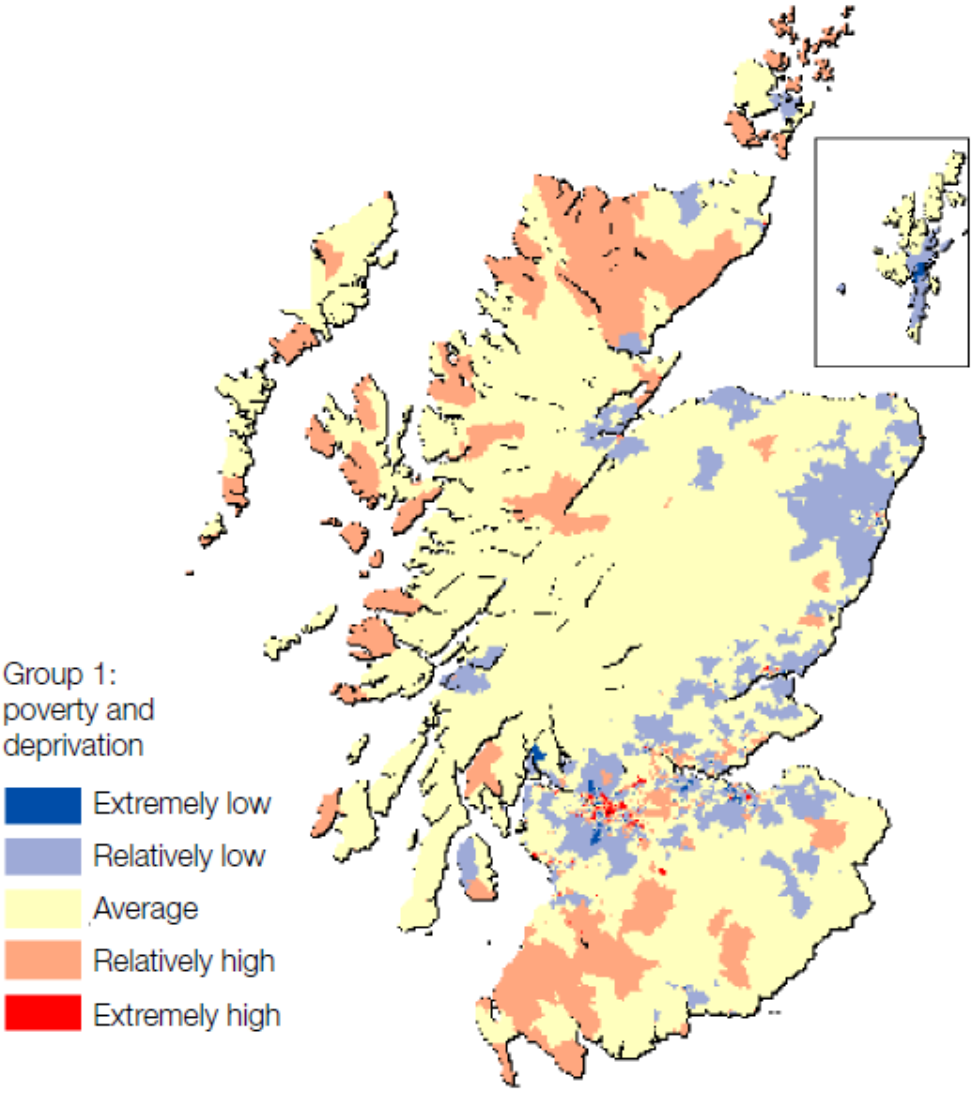
As an alternative perspective to the main assessment of social vulnerability to climate change, Lindley et al. (2011) used PCA to identify socially vulnerable groups in Scotland, i.e. based on composite factors which helped to explain most of the variation seen across Scottish neighbourhoods. The analysis found 5 groups:

- Poverty and deprivation (shown in Figure 5);
- New arrivals - measures associated with transience of communities and lack of local knowledge;
- Work and work-related transport – related to distance to work and reliance on public transport;
- Age and household composition; and,
- Poorer social networks[10].

Factor analysis retains some information about the underlying causes of vulnerability, therefore it has an advantage over methods of assessment that develop one cumulative index only. However, the grouping of indicators according to statistical associations between them may result in rather

[10] This group contains high values of two indicators for poorer social networks: percentage of single-person households and higher proportions of private renting. However, the group is also linked to higher proportions of above street-level accommodation, therefore this is likely to offset social vulnerability to flooding because of the lower enhanced exposure (Lindley et al., 2011).

cumbersome indices, grouping a variety of different issues together, which as a result are too far removed from the practitioners' perspective to be easily applicable. The approach presented here aims to avoid these pitfalls and categorise the indicators into topical groups, or domains, which may be easier to decipher by practitioners without losing the richness of data.



Source: Boundary data: EDINA UKBORDERS, Crown copyright

Figure 5. An example of a map representing an underlying factor of vulnerability: 'poverty and deprivation' (Lindley et al., 2011).

8. Recommendations for future assessments of flood disadvantage

Assessment of social vulnerability to flooding and other climate-related extreme events is a relatively new area of research and practice which will likely develop in the decades to come. Based on the experiences gained in this project, and in the previous assessments of vulnerability for other locations (e.g. ClimateJust for England), the following recommendations can be made:

- Spatial units: the end users should decide on the most appropriate spatial units to be applied in the assessment to best serve their needs.
- Indicators of social vulnerability to flooding:
    - New indicators could be relatively easily developed to identify more precisely the areas where people are affected by multiple social, personal and environmental issues that increase their vulnerability to flooding. For example, identifying the number of older people suffering from health problems, or private tenants who are income deprived, would offer more useful information than identifying the people who are older, in poor health, tenants, or income deprived independently from each other.
    - In collaboration with SEPA, the data on the uptake of flood warnings in flood risk areas could be incorporated in future assessments to better reflect 'local knowledge'.
    - Up to date information on the proportion of households with the lowest floor at the ground/basement level could be collected from the Scottish Property Dataset. Whilst this may help to represent the enhanced exposure for some properties more accurately, there is still a level of uncertainty associated with this dataset.
    - Indicators relating to insurance cost and availability should be amended once the Flood Re agreement is in place[11].
    - In collaboration with each local authority, e.g. through the use of local data holdings, local knowledge and community participation, the data limitations of this assessment should be addressed[12]. For example, information on the vulnerable individuals living

[11] http://www.floodre.co.uk/

[12] Follow-on work based on the Climate Just mapping has used a range of alternative externally licensed (e.g. Experian MOSAIC and Ordnance Survey) and internal local datasets (e.g. from Adult and Children Social Services) to further develop and refine local profiles of vulnerability. See case studies section on www.climatejust.org.uk

outside the areas identified as vulnerable should be incorporated into the assessment. Also, information on other vulnerable groups not captured here due to data paucity (e.g. the homeless) should be included.

- Flood hazard-exposure indicators:
    - Amend the flood risk data used in the assessment of disadvantage as the datasets are updated by SEPA.
    - Use 1 in 10 years flood extents to identify the socially vulnerable areas with the highest probability of flooding as those where preventative actions should be prioritised.
    - In addition to the Scottish Flood Defence Asset Database, local authorities should develop a database on PLP in their area and incorporate this information in future assessments.
- Building the indices: stakeholders' knowledge could be used to develop weightings of indices that reflect local priorities. Ideally, a model presenting the data that would allow stakeholders to visualise the effects of amended weightings of indicators in real time could be developed.
- The flood disadvantage index could be usefully accompanied by a 'response' layer presenting aspects such as: investment in flood management; spatial distribution and capacity of the emergency services; presence of rest centres; and, other supporting social infrastructure.

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Appendix 1: Indicators used in the assessment

The table describes the processing of indicators and their modification in relation to the first flood disadvantage assessment in Scotland (Lindley and O'Neill, 2013). Confidence level reflects the project team's certainty that the indicator reflects the domain of social vulnerability to flooding. High level of confidence indicates good grounding in literature and a direct link between the indicator used and the phenomenon it desribes. Medium level describes the indicators that are proxies for the domains they represent and/or have less evidence supporting them. Low confidence indicators have not been included in the assessment.

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Age	Young children (% people under 5 years)	Scotland's census	2011	Census table KS102SC. Number of people aged 0-4 years was divided by the population and multiplied by 100.	Data zone	Higher proportion of children under 5 in an area indicates a higher vulnerability.	High	No change.	0.500
Age	Older people (% people over 75 years)	Scotland's census	2011	Census table KS102SC. Number of people aged 75 years or more was divided by the population and multiplied by 100.	Data zone	Higher proportions of people over 75 in an area indicates a higher vulnerability.	High	No change.	0.500

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Health	Disability / people in ill-health (% people whose day-to-day activities are limited)	Scotland's census	2011	Census table KS301SC. Number of people whose day to day activities are limited a lot + number of people whose day to day activities limited a little, divided by the total population and multiplied by 100.	Data zone	Higher proportions of disabled people / people in ill-health in an area indicate a higher vulnerability	High	The census question has changed: in 2001 census the question was: "Do you have any long-term illness, health problems or disability which limits your daily activities or the work you can do?" and the answer options was "yes" and "no". In 2011, the question was rephrased as "are your day-to-day activities limited because of a health problem or disability which has lasted, or is expected to last, at least 12 months" and respondents were given the answer options "yes, limited a lot"; "yes, limited a little" and "no".	0.500
Health	% households with at least one person with long term limiting illness	Scotland's census	2011	Census table KS106SC. Number of households with one or more persons with a long-term health problem or disability divided by the total number of households and multiplied by 100.	Data zone	Higher proportions of households containing at least one person in ill-health indicate a higher vulnerability	High	No change	-0.500

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Income	Low income occupations (% in routine or semi-routine occupations)	Scotland's census	2011	Census table KS611SC. Number of people aged 16-74 in routine occupations + number of people in semi-routine occupations divided by all people aged 16 to 74 and multiplied by 100.	Data zone	Higher proportions of people employed in routine and semi-routine jobs in an area indicate a higher vulnerability because of their likelihood to be on lower incomes relative to other people.	High	No change	0.143
Income	Long-term unemployed (% who are LTU or who have never worked)	Scotland's census	2011	Census table KS611SC. Number of people aged 16-74 'never worked and long-term unemployed' divided by the total number of people aged 16-74 and multiplied by 100.	Data zone	Higher proportions of people in an area who are long-term unemployed or who have never worked indicate a higher vulnerability because of their likelihood to be on lower incomes relative to other people.	High	No change	0.143

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Income	Households with dependent children and no adults in employment (%)	Scotland's census	2011	Census table KS106SC. Number of households 'No adults in employment in household: With dependent children' divided by the total number of households and multiplied by 100.	Data zone	Higher proportions of unemployed people with dependent children in an area indicate a higher vulnerability because of their likelihood to be on lower incomes relative to other people.	High	No change	0.143
Income	Number of Income Support claimants	Scottish Neighbourhood Statistics	2012	Average number for four quarters for 2012	Data zone	Higher number of claimants indicates higher vulnerability	High	New indicator - this indicator replaced the SIMD Income index, i.e "percentage of people income deprived"	0.143
Income	Number of Job Seeker Allowance claimants	Scottish Neighbourhood Statistics	2012	Average number for four quarters for 2012	Data zone	Higher % of income-deprived people equals higher vulnerability	High	New indicator - this indicator replaced the SIMD Income index, i.e "percentage of people income deprived"	0.143
Income	Number of Pension Credit claimants	Scottish Neighbourhood Statistics	2012	Average number for four quarters for 2012	Data zone	Higher % of income-deprived people equals higher vulnerability	High	New indicator - this indicator replaced the SIMD Income index, i.e "percentage of people income deprived"	0.143

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Income	Number of families receiving tax credits: Working Tax Credits or Child Tax Credits	Scottish Neighbourhood Statistics	2009	This dataset contains a count of all families in work receiving either Working or Child Tax Credits (WTC or CTC) and reflect the finalised figures for the tax year.	Data zone	Higher % of income-deprived people equals higher vulnerability	High	New indicator - this indicator replaced the SIMD Income index, i.e "percentage of people income deprived"	0.143
Information use	Recent arrivals to UK	Scotland's census	2011	Census table QS801SC. Number of people with year of arrival 'Arrived 2010-2011' divided by the total number of people and multiplied by 100.	Data zone	Higher proportions of people recently arrived from outside the UK in an area indicate a higher vulnerability.	Medium	No change	0.500
Information use	Level of proficiency in English	Scotland's census	2011	Census table QS205SC. Number of people 'Does not speak English at all' + 'Does not speak English well', divided by the total number of people and multiplied by 100.	Data zone	People who cannot speak English are more likely to have difficulty obtaining and using information and guidance provided to the general public.	High	New indicator, replacing the previously used 'proportion of people born outside the UK'	0.500

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Insurance	Insurance availability	OS Addressbase and SEPA flood extents	2015	Number of residential properties built after 1st January 2009 and located within flood risk areas (any flooding; 1 in 200 + cc extent) divided by the total number of residential properties in the data zone and multiplied by 100.	Point data: exact location of the residential addresses and polygon data: EPA flood extents.	The properties built after 1st January 2009 and located in flood risk areas may not be not covered by Flood Re Homes (as applied under the old Flood Insurance Statement of Principles) and thus insurance may not be available to them. The higher the proportion of residential properties with limited insurance availability, the higher the vulnerability.	Medium	New indicator	0.500
Insurance	Insurance cost	SEPA Historic Flood Data	2015	Number of historic flood events (since 1980) recorded in data zone	Point data: location of the flood event.	The higher the number of past flood events, the higher the insurance premium is likely to be.	Medium	New indicator	0.500

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Local knowledge	Access to flood warnings	SEPA	2015	Number of address points covered by Flood Warning Target Area divided by all address points in the data zone and multiplied by 100.	Polygon data: FWTA outlines.	The higher the percentage of address points covered by the FWTA, the greater the number of people aware of the flood risk	Medium	New indicator	-0.500
Local knowledge	New migrants from outside the local area	Scotland's census	2011	Census table UKMIG001. Number of people who 'Lived elsewhere one year ago outside the area but within 'associated area'' + 'Lived elsewhere one year ago outside the 'associated area' but within the UK' (where associated area is the next level up in the census geography hierarchy, i.e. local authority in this case), divided by the total number of residents and multiplied by 100. All data zones within the intermediate geography unit were assumed to have the same value.	Intermediate geography	The higher the proportion of new residents in the area, the higher the number of people who may not be aware of the flood risk.	High	No change	0.500

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Tenure	Social renters (% Households renting from Social or Council landlords)	Scotland's census	2011	Census table KS402SC. Number of households 'Rented: Council (Local authority)' + 'Rented: Other social rented', divided by the total number of households and multiplied by 100.	Data zone	Higher proportions of social renters in an area indicate a higher vulnerability as renters have a lower ability to adapt their homes.	High	No change	0.500
Tenure	Private renters (% Households)	Scotland's census	2011	Census table KS402SC. Number of households 'Rented: Private Landlord or Letting Agency' + 'Rented: Other', divided by the total number of households and multiplied by 100.	Data zone	Higher proportions of private renters in an area indicate a higher vulnerability as renters have a lower ability to adapt their homes.	High	No change	0.500
Mobility	% of incapacity benefit/severe disablement allowance claimants in the population	Scottish Neighbourhood Statistics	2012	A number of IBSDA claimants (average of four quarters for 2012) divided by the total population and multiplied by 100.	Data zone	The higher proportion of IBSDA claimants in the population means higher vulnerability.	High	No change	0.333

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Mobility	% people living in medical and care establishments	Scotland's census	2011	Census table QS421SC. Number of people in 'Medical and care establishments' divided by the total population and multiplied by 100.	Data zone	Areas with a higher proportion of people living in communal medical and care establishments, e.g. residential and nursing homes, have lower mobility of people and higher vulnerability	High	New indicator	0.333

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Mobility	Lack of private transport (% households with no car or van)	Scotland's census	2011	Census table KS404SC. Number of households where 'Number of cars or vans in household: No cars or vans' divided by the total number of households and multiplied by 100.	Data zone	Areas with higher proportions of households which have no private transport are more likely to be communities with mobility problems and therefore have higher social vulnerability compared with communities with lower proportions of households with no private transport.	High	No change	0.333

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Social networks	% children of primary school age (4-11) in the population	Scotland's census	2011	Census table QS103SC. Number of people aged '4-11 years' divided by the total population and multiplied by 100.	Data zone	Areas with higher proportions of primary school children are likely to have more social ties as the children know each other and the parents are more likely to know each other through participating in school-related activities.	Medium	New indicator	-0.333

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Social networks	Presence of voluntary organisations	Scottish Charity Register and Ordnance Survey postcode data	2014	The records of charities with a focus on a specific point, neighbourhood or community were extracted from the Scottish Charity Register. The number of charities registered per postcode was calculated by using Pivot Table. The resulting number of charities was joined spatially to the OS Code Point Data. The number of charities per intermediate geography unit was summed. Then it was divided by the number of data zones in the intermediate geography unit and this average number was assigned to the data zones within the intermediate geography unit.	Database of addresses (including postcodes) of charities joined to OS Code Point data (point data; location of the postcode centroids).	The areas with a higher number of charities (in particular location-specific charities) may have denser social networks and thus be more able to respond to and recover after flooding.	Medium	New indicator.	-0.333

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Social networks	% single pensioner households	Scotland's census	2011	Census table QS113SC. Number of households 'One person household: Aged 65 and over' divided by the total number of households and multiplied by 100.	Data zone	Areas with higher proportions of single pensioner householders are more likely to have socially isolated people and therefore higher social vulnerability compared to areas with lower proportions of single pensioner households.	Medium	No change	0.333
Access	People working far away from home	Scotland's census	2011	Census table LC7701SC. Number of people travelling to place of work or study '30km and over' divided by the total number of people and multiplied by 100.	Data zone	The higher the number of people travelling long distances to place of work or study, the more vulnerable the population	Medium	Amended: Percentage of people in the population working or studying further than 30km from home	0.500

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Access	Low road density	OS Mastermap Integrated Transport Network Layer	2014	Density of roads: Total length of roads in the data zone (km) divided by the area of data zone (km^2)	Polyline data (exact location of roads) intersected with the data zones.	People living in area with lower road density have lower general accessibility and therefore higher social vulnerability compared with communities with higher road density.	Medium	New indicator - the 2013 assessment did not include the general accessibility domain; this type of indicator was used in the 2013 disadvantage assessment for England.	-0.500
Crime	Domestic break-ins	Scottish Neighbourhood Statistics	2007/08	Number of domestic breakings per 10,000 total population. Data zones were assumed to have the same number of break-ins as the intermediate geography unit they are located within.	Intermediate geography	People living in areas with higher rates of crime may be more reluctant to take preventative measures in reaction to warnings of extreme events and therefore have higher social vulnerability compared with communities with lower crime rates.	Medium	Amended indicator. The first flood disadvantage assessment used the SIMD 2004 Crime Index, which is a compilation of recorded instances of variety of types of crime (crimes of violence, sexual offences, domestic housebreaking, vandalism, drugs offences and common assault); the current assessment focuses specifically on domestic breakings.	1.000

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Access to services	Travel time to GP surgery - private transport	Scottish Neighbourhood Statistics	2012	Average travel time (in minutes) to the nearest GP by private transport	Data zone	People's health (physical and mental) is likely to be affected by flooding and in the recovery stage those with an easy access to GPs may be able to recover more quickly.	Medium	New indicator - it was not used in the first flood disadvantage assessment. However, it was used in the climate disadvantage assessment for England in the context of vulnerability to high temperatures.	0.500
Access to services	Travel time to GP surgery - public transport	Scottish Neighbourhood Statistics	2012	Average travel time (in minutes) to the nearest GP by public transport	Data zone	People's health (physical and mental) is likely to be affected by flooding and in the recovery stage those with an easy access to GPs may be able to recover more quickly.	Medium	New indicator - it was not used in the 2013 assessment by Lindley and O'Neill. However, it was used in the climate disadvantage assessment for England in the context of vulnerability to high temperatures.	0.500

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Housing Characteristics	% households with the lowest floor level: ground floor	Scotland's census	2001	Census 2001 table KS19. Percentage of households: Lowest floor level Ground level (street level)	Data zone	The higher the proportion of ground level dwellings in an area, the more residents are likely to be affected by flooding compared to areas with two or more storey dwellings.	High	Data from census 2001. Indicator for 2011 not available - data not collected in census 2011	0.333
Housing Characteristics	% households with the lowest floor level: Basement or semi-basement	Scotland's census	2001	Census 2001 table KS19. Percentage of households: Lowest floor level Basement or semi-basement	Data zone	The higher the proportion of dwellings with basements in an area the more residents are likely to be affected by flooding, relative to areas with large proportions of other dwelling types.	High	Indicator for 2011 not available - data not collected in census 2011	0.333

Domain	Indicator	Source	Date	Indicator - processing details	Spatial unit of the raw data	Assumptions	Confidence level	Change from the first flood disadvantage assessment	Weighting
Housing characteristics	% Caravan or other mobile or temporary structures in all households	Scotland's census	2011	Census table KS401SC. 'All household spaces: Caravan or other mobile or temporary structure' divided by the total number of households and multiplied by 100.	Data zone	The higher the proportion of mobile or temporary structures among the households, the higher the vulnerability as they are likely to be affected by flooding to a greater extent.	High	New indicator	0.333
Physical environment	% urban	Land Cover Map 2007	2007	The polygons representing the 'urban' class of LCM2007 was extracted from the dataset and intersected with the data zones. The total area of the 'urban' land cover class per data zone was calculated, divided by the data zone area and multiplied by 100.	Polygon data: land cover classes with a minimum mapped unit of 0.5ha and a minimum feature width of 20m.	The land class classified as urban has little permeable surface and is prone to flooding	High	Amended indicator - the 2013 assessment used the SG urban-rural classification dataset. LCM2007 offers a more accurate picture of built-up areas.	1.000

Appendix 2: Selection of the indicators reflecting low income

The aim of this exercise was to select indicators representing different aspects of low income (associated with either being out of work or employed in low-income jobs, and also taking into account household composition). The indicators representing low-income communities were based on the 2013 flood disadvantage assessment (Lindley and O'Neill, 2013) and additional indicators were drawn from the literature and verified through consultations with stakeholders from local authorities and the Scottish Government.

The Scottish Index of Multiple Deprivation – Income, which was used originally in the assessment of social vulnerability to flooding (Lindley et al., 2011) and flood disadvantage assessment (Lindley and O'Neill, 2013) was disaggregated to provide more meaningful information rather than an abstract index. The initial list of indicators considered was as follows:

- i5 – percentage of people unemployed (from 2013 disadvantage assessment)
- i6 – percentage of all pensioner households (from 2013 disadvantage assessment)
- i7 – percentage of people in routine or semi-routine jobs, indicating low-income occupations (from 2013 disadvantage assessment)
- i8 – percentage of people in long-term unemployment or who have never worked (from 2013 disadvantage assessment)
- i9- percentage of households with no adults in employment and with children (from 2013 disadvantage assessment)
- i10 – Percentage of people income deprived (Scottish Index of Multiple Deprivation 2012 – Income; from 2013 disadvantage assessment)
- i10a – Number of people claiming Income Support (used to calculate SIMD 2012 Income)
- i10b – number of people claiming Job Seeker's Allowance (used to calculate SIMD 2012 Income)
- i10c – number of people claiming pension credits (used to calculate SIMD 2012 Income)
- i10d – number of families in work claiming Work Tax Credits or Child Tax Credits (used to calculate SIMD 2012 Income)

Spearman's rank correlation was calculated among these indicators for all data zones (6500) and the results are reported in Table A.1. The correlation results would suggest removing some indicators when:

- There is a very strong correlation between a pair of indicators, thus it can be assumed that they reflect the same phenomenon and that therefore one of them is redundant.
- There is a negative correlation between the indicator and the remaining ones, and thus it can be assumed that it does not reflect the phenomenon at all.

Based on the above, the correlations suggest removing indicator i10 (SIMD 2012 income index) because it is highly correlated with most of the indicators (this is not surprising for the indicators used to build the SIMD index, e.g. i10a and i10b).

It was decided to remove the more generic % of people unemployed (i5) indicator and retain the number of Job Seeker's Allowance claimants (i10b) and percentage of people long-term unemployed or who have never worked (to cover two different aspects of unemployment: short- and long term).

The indicator of percentage of all pensioner households (i6) is negatively correlated with all other indicators, which would suggest removing it too, since it does not reflect low income. This was also supported by existing literature that all pensioner households are not more income-deprived than other households[13]. The number of people in receipt of pension credits (i10c) seems to be a more valid indicator due to its strong, but not very strong correlation with other indicators.

Table A.1 Spearman's rank correlation among the income indicators (r – correlation coefficient; p – statistical significance). The number of data zones is 6500; very strong correlations (r >0.8) are highlighted.

Included in the final set?			i5	i6	i7	i8	i9	i10	i10a	i10b	i10c	i10d
No	i5	r	1.000	-.206**	.728**	.877**	.802**	.869**	.797**	.838**	.576**	.344**
		p	.	.000	.000	.000	.000	.000	.000	.000	.000	.000
No	i6	r		1.000	.005	-.165**	-.253**	-.088**	-.206**	-.289**	.258**	-.278**
		p		.	.677	.000	.000	.000	.000	.000	.000	.000
Yes	i7	r			1.000	.695**	.718**	.819**	.711**	.641**	.635**	.422**
		p			.	.000	.000	.000	.000	.000	.000	.000
Yes	i8	r				1.000	.791**	.884**	.850**	.818**	.630**	.295**
		p				.	.000	.000	.000	.000	.000	.000
Yes	i9	r					1.000	.823**	.782**	.740**	.489**	.408**
		p					.	.000	.000	.000	.000	.000
No	i10	r						1.000	.905**	.853**	.764**	.333**
		p						.	.000	.000	.000	.000
Yes	i10a	r							1.000	.876**	.712**	.439**
		p							.	.000	.000	.000
Yes	i10b	r								1.000	.639**	.446**
		p								.	.000	.000
Yes	i10c	r									1.000	.328**
		p									.	.000
Yes	i10d	r										1.000
		p										.

[13] Older people in low-income households, The Poverty Site http://www.poverty.org.uk/s64/index.shtml

The final set of indicators representing the income domain includes: i7, i8, i9, i10a, i10b, i10c, i10d (see the spreadsheet). There is still correlation between these, which can be expected due to concentrations of income deprivation associated with low income occupations or unemployment in certain areas, but only a couple of very strong correlations remain (i10b with i10a and i8), thus the overlap in data is minimal.

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The views expressed in this report are those of the researcher and do not necessarily represent those of the Scottish Government or Scottish Ministers.

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