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Glasgow's spatial arrangement of deprivation over time: methods to measure it, and meanings for health.

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Abstract

Background

Socio-economic deprivation is a key driver of population health. High levels of socio-economic deprivation have long been offered as the explanation for exceptionally high levels of mortality in Glasgow, Scotland. A number of recent studies have, however, suggested that this explanation is partial. Comparisons with Liverpool and Manchester suggest that mortality rates have been higher in Glasgow since the 1970s despite very similar levels of deprivation in these three cities. It has, therefore, been argued that there is an “excess” of mortality in Glasgow; that is, mortality rates are higher than would be expected given the city’s age, gender, and deprivation profile. A profusion of possible explanations for this excess has been proffered. One hypothesis is that the spatial *arrangement* of deprivation might be a contributing factor. Particular spatial configurations of deprivation have been associated with negative health impacts. It has been suggested that Glasgow experienced a distinct, and more harmful, development of spatial patterning of deprivation. Measuring the development of spatial arrangements of deprivation over time is technically challenging however. Therefore, this study brought together a number of techniques to compare the development of the spatial arrangement of deprivation in Glasgow, Liverpool and Manchester between 1971 and 2011. It then considered the plausibility of the spatial arrangement of deprivation as a contributing factor to Glasgow’s high levels of mortality.

Methods

A literature review was undertaken to inform understandings of relationships between the spatial arrangement of deprivation and health outcomes. A substantial element of this study involved developing a methodology to facilitate temporal and inter-city comparisons of the spatial arrangement of deprivation. Key

contributions of this study were the application of techniques to render and quantify whole-landscape perspectives on the development of spatial patterns of household deprivation, over time. This was achieved by using surface mapping techniques to map information relating to deprivation from the UK census, and then analysing these maps with spatial metrics.

Results

There is agreement in the literature that the spatial arrangement of deprivation can influence health outcomes, but mechanisms and expected impacts are not clear. The temporal development of Glasgow's spatial arrangement of deprivation exhibited both similarities and differences with Liverpool and Manchester. Glasgow often had a larger proportion of its landscape occupied with areas of deprivation, particularly in 1971 and 1981. Patch density and mean patch size (spatial metrics which provide an indication of fragmentation), however, were not found to have developed differently in Glasgow.

Conclusion

The spatial extent of deprivation developed differently in Glasgow relative to Liverpool and Manchester as the results indicated that deprivation was substantially more spatially prevalent in Glasgow, this was particularly pronounced in 1971 and 1981. This implies that exposure of more affluent and deprived people to each other has been greater in Glasgow. Given that proximal inequality has been related to poor health outcomes, it would appear plausible that this may have adversely affected Glasgow's mortality rates. If this is the case, however, it is unlikely that this will account for a substantial proportion of Glasgow's excess mortality. Further research into Glasgow's excess mortality is, therefore, required.

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Acknowledgements

Completing this thesis would not have been possible without the assistance and support of a number of people. It is a pleasure to be able to formally thank those who have played a role in this thesis coming to fruition. I was extremely fortunate to have three fantastic supervisors: Professor Rich Mitchell, Dr Mark Livingston, and Dr David Walsh. Their combined expertise has been incredibly useful, and I would particularly like to thank them for their guidance, support, and patience.

I have hugely benefited (both academically and socially) from being a part of a several academic units and would very much like to thank people (past and present) in the Institute of Health and Wellbeing (particularly folk in Public Health and HEHTA), the Department of Urban Studies, the Urban Big Data Centre, and the CRESH team. Specific thanks are due to Nigel Sprigings for sharing his wisdom on Manchester and spending a day showing me different parts of the city; Keith Kintrea for driving myself and some others round some of Glasgow's more deprived areas; and Phil Hanlon and Danny MacKay for their guidance and interest in my work every year during the annual review process.

I would also like to thank the Glasgow Centre for Population Health for funding this study.

Thanks goes to my family and friends for their unwavering love, support, and encouragement. The following are all more than worthy of a particular 'shout out': Iain McFadyen, Stuart White (who I am happy to say lost our bet and became a Professor before this thesis was submitted), Ross Loveridge, and the Jenkins families. A number of friends and family had babies during the course of this study. My final thanks, therefore, goes to those who were born during (or just before) this study. Thank you for providing welcome distractions, but mostly for never asking whether I had nearly finished my thesis!

Author's Declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

Signed:

Printed name: Joanna L. Stewart

Publications, Working Papers and Presentations

The following conference presentation was based on the preliminary findings of this PhD:

Stewart, J., Mitchell, R., Livingston, M. and Walsh, D. Does the development of Glasgow's socio-spatial structure explain its excess mortality? Geographic Information Systems Research UK (GISRUK) Conference, Glasgow, April 2014.

Abbreviations

ASCII - American Standard Code for Information Interchange

CHD – Coronary heart disease

CI - Confidence Interval

CHD - Coronary heart disease

COPD - Chronic obstructive pulmonary disease

CSV - Comma-separated values

GCPH – Glasgow Centre for Population Health

GIS – Geographic Information System

IHD - Ischaemic heart disease

IMD – English Indices of Deprivation

LSOA - Lower Super Output Areas

MAUP - Modifiable areal unit problem

MB - Meshblock

MPS - Mean patch size

SD - Standard deviation

SES – Socio-economic status

SIMD – Scottish Index of Multiple Deprivation

SMR – Standardised mortality ratio

UGCoP - Uncertain geographic context problem

WCS – West Central Scotland

Chapter 1 : Introduction

1.1 Thesis background

Scotland has the highest mortality rate and the lowest life expectancy in Western Europe (Walsh et al., 2010a, 2010b; McCartney et al., 2012). Within Scotland, the area with the poorest health is Glasgow (McCartney et al., 2012a) where life expectancy at birth is just 78.5 years for females and 73 years for males, compared to 80.9 years and 76.8 years respectively in Scotland (National Records of Scotland, 2015).

Socio-economic deprivation is a key driver of population health, with higher levels of deprivation known to be causally linked to higher rates of poor health and mortality (Marmot, 2010). Poor health in both Glasgow and Scotland have, therefore, long been attributed to their high levels of deprivation (Carstars and Morris, 1989). Recent studies, however, suggest this may only be a partial explanation (Hanlon et al., 2005, Walsh et al., 2010a, 2010b). The highest quality studies investigating Glasgow's poor health, compare the city with Liverpool and Manchester. These three cities have very similar levels of income and employment deprivation, and similar social and economic histories. Despite these similarities however, mortality rates are higher in Glasgow; premature mortality, for example, is 30% higher in Glasgow and all age mortality approximately 15% higher (Walsh et al., 2010a, 2010b). It has, therefore, been suggested that there is an 'excess' of mortality in Glasgow over and above that which would be expected for a city with its age, gender, and deprivation profile. This excess has been evident from the 1970s, and, whilst observed across the city, is most pronounced in Glasgow's more deprived neighbourhoods.

A profusion of hypotheses have been proffered to explain the excess mortality (McCartney et al., 2012a). One hypothesis, which inspired this thesis, is that the spatial *arrangement* of deprivation is implicated in Glasgow's relatively poor health record. Perhaps, it is argued, the spatial patterning of deprivation developed differently, or is different today in Glasgow to comparable areas, and this could have had negative effects on the health of its citizens.

1.2 Thesis aims and research questions

Inspired by this hypothesis, the study set out to ascertain whether Glasgow's spatial arrangement of deprivation developed differently between 1971 and 2011 to that observed in Liverpool and Manchester and, if it did, to consider the plausibility of this as a contributing factor to Glasgow's high levels of mortality. To meet this aim the thesis sought to answer three research questions:

Research question 1: What techniques best facilitate comparisons of the development of the spatial arrangement of deprivation?

Research question 2: Did the spatial arrangement of deprivation develop differently in Glasgow, Liverpool, and Manchester between 1971 and 2011?

Research question 3: If the spatial arrangement of deprivation did develop differently in Glasgow, could these differences be a plausible contributor to Glasgow's excess levels of mortality?

1.3 Thesis outline

The thesis has six chapters. Chapter 2 is a literature review which identifies the key concepts of 'poverty', 'deprivation', and 'health inequalities' before exploring the relationship between deprivation and health. This sets the context for a second literature review chapter (Chapter 3) which explores health outcomes observed in Scotland relative to England and Wales, the extent to which they are, or are not, explained by levels of deprivation and what other explanations there might be. Mechanisms by which the spatial arrangement of deprivation might influence health outcomes, and evidence for these, is then discussed. The case is made for a longitudinal study, at a landscape scale, comparing the spatial arrangement of deprivation in Glasgow with other cities, over time. It is argued that there was no established method for conducting this kind of study. A substantial element of the thesis is therefore given over to the development and testing of a novel method.

Two methods chapters (4 and 5) explore issues in mapping deprivation and detail the innovative ways in which temporally and spatially comparable maps of deprivation were produced. The novel use of surface mapping techniques to produce maps of deprivation from census data is detailed in Chapter 4, whilst Chapter 5 describes a further innovation: the use of spatial metrics to quantify the landscapes depicted in the maps, enabling objective comparison and analysis. Chapter 6 then presents and interprets the results, finding that some aspects of Glasgow's spatial arrangement of deprivation did develop differently to those observed in Liverpool and Manchester. Chapter 7 discusses the findings, evaluates the methods developed, answers the research questions, looks ahead to future research priorities and offers conclusions.

The thesis is the culmination of work I undertook at the Institute of Health and Wellbeing following the award of an advertised PhD studentship. The original studentship, focused on assessing health, was proposed by my three supervisors: Professor Rich Mitchell, Dr Mark Livingston, and Dr David Walsh, and funded by the Glasgow Centre for Population Health (GCPH). The project subsequently developed under my own direction, with my focus on methodological innovation coming to the fore.

Chapter 2 Literature Review Part 1: deprivation and health

2.1 Introduction

The purpose of this thesis is to establish whether Glasgow's spatial landscape of deprivation developed differently to that observed in Liverpool and Manchester, and, if it did, ascertain whether it is plausible that this could be a contributing factor to why worse health outcomes are witnessed in Glasgow. To facilitate an understanding of how the development of Glasgow's spatial arrangement of deprivation could negatively influence health outcomes, it is first necessary to discuss what is understood about the relationship between deprivation and health. In turn, to understand this relationship, it is necessary to outline what is meant by terms such as 'poverty', 'deprivation', and 'health inequality'. This chapter will outline these terms before moving on to explore the relationship between them.

2.2 Poverty and deprivation

This section introduces concepts of poverty from the literature, specifically regarding understandings of poverty and deprivation which are of importance in the context of this study.

2.2.1 A brief history of UK poverty research

Research on British poverty dates back to the work of Charles Booth in the 1880s and 1890s, and Seebohm Rowntree in the 1890s (Alcock, 2006, 2008, Lister, 2004). Booth carried out a large survey of social, economic, and working conditions in inner London; the results of which were published between 1889 and 1903 in a seventeen volume work entitled 'Life and Labour of the People of London' (Orford et al., 2002). This is credited as being the first scientific social survey and for strongly influencing social surveys which followed (Bales, 1996).

From this work Booth ascertained that 30% of London's population were poor (Alcock, 2006). Inspired by Booth (although using different methods), Rowntree researched poverty in the city of York. Surveying more than 11,000 people, Rowntree's 1901 study revealed that 28% of York's population lived in poverty (Alcock, 2006). Both Booth and Rowntree[1] have had a very strong influence on the study of poverty, particularly with regards to developing measures and understandings of poverty (Lister, 2004, Alcock, 2006).

The understandings of poverty used by early poverty researchers, such as Booth and Rowntree, have traditionally been described as being 'absolute' (Lister, 2004). Absolute poverty is based on the notion of subsistence. Absolute understandings of poverty adopted by early poverty researchers were based on the notion of only having enough resources to have a "*basic standard of physical capacity necessary for production (paid work) and reproduction*" (Lister, 2004:21) – termed 'physiological efficiency' by Rowntree. Absolute poverty, therefore, views primary human needs as being of a purely physical nature (for example food, water, and shelter).

Using this absolute understanding of poverty, Rowntree's 1901 work pioneered the development of a poverty threshold. He estimated the cost of a nutritionally adequate diet and the cost of clothing and rent, and those with an income lower than this were defined as being in primary poverty (Ruggeri Laderchi et al., 2003). A second category – secondary poverty – was used by Rowntree to describe people who were above the poverty line but observed to be living in "*obvious want and squalor*" (Ruggeri Laderchi et al., 2003:248). Booth also recognised that there were different levels of poverty as he categorised households into seven[2] social classes, shown in Table 2-1, of which the top four were viewed as poor.

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[1] Rowntree's work also included two further studies on York in the 1930s and 1950s.

[2] Booth added an eighth category in the first volume of his final edition, however because he only mapped seven categories (and this study is interested in mapping) his seven will be referred to here.

1. Lowest class, vicious semi-criminal.	Poor
2. Very poor, casual labour, chronic want.	
3. Poor 18-21 shillings a week for a moderate family.	
4. Mixed, some comfortable, others poor.	
5. Fairly comfortable, good ordinary earnings.	Not poor
6. Well to do, middle class.	
7. Wealthy, upper middle and upper classes.	

Table 2-1 Booth's seven social classes (adapted from Orford et al., 2002:27)

This absolute/subsistence concept of poverty was used by poverty researchers throughout the first half of the 20th century. Indeed, it was this understanding of poverty which was adopted by Beveridge in his landmark 1942 report which lay the foundations of the British welfare state. With regard to setting new benefit rates, for example, Beveridge stated:

> “*In considering the minimum income needed by persons of working age for subsistence during interruptions of earnings, it is sufficient to take into account food, clothing, fuel, light and household sundries and rent, though some margins must be allowed for inefficiency in spending.*” (Beveridge, 1942 cited in Gordon and Pantazis (1997:10).

Absolute understandings of poverty continue to be used today in some circumstances. However, beginning in the 1960s with the work of Townsend, poverty researchers have developed alternative understandings of measures of poverty focussed on relative comparisons. This concept of relative poverty is “*based on the idea that the nature of poverty will be different in different social circumstances and therefore will change as society itself changes*” (Alcock, 2008:39). Relative poverty, therefore, takes into account what it is usual for people in a particular society to have access to; those who do not have access to those things are viewed as poor. Understandings of relative poverty were pioneered by Townsend (Howard et al., 2001, Lister, 2004, Gordon, 2006) whose oft-quoted and seminal definition of (relative) poverty is:

> "*Individuals, families and groups in the population can be said to be in poverty when they lack the resources to obtain the types of diet, participate in the activities and have the living conditions and amenities which are customary, or at least widely encouraged or approved, in the societies to which they belong.*" (Townsend, 1979:31).

So, whereas absolute conceptualisations of poverty view human needs as being purely physical, relative conceptualisations of poverty view human needs to be both physical and social. There has been considerable debate regarding differences between absolute and relative understandings and measures of poverty (see Lister (2004) for example), some of which has been politically motivated[3]. Of importance here, however, is that the current predominant conceptualisation of poverty in UK research is a relative one.

2.2.2 Relative deprivation

Deprivation can be a consequence of people/households/areas experiencing poverty. This distinction between poverty and deprivation is succinctly described in Gordon's (2006:32) statement that "*(p)overty is the lack of resources and deprivation is the consequence of poverty.*" Relative deprivation is, therefore, a consequence of relative poverty and occurs when people:

> "*cannot obtain, at all or sufficiently, the condition of life – that is, the diets, amenities, standards and services – which allow them to play the roles, participate in the relationships and follow the customary behaviour which is expected of them by virtue of their membership of society*" (Townsend, 1993:36).

This understanding of deprivation has been widely adopted in the UK (Carstairs and Morris, 1989, Gordon and Pantazia, 1997, Ridge and Wright, 2008, Vaucher

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[3] Definitions and discourses of poverty tend to be constructed by more powerful groups in society and often have political implications. Defining poverty is thus viewed a political act as well as being a scientific measure (Lister, 2004, Ridge and Wright, 2008).

et al., 2012). Townsend's definition of relative deprivation is particularly pertinent to the Scottish context. Following a project commissioned by the Scottish Executive[4] to produce a long-term strategy for measuring deprivation in Scotland, Bailey et al. (2003) recommended that Townsend's understanding of deprivation should be adopted and built upon for measuring deprivation in Scotland. Their report was influential in the development of the Scottish Index of Multiple Deprivation 2004 (SIMD) (Scottish Executive Office of the Chief Statistician, 2004). As will be discussed in the methods chapter, the SIMD has become the predominant measure of deprivation in Scotland. In their recommendation Bailey et al. (2003) argue that there are four elements to Townsend's definition:

1. Deprivation is multi-dimensional because there are different ways in which people can be deprived, for example "*by virtue of their lack of basic necessities of diet or clothing, or by virtue of the poor environment or social conditions in which they live*" (Bailey et al., 2003:3). It is therefore related to the concept of multiple deprivation and consequently requires measurement across multiple domains.

2. Related to the first point that deprivation is multi-dimensional, Townsend's definition of deprivation is concerned with social dimensions as well as material dimensions. If, as a consequence of poverty, people are unable to participate in what are normal societal activities they are deprived. (In the UK, such activities would include visiting friends and family, attending funerals, for example).

3. Townsend's definition of deprivation is relative as it is based on norms which are socially accepted in one society at a particular time point. What constitutes being deprived therefore differs between societies and across time.

4. Townsend's focus is on individuals, not areas. That is, it is people who experience deprivation, not areas, and just because someone moves into

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[4] The Scottish Executive was rebranded The Scottish Government in 2007 and formally renamed as such in 2012 under the Scotland Act 2012.

an area with high a concentration of deprivation does not mean that they will become deprived.

2.2.3 Individual deprivation and area deprivation

Bailey et al.’s (2003) fourth point highlights an important distinction made in the literature between personal/household deprivation and neighbourhood deprivation. As discussed above, personal/household deprivation relates to whether or not individuals/households lack resources which are common to the majority of a particular society. Neighbourhood deprivation relates to whether or not an area, and the population within the area, lack resources and economic opportunities relative to other areas. However, area deprivation measures and studies often also focus on other characteristics, such as crime rates and educational attainment. There is a strong consensus that studying and measuring both individual and area deprivation are important and of relevance (Bailey et al., 2003). Indeed, residence in a deprived area is often used as a proxy for individual measures of deprivation, where individual measures are otherwise not readily available.

An important part of this thesis was the development of methods to measure and then map individual/household deprivation. As such, approaches to deprivation measurement will be discussed in more detail in the methods section rather than in this chapter. It is sufficient to say here that, partly driven by data availability, individual and household indicators of deprivation were utilised in this study to identify spaces which were likely to have a larger number of deprived individuals relative to other parts of the city.

2.2.4 Mapping poverty and deprivation

An innovative feature of early poverty research of particular relevance to this study was the use of maps to demonstrate the spatial location and distribution of absolute poverty. Booth plotted his seven classifications of households (Table 2-1) on street maps to show the social geography of London. These maps enabled areas with poor households to be identified, and also demonstrated how extensive poverty was in the city. Rowntree's 1901 study of York included a map of the city shaded by population characteristics; from this, he identified the two poorest areas (Dorling et al., 2007). By mapping poverty, Booth and Rowntree provided a historical record of the spatial manifestation of poverty in London and York in the late 19th century. Their maps represent the origins of the 'cartography of poverty' in Britain (Dorling and Pritchard, 2010)

Producing and analysing maps of poverty remains highly relevant for many reasons including that they enable the spatial extent of poverty to be illustrated and that they act politically, to draw attention to the issue (as was done by Booth and Rowntree). By identifying areas where poverty is particularly prolific, maps of poverty can also be used as a tool for resource allocation. Furthermore, maps of poverty facilitate comparisons of the spatial extent of poverty temporally and between places- something which is done in this thesis.

A crucial feature of maps of poverty is that they demonstrate poverty is not randomly distributed across urban areas; it is spatially arranged. Based on Marxist ideas, geographers and economists often regard areas of poverty to be *"a structural property of capitalism"* (McCormick and Philo, 1995). McCormick and Philo (1995:8) argue that capitalism requires a geography of poverty. Capitalism is compelled:

> "*to generate spatial concentrations of capital and resources ('rich places') set apart from areas where capital and resources are more thinly spread or even non-existent ('poor places').*"

By extension, this study explores whether such spatial structures have implications for health, and whether they developed differently in three specific cities.

As with measuring deprivation, mapping deprivation formed a (substantial) part of the methodology used in this study. Different approaches to mapping deprivation will, therefore, also be discussed in the methods section.

2.2.5 Section Summary

This section has introduced understandings of poverty and deprivation, both in absolute and relative terms, and relating to individuals and areas, and in doing so explained that this study is interested in mapping the spatial arrangement of relative deprivation at the individual/household level. The next section discusses health and inequalities in health, with specific emphasis on exploring evidence for, and understandings of, the relationships between deprivation and health.

2.3 Inequalities in health and the determinants of health

Understanding why the spatial arrangement of relative deprivation could influence health outcomes requires an understanding of what influences health and how it becomes unequally distributed. This section discusses these issues and, in doing so, sets the context for the discussion in the next chapter regarding both health inequalities in Glasgow, and themes regarding how the spatial arrangement of deprivation might influence health outcomes.

2.3.1 Inequalities in health

The constitution of the World Health Organization (2006:1) states that:

> "*(t)he enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social conditions.*".

Unfortunately, for many this human right is breached. Health outcomes differ between places and population groups. Such variations in health outcomes are referred to as *health inequalities* and *health inequities*. Although both terms refer to differences in health outcomes, there are subtle differences between them. A useful definition of health inequality is provided by Kawachi et al. (2002:647) who states:

> *"(h)ealth inequality is the generic term used to designate differences, variations, and disparities in the health achievements of individuals and groups."*

Whilst health inequities also refer to differences in health outcomes between individuals and population groups, the usage of this term has moral overtones. Health inequity, as Kawachi et al. (2002:647) explains,

> "*refers to those inequalities in health that are deemed to be unfair or stemming from some form of injustice*".

Whilst the author's personal opinion is that most differences in health outcome are unfair, to avoid overcomplicating this study, and/or inadvertently making moral judgements about which differences are unjust, the term health inequality will be used throughout this study.

Health inequalities exist both between places and between population groups, for example between socio-economic groups, ethnic groups, and between men and women. All types of healthy inequality are important and worthy of study. As this study is focused on comparing the development of spatial patterns of deprivation in Glasgow with Liverpool and Manchester, it is the literature on spatial and socio-economic health inequalities and the interactions between them –socio-spatial health inequalities- which is most pertinent to this study and which is discussed in this review.

Spatial health inequalities are well established at a variety of scales and authors such as Marmot (2005:1099) highlight the presence of "*gross inequalities in health between countries*" as well as within countries. Whilst the mean life expectancy of the global population was 70 years for males and females combined in 2012, this ranged from as low as 46 years in Sierra Leone[5] to 84 years in Japan (World Health Organization, 2014) (Figure 2-1). The figure for the UK was 81 years.

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[5] Note that this was prior to recent outbreak of the Ebola virus

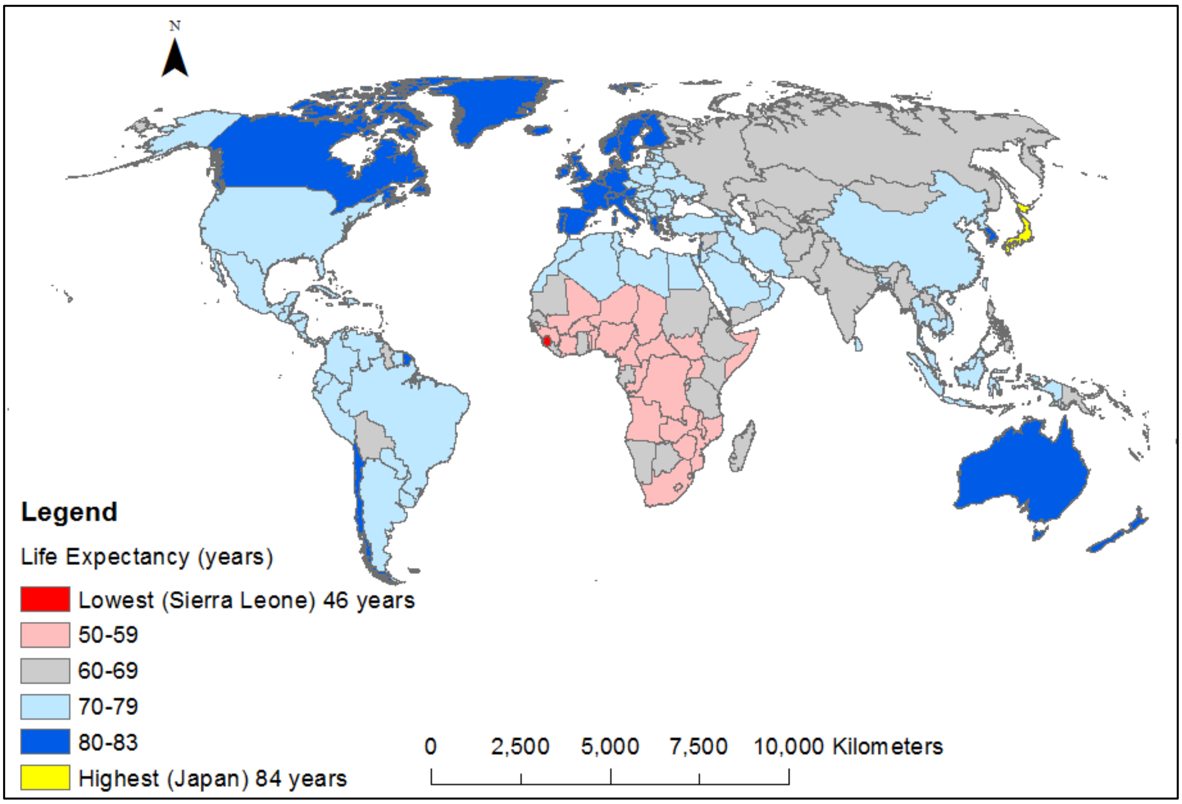

Figure 2-1 2012 National Life Expectancy (combined for males and females). (Source: boundary data from ESRI, life expectancy data from World Health Organization, 2014).

Spatial health inequalities occur within countries as well as between them. Spatial variations in 2012 male life expectancy at birth in Great Britain are shown in Figure 2-2. Whilst the range of life expectancy is much lower than at the global level, there are still substantial differences, ranging from 72.6 years in Glasgow City to 82.9 Hart (in Hampshire) and East Dorset (National Records for Scotland, 2014, Office for National Statistics, 2014). The general trend (visible in Figure 2-2) is for southern England to have higher male life expectancy at birth than the rest of Great Britain. It is well established that Scotland and the north of England have worse health outcomes than the south of England. The Black Report of 1980 (discussed in further detail in a later section), for example, drew attention to southern Britain having better health (when measured by standardised mortality ratios) than other regions in the early 1970s, and Shaw et al. (1998) argue that this has been the established trend for over a century.

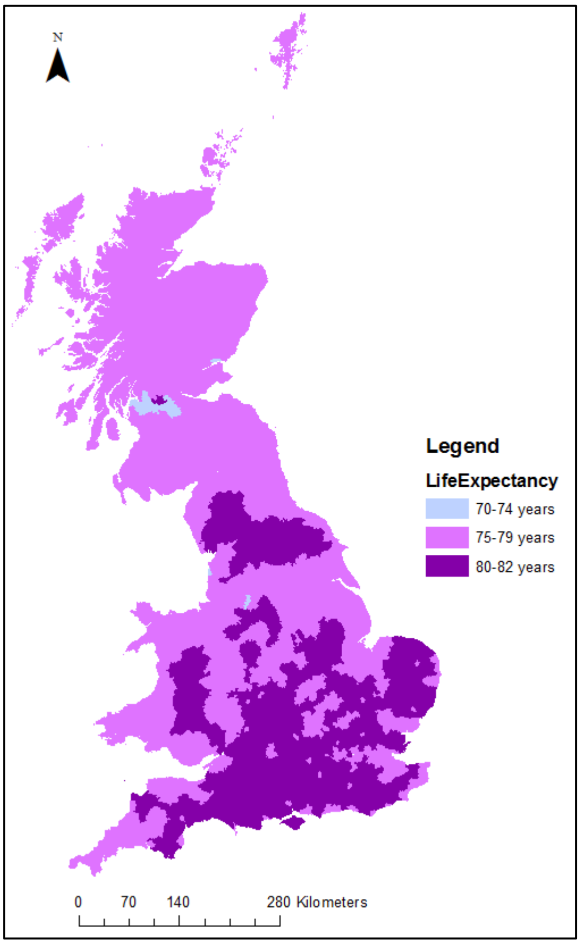

Figure 2-2 Choropleth map showing male life expectancy at birth in the UK in 2012 (by local authority area in Scotland and Unitary Authority in England and Wales. (Source: data for England and Wales from Office for National Statistics (2014) (Contains National Statistics data © Crown copyright and database right 2012). Data for Scotland National Records for Scotland (2014) Boundary data contains Ordnance Survey data © Crown copyright and database right 2012.)

2.3.2 Socio-economic health inequalities

Having introduced the concept of spatial inequalities in health, the discussion will now move to discuss socio-economic inequalities in health. There is a long history of evidence demonstrating strong associations between socio-economic position and health dating back as far as ancient Greece (Krieger et al., 1997). The term 'socio-economic health inequalities' refers to there being a social gradient in health whereby better health outcomes are observed in wealthier populations than in less affluent populations. Socio-economic health inequalities occur at a range of scales and are often interconnected with (and sometimes explain) spatial health inequalities. As is implied by Figure 2-1, the trend is for wealthier countries to have better health than less affluent countries. At the intra-national level, a social gradient in health is observed in many wealthy and less wealthy countries. It is important to stress that socio-economic health inequalities are not just evident between those in lowest and highest socio-economic groups, rather there is a social gradient in health. As Bartley (2004:79) states:

> *"in country after country, study after study, what we see is not a group of very poor people at the bottom of the income distribution who have poor health while everyone else is fine. Instead, what we see is a steady gradation from the very top to the very bottom."*

In Britain, concern regarding socio-economic health inequalities dates back as far as Chadwick's 1842 report 'The Sanitary Condition of the Labouring Population'. In this Chadwick identified a social gradient in average life expectancy of family members across three social groups (gentry and professionals, farmers and tradesmen, and labourers and artisans). In Liverpool, for example, the average age of death was 15 for labourers, mechanics and servants, compared to 22 for tradesmen, and 35 years for gentry and professionals (Macintyre, 1997). Whilst there have been vast improvements in health since the 19th century, socio-economic health inequalities remain. As Graham (2009a:1) writes:

> *"The opportunity to live a long and healthy life remains profoundly unequal. In both childhood and adulthood, social disadvantage is associated with a higher risk of disease, disability and premature death."*

Over the past 40 years a wealth of research into socio-economic health inequalities has been produced (Smith and Eltanani, 2015). This research has been presented in both government commissioned reports, independent reports, studies published in peer reviewed journals, and books (and other sources) and provides evidence of socio-economic health inequalities occurring at both the individual level and the area level.

At the individual level, studies have demonstrated inequalities in health outcomes whereby individuals with lower socio-economic status have worse health outcomes than those of higher socio-economic status. Often cited examples of such studies include two government commissioned reports: the

Black Report (Black et al., 1980) published in 1980, and the Acheson Report (Acheson, 1998) published 18 years later in 1998. Using occupational class as an indicator of social class, both the Black Report and the Acheson Report demonstrated a relationship between occupational class and health outcomes.

As well as demonstrating a relationship between occupational class and health, the Black Report found a similar result using other indicators of social class – such as home ownership. Males who owned their own homes, for example, were found to have lower mortality rates than those who privately rented, who, in turn, had lower mortality rates than those who rented from local authorities (Black et al., 1980). Differences in health were shown to be apparent throughout the life-span but were most marked in childhood.

Both the Black Report and the Acheson Report found that socio-economic health inequalities had been increasing since the 1950s. The Black Report showed that whilst the mortality rates of those in the wealthier classes had steadily fallen between the 1950s and 1970s, it had remained relatively stagnant or had even increased in the poorer classes. The Acheson Report identified that socio-economic health inequalities continued to increase between the early 1970s and the early 1990s due to greater improvements in health outcome amongst wealthier classes than in poorer classes. Rates for working-age male mortality, for example, between the early 1970s and early 1990s:

> *"fell by about 40 per cent for classes I and II, about 30 per cent for classes IIIN, IIIM and IV, but only 10 per cent for class V[6]"* (Acheson, 1998:13).

The Marmot Review (Marmot, 2010) was a government commissioned review tasked with examining evidence on health inequalities in England and developing a health inequalities strategy. Whereas the Black Report and the Acheson Report provided strong evidence linking the socio-economic status of individuals and poor health outcomes, the Marmot Review (Marmot, 2010) furthered this by also providing evidence of socio-economic inequalities at the area level. Figure 2-3, for example, is taken from the Marmot Review and shows the existence of a

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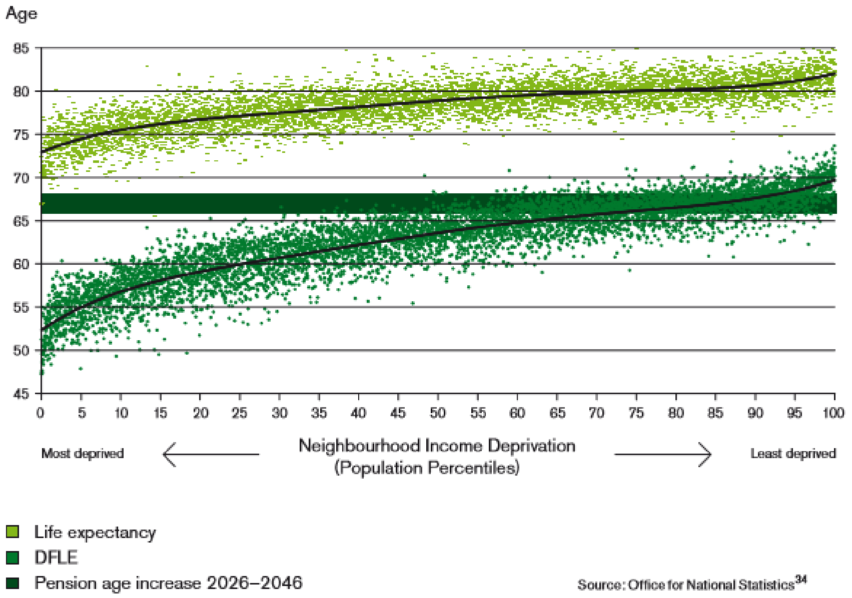
[6] Class I = Professional, Class II = Managerial & Technical/Intermediate, IIIN = Non-manual Skilled, IIIM = Manual Skilled, IV Partly Skilled, V = Unskilled (Acheson, 1998).

social gradient in life expectancy and disability free life expectancy in England between neighbourhoods based on income deprivation. The top curve shows that:

> *"people living in the poorest neighbourhoods, will, on average die seven years earlier than people living in the richest neighbourhoods"* (Marmot et al, 2010:16).

Furthermore, the bottom curve shows that disability free life expectancy is, on average, 17 years lower for those living in the poorest neighbourhoods than those living in the wealthiest. Marmot et al. (2010:16) are keen to stress that, for both life expectancy and disability-free life expectancy, there is a *gradient* and not just differences between the very poorest and very wealthiest neighbourhoods:

> *"even excluding the poorest five per cent and the richest five per cent the gap in life expectancy between low income and high income neighbourhoods is six years, and in disability-free life expectancy 13 years."*



Source: Office for National Statistics[34]

Figure 2-3 Life expectancy and disability-free life expectancy (DFLE) at birth, persons by neighbourhood income level, England, 1999-2003 (Source Marmot et al., 2010:38)

The mechanisms which produce health inequalities are multiple and complex, and the literature reflects this. The Black Report (Black et al., 1980) stated that explanations for health inequalities could be divided into four categories: artefactual explanations, theories of natural and social selection, materialistic or structuralist explanations, and cultural/behavioural explanations. In a review of her work and that of others, Bambra (2011) adds two further theoretical categories: psycho-social and life course. These six theories are summarised in Figure 2-4. Regardless of the complex nature of heath inequalities, a common thread running through most theories is that inequalities in health are principally driven by inequalities in the main determinants of health. An appreciation of the determinants of health is therefore required when examining health inequalities; these will be discussed in the next section.

Artefact

Socio-economic health inequalities do not really exist but are a consequence of inadequate measurement of socio-economic status (such as the use of occupational or social class) and or health (Black et al., 1980, Whitehead, 1987, Bambra et al., 2011).

Health selection (termed natural and social selection by Black et al. (1980).
Socio-economic status is determined by health as opposed to socio-economic status influencing health (Black et al., 1980, Whitehead, 1987, Bambra et al., 2011).

(Neo) Materialistic

Socio-economic health inequalities are driven by economic and structural factors. This approach gives "*primacy to structure in their explanation of health and health inequalities, looking beyond individual-level factors (agency), in favour of the role of public policy and services such as schools, transport and welfare*" (Bambra, 2011:742).

Cultural/behavioural

Cultural differences between socio-economic groups lead to differences in health related behaviours – resulting in socio-economic health inequalities. Difference in health behaviours are themselves viewed "*as a consequence of disadvantage, and unhealthy behaviours may be more culturally acceptable among lower socioeconomic class[es]*" (Bambra, 2011:742).

Psycho-social

The presence of inequality leads to stress and feelings of inferiority amongst those who are more economically disadvantaged. This stress has health consequences which drive socio-economic health inequality.

Life course

This is a combination of aspects of some of the above approaches and views health inequalities as the "*result of inequalities in the accumulation of social, psychological and biological advantages and disadvantages over time.*" (Bambra, 2011:742)

Figure 2-4 Theories explaining health inequalities

2.3.3 What influences health?

Although debate regarding health determinants continues, an understanding has emerged that a multitude of often interwoven factors influence health from prior to conception until death. It is well recognised that an individual’s health can be influenced by wider social, environmental, and economic factors; such factors are commonly known as the social determinants of health. It is beyond the scope of this review to provide an in depth analysis of the vast literature on models of health and the social determinants of health. However, a brief outline of socio-ecological understanding of health, which is the predominant framework of public health thinking today, is important for understanding socio-economic health inequalities and their relationship to geographical space.

2.3.3.1 Socio-ecological models of health

Models of health are conceptual frameworks which provide a way of thinking about health. Numerous socio-ecological models of health have been proposed. Examples (in chronological order) include Morris’s (1975) socioecological model of health, Bronfenbrenner’s (1979) ecological model of human development, Hancock and Perkin’s (1985) mandala of health, Evans and Stoddart’s (1990) conceptual framework for patterns of determinants of health, and Dahlgren and Whitehead’s (1991) model of the main determinants of health. All of these reflect the role of wider social and environmental influences on health, and the many links between them. Whilst there are some small differences between the various socio-ecological models of health, they are all a variation on a theme and show that health results from complex linkages between multiple influences, at multiple levels. The example given here is Dalhgren and Whitehead’s (1991) model of the main determinants of health, shown in Figure 2-5. This is one of the most cited models and has been referred to as being iconic; it has also informed both academic and policy understandings of health (Graham, 2009b).

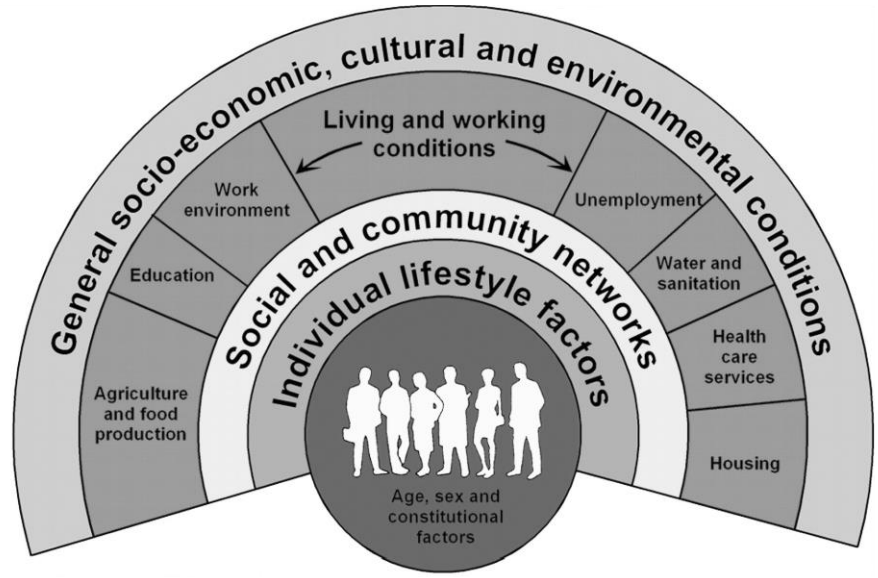


Figure 2-5 Dahlgren and Whitehead's (1991) model of the determinants of health

Dahlgren and Whitehead's hierarchical 'rainbow' model of health provides a visual representation of the various layers of influence on an individual's health. The individual is at the centre of the model and the main determinants of health are represented as a set of concentric rings around the individual. More proximal to the individual are influences on health such as age, sex, hereditary factors, and individual lifestyle factors; these, in turn, are influenced by social and community networks, and then by broader living and working conditions (which include health care services), which themselves are influenced by macro socio-economic, cultural, and environmental factors. The model therefore:

> "*makes clear that these factors are social in origin: overarching societal factors operate through people's living and working conditions to influence health both directly and through health behaviour*" (Graham, 2009b:468).

The model also indicates that there are some factors which individuals have no control over (for example age and genetics), and some control over (for example lifestyle and employment), but that all of these are influenced by, and exist within, the macro socio-economic, cultural and environmental context. Inequalities in these contexts are therefore likely to directly contribute to inequalities in health.

A feature of most socio-ecological models of the determinants of health is that many of the determinants have a spatial aspect. Where people live, work, socialise, and learn, for example, is explicitly spatial; people's health is thus influenced by where they are (and have been) situated. Space, place, the social, physical and built environments all have, therefore, an important influence on health outcomes and contribute to health inequalities.

2.3.3.2 Context and composition

Health is thus influenced by both environmental and individual characteristics which may, respectively, be more or less influenced by spatial location. Some of what influences health is, therefore, aspatial and some spatial. When assessing what affects the apparent variation in health from area to area, it is helpful to divide the influences into those which primarily reflect the influence of individual characteristics (the 'composition' of an area's population), and those which primarily reflect the influence of social, economic or physical environmental characteristics (the so-called contextual). A helpful visualisation of the distinction between context and composition is provided by Shaw et al. (2001) and shown in Figure 2-6.

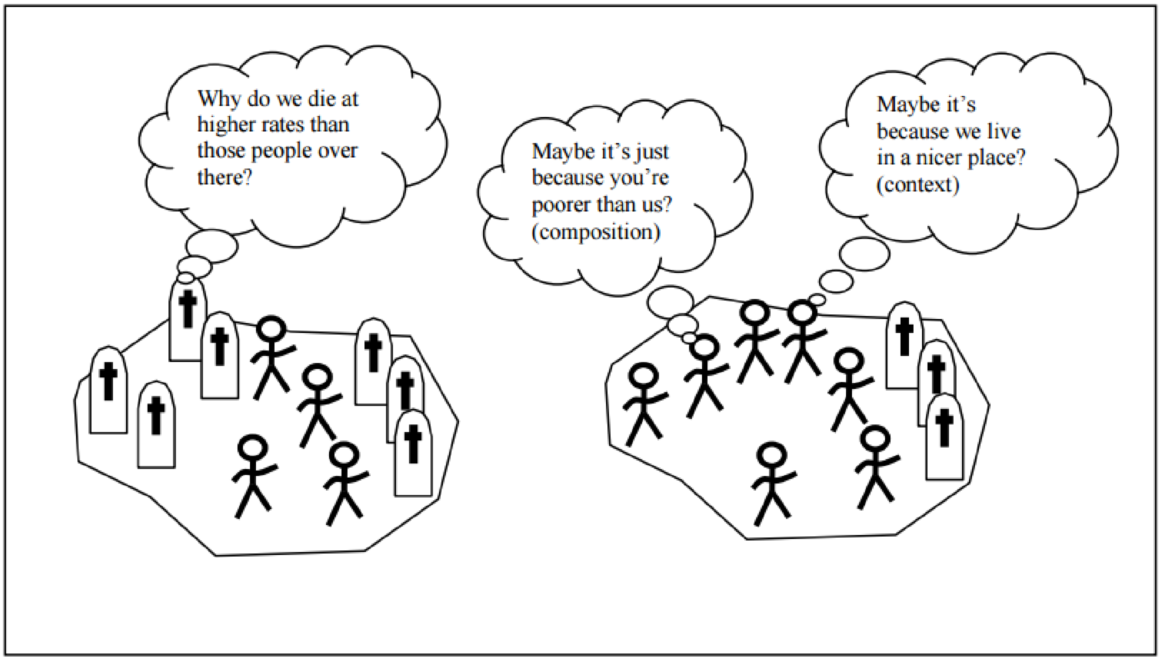


Figure 2-6 Composition or context? (Taken from Shaw et al., 2001:127)

In Shaw et al.'s (2001) visualisation (Figure 2-6), context and composition appear to be competing explanations for spatial health inequalities. However, as Shaw et al. (2001:128) explain, context and composition are not mutually exclusive concepts, rather:

> "*the question is one of balance. How much of the health differences between different groups or different areas is accounted for by population composition or by the context in which those people live.*"

A further complexity relates to the difficulties involved in distinguishing contextual and compositional characteristics. The reality is that they are often interconnected (Macintyre et al., 2002). The employment rate, for example, among residents within an area reflects both their individual characteristics *and* the local labour market and economy; employment is simultaneously an individual and area characteristic.

In developing understandings of context and composition, Cummins et al. (2007:1835) argue that research into health and place has been hindered by a "*false dualism of context and composition*", and that doing so has potentially underestimated the contribution of place to health. Furthermore, they argue that studies on place and health have tended to be grounded in conventional euclidean understandings of place. Such understandings view places as "*single, integrated, unitary, material objects*" (Graham and Healey, 1999:624). Cummins et al. (2007) advocate that instead of using this traditional understanding of place, studies on place and health should instead adopt what they term 'relational' understandings of place. Relational understandings recognise that place, and its meaning, are flexible concepts that operate at a multitude of scales. Examples of differences between traditional and relational views of place are shown below in Table 2-2, reproduced from Cummins et al. (2007:1826). This relational understanding better captures the complexity of place, as well as the complexity of interactions between place and health. By doing so it advocates that context and composition should not necessarily be considered separately. Whilst this relational understanding of place is useful in broadening understandings of how people interact, understand, and are impacted by place, what is less clear is how to actually model the relational view of place in empirical research, and apply this to understandings of health and health inequality.

‘Conventional’ view	**‘Relational’ view**
Spaces with geographical boundaries drawn at a specific scale.	Nodes in networks, multi-scale
Separated by physical distance.	Separated by socio-relational distance.
Resident local communities.	Populations of individuals who are mobile daily and over their life course.
Services described in terms of fixed locations often providing for territorial jurisdictions, distance decay models describe varying utility in space	‘Layers’ of assets available to populations via varying paths in time and space. Euclidian distance may not be relevant to utility
Area definitions relatively static and fixed	Area definitions relatively dynamic and fluid
Characteristics at fixed time points, e.g. ‘deprived’ verses ‘affluent’	Dynamic characteristics e.g. ‘declining’ verses ‘advancing’
Contextual features described systematically and consistently by different individuals and groups	Contextual features described variably by different individuals and groups

Table 2-2 'Conventional' and 'relational' understandings of 'place' (Cummins et al., 2007:1826)

The purpose of this study is not to ascertain whether context is more influential than composition, or vice versa; consequently, an in depth discussion of literature exploring these issues is not required here. Rather, the point to be made is that both composition and context contribute to the manifestation of spatial health inequalities, and that often context and composition are interrelated. This is an important point with regard to this study of the spatial arrangement of deprivation: *spatial arrangement* may be a contextual influence on health; *deprivation* is partly compositional.

2.3.4 Temporal relationships between area deprivation and mortality

Having argued that spatial and socio-economic health inequalities exist and are influenced by a wide range of contextual and compositional factors, it is important to add a further variable: time. Comparisons of the spatial arrangement of deprivation in Britain in the late 19th and early 20th century have shown that historical patterns of deprivation can be related to contemporary mortality patterns (Dorling et al., 2000, Gregory, 2009). Dorling et al.'s (2000) study of London included the use of a geographical information system (GIS) and information from Booth's poverty survey of inner London (discussed in 2.2.1) and the 1991 census to calculate a ward index of poverty for each time period. From this, they found that the distribution of poverty in inner London was relatively similar in 1896 and 1991. Despite there being some changes Dorling et al. (2000:1549) state that "*(o)n the whole, though, affluent places have remained affluent and poor places have remained relatively poor*".

From an analysis of standardised mortality ratios for deaths which occurred between 1991 and 1995, Dorling et al. (2000) demonstrated that all-cause mortality over the age of 65, and mortality from stomach cancer, lung cancer, and strokes were more strongly predicted by the geography of poverty in 1896 than that of 1991. However, all other causes of mortality were more strongly predicted by the 1991 geography of poverty.

Gregory's (2009) study of England and Wales found that areas in 1900 with the highest deprivation scores continued to have high standardised mortality ratios in 2001. Furthermore, he found a significant correlation between standardised mortality ratios from the early 1900s and mortality in the early 2000s, even after adjusting for modern deprivation. From this, Gregory (2009:6) concluded that:

> "*(p)atterns of mortality and deprivation are deeply entrenched such that in both cases the patterns of a century ago are strong predictors of*

> *today's patterns. This is not simply because of inertia in socioeconomic conditions*".

Dorling et al. (2000) and Gregory (2009) both, therefore, demonstrate that the historical geography of poverty can influence contemporary mortality. Indeed, Dorling and Pritchard (2010:90) goes as far as to assert that "*areas inherit disadvantage more than do people*". Given that it was argued earlier that poverty is not randomly distributed, but rather a consequence of capitalism, it is probable that this consistent spatial patterning of poverty is also a feature of capitalism. The processes rendering poor areas poor, are relatively stable. This means that poor areas can remain poor over long periods of time. When studying the spatial arrangement of deprivation, it is therefore important that the history of the area under study is considered and that, as well as examining the contemporary geography of poverty, other time points are also considered.

2.3.5 Section Summary

This section has shown that health inequalities exist spatially and between population groups – and in particular that there is a social gradient in health. An individual's health can be influenced by social, environmental, and economic factors. Health variations between areas are influenced by both contextual and compositional factors, and interactions between these factors.

2.4 Chapter summary

This chapter has introduced understandings of absolute and relative poverty and deprivation and highlighted that poverty can be measured at both the level of the individual and at the area level. Health inequalities have also been shown to exist between population groups and between the places. The health of an individual is influenced by social, environmental, and economic factors. Health variations between areas can be due to both contextual and compositional factors - and an interplay of the two. This chapter sets the context for the next chapter, which examines health inequalities in Glasgow and explores explanations for how the spatial arrangement of deprivation might influence health.

Chapter 3 Literature Review (part 2): Glasgow's excess mortality

3.1 Introduction

This chapter builds upon the work of the previous chapter by exploring health outcomes in Scotland and Glasgow. It will be shown that Scotland has poor health outcomes relative to England and Wales. Deprivation was traditionally blamed for this situation; however, evidence that deprivation is now only accountable for some of this difference will be discussed. This will be followed by a section on health outcomes in Glasgow – where it will be shown that there is also an excess of mortality not attributable to deprivation. The focus will then move on to explore a hypothesis which has been put forward suggesting that the spatial arrangement of deprivation in Glasgow could be a contributing factor to this excess mortality. Causal mechanisms for how the spatial arrangement of deprivation might influence health outcomes will be introduced and evidence for this discussed.

3.2 Inequalities in health – the case of Scotland

Poorer health outcomes in Scotland relative to other western European countries have been shown to date back to early 1950s when Scottish life expectancy started to improve at a slower rate than other such countries (Leon et al., 2003, Mccartney et al., 2012b). From the 1980s onwards this slower rate of improvement became more pronounced. As discussed in the previous chapter, the presence of regional inequalities in mortality within Britain has been well established, with higher mortality rates being shown to exist in Scotland and the north of England for over a century (Shaw et al., 1998). Whilst spatial differences in health in Britain are therefore nothing new, research undertaken during the 1990s revealed that these differences were becoming more polarised (Dorling, 1997, Shaw et al., 1998, Leyland, 2004), a trend which Thomas et al. (2010) have shown continued in the 2000s. Dorling's (1997) comparison of standard mortality ratios for Scotland relative to England and Wales, for example, demonstrated that the difference in morality between Scotland and England and Wales increased from the 1980s onwards. This difference had remained stagnant between 1950 and 1985 at 11-12% higher in Scotland, however by 1993-95 the standard mortality rate was 23% higher in Scotland relative to England and Wales. Using mortality data from the Human Mortality Database to calculate rate ratios for mortality in Scotland relative to England and Wales, and produce Lexus diagrams, Campbell et al. (2013) built upon Dorling's (1997) work and demonstrated that this divergence actually began in the 1970s. Just as the widening gap in life expectancy between Scotland and other western European countries was due to improvements occurring at a slower rate in Scotland, the increasing difference in mortality rates in Scotland relative to England and Wales was also due to mortality rates improving less rapidly in Scotland.

3.2.1 Deprivation – the traditional explanation for Scotland's higher mortality levels relative to England and Wales

Research highlighting increases in regional inequalities became a catalyst for further investigations into Scotland's mortality rates, work which continues to this day. Until the mid-2000s the canonical explanation for higher levels of mortality in Scotland relative to the rest of Britain was deprivation (Hanlon et al., 2005). Carstairs and Morris (1989) indicated that in 1981 Scotland had much higher levels of deprivation than England and Wales and, they argued, this explained all but 3% of Scotland's higher mortality rate. Whilst Carstairs and Morris's (1989) work reinforced notions that deprivation explained Scotland's higher mortality levels, their findings were based on methods which were problematic. Differences in the availability of data, for example, meant that different specifications of areal unit were used for Scotland and England. Of particular note was the large size of areal unit used by Carstairs and Morris (1989) in their analysis. In Scotland, for example, the areal unit used was postcode sectors which had a mean population of 4,756 people. Bailey et al. (2003) (whose discussion of Townsend's definition of deprivation was discussed in the previous chapter) recommend that deprivation is more accurately measured at the smallest spatial scale available as this increases the likelihood that areas are socio-economically homogenous, and in turn reduces the risk of ecological fallacy. The size of units used by Carstairs and Morris might, therefore, have affected how well they measured deprivation, and consequently how well they could adjust for it.

McLoone and Boddy (1994) used the same methods as Carstairs and Morris (1989) (and are thus subject to the same criticisms) to analyse data from the 1991 census. Their study yields four findings of relevance to this study. First, whilst age standardised mortality decline by 22% during the 1980s in Scotland, the reduction in mortality in deprived areas was only 50% that of affluent areas, thus providing further evidence of the increasing polarisation of health outcomes between affluent and deprived areas. Second, primarily attributable to a rise in suicide rate, there was an *increase* in death rates between 1981-82 and 1991-92 for people aged 20-29 living in deprived areas (an increase of 29% for males and 11% for females). Third, Glasgow (when defined using the Greater Glasgow Health Board boundary) had 52% of postcode sectors in Scotland categorised as being either the most deprived or the second most deprived of their seven categories. Fourth, not only were death rates found to be considerably higher in Glasgow but through an examination of the standardised mortality ratios (SMRs) for people aged 0-64 in the different deprivation categories, they also ascertained these SMRs had worsened in Glasgow for those in the most deprived categories between 1981-82 and 1991-92 and argued that this was attributable to deprivation. However, it is important to note that when comparing death rates with the rest of Scotland, McLoone and Boddy (1994) did not adjust for deprivation status. Their work also just focussed on Scotland and so did not provide comparisons of Scotland's mortality rates with other parts of the UK or Europe.

Thus, Carstairs and Morris (1989) attributed Scotland's high mortality rates to deprivation, and McLoone and Boddy (1994) argued that worsening SMRs in Glasgow relative to Scotland was attributable to deprivation. However, as previously mentioned, evidence started to emerge during the 1990s that regional inequalities in health outcomes were growing (e.g. Dorling, 1997); this led to a re-examination of the relationship between deprivation and health in Scotland.

3.2.2 Does deprivation explain the mortality gap between Scotland and the rest of Britain?

The Scottish Council Foundation (1998a) were the first to propose in writing that Scotland’s high mortality levels were not solely attributable to deprivation. This was prompted by the identification of a paradoxical situation whereby, despite rising levels of income and living standards, Scotland’s relative position with regard to mortality had worsened. Arguing that further research was required into underlying causal factors for Scotland’s poor health, they suggested that:

> “*there may be factors other than relative deprivation which underlie Scotland’s poor figures. There may be an additional Scottish Effect.*” (Scottish Council Foundation, 1988a:6).

A second report published later the same year (Scottish Council Foundation, 1998b) examined in more detail whether deprivation alone explained Scotland’s high mortality levels relative to the rest of Britain. The report stressed that, despite increasing differences in mortality rates, Scotland’s poverty relative to the British average had not worsened. Importantly, the Scottish Council Foundation’s (1998b) analysis indicated that Scotland’s mortality levels were higher than expected given its socio-economic profile, and despite overall improvements in health “*Scotland’s overall indicators of economic wellbeing ought to promote better health*” (Scottish Council Foundation, 1998b:11).

Evidence from academia also started to emerge around this time indicating that that there might be more to Scotland’s relatively high mortality than just deprivation. Shaw et al. (1999) performed a range of analyses comparing premature mortality (defined as death under the age of 65) in British parliamentary constituencies with the highest and lowest rates of deprivation. The constituencies in the “worst” group are shown in rank order of mortality rate in Table 0-1. Two points are particularly salient. First, Glasgow constituencies dominate the table with the worst six constituencies, seven of the top ten, and eight of the top 15 being in Glasgow. Second, constituencies with very similar poverty rates sometimes experienced different levels of premature mortality. Glaswegian constituencies often had the similar poverty rates to other constituencies, but higher premature mortality. Glasgow

Anniesland, for example had the same poverty rate (34%) as Manchester Blackley and Salford, yet a much higher premature standardised mortality ratio (SMR) (181) than the other two (169 and 163 respectively). So, whilst Shaw et al.'s (1999) analysis confirmed the well-established relationship between health and socio-economic circumstances, it also hinted that this relationship may differ or be stronger in Glasgow compared with other, similarly deprived, cities.

Rank (Highest SMR)	Constituency	SMR<65 1991-95	Households living in poverty in 1991		% avoidable deaths
			%	Rank relative to other constituencies	
1	Glasgow Shettleston	234	42	=1	71
2	Glasgow Springburn	217	41	3	69
3	Glasgow Maryhill	196	42	=1	65
4	Glasgow Pollock	187	36	9	64
5	Glasgow Anniesland	181	34	=10	63
6	Glasgow Baillieston	180	39	=5	62
7	Manchester Central	173	40	4	61
8	Glasgow Govan	172	31	=13	61
9	Liverpool Riverside	172	39	=5	61
10	Manchester Blackley	169	34	=10	60
11	Greenock & Inverclyde	164	31	=13	59
12	Salford	163	34	=10	59
13	Tyne Bridge	158	37	8	57
14	Glasgow Kelvin	158	30	15	57
15	Southwark North & Bermondsey	156	38	7	56

Table 0-1 15 parliamentary constituencies with worst premature mortality SMRs and highest % of avoidable deaths. (Adapted from Shaw et al., 1999:237)

Further analysis by Mitchell et al. (2000) suggested that Glasgow's health might be influenced by additional factors to the principal socio-economic determinants. They ascertained that in 95% of British parliamentary constituencies, changes in social class composition between the 1980s and 1990s explained changes in premature mortality to within 5%. However, they also identified a

> "*core set of areas...(notably within Glasgow, Birmingham, and Liverpool) where the chances of premature mortality have remained or become inexplicitly higher than the national average*" (Mitchell et al., 2000:22).

These two studies, albeit from the same team, (Shaw et al., 1999, Mitchell et al., 2000), thus suggested levels of poor health were influenced by unknown factors in addition to socio-economic determinants, and that Glasgow appeared most affected. Glasgow will be discussed in the next section. First, however, it is necessary to continue the examination of the literature on Scotland because much of the investigation into Glasgow's poor health is closely linked to, or stems from, that exploring Scotland's poor health outcomes.

More substantial evidence that Scotland's high mortality levels were not exclusively attributable to deprivation emerged in a 2001 report commissioned by the Public Health Institute of Scotland (Hanlon et al., 2001). Using 1990-92 mortality data, and Carstairs and Morris's technique to categorise deprivation from 1991 census data, Hanlon et al. (2001) found that the proportion of Scotland's excess mortality explained by deprivation had decreased between 1981 and 1991. By 1991 deprivation only accounted for: "*approximately 40% of the excess deaths for all ages...and 60% of those under 65*" (Hanlon et al., 2001:19). This report also used the term 'Scottish effect' as a label for the portion of mortality not attributable to deprivation. It should however be noted that Hanlon et al.'s (2001) research is subject to the same limitations as Carstairs and Morris (1989), including the use of postcode sectors as the geographical unit of analysis.

Three further key points of relevance can be drawn from Hanlon et al.'s (2001) study. First, in 1991, relative to England and Wales, Scotland had a higher proportion of its population classified as living in areas of high deprivation (18% compared to 8%). Second, as highlighted by the Scottish Council Foundation (1998a, 1998b), the difference in mortality levels between affluent and deprived areas was greater in Scotland than in England and Wales. Therefore "*health inequalities in this period were much more manifest in Scotland than in the rest* *of Great Britain*" (Hanlon et al., 2001:17). Third, regional variations within Scotland persisted. Using SMRs adjusted for age, sex, and deprivation to compare Scottish regions with England and Wales, it was found that the highest levels of excess were in Strathclyde[7]. Whilst the report noted that Strathclyde had a strong influence on the Scottish SMR, it stressed that even when Strathclyde was excluded from the analysis, there was an excess mortality in Scotland, not accounted for by deprivation.

Although Hanlon et al. (2001) clearly stated their study could not identify the causal factors behind the Scottish effect, they proffered two explanations. The first acknowledged that their deprivation capturing methods might have been flawed. Hanlon et al. (2001) used the same four census variable used by Carstairs and Morris (1991) (car ownership, overcrowding, male unemployment, and proportion in social class IV and V) which, they admitted, might not have been as appropriate a gauge of deprivation in 1991 as it was in 1981. If the variables were no longer an accurate a measure of deprivation in 1991, Hanlon et al. (2001) conceded that deprivation was a likely explanation for the higher levels of mortality experienced in Scotland, compared to England and Wales. If, however, their measure of deprivation was accurate, Hanlon et al.'s (2001:20) second suggestion was that this higher mortality could be

> "*due to a wider set of psychological, social or behavioural factors which were less important in 1981 and had become more influential by 1991.*"

Hanlon et al.'s (2001) study was important in drawing attention to excess mortality in Scotland.

Using 2001 census data, Hanlon et al. (2005) then provided a more contemporary analysis of excess mortality levels in Scotland, which, unlike their previous work, was published in a peer reviewed journal. By performing a Spearman's rank coefficient between 2001 deprivation scores and the recently developed Scottish Index of Multiple Deprivation (SIMD), Hanlon et al. (2005) ascertained that Carstairs and Morris's (1991) method continued to provide an accurate method of measuring deprivation within small areas. Using the Carstairs and Morris

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[7] Strathclyde is a term used to describe the wider area of Scotland in which Glasgow is located (and is also the principal city).

method, area deprivation scores for the same geographical areas were calculated for 1981, 1991, and 2001. This enabled Hanlon et al. (2005) to compare Scottish mortality rates with those of the rest of Great Britain through the use of direct standardisation by 10 year age category, sex, and deprivation decile. Their results confirmed previous findings (Scottish Council Foundation, 1998b, Scottish Council Foundation, 1998a, Hanlon et al., 2001) that there was an excess of mortality in Scotland relative to the rest of Britain which was not attributable to deprivation.

Hanlon et al. (2005) also demonstrated that age and sex standardised all-cause mortality rates decreased across Britain over the same time period, but that the gap between Scotland and the rest of Britain widened due to a smaller fall in mortality rates in Scotland. Scottish mortality rates were 12% higher than for the rest of Britain in 1981, this rose to 14% in 1991 and 15% in 2001 (see Table 0-2). When this mortality rate was also adjusted for deprivation, the relative excess between Scotland and the rest of Britain decreased, indicating that deprivation was a contributory factor to Scotland's higher rates of mortality. However, as can be seen from Table 0-2, the residual difference in mortality rates, after adjustment for deprivation, *increased* over the 20 year period. By 2001, 8% of Scotland's higher mortality levels could not be explained by differences in deprivation levels. Further, an excess of mortality not explained by deprivation was shown to occur across all Scottish deprivation deciles (Figure 0-1). It was, however, most pronounced in the most deprived deciles. This is of particular relevance to this research since the majority of Scotland's most deprived deciles are located in Glasgow and the surrounding area.

	1981	1991	2001
SMR for Scotland relative to England and Wales adjusted for age and sex (%)	112.4	113.8	115.1
SMR for Scotland relative to England and Wales adjusted for age, sex, and deprivation (%)	104.7[8]	107.8	108.0

Table 0-2 Summary of Hanlon et al.'s (2005) Standardised Mortality Ratios for Scotland relative to England and Wales 1981-2001

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[8] This is slightly higher than the figure of 103 which was calculated by Carstairs and Morris (1989) for the same time period.

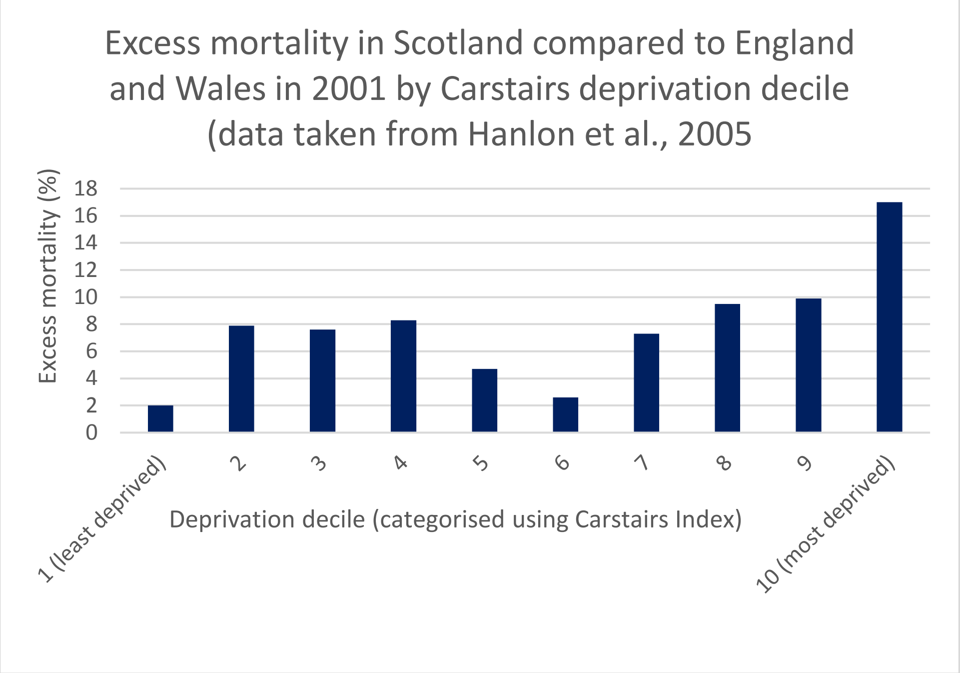

Figure 0-1 Excess mortality in Scotland relative to England and Wales in 2001 by Carstairs deprivation decile (data from Hanlon et al., 2005)

Hanlon et al. (2005) also showed that, with the exception of respiratory diseases, most specific causes of death were higher in Scotland relative to England and Wales (Table 0-3). After adjusting for age, sex, and deprivation, cerebrovascular disease (stroke), ischemic heart disease, lung cancer, and intentional self-harm and events of an undetermined nature were 23.9%, 11.7%, 25.9%, and 41.3% higher respectively, relative to England and Wales.

Cause	% excess		
	1981	1991	2001
All causes	4.7	7.9	8.2
Respiratory disease	-23.9	12.7	-15.2
Cerebrovascular disease	29.8	22.9	23.9
Ischaemic heart disease	12.6	12.3	11.7
All malignant neoplasms	0.6	3.3	10.8
Lung cancer	2.2	14.2	25.9
Intentional self-harm and events of undetermined intent	1.2	15.1	41.3

Table 0-3 Cause-specific mortality rates for Scotland as a percent excess relative to England and Wales based on log-linear regression models adjusted for age, sex, and deprivation decile (based on Hanlon et al., 2005:202)

A limitation of Hanlon et al.'s study is that they did not include drug-related deaths. Bloor et al.'s (2008) analysis indicated that a third of Scotland's excess mortality, in the 15-54 age category, may be accounted for by a higher prevalence of problem drug use in Scotland. However, this figure was based on a relatively small cohort of drug users (n=1033) and so the accuracy of this figure is questionable (BMJ, 2008).

3.2.3 Section summary

This section has detailed how, since the 1950s improvements in mortality in Scotland have occurred at a slower rate relative to other Western European countries in general, and particularly England and Wales. This trend became more pronounced in the 1970s/1980s. The traditional explanation for Scotland's high mortality levels relative to England and Wales was deprivation. However, since 1998 research has been emerging indicating that deprivation does not account for all of Scotland’s high mortality rate. It has been shown that an excess level of mortality exists in Scotland after accounting for deprivation.

Many of the Scotland-wide studies cited here noted that West Central Scotland, and Glasgow especially, had a particular influence on Scotland’s poor health status. This is partly because the Glasgow area contained a very high proportion of Scotland’s most deprived areas. However, whilst excess mortality was seen across Scotland, there was a particularly concentrated version of this excess in and around Glasgow. This, turn, led to the idea that there might be a more specific “Glasgow Effect”, a concept which will be discussed in the next section.

3.3 Inequalities in health – the case of Glasgow

Excess mortality in Scotland, relative to England and Wales exists across all social classes and regions, but is most pronounced in the most deprived areas (Hanlon et al., 2001, Hanlon et al., 2005). As Glasgow has the highest concentration of deprivation in Scotland (The Scottish Government, 2012), it is unsurprising that within Scotland this is where excess mortality levels are highest. Consequently, research has been undertaken examining excess mortality and establishing the existence of a “Glasgow Effect”. As will be shown in this section the main contributions to this research have been based on showing that other similarly sized cities, with comparable socio-economic histories and levels of deprivation (primarily Liverpool and Manchester), have lower mortality rates than Glasgow.

The Glasgow Centre for Population Health (GCPH) produced a comprehensive report on health and its determinants in Glasgow and West Central Scotland (Hanlon et al., 2006 p11). A key finding was that health inequalities exist both within Glasgow, and between Glasgow and the rest of Scotland, not all of which could be attributed to deprivation. Hanlon et al. (2006, p11) stated:

> “*(t)here is a ‘Glasgow effect’- that is, an excess of mortality beyond that which can be explained by current indices of deprivation.*”

Hanlon et al. (2006) also demonstrated that the gap in life expectancy between those living in the most and least deprived areas of Glasgow widened between the early 1980s and early 2000s (see Figure 3-2 and Figure 0-3). This confirmed McLoone and Boddy's (1994) findings (discussed in section 3.2.1) of an increase in the mortality gap between affluent and deprived areas since the early 1980s. This echoes analysis undertaken at the Scottish level, by Leyland et al. (2007), illustrating increased premature mortality between 1991/92 and 2000/02 among those living in the most deprived areas. Of interest is that Norman et al. (2011) ascertained there was no rise in premature mortality in other 'persistently deprived' areas of the UK between the early 1990s and 2000s. Norman et al.'s (2011) analysis revealed that this phenomenon was unique to Scotland and principally driven by increases in mortality in Glasgow.

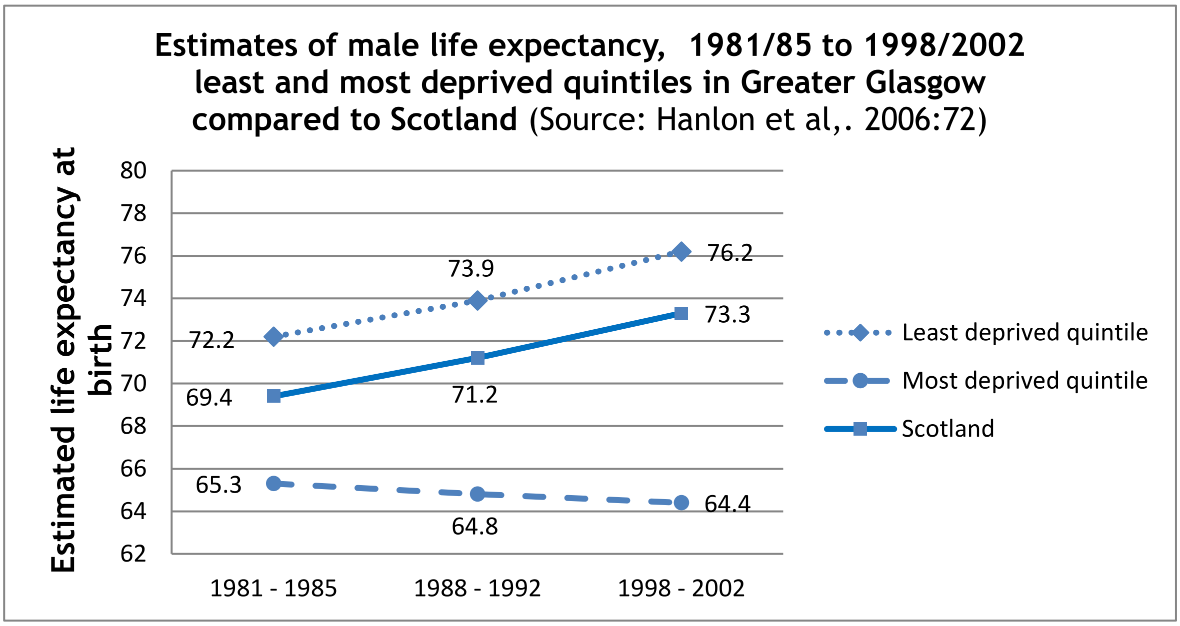

Figure 0-2 Estimates of male life expectancy, 1981/85 to 1998/2002 in least deprived and most deprived quintiles in Greater Glasgow compared to Scotland (Source: Hanlon et al., 2006:72)

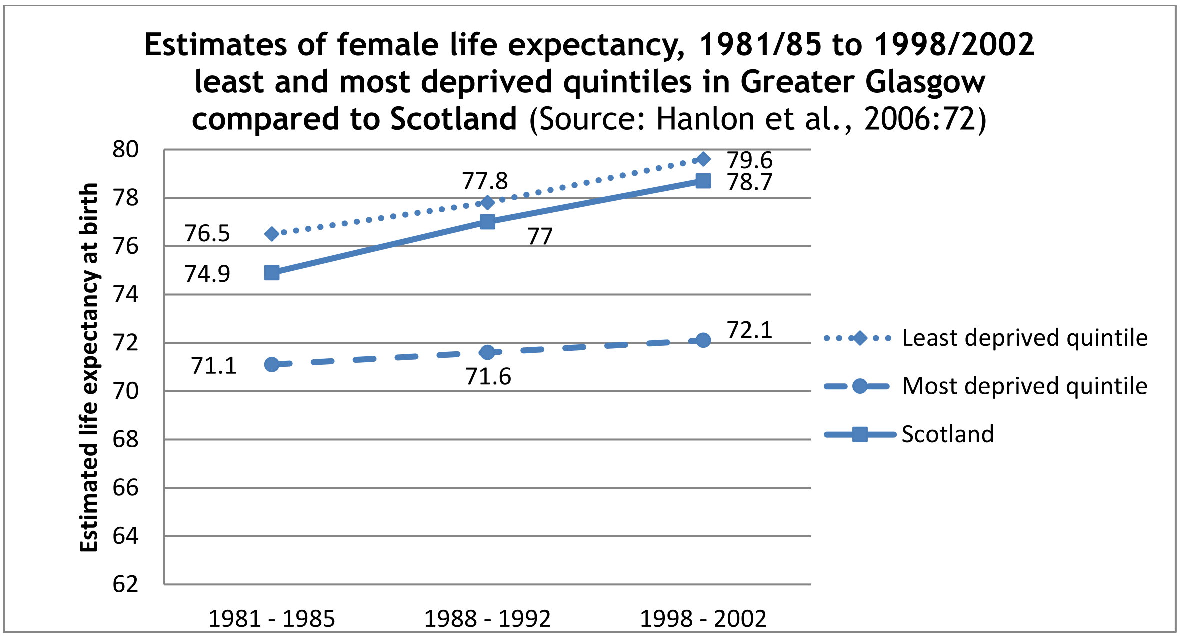

Figure 0-3 Estimates of female life expectancy, 1981/85 to 1998/2002 in least and most deprived quintiles in Greater Glasgow compared to Scotland (Source: Hanlon et al., 2006:72)

Glasgow experienced mass deindustrialisation resulting in post-industrial decline in the second half of the 20th century. This had an enormous impact on the city's physical and social fabric (Pacione, 1995, 2009) and has been associated with socio-economic deprivation (Walsh et al., 2010c). A further GCPH study (Walsh et al., 2008, Walsh et al., 2010c) tested the hypothesis that this post-industrial decline was a major underlying reason for Scotland's, and particularly the West of Scotland's, poor health profile. Using detailed mortality and population data, Walsh et al. (2008) compared mortality trends of 20 deindustrialised regions in the UK and mainland Europe from the mid-1980s onwards. They concluded that post-industrial areas tend to experience poor health outcomes relative to their host country (with the majority of regions having either the highest, or one of the highest all cause mortality rates in their country), but that Scotland (and particularly West Central Scotland (WCS)) was a '*conundrum*'. The conundrum was that Scotland/WCS was found to be wealthier than most of the other regions, but had higher mortality rates. In WCS these higher levels were shown:

> "*to be driven especially by rising levels of mortality in the 15-44 age group (especially among men) and significantly higher rates among middle-aged (45-64) females.*" (Walsh et al., 2008:97).

Increasing mortality levels in the 15-44 age group were driven by external causes (and suicides in particular) and chronic liver disease; and in the 45-64 age group they were shown to be attributable to cancer, ischemic heart disease (IHD) and stroke, chronic obstructive pulmonary disease (COPD), and chronic liver disease and cirrhosis. A further finding of the study was that mortality rates in WCS were improving more slowly than in other regions.

Walsh et al. (2008, 2010c), therefore, cautioned against post-industrial decline as the sole explanation for poor health in WCS. However, some care should be exercised in accepting their findings due to the nature of their study. Although explicit in explaining how comparator regions were selected, and the selection criteria appearing appropriate, the comparability of some of the regions with WCS is questionable. The scale of deindustrialisation (measured by loss of industrial employment) between these regions varied substantially from 16% in Limburg (Netherlands) between 1968 and 2005, to 63% in Merseyside (England) between 1971 and 2005. Other characteristics of the regions selected also differed markedly and this may have affected the impact of deindustrialisation. Limburg, for example, has a number of small cities (each of which has a low population density) rather than being dominated by one big city (as is the case in WCS). The Limburg region therefore appears to be of a different character to WCS.

Further comparability issues with Walsh et al.'s (2008, 2010c) analysis arise from their use of "*cross-national, routine administrative and survey-based measures*" (Walsh et al., 2010c:63). This, as Walsh et al. (2008, 2010c) recognise, is likely to be problematic in that the data might not be robust in all places, and methods of collection vary. The data were also limited as they were collected at regional level. As noted by Walsh et al. (2008, 2010c), this level of aggregation has implications because it hides sub-regional variation. Walsh et al. (2008, 2010c), for example, suggest that it is feasible that inequality is greater in WCS than other regions. Indeed, in the second phase of this study, it was found that income inequality was greater in WCS (Taulbut et al., 2014).

These limitations notwithstanding, Walsh et al.'s work indicated that WCS had higher mortality rates than other regions which had also experienced deindustrialisation, despite not appearing to have higher poverty rates. Their work furthered the argument that deprivation does not entirely explain poor health in Scotland, and showed that this was particularly pronounced in WCS. Whilst the focus of their analysis was WCS, Glasgow is a significant portion of WCS both economically and in terms of population size. Walsh et al. (2008, 2010c) did not actually use the term “Glasgow Effect”, but did imply that further research should be undertaken on Glasgow specifically.

Answering their own call, Walsh et al.’s (2008, 2010c) study led to further research comparing Glasgow with two other UK cities which had undergone deindustrialisation, were of a similar population size, and had similar levels of deprivation to Glasgow: Liverpool and Manchester (Walsh et al. 2010a, 2010b). This work is seminal in literature on excess mortality in Glasgow, and it also forms the context for this study. It will therefore now be discussed in detail.

3.3.1 Mortality and deprivation – comparing Glasgow to Liverpool and Manchester

The methods used by Walsh et al. (2010a, 2010b) to compare levels of deprivation and mortality rates in Glasgow with two other UK cities: Liverpool and Manchester were a methodological leap forward in comparison to previous work.

3.3.1.1 Methods used to compare mortality and deprivation in Glasgow with Liverpool and Manchester

Previous analyses of excess mortality in Scotland and Glasgow had used the Carstairs deprivation index which, as discussed in an earlier section, was calculated from census data. By 2010, when Walsh et al. (2010b, 2010a) were writing, census data were nine years old and thus outdated. Furthermore, the authors deemed the use of the Carstairs deprivation index to be potentially problematic for measuring the effects of areas based deprivation because of two issues relating to the size of geographical unit use. First, cross-border comparisons were potentially inaccurate due to different sized geographies used in Scotland and England: postcode sectors in Scotland (mean population of 5,500), electoral wards in England (mean population 13,000 in Liverpool and 11,900 in Manchester). Second, the large size of the geographical units used was deemed problematic for measuring the effects of area based deprivation, greatly raising the likelihood of misclassification and ecological fallacy.

To circumvent issues relating to the use of the Carstairs deprivation index, Walsh et al. (2010a, 2010b) created a comparable measure of 'income deprivation'[9] for areal units of similar size in each of the cities. A high level of correlation with other measures of deprivation (such as the Scottish Index of Multiple Deprivation (SIMD) and the Indices of Multiple Deprivation (IMD)) was found, indicating their method had validity. However, Walsh et al. (2010a, 2010b) cautioned that their measure was not flawless, noting that their results could be "*simply a reflection that true 'deprivation' cannot be adequately captured by indicators derived from routine data sources*" (Walsh et al., 2010c:493). In Liverpool and Manchester, Lower Super Output Areas[10] (LSOA's) were used as the areal unit. These do not exist in Scotland; the nearest comparable unit being datazones, which on average have half the population of LSOAs. To enable comparability between Glasgow and the English cities, Walsh et al. (2010a, 2010b) used Geographic Information System (GIS) to merge pairs of neighbouring datazones with comparable levels of income deprivation. These merged datazones had an average population of 1650, thus were of a similar size to LSOAs. This process enabled a contemporary measure of deprivation to be used, and analysis to be undertaken at a finer spatial scale than before.

3.3.1.2 'It's not just deprivation' – the results of Glasgow, Liverpool and Manchester comparisons

Using this method, Walsh et al. (2010a, 2010b) found that Glasgow, Liverpool, and Manchester had almost identical levels of income deprivation (24.8%, 24.6%, and 23.4% of the total population were classed as 'income deprived'

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[9] This measure was based on people in receipt of low-income related social security benefits.

[10] Which had an average population size of 1502 in Liverpool, and 1717 in Manchester (Walsh et al., 2010b).

respectively), and a very similar distribution of income deprivation across the small areas of each city. However, despite these similarities, examination of the SMRs (calculated standardising for age, sex, and deprivation decile) revealed that mortality levels were different in Glasgow. The SMRs for all-cause mortality in Glasgow relative to Liverpool and Manchester (combined[11]) calculated by Walsh (2010a, 2010b) are shown in Table 0-4. All-cause mortality was 14% higher in Glasgow relative to Liverpool and Manchester (combined), and premature mortality was 30% higher.

Age group (years)	**Standardised all-cause mortality ratios 2003-2007 relative to Liverpool and Manchester (combined), indirectly standardised by 5-year age band, gender and income deprivation decile**		
	Total population	**Males**	**Females**
<65 (premature mortality)	131.4	135.6	124.4
All ages	114.4	122.4	107.7
0-14	81.3	78.8	84.7
15-44	145.8	160.4	121.4
45-64	130.3	131.6	128.1
≥65	109.8	117.0	104.8

Table 0-4 Standardised all-cause mortality ratios 2003-2007 relative to Liverpool and Manchester (combined), indirectly standardised by 5-year age band, gender and income deprivation decile. (Data from Walsh et al., 2010a, 2010b).

Through examining mortality by age category, Walsh et al. (2010a, 2010b) demonstrated that much of Glasgow's higher rates were driven by deaths in the 15-44 and 45-64 age categories (which they referred to as the working-age groups). Higher working-age group mortality was evident for both males and females, but it was particularly note-worthy that mortality was 60% higher in

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[11] Walsh et al. 2010a, 2010b calculated mortality ratios for Glasgow relative to Liverpool, Glasgow relative to Manchester, and Glasgow to Liverpool and Manchester combined. By doing so they found that the results of Glasgow Liverpool and Glasgow Manchester comparisons were very similar to those from the comparison of Glasgow with both English cities combined. Consequently they reported on these latter results.

Glasgow in the male 15-44 age group. Walsh et al. (2010a, 2010b) therefore ascertained that, despite the three cities having almost identical levels of income deprivation, Glasgow had higher all-cause mortality rates relative to Liverpool and Manchester (combined) across all adult age groups.

In addition to examining all-cause mortality by age group, Walsh et al. (2010a, 2010b) produced all-cause SMRs by income deprivation decile (Table 0-5 for all deaths, and Table 0-6 for premature deaths). The SMRs for all deaths (Table 0-5) were higher in all deprivation deciles in Glasgow. This was important because it revealed that higher mortality levels existed across income groups in Glasgow, and not just in the more deprived groups. For example, the SMR for Glasgow's least deprived decile is 15% higher than in the least deprived decile in Liverpool and Manchester (combined). Of particular interest, however, is the information revealed by examining the standardised all-cause mortality ratios for premature deaths (Table 0-6). These, again, reveal that (with the exception of males in the least deprived decile) Glasgow had higher SMR across all deprivation deciles, but the highest SMRs tend to be for those in the more deprived deciles.

Three-city income deprivation decile	**Standardised all-cause mortality ratios 2003-2007 relative to Liverpool and Manchester (combined), broken down by deprivation decile, for all deaths.**		
	Total population	**Males**	**Females**
1 (Least deprived)	115.1	115.6	114.8
2	119.7	118.8	120.3
3	108.0	112.8	103.8
4	105.4	114.4	98.7
5	115.5	122.8	109.3
6	118.0	128.7	106.8
7	116.0	127.5	107.0
8	108.4	118.1	100.5
9	119.8	131.5	109.1
10 (Most deprived)	118.6	125.3	112.2

Table 0-5 Standardised all-cause mortality ratios 2003-2007 for all deaths relative to Liverpool and Manchester (combined), broken down by deprivation decile (Data from Walsh et al., 2010a, 2010b)

Three-city income deprivation decile	Standardised all-cause mortality ratios 2003-2007 relative to Liverpool and Manchester (combined), broken down by deprivation decile, for premature deaths (<65 years)		
	Total population	Males	Females
1 (Least deprived)	100.7	94.0	110.6
2	115.2	111.3	122.2
3	120.1	121.1	135.3
4	129.7	135.9	119.6
5	130.5	141.0	114.4
6	144.3	154.1	127.8
7	140.0	146.5	128.8
8	132.6	131.9	133.8
9	130.8	144.0	109.9
10 (Most deprived)	139.6	143.0	132.6

Table 0-6 Standardised all-cause mortality ratios 2003-2007 for premature deaths relative to Liverpool and Manchester (combined), broken down by deprivation decile (Data from Walsh et al., 2010a, 2010b)

Walsh et al.'s (2010a, 2010b) examination of specific cause of death (Table 0-7) also revealed substantial differences between Glasgow, and Liverpool and Manchester. For the total population, deaths in Glasgow from lung cancer were 27% higher than in Liverpool and Manchester, external causes were 32% higher, suicide was 68% higher, and deaths from alcohol related causes and drug related poisonings were almost 2.3 and 2.5 times higher respectively. When broken down by gender, both male and female SMRs were higher in Glasgow relative to Liverpool and Manchester. The difference in SMRs by cause of death for Glasgow relative to Liverpool and Manchester was higher for males, with the exception of suicide. Male suicide was 54% higher in Glasgow, but female suicide was more than 2 times higher.

Cause of death	All ages cause specific standardised mortality ratios 2003-07, Glasgow relative to Liverpool and Manchester, standardised by age, sex, and deprivation decile.		
	Total population	**Males**	**Females**
All cancers **(malignant neoplasms)**	112.2	116.6	108.1
Circulatory system	111.9	113.9	110.2
Lung cancer	126.7	129.2	124.0
External causes	131.7	141.5	116.2
Suicide (including no underdetermined intent)	168.0	154.4	216.5
Alcohol	229.5	255.9	182.3
Drug related poisoning	248.5	279.0	190.1

Table 0-7 All ages cause specific standardised mortality ratios 2003-07, Glasgow relative to Liverpool and Manchester, standardised by age, sex, and deprivation decile. (Data from Walsh et al., 2010a, 2010b)

Analysis by cause of death is, in theory, useful because it can suggest mechanisms through which excess mortality might operate. Different processes are needed to produce deaths from different causes. Deaths at all ages, for example, tend to be more related to chronic conditions, whereas premature mortality is more likely to be associated with alcohol and drug use, and suicide. However, seeing the excess across many different types of death, with different aetiologies, might suggest that there are multiple causes of Glasgow's excess mortality.

There are number of weaknesses associated with Walsh et al.'s (2010a, 2010b) study. Of particular note is the population size of the neighbourhoods used. Although Walsh et al.'s (2010a, 2010b) study should be credited with developing a method that enabled the comparison of similar size neighbourhoods in Scotland and England, the size of the neighbourhood (average population 1,500) was still relatively large. Indeed, it was twice the size of that currently used in deprivation analysis in Scotland. The results are therefore more vulnerable to ecological fallacy than if smaller neighbourhoods had been studied.

Whilst the limitations to the work of Walsh et al. (2010a, 2010b) are important, it must be recognised that Walsh et al. (2010a, 2010b) facilitated, for the first time, a method of comparing deprivation levels at the same spatial scale in England and Scotland, and that this was at a finer spatial scale than had previously been used. Their research provided invaluable evidence for, and insight, into understandings of excess mortality in Glasgow.

A very important aspect of Walsh et al.'s work was their use of historical mortality data to track the development of mortality rate differences between Glasgow, Manchester and Liverpool, over time. They calculated age-standardised premature mortality rates for the three cities between 1921/25 to 1936/39, and then from 1969/73 to 2001/05[12]. The results demonstrated that Glasgow actually had similar levels of premature mortality to Liverpool and Manchester in the earlier period. From the 1970s onwards rates of premature mortality decreased at quicker rate in the English cities, widening the gap between them and Glasgow. Walsh et al. (2010a, 2010b) therefore provide evidence that the Glasgow's excess mortality is a relatively recent phenomenon

Walsh et al. (2010a, 2010b) established that, despite having similar levels of income deprivation as Liverpool and Manchester, Glasgow had higher mortality rates. Using the term 'excess mortality' to describe:

> "*additional deaths experienced in Glasgow over and above what might be expected if Glasgow displayed the same age-, gender-, and deprivation-specific mortality profile as Liverpool and Manchester*" (Walsh et al., 2010b:492),

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[12] The gap was due to data not being available between 1936/39 and 1969/73.

they calculated that there were more than 4,500 excess deaths in Glasgow between 2003 and 2007, of which 2,090 were in the people under the age of 65. For all excess deaths, 23% were due to all cancers, 27.5% due to diseases of the circulatory system, and 20% due to alcohol-related conditions. For excess premature deaths, 32% were due to alcohol-related causes, and 17% were due to drug-related poisonings (Walsh et al., 2010a, 2010b). Crucially, they also identified that the ‘gap’ between Glasgow and the other cities was a relatively recent phenomenon.

3.3.2 Where is research currently into Glasgow’s excess mortality?

The emphasis in research on excess mortality in Glasgow and Scotland has recently moved from identifying and describing the phenomenon to exploring potential causes for it. McCartney et al. (2012a) identified 17 hypotheses for the unexplained excess in Scotland (Table 0-8). These include a mixture of downstream, midstream, and upstream explanations. Although this approach was taken for Scotland, rather than Glasgow specifically, many of the hypotheses are of direct relevance. An in depth discussion of all of these is not feasible here (indeed some could form PhD topics in themselves), nor necessary. Investigations into some of them have already been undertaken[13] and new hypotheses have also emerged[14]. What is specific to this research is that McCartney et al. (2012a) propose the concentration of deprivation, that is to say its spatial pattern, may have an influence on poor health outcomes and that this spatial pattern may be different in Glasgow.

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[13] An example of this includes Graham et al.’s (2012) study comparing health outcomes in Belfast and Glasgow from which it was concluded that sectarianism is unlikely to be a causal factor of Glasgow’s excess mortality.

[14] Talbut et al.’s (2016) study exploring if differences in the scale of urban change could contribute to Glasgow’s excess mortality.

Hypothesis title	Hypothesis
Deprivation	There are higher levels of deprivation in Scotland, particularly WCS and Glasgow, which are not captured through current measures of deprivation. Thus, excess mortality is actually an artefact of '*inadequate deprivation measures*' not accurately capturing the real nature of deprivation. (p461)
Migration	Emigration of healthy individuals was greater than from other areas.
Genetic differences	Due to genotype, the population is either predisposed to negative health behaviours or is particularly vulnerable to the effects of such behaviours.
Health behaviours	A higher prevalence of unfavourable health behaviours is responsible for the mortality patterns. (p461)
Individual values	A higher prevalence of individuals who are more hedonistic than elsewhere, or have lower aspirations, leads to a higher prevalence of adverse health behaviours and higher mortality. (p463)
Different culture of substance misuse	Although the consumption rate per capita of substance (illicit drugs, tobacco, and alcohol) consumption is similar to other places, the way in which they are consumed differs and/or there is a unique culture surrounding their use which exacerbates their effects. (P463).
Culture of boundlessness and alienation	There is a culture of boundlessness, hopelessness and alienation which is a cause of the higher mortality. (p463)
Family, gender or parenting differences	Higher prevalence of family breakdown, acrimony between partners or dysfunctional parenting has a negative influence on health.
Lower social capital	Lower 'social capital' is responsible for the mortality patterns. (p463)
Sectarianism	Sectarian divisions between Catholics and Protestants (particularly in the West of Scotland and Glasgow) causally contributes to mortality patterns.
Culture of limited social mobility	A culture of limited aspirations and social immobility linked to lack of confidence and other inhibiting social norms, is a cause of the higher mortality. (p463-464)
Health service supply or demand	The quality, accessibility or demand for health services influences higher mortality. (p464)
Deprivation concentration	***"The deprived areas in Scotland and Glasgow form large, concentrated, monocultural communities to a greater extent than elsewhere, and this has a negative causal impact on health."*** **(p464)**
Greater inequalities	Greater income inequality has a negative effect on health.
De-industrialisation	De-industrialisation was particularly acute in Scotland and this has had health consequences.
Political attack	Post-1979 the UK was subjected to a form of neoliberalism other Europeans countries were not exposed to; this amounted to a political attack on the organized working class. Scotland, and particularly Glasgow, was more vulnerable than other parts of the UK. (p464).
Climatic differences	Vitamin D deficiency due to lack of sunlight; exposure to harsher winters increases mortality through the effects of the cold.

Table 0-8 McCartney et al.'s (2012a) 17 hypotheses for excess mortality in Scotland (bold added)

3.4 Could the concentration of deprivation explain Glasgow's excess mortality

The specific hypothesis identified by McCartney et al.'s (2012a) was that:

> "*deprived areas in Scotland and Glasgow form large, concentrated, monocultural communities to a greater extent than elsewhere, and this has a negative causal impact on health*" (McCartney et al., 2012a:464).

The map of Glasgow in Figure 0-4 shows that some parts of Glasgow are indeed characterised by large expanses of deprivation. This map was produced from SIMD data for 2012. The maps alongside for Liverpool and Manchester were produced using the English Indices of Multiple Deprivation (IMD) and so are not directly comparable to the map of Glasgow (Livingston and Lee, 2014). However, the maps do show that Liverpool and Manchester *also* have large amalgamations of areas classified as deprived. Indeed, it appears as though deprived areas are more dispersed in Glasgow than in Liverpool or Manchester. That the spatial arrangement of deprivation differs in Glasgow to other cities is therefore certainly plausible; however it is perhaps a little strange that the initial hypothesis was that deprived areas of Glasgow were more concentrated than elsewhere, given that the maps in Figure 0-4 seem to indicate otherwise. It is important to note that Figure 0-4 shows the patterns at one point in time. Given the lags in some causes of mortality, and the rapid and deep changes to the urban fabric of all three cities in the last decades, a longitudinal analysis of these patterns is required.

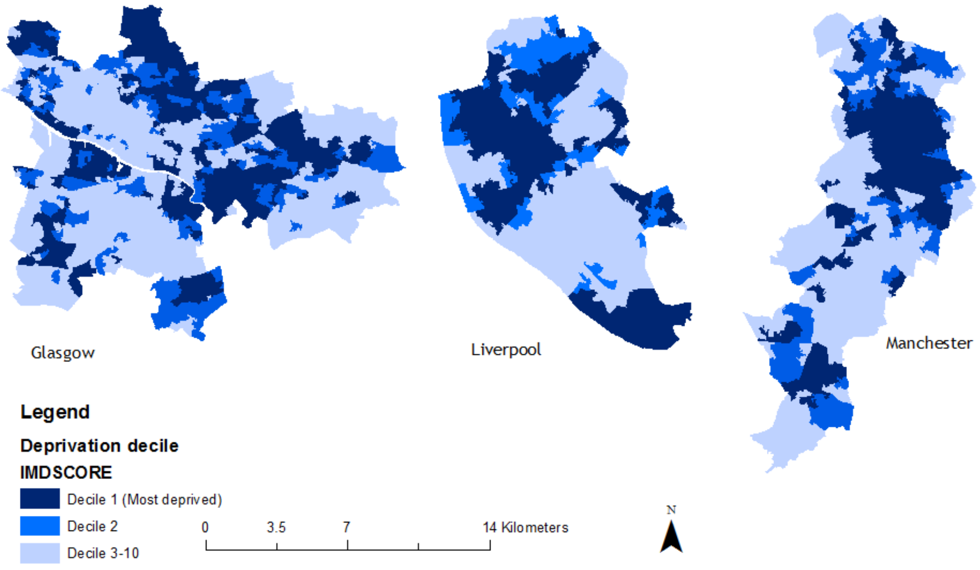

Figure 0-4 Areas in the two most deprived deciles in Glasgow, Liverpool, and Manchester as measured by the SIMD in 2012 and the IMD 2010 (Source: Scottish data from The Scottish Government, 2012; English data from Department for Communities and Local Government, Indices of Deprivation 2010. Boundary data from the UK Data Service Census Support. Contains Ordnance Survey data © Crown copyright and database right 2013.)

The hypothesis that the spatial arrangement of deprivation has implications for health outcomes is based on evidence that the contextual characteristics of an area are associated with residents' health (as discussed in the previous chapter). Whilst the link between area deprivation and poor health is well established (also discussed in the previous chapter), most analysis has tended to treat the areal units (and therefore the 'neighbourhoods', for example datazone, LSOA, postcode sector) as *"islands" that are unaffected by neighbouring units"* (Sridharan et al., 2007:1951). Cummins agrees (2007:355) arguing that studies examining the relationship between health and deprivation have tended to view small areas or neighbourhoods as the "*only meaningful unit of interest*". The reality, however, is that people are influenced by areas further away as well as by their immediate surroundings (Caughy et al., 2007). Cummins (2007) and Caughey et al. (2007) both argue that the small local area may not always be the most pertinent or potent scale of influence on health, and therefore not always the most appropriate scale of analysis.

Kwan (2012a, 2012b) has furthered this thinking in her work on 'the uncertain geographic context problem' (UGCoP). She argues that this refers to:

> *"the problem that findings about the effects of area-based attributes could be affected by how contextual units or neighbourhoods are geographically delineated and the extent to which these areal units deviate from the "true causally relevant" geographic context."* (Kwan, 2012a:959).

So, whilst someone may reside within the areal unit under investigation this is unlikely to be the only place they encounter; there are other places and scales exerting contextual influences on them. The UGCoP is particularly salient to studies examining neighbourhood effects on health and highlights the importance of studying the wider spatial context of an area, rather than simply treating geographical units as islands.

The importance of incorporating the spatial context of an area into an analysis of a neighbourhood is eloquently explained by Caughey et al. (2007:790) in their study on child developmental competence:

> *"(b)y not capturing the spatial nature of neighbourhoods, we neglect the very real possibility that the effects of the immediate neighbourhood environment might be further moderated by the effects of more distal neighbourhood environments. For example, one would hypothesise that living in a poor neighbourhood surrounded by poor neighbourhoods might have qualitatively different effects on children than living in poor neighbourhoods surrounded by non-poor neighbourhoods."*

Indeed, as will be discussed below in the discussion of Sridharan et al.'s (2007) research, there is already some evidence indicating that the health outcomes of a neighbourhood can be influenced by levels of deprivation in surrounding neighbourhoods. Sridharan et al. (2007), for example, demonstrated that spatial patterns of deprivation, rather than just levels of deprivation, might be implicated in explaining variations in mortality rates.

3.4.1 The impact of neighbouring deprivation on health: evidence from Scotland

Sridharan et al.'s (2007) study took as its starting point that the geography of poverty in Scotland might be a contributing factor for Scotland's unexplained mortality; that is:

> "*the actual spatial arrangement, the spatial patterns, of deprivation may be significant to understandings high mortality rates in Scotland*" (Sridharan et al., 2007:1943).

Rather than compare spatial patterns of deprivation between Scotland and other parts of Britain, Sridharen et al.'s (2007) focus was wholly on Scotland and aimed to ascertain whether the spatial pattern of deprivation influenced mortality in Scottish communities.

To do this, Sridharan et al. (2007) used postcode sectors as their geographical unit and examined the relationship between deprivation and mortality in spatially contiguous[15] postcode sectors. 2001 Carstairs scores were used as the measure of deprivation. The mortality data was age and sex SMRs for all-cause mortality under the age of 75 for the three year period around the 2001 census.

Sridaharan et al. (2007) analysed these data using a three step process. First, the spatial distribution of both the Carstairs scores and SMRs was visualised. The second step was to use non-spatial descriptive statistics (such as the Pearson product-movement correlation). The third step was to undertake exploratory spatial data analysis (ESDA) methods. This focussed on three aspects of the spatial pattern:

- The overall global spatial clustering in mortality and deprivation (measured using Global Moran's *I*[16]*)*;

- The bivariate spatial relationship between mortality and deprivation (studied using bivariate Moran's *I*)

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[15] Using the queen's contiguity matrix.

[16] Moran's I is a measure of spatial autocorrelation.

- The local relationships between mortality and deprivation (using Local Indicators of Spatial Association (LISA)).

From this analysis, Sridharan et al. (2007) found that deprivation in one area had a negative influence on mortality in proximate neighbourhoods. Thus, they concluded that in Scotland (when using Carstairs scores) the spatial patterning of deprivation was strongly associated with SMRs for deaths under the age of 75. They clarify that this:

> "*is not the same as finding an association between mortality and deprivation across Scotland. It suggests that the actual spatial patterns of deprivation might be implicated in the levels of mortality* (Sridharan et al., 2007:1950).

Further research is therefore required to ascertain whether or not the spatial patterning of deprivation is different in other parts of Britain, and whether or not this contributes to excess mortality in Scotland generally and Glasgow specifically.

A disadvantage of Sridharan et al.'s (2007) approach is that by being based on areal units it is likely to have been sensitive to the modifiable areal unit problem (MAUP) highlighted in the work of Openshaw (1984). MAUP refers to the fact that relationships identified in data by aggregation to a set of areal boundaries (such as census output areas or postcode sectors) are dependent on the boundaries or scales used. These boundaries are often arbitrary and of an irregular shape. This is problematic because individual data has been aggregated into imposed areal units with the consequence that: "*the data values for each zone may be as much a function of the zone boundary locations as of the underlying distribution*" (Martin, 1989:90). The MAUP can also be understood as:

> "*geographic manifestation of the ecological fallacy in which conclusions based on data aggregated to a particular set of districts may change if one aggregated the same underlying data to a different set of districts*" (Waller and Gotway, 2004:104).

The visualizations and analysis produced by Sridharan et al. (2007) could therefore show patterns driven more by arbitrary boundaries than by actual patterns. The MAUP is an issue for all studies which use areal units, however it might have been exacerbated in Sridharan et al.'s work due to their use of postcode sectors as the areal unit. Postcode sectors cover a relatively large population[17], and have a population which is unlikely to have homogenous characteristics.

Despite these limitations, however, Sridharan et al.'s (2007) study is important as it indicates that the spatial arrangement of deprivation might be implicated in mortality levels. This indicates that it is entirely plausible that the spatial arrangement of deprivation in Glasgow might be a contributing factor to excess levels of morality. This plausibility is reinforced by evidence from other studies identified through a systematic search, discussed in the next section, which indicate that the spatial arrangement of deprivation can influence health outcomes.

3.4.2 The influence of the socio-economic context of surrounding areas on health – a systematic literature search

A systematic literature search was undertaken in September/October 2015 to identify previous research (in addition to that of Sridharan et al., 2007) undertaken examining the influence of the socio-economic context of surrounding areas on the health of an area. Two electronic databases, PubMed and Web of Science, were searched. The search terms used are shown in Table 0-9. Several studies of relevance to this review had previously been identified. From these it was apparent that there were opposing hypotheses for how and why the spatial arrangement of deprivation could influence health behaviours and outcomes: the psycho-social/relative deprivation hypothesis and the "pull up-pull down" hypothesis (these will be discussed in further detail below). These terms were therefore included in the search terms. To test the robustness of the search terms it was ascertained that all studies which had previously been

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[17] As indicated by the fact for the period of time covered by Sridharan et al.'s study, the population of Scotland was just over 5 million and there were 1040 postcode sectors in Scotland.

identified as relevant had been found using the search terms (shown in Table 0-9). As can be seen from Figure 0-5, this identified a total of 1,902 references. Once duplicates had been deleted this was reduced to 1,086 references. The titles of all the 1,086 references were screened to remove obviously irrelevant studies. This screening process was repeated with abstracts. As indicated by Figure 0-5, this reduced the number of references to 47. The full text of each of these 47 references was then reviewed. From this, 22 studies were indented as being potentially relevant.

- ‘spatial arrangement’ AND ‘deprivation’ AND ‘health’
- ‘spatial arrangement’ AND ‘poverty’ AND ‘health’
- ‘spatial pattern*’ AND ‘deprivation’ AND ‘’health’
- ‘spatial pattern*’ AND ‘poverty’ AND ‘health’
- ‘geographical pattern*’ AND ‘deprivation’ AND ‘’health’
- ‘geographical pattern*’ AND ‘poverty’ AND ‘health’
- ‘neighbouring deprivation’ AND ‘health’
- ‘neighbouring poverty’ AND ‘health’
- ‘spatial analysis’ AND ‘health’ AND ‘deprivation’
- ‘spatial analysis’ AND ‘health’ and ‘poverty’
- ‘pull up/pull down hypothesis’ AND ‘health’
- ‘relative deprivation hypothesis’ AND ‘health’
- ‘psycho-social hypothesis’ AND ‘deprivation’ AND ‘health’
- ‘psychosocial hypothesis’ AND ‘deprivation’ AND ‘health’.

Table 0-9 Search terms used to identify studies for the systematic review

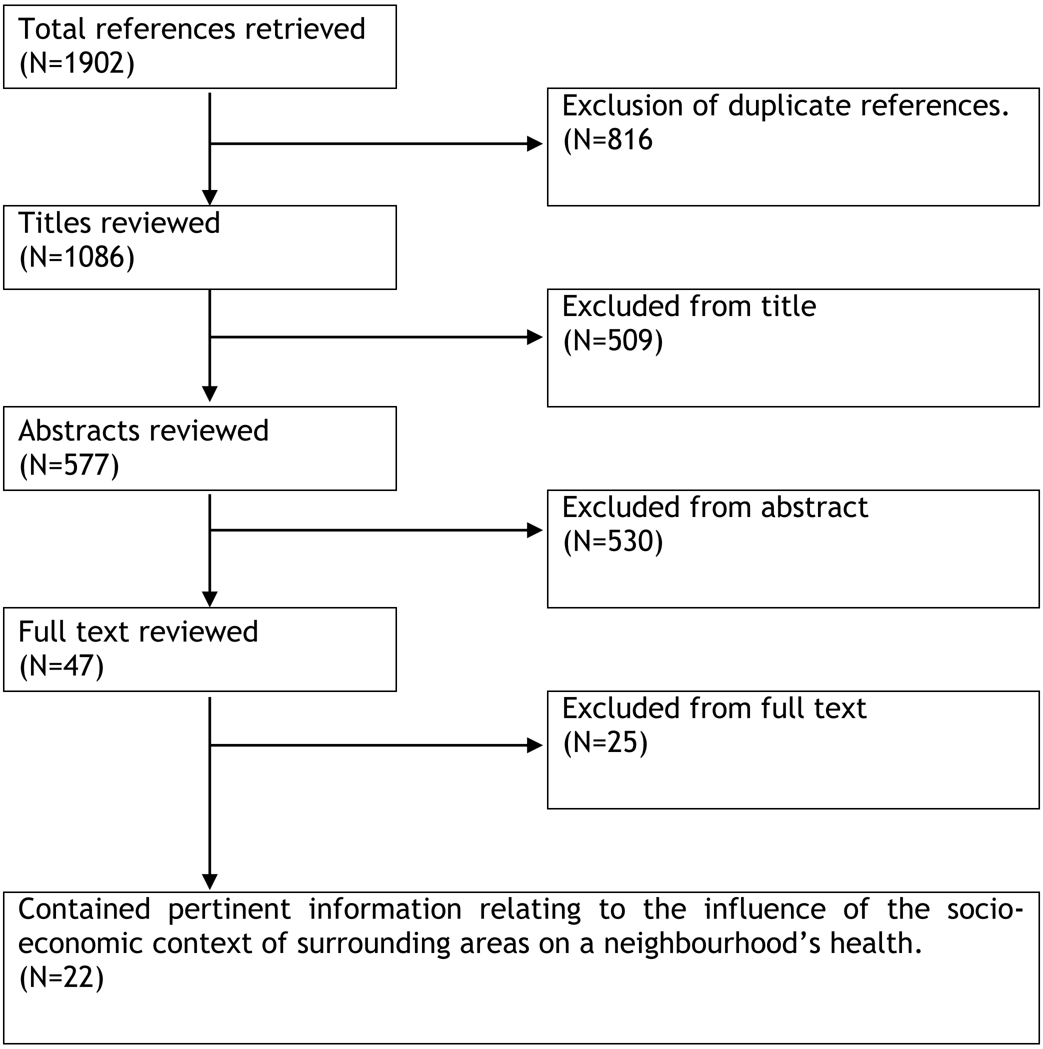

Figure 0-5 Systematic search flow chart

3.4.2.1 Findings from the systematic search

The systematic search of the literature found 22 peer reviewed journal articles containing information pertinent to enhancing understandings of the influence of the socio-economic context of proximal areas to an area's health outcomes. An analysis of these articles confirmed that two opposing hypotheses regarding the influence of the socio-economic context of surrounding areas have been postulated. The first is that living in a large concentration of deprivation (deprived areas surrounded by other deprived areas) has a negative influence upon health. Such areas have been termed areas of "*landlocked deprivation*" (Dunn and Cummins, 2007). The opposing hypothesis is that living in a deprived areas surrounded by more affluent areas can have a negative influence upon health. Such areas have been termed "*islands of deprivation*" (Dunn and Cummins, 2007) and "*socioeconomically isolated areas*" (Pearson et al., 2013).

The aims and themes of the 22 articles varied but can be broadly categorised into 4 groups:

- Group 1: Ascertaining whether an area's health outcomes are influenced by the presence of deprivation in spatially proximate areas (e.g. Sridharan et al., 2007).

- Group 2: Testing the competing hypotheses by investigating whether health outcomes are better in deprived areas surrounded by other deprived areas, or in deprived areas surrounded by non-deprived areas.

- Group 3: Testing the competing hypotheses by investigating whether the health behaviours and/or outcomes of individuals of a particular socio-economic group are influenced by living in an area categorised as having a different socio-economic profile (for example do people classified as having a low socio-economic status have better health behaviours if they live in a deprived area or a more affluent area?). Whilst such studies are not explicitly about the spatial arrangement of deprivation, they are relevant to understandings of how the spatial arrangement of deprivation might influence health. This is because understandings of different health outcomes experienced by deprived people living in a more affluent area, compared to deprived people living in a deprived area, may be applicable to small areas; it is feasible that a deprived individual living in an affluent area is comparable to an area which is an island of deprivation, and a deprived person living in a deprived area is comparable to an area of landlocked deprivation.

- Group 4: Examining whether difference in health outcomes of a selection of cities with similar socio-economic profiles are related to differences in the spatial patterning of deprivation within these cities.

The first group of studies has already been discussed above. Before moving onto discuss the evidence for opposing hypotheses (groups 2 to 4), the causal mechanisms underlying these hypotheses will be discussed.

3.4.2.2 Postulated causal mechanisms for how the spatial arrangement of deprivation might influence health: competing hypotheses

Reasons given in the literature for why large concentrations of deprivation/living in landlocked deprivation might have a negative influence on health tend to be based on 'collective resources' models. This is a neo-materialistic approach which implies that that living in 'landlocked deprivation' has a negative influence on health as more deprived areas are typically areas of under-investment. Consequently they are more likely to have poorer social, physical, and health infrastructures than less deprived areas (Cox et al., 2007). The larger the concentration of deprivation, the further people who live away from the edges have to travel to access these better facilities. The collective resources of such areas is therefore likely to be lower than that of 'islands of deprivation'. It could therefore be expected that poorer areas surrounded by more affluent areas would have better health than poorer areas surrounded by other poor areas.

This has also been referred to as pull up/pull down hypothesis (Cox et al., 2007; Livingston and Lee, 2014; and Zhang et al., 2011) which suggests that health outcomes in deprived areas are pulled up if they are in close proximity to more affluent areas, and that health outcomes in affluent areas are pulled down if they are in close proximity to less affluent areas. Cox et al. (2007) proffer that living in close proximity to more affluent areas might be beneficial due to increased exposure to social models of behaviour which have greater regard for health promoting behaviours, having better employment opportunities, and better access to facilities such as parks, health services, and reasonable food outlets. Being surrounded by areas of lower affluence might, Cox et al. (2007:1961) argue, have a negative effect on health due to the introduction of "*rather more negative social, economic and cultural lifestyle influences.*"

Strongly related to this is an idea put forward by Sridharan et al. (2007). They suggested that, because exposure to a deprived area can impact negatively on health, residing in a large expanse of deprivation might strengthen this impact due to having fewer "*opportunities to regularly 'escape' a deprived* *environment, to experience socially and physically other types of place*" (Sridharan et al., 2007:1943). That is, large geographical concentrations of deprivations might increase exposure to the negative effects of deprivation thereby strengthening its impacts and 'pulling down' health in such areas. Mulia and Karriker-Jaffe (2012) add to this by suggesting that this greater exposure to multiple forms of deprivation and lack of opportunity to escape could increase stress. Such stress is likely to directly cause some health problems, but could also indirectly cause health problems by encouraging poor health behaviours such as smoking, heavy drinking, and drug abuse. Mulia and Karriker-Jaffe (2012) refer to this as the 'double jeopardy' hypothesis.

The hypothesis that islands of deprivation have poorer than expected health outcomes is primarily based on psycho-social interpretations of health outcomes informed by debates on income inequality. The psycho-social model is based on the work of Wilkinson (2005) and Wilkinson and Pickett (2009), and proponents of this suggest that income inequality might have detrimental implications for health because poorer people might unfavourably compare themselves with others in the same society. This might result in them experiencing chronic low-level stress which could result in a physiological response affecting "*neuroendocrinic, physiological and immunological variables*" (Cox et al., 2007:1955).

Wilkinson (2005) and Wilkinson and Pickett's (2009) discussion on inequalities were based at the national level. However, it has been suggested that such social comparisons are also made at a more local level, such as within a neighbourhood or city (Astell-Burt and Feng, 2015). It is feasible, therefore, that those living in "islands of deprivation" have poorer health outcomes because of the proximal effects of inequality. This has also been called the relative deprivation hypothesis (Mulia and Karriker-Jaffe, 2012, Pearson et al., 2013).

Two further mechanisms through which relative deprivation might impact upon stress levels are highlighted by Pearson et al. (2013). First they argue:

> "*varying levels of deprivation across neighbourhoods may lead to community fragmentation and evidence suggests that these areas*

> *experience less volunteerism, less socialising and trust of others and associated declines in psychosocial function*" (Pearson et al., 2013:56).

Second, they draw attention to evidence that occurrences of racism and other forms of discrimination are increased by negative social interactions between affluent and deprived groups. Both of these have been associated with increased psycho-social stress (Pearson et al. 2013).

References will be made to these two hypotheses throughout the remainder of this study, summaries of which can be found in Figure 0-6 and Figure 0-7. Attention will now turn to a discussion of the empirical evidence relating to these two competing hypotheses.

Pull up/pull down hypothesis

Neo-materialistic approach, based on ideas of collective resources, which suggests that 'islands of deprivation' are likely to have better health outcomes that 'landlocked deprivation.' Proposes that being in close proximity to more affluent areas is advantageous as more affluent areas are likely to have better resources (such as health services, facilities such as parks, and employment opportunities) and 'healthier' social models of health behaviour.

Areas of landlocked deprivation, however, viewed as having a negative influence on health as large geographical concentrations of deprivation are likely to be under resourced. Greater exposure to the negative effects of deprivation is viewed as being likely to strengthen the impact of deprivation on health. Furthermore, exposure to multiple forms of deprivation and the lack of opportunity to escape this deprivation is perceived to increase stress, which, under the double jeopardy hypothesis, could encourage poor health behaviours and further impact upon health.

Figure 0-6 Pull up/pull down hypothesis –positive health benefits of islands of deprivation, negative effects of landlocked deprivation.

Relative deprivation hypothesis/psycho-social hypothesis

Proposes that those living in islands of deprivation will have poorer than expected health outcomes. This is due to ideas that more deprived people unfavourably compare themselves to more affluent people, resulting in stress which has can have a negative impact on health and health behaviours. Living in an island of deprivation means living in greater proximity to more affluent areas and thus is likely to increase exposure to more affluent people and areas – resulting in more psycho-social stress. Furthermore, it has been suggested that varying levels of deprivation and affluence in a neighbourhood can increase community fragmentation and also lead to an increase in negative social interactions between groups in society – thus further increasing the likelihood of experiencing stress.

Figure 0-7 Relative deprivation/psycho-social hypothesis - negative effects of islands of deprivation

3.4.2.3 The influence of the socio-economic context of surrounding areas on health – the evidence

The findings of research on the influence of the socio-economic context of neighbouring areas upon health outcomes within a deprived neighbourhood are mixed. Some studies have found better health outcomes in islands of deprivation and worse health outcomes in landlocked deprivation (and thus support the pull up-pull down hypothesis), whilst others have found the reverse (and thus support the relative deprivation hypothesis).

Research that has found support for the pull up/pull down hypothesis include that of Cox et al. (2007) and Maheswaran et al. (2009). Cox et al.'s (2007) study in Tayside examined whether incidence of Type 2 diabetes was higher in islands of deprivation or areas of landlocked deprivation. This is particularly pertinent to Type 2 diabetes as Cox et al. (2007) argue there is evidence that the development of Type 2 diabetes could be influenced by chronic stress leading to the over stimulation of neuroendocrine pathways. If, therefore, the relative deprivation hypotheses regarding people experiencing increased stress due to proximal and visible inequality is correct, it would be expected that this would be particularly apparent by islands of deprivation having higher incidence of

Type 2 diabetes relative to areas of landlocked deprivation. However, Cox et al. (2007) did not find evidence for this, rather they found evidence supporting the pull up/pull down hypothesis.

Cox et al. (2007) used data on Type 2 diabetes in Tayside drawn from the Diabetes Audit and Research Tayside Scotland (DARTS) dataset, and deprivation data[18] from the 2001 census as well as the Carstairs deprivation index. Their study was interested in incidence (not prevalence[19]) of Type 2 diabetes recorded between 1 January 1998 and 31 December 2001. The incidence for this period was 3,917. The geographical scale of analysis was 2001 census output areas[20]. Cox et al. (2007) measured deprivation inequality using a gravity model approach; this enabled the influence of all output areas within Tayside or within 20km of Tayside to be weighted. This was deemed superior to simply comparing deprivation scores between contiguous output areas, and, they argue, produced a "*genuinely contextual*" relative deprivation index. Cox et al. (2007) do not explicitly mention the UGCoP (indeed they were writing five years before Kwan (2012a, 2012b) first articulated the term); however, by using this gravity model they took into account the wider locality in which people live. Cox et al. (2007) then undertook a series of univariate negative binomial regression and multivariate regression models.

Cox et al.'s (2007) findings confirmed that Type 2 diabetes in Tayside was more common in deprived areas. Two other findings are of particular relevance to this study. First, incidence of Type 2 diabetes was lower than would be expected in deprived areas surrounded by areas which were relatively less deprived. To continue the "island" analogy, this means that "island of deprivation" had lower than expected incidence of Type 2 diabetes. Second, less deprived areas surrounded by relatively more deprived areas had higher than expected incidence of Type 2 diabetes.

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[18] Percentage of residents in households without a car, percentage of residents in overcrowded households, percentage of residents in households with a head of household in social class IV and V, unemployed males > 16 as a proportion of all residents >16.

[19] Incidence refers to the number of new cases diagnosed during a specific time period. Prevalence refers to all the cases of an illness or disease at a certain time point.

[20] The average size of Scottish Output Areas in the 2001 census was 50 households and 120 persons (Office for National Statistics, 2004).

Cox et al. (2007:1961) argue that their results for Type 2 diabetes in Tayside are "*compatible with a pull-up/pull down materialist hypothesis*". Living in close to proximity to more affluent areas therefore appears to "pull-up" the health of those living in more deprived areas. However, the health of people living in a more affluent areas appears to be pulled down if these areas are surrounded by less affluent areas.

Whilst Cox et al.'s (2007) study is important to this research in providing support for the pull up/pull down hypothesis, there are three potentially relevant limitations with Cox et al.'s (2007) research. First, they were unable to control for individual circumstances other than age and sex due to data availability. Consequently they were therefore unable to examine aspects such as length of exposure to the area of residence. It is feasible that this could have had an impact on the results. Second, and related to the idea of exposure, it is also feasible that levels of affluence in the area of residence might have changed thereby influencing the results. It is, for example, possible that affluent areas surrounded by less affluent areas had previously been more similar to the less affluent areas, and the pull-down effect was actually just a lag effect. Third, only one outcome was included – Type 2 diabetes. It is important to be aware that their results might have been different had other diseases been studied.

Maheswaran et al.'s (2009) study was interested in testing the use of graph theory in spatial epidemiology. The hypothesis was that areas of landlocked deprivation would have higher mortality levels than islands of deprivation. Their paper focused on the methods used to test this. Of interest, however, is that they found some evidence (in the area of England covered by the Trent Regional Health Authority) of deprived areas surrounded by other deprived areas (landlocked deprivation) having higher mortality levels than islands of deprivation. Maheswaran et al. (2009) noted, however, that with a p value of 0.07 their results were of "*borderline*" significance.

A limitation of Cox et al.'s (2007) study (discussed above) was that the findings might have been different had diseases other than Type 2 diabetes been included. Zhang et al. (2011) sought to overcome this limitation by using all-cause mortality, instead of a specific disease, in their examination of the influence of socio-economic conditions of neighbouring areas on health outcomes. Interestingly, their findings were "*the reverse of the relationship shown in Cox et al.'s study*" (Zhang et al., 2011:1270-1271). Whereas Cox et al. (2007) found that areas surrounded by more deprived areas experienced higher incidence of Type 2 diabetes, Zhang et al. (2011:1271) found that mortality increased with deprivation inequality so that the "*more deprived an area is compared with its surrounding areas, the higher the mortality rate.*" Using the island analogy, this means that Zhang et al.'s (2011) study indicates that 'islands of deprivation' have worse health outcomes than 'landlocked deprivation'.

A further interesting finding of Zhang et al.'s (2011) research was that deprivation inequality also had a negative impact on health outcomes in affluent areas. Mortality was shown to be higher in affluent areas in close geographical proximity to deprived areas, than in affluent areas further away from deprived areas. Indeed, Zhang et al. (2011) found that the effect of deprivation inequality on mortality was higher in affluent areas than in deprived areas. Whilst, therefore, contradicting the theory that deprived areas are "pulled up" by being in close proximity to affluent areas, these findings indicate that that affluent areas are "pulled down" by being in close proximity to deprived areas. Zhang et al.'s (2011) findings therefore contradict Cox et al. (2007) findings, and support the relative deprivation hypotheses that inequality can have a negative influence on health.

As well as examining a different health outcome to that of Cox et al. (2007), other aspects of the methods used by Zhang et al. also differed. The geographic location was England, and the spatial scale of analysis was larger as LSOAs, which have an average population of 1,500, were used. The measure of deprivation employed by Zhang et al. (2011) also differed slightly as, being a study of England, the IMD[21] for 2007 were used. It is therefore possible that differences between the finding of Cox et al. (2007) and Zhang et al. (2011) are due to these variations in methodologies.

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[21] As already discussed in the previous chapter the IMD and SIMD are similar but not directly comparable due to different weightings.

Support for the relative deprivation hypothesis also comes from the findings of Pearson et al.'s (2013) study examining spatial patterns of deprivation and rates of treatment for anxiety/mood disorders in Auckland (New Zealand). Using area level data, Pearson et al.'s (2013) study used spatial segregation methodologies to develop a socio-economic isolation[22] measure. The geographical unit of analysis used in their study was the 'meshblock' (MB). This was the smallest geographical area at which population and health data were available, and, on average, covered 0.04km^2 and had a population of 4093 (Pearson, et al., 2013). Pearson et al. (2013) extracted counts of people receiving care or treatment for anxiety/mood disorders for a 12 month period from July 2008 from the New Zealand Ministry of Health. They used 'NZDep' 2006 deprivation data[23] to rank meshblocks in Auckland, with the 33% most deprived being categorised as deprived (n=1040). Population weighted centroids were generated for each of the 33% most deprived meshblocks, and five minute walking buffers around these centroids were then calculated using network buffers. The influence of differing levels of affluence among proximal areas were prioritised using those distances. Pearson et al. (2013:161-162) then:

> "*translated the high to low deprivation levels into values for all MBs in Auckland, where high deprivation had a value of 0, medium deprivation had a value of 1 and low deprivation had a value of 2. Values for every centroid falling within each deprived buffer were totalled to yield an isolation score*."

These scores were then ranked into quintiles, with quintiles 4 and 5 being categorised as 'highly isolated' and quintiles 1 and 2 being 'non-isolated'. Regression analysis and T-tests were then undertaken by Pearson et al. (2013).

Pearson et al.'s (2013) findings supported the relative deprivation hypothesis. They found that as the level of isolation increased, the incidence rate ratio for anxiety/mood disorders also increased, with the most isolated area having a 50%

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[22] In this instance socio-economic isolation is the same as islands of deprivation.

[23] This is a New Zealand small area measure of socio-economic deprivation based on information from the 2006 New Zealand census.

higher incidence rate ratios than the least isolated areas. This led Pearson et al. (2013:164) to argue that:

> "*mental health within small areas may be sensitive to the types of interactions within walking distance of homes, through social comparison or feelings of discrimination which lead to psychosocial stress and subsequent mental health problems.*"

This finding therefore supports the relative deprivation hypothesis.

Another finding by Pearson et al. (2013), however, indicates that the relationship between anxiety/mood disorders and isolation in Auckland may not be as well defined as implied in their above statement. They found the most isolated areas had lower levels of dual diagnoses of drug/alcohol abuse and anxiety/mood disorder. Consequently, Pearson et al. (2013:164) postulate that:

> "*the most severe mental illnesses may be in deprived areas surrounded by similarly deprived places suggesting that alcohol and drug abuse may become norm or coping strategies in enclaves of deprived places.*"

Consequently, they provide some empirical evidence supporting the 'double jeopardy' hypothesis (see Figure 0-6).

Returning to the UK context, the findings of Allender et al.'s (2012) study, on coronary heart disease (CHD) mortality rates and deprivation inequality in small areas, supported the relative deprivation hypothesis. Allender et al. (2012) found that poor areas surrounded by rich areas (islands of deprivation) had worse CHD mortality rates than poor wards surrounded by other poor wards (landlocked deprivation). The same study also found that rich areas surrounded by poor areas (islands of affluence) had worse CHD mortality rates than rich areas surrounded by other rich areas (landlocked affluence). It therefore appears that in Allender et al.'s (2012) study poorer wards had a pull down effect on more affluent wards. Interestingly this was also found in Cox et al.'s study on incidence of diabetes in Tayside – despite Cox et al. (2007) finding the opposite to Allender et al. (2012) with regards to the influence of affluent areas on the incidence of Type 2 diabetes in deprived areas.

The findings of studies which have examined how the socio-economic context of surrounding areas impact on a neighbourhood's health outcomes have, therefore, been mixed. Some findings support the collective resources and pull up/pull down hypotheses (e.g. Cox et al., 2007 and Maheswaran et al., 2009). Other findings (e.g. Allender et al., 2012, Pearson et al., 2013, and Zhang et al., 2011), however, support the relative deprivation hypothesis. It appears that the relationships between a neighbourhood's health outcomes and its proximity to areas of more or less affluence are complex, and potentially dependent on other contextual factors.

The studies discussed above have all examined the influence of the socio-economic context of surrounding areas on the health outcomes of a neighbourhood. What these studies have not done, however, is to examine the general landscape of affluence and deprivation of an entire area (such as a city) and see if this has an influence on health. It is feasible that an examination of landscapes of deprivation and/or landscapes of affluence might shed light on this complex relationship. This is a theme which will be returned to later in this chapter.

3.4.2.4 The influence on health of having a different socio-economic profile to that of the area of residence – the evidence

As with the above section, the findings of investigations into the influence on health outcomes and/or behaviours of individuals residing in an area with a different socio-economic profile to that of themselves is mixed. Some studies have found that people of a low socio-economic status have better health outcomes/behaviours when they reside in an area with a higher socio-economic status. Others, however, have found the reverse. Consequently, amongst such studies there is support for both the pull up/pull down hypothesis and the relative deprivation hypothesis.

The findings of a very recent Australian study undertaken by Astell-Burt and Feng (2015), for example, support the pull up/pull down hypothesis. They tested the local relative deprivation hypothesis by examining how differences between an individual's socio-economic status and the socio-economic status of the area they resided in influenced the odds of experiencing psychological distress. Astell-Burt and Feng's (2015) findings supported the evidence discussed in the previous chapter that, at both the individual and area level, low socio-economic status is related to greater odds of people experiencing psychological distress. Of interest here, however, is that Astell-Burt and Feng's (2015:30) findings indicated that "*people on lower incomes tended to do better if they were resident in more affluent surroundings than their peers living in deprived neighbourhoods*" and that this difference was statistically significant. Their work therefore supports the pull up/pull down hypothesis. Interestingly these findings contradict those of Pearson et al. (2013), whose New Zealand study found that anxiety and mood disorders were more prevalent in areas of low income that were close to areas of higher income.

Mulia and Karriker-Jaffe's (2012) study examining the influence of neighbourhood socio-economic status and individual socio-economic status on alcohol consumption in the USA, however, provides support for the relative deprivation/psycho-social hypothesis. Whilst there may be different cultural influences on alcohol consumption in the UK and the USA, understandings of alcohol behaviour are of particular relevance to this study because, as was shown earlier, Glasgow's excess mortality is partly driven by alcohol related deaths (which Walsh et al. (2010a, 2010b) found to be 2.3 times higher than in Liverpool and Manchester). Mulia and Karriker-Jaffe (2012) classified adult respondents to the (American) National Alcohol Surveys of 2000 and 2005, with census linked data into three socio-economic status (SES) groups[24] – low SES, medium SES, high SES. The neighbourhoods in which individuals lived were also classified (using indicators from the 2000 census) into low SES neighbourhoods, medium SES neighbourhoods, and high SES neighbourhoods. The alcohol consumption of nine groups of people (shown in Table 3-10) was then compared.

Mulia and Karriker-Jaffe (2012) used both descriptive analysis and multivariate logistic regression to analyse their data, the particularly salient findings of which

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[24] Individuals were categorised into SES group principally by educational attainment; if, however, those categorised into medium SES or high SES had a household income below the federal poverty line, or had applied for welfare in the previous 12 months, they were reclassified as low-SES.

will be discussed here and are shown in Table 3-11. As can be seen in Figure 0-8, there were positive SES gradients in the prevalence of alcohol use at both the individual and neighbourhood levels. However, as shown in Table 3-11, this was found not to be the case with regard to alcohol consumption patterns associated with poor health outcomes: risk drinkers[25], alcohol problems[26], and monthly drinking[27]. From it can be Table 3-11 seen that Mulia and Karriker-Jaffe (2012) found that people of low SES living in high socio-economic neighbourhoods had the highest percentages of these three drinking behaviours. Mulia and Karriker-Jaffe (2012) found there to be a statistically significant difference ($p=<0.01$) for monthly drunkenness and alcohol problems but not for risk drinking. So, although a smaller percentage of individuals with low SES consumed alcohol relative to those of middle or higher SES, those of a low SES who did consume tended to consume more alcohol relative to people of middle or high SES. Also of note is that these findings showed that amongst respondents with a low individual SES, it was those that lived in areas with high neighbourhood SES that had higher alcohol consumption. Mulia and Karriker-Jaffe's (2012) findings therefore contradict the idea that health behaviours are likely to be better in islands of deprivation. Unlike Astell-Burt and Feng's (2015) findings that the mental health of low income individuals was better if they lived in more affluent areas (thus supporting the pull up/pull down hypothesis), Mulia and Karriker-Jaffe's (2012) results support the relative deprivation hypothesis. It is important to note, however, that when they used multivariate models to study males and females separately the results of their logistic regressions showed that support for the relative deprivation hypothesis "*pertained only to male drinkers, and not to women. In fact, there were not significant cross-level SES interactions found for women*" (Mulia and Karriker-Jaffe, 2012:184).

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[25] Defined by Mulia and Karriker-Jaffe (2012) as respondents who in the previous 12 months exceeded the National Institute on Alcohol Abuse and Alcoholism's low risk guidelines for daily and weekly alcohol consumption. This is expressed in Figure 0-8 as a percentage of respondents who had consumed alcohol in the previous 12 month period.

[26] Alcohol problems (also expressed as a percentage of respondents who had consumed alcohol in the previous 12 months) were categorised by using "*a dichotomous variable indicating whether the respondent either (a) experienced 2 or more of 15 negative consequences they attributed to their alcohol use, including social, legal, workplace or health consequences, and/or (b) reported experiencing at least one symptom in three or more of the seven domains of alcohol dependence as defined by the American Psychiatric Association (1994)*" (Mulia and Karriker-Jaffe, 2012:180).

[27] Monthly drinkers refers to respondents who had been drunk at least once a month in the previous year expressed as a percentage of those who had consumed alcohol in the previous year. This was viewed as an indicator of regular heavy drinking.

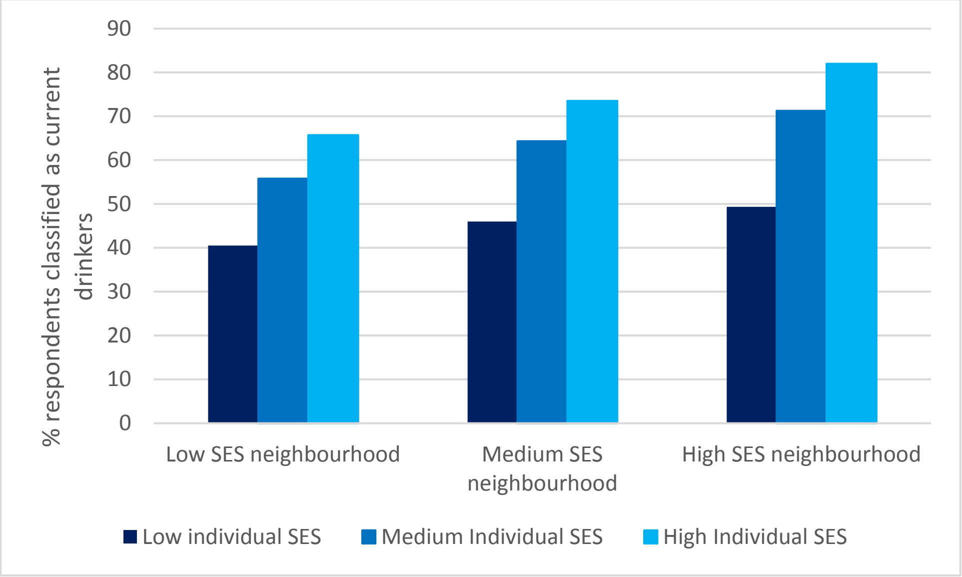

Figure 0-8 Percentage of respondents in the USA's National Alcohol Surveys for 2000 and 2005 who reported being current drinkers by individual and neighbourhood socio-economic status (Data taken from Mulia and Karriekr-Jaffe, 2012)

	Individual socio-economic status		
Neighbourhood socio-economic status	Low (n= 3115)	Medium (n=5990)	High (n=3956)
High (n=2953)	Low individual SES living in high SES neighbourhood (n=262)	Medium individual SES living in high SES neighbourhood (n=1131)	High individual SES living in high SES neighbourhood (n=1560)
Medium (n=6369)	Low individual SES living in medium SES neighbourhood (n=1287)	Medium individual SES living in medium SES neighbourhood (n=3327)	High individual SES living in medium SES neighbourhood (n=1755)
Low (n=3739)	Low individual SES living in low SES neighbourhood (n=1566)	Medium individual SES living in low neighbourhood SES (n=1532)	High individual SES living in low neighbourhood SES (n=641)

Table 0-10 The 9 groups of people in Mulia and Karriker-Jaffe's (2012) study on alcohol consumption. (Source: table constructed from information provided in Mulia and Karriker-Jaffe, 2012).

Neighbourhood socio-economic status	Individual socio-economic status		
	Low (n= 3115)	Medium (n=5990)	High (n=3956)
High (n=2953)	**Risk drinking = 50.2%** **Alcohol problems = 11.8%** **Monthly drunkenness =22.2%** (n=262)	Risk drinking =41.5% *Alcohol problems =2.4%* Monthly drunkenness =8.4% (n=1131)	Risk drinking =38.5% Alcohol problems =2.8% Monthly drunkenness =7.5% (n=1560)
Medium (n=6369)	Risk drinking =39.1% Alcohol problems =7.9% Monthly drunkenness =11.7% (n=1287)	Risk drinking =40.2% Alcohol problems =3.9% Monthly drunkenness =8% (n=3327)	Risk drinking =37.7% Alcohol problems =2.7% Monthly drunkenness =9.2% (n=1755)
Low (n=3739)	Risk drinking =44.6% Alcohol problems =11.7% Monthly drunkenness =13.1% (n=1566)	Risk drinking =38.1% Alcohol problems = 6% Monthly drunkenness =7.9% (n=1532)	*Risk drinking =36.6%* Alcohol problems =6.4% *Monthly drunkenness =6.8%* (n=641)

Table 0-11 Drinking behaviour of people who had consumed alcohol in the previous 12 months: results from Mulia and Karriker-Jaffe's (2012) study. (Source: table constructed from information provided in Mulia and Karriker-Jaffe, 2012).

As was discussed earlier and shown in Table 0-7, deaths from alcohol related causes are one of the prominent drivers of excess mortality in Glasgow. Mulia and Karriker-Jaffe's (2012) analysis of the relationship between drinking behaviours, and individual SES and neighbourhood SES, provide an insight into how this might be impacted by the spatial arrangement of deprivation. Although they were looking at groups of individuals rather than areas, the principle might apply at a small local scale. On the basis of Mulia and Karriker-Jaffe's (2012) study, therefore, it is therefore entirely plausible therefore that Glasgow's high alcohol death rates are influenced by its spatial arrangement of deprivation. If this is the case it would be expected that this study would find that areas of deprivation are more dispersed in Glasgow than in Liverpool and Manchester.

3.4.3 Section summary

This section has discussed evidence and hypotheses of causal mechanisms for how the spatial arrangement of deprivation can influence health outcomes. The relative deprivation hypothesis propose that living in an island of deprivation has a negative effect on health due to the proximal effects of inequality. However, based on neo-materialist thinking an opposing hypothesis is that living in an island of deprivation has a beneficial effect on health. Often referred to as the pull up/pull down hypothesis, proponents of this argue that those living in islands of deprivation benefit from higher collective resources of nearby affluent area, and possibly through adopting beneficial health behaviours more commonly found in affluent areas. The evidence is mixed and contradictory with some studies finding evidence in favour of the relative deprivation hypothesis and others finding support for the pull up/pull down hypothesis. What this does, however, indicate is that the spatial arrangement of deprivation can influence health, and could, therefore, be a contributing factor to Glasgow's health outcomes.

Having demonstrated that is possible that the spatial arrangement of deprivation could be a contributory factor to Glasgow's excess mortality, the focus of this review will now move onto discuss a study which has specifically explored whether the spatial arrangement of deprivation is different in Glasgow to that of the Liverpool and Manchester.

3.5 Is there any evidence that the spatial pattern of deprivation is different in Glasgow to other cities?

Livingston and Lee (2014) tested the specific hypothesis that the contemporary geographical patterning of deprivation in Glasgow could be a contributory factor for the excess mortality observed in the city compared to Liverpool and Manchester. Using cross-sectional data at the neighbourhood scale for the period 2003 to 2007, they compared the spatial arrangement of deprivation in Glasgow, Liverpool, and Manchester. Despite both England and Scotland having established indices of deprivation[28], Livingston and Lee (2014) recognised that these are not directly comparable. To overcome comparability issues they instead used the same measure of income deprivation used by Walsh et al. (2010a, 2010c, 2010b). They also used the same all-cause mortality and population data for 2003-2007, and the same areal units used by Walsh et al. (2010a, 2010b).

Livingston and Lee (2014) ascertained that Glasgow’s spatial pattern of deprivation in the mid-2000s was different to that observed in Liverpool and Manchester. However, rather than Glasgow having larger and more concentrated deprived areas as hypothesised by McCartney et al. (2012a), they found Glasgow had more spatially *dispersed* deprivation (as was suggested in section 3.4 and the maps in Figure 0-4). Livingston and Lee (2014) also confirmed a small positive association between mortality in a neighbourhood (where neighbourhood was defined by small area units with an average population of 1,500 people), and levels of deprivation in surrounding neighbourhoods.

Livingston and Lee’s (2014) work indicates that, in the mid-to-late 2000s, the spatial arrangement of deprivation in Glasgow was different to that observed in Liverpool and Manchester. Their work provided an important first exploration of spatial patterning of deprivation in Glasgow and its relationship with health. Their study, however, is subject to some methodological problems common to other studies discussed in this chapter examining the spatial arrangement of deprivation and health, problems discussed in the next section.

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[28] Indices of Multiple Deprivation (IMD) in England, and Scottish Index of Multiple Deprivation (SIMD) in Scotland.

3.6 Common methodological problems with studies examining the spatial arrangement of deprivation and health

The studies discussed in this review which examined the relationship between the arrangement of deprivation and health were subject to three common methodological problems. The first is the modifiable areal unit problem (MAUP) (as discussed in section 3.4.1). Without individual level data and mapping the spatial arrangement of deprivation household by household, the MAUP is likely to be inevitable. There should, however, be ways of mapping the data which minimises the effect of MAUP.

Second (as discussed in section 3.4) the uncertain geographic context problem is also likely to have been an issue and is known to be particularly salient in studies examining neighbourhood effects on health (Kwan 2012a, 2012b). This issue could be addressed by simply using larger spatial units, however the benefits of doing so would be outweighed by problems related to the accompanying loss of detail. To recognise that the wider context is important, but to retain the nuance of finer scale variation, ecological understandings of the concept of ‘landscape’ can be very useful. Concepts of landscape will be explored in further detail in chapter 5, but it is worth noting here that landscapes in ecology are understood to be spaces comprised of interacting ecosystems (Leitao et al., 2006). Ecological landscapes can be of any scale, but what is important is that they are spatially heterogeneous. Cities are units of space (defined by city boundaries) which are spatially heterogeneous both in terms of land use, landforms, and demographics. An ecological lens could therefore be used to view cities whereby rather than examining biological ecosystems making up the landscape, the focus is on the mosaic of neighbourhoods making up the city landscape. Using a landscape perspective to view the city would therefore enable the wider context to which people are exposed to be studied, but without the loss of detail associated with studying small areas.

Third, these studies have all been cross-sectional. As has already been discussed, excess levels of mortality in Glasgow not directly attributable to deprivation can be observed from the 1970s. Cities may often be built with stone, however, their physical and socio-spatial structure are not set in stone. Cities are dynamic environments subject to changes in their built environment and social structure as a result of global, national, and local factors. It is therefore entirely plausible, and highly probable, that the socio-spatial arrangement of deprivation has changed over time in Glasgow, Liverpool, and Manchester since the emergence of the excess mortality in Glasgow in the 1970s. Livingston and Lee (2014) ascertained that in the mid-2000s the spatial arrangement of deprivation was more dispersed in Glasgow than in either Liverpool or Manchester. However, this does not necessarily mean this was the case in 1970s, 1980s, or 1990s. A longitudinal approach is therefore required to ascertain whether the spatial arrangement of deprivation developed differently across the cities. Furthermore, it is well known in epidemiology that there is often a lag effect between exposure and the onset of disease (Rachet et al., 2003). Indeed, with regard to income inequality Blakely et al. (2000) and Subramanian et al. (2004) suggested that the lag effect of income inequality on health was 15 years. A longitudinal study is therefore advantageous as it is more likely to identify lag effects and in trying to infer causality.

3.7 Chapter summary

This chapter has demonstrated that Glasgow has poor health outcomes relative to other parts of Western Europe and the UK. Until recently the canonical explanation for this was deprivation. However, through comparisons with two cities with similar deprivation profiles (Liverpool and Manchester) that deprivation does not account for all of Glasgow’s high mortality. Indeed, Glasgow has an excess of mortality to what would be expected for a city with its deprivation profile. One hypothesis which has been proposed is that the spatial arrangement of deprivation is different in Glasgow to that of other cities, and that this is a contributory factor to Glasgow’s excess mortality.

Section 3.4 reviewed recent literature identifying and exploring relationships between the spatial arrangement of deprivation and health. It commenced with a discussion of the two opposing hypotheses put forward to explain the causal mechanisms through which the socio-economic context of surrounding areas could influence the health outcomes of an area. The first is based on psycho-social interpretations of health outcomes which have informed debates on income inequality. Termed the relative deprivation hypothesis, this postulates that less affluent people are likely to unfavourable compare themselves to more affluent people living nearby, and this might lead to low level stress. Such stress might have a physiological impact upon them and thus be detrimental to their health. The relative deprivation hypothesis, therefore, suggests that deprived areas surrounded by more affluent areas (islands of deprivation) are likely to have worse health outcomes than deprived area which are part of a large concentration of deprivation (landlocked deprivation).

The opposing hypothesis, primarily based on a collective resources model, postulates that landlocked deprivation has a negative influence on health, and will experience poorer health outcomes than islands of deprivation. Known as the pull up/pull down hypothesis, this suggests that deprived areas are often areas of underinvestment with less access to social and physical infrastructures and resources which aid health. The larger the deprived area, the further people who live away from the edge have to travel to access better facilities. The pull up/pull down hypothesis suggests, therefore, that the collective resources of such areas are likely to be “pulled down” and lower than for islands of deprivation which are likely to benefit from, and be “pulled up” by, being in close proximity to more affluent areas. Furthermore, it has been suggested that large spatial concentrations might further pull down health due to the negative effects of greater exposure to deprivation which might cause further stress and lead to poor health behaviours.

There is evidence for both the relative deprivation hypothesis (Zhang et al., 2011, Mulia and Karriker-Jaffe, 2012, Pearson et al., 2013) and the pull up/pull down hypothesis (Cox et al., 2007, Maheswaran et al., 2009, Astell-Burt and Feng, 2015). This somewhat contradictory evidence shows that there is not a consensus in the literature regarding whether the islands of deprivation have better health outcomes relative to landlocked deprivation, or vice versa. Potential reasons for these differences include contextual differences, methodological differences, cultural differences, and differences related to the disease or outcome being studied. Regardless of why the evidence appears contradictory, what it does do is indicate is that the spatial arrangement of poverty, deprivation, and affluence appears to influence health, and might be implicated in explaining Scottish variations in mortality rates. It is therefore feasible that the spatial arrangement of deprivation in Glasgow is a contributory factor to Glasgow’s excess mortality. If this is the case, it would be expected that Glasgow has a different spatial arrangement of deprivation than other similar cities, such as Liverpool and Manchester.

An important first exploration of the spatial arrangement of deprivation in Glasgow and its relationship with health is provided by the work of Livingston and Lee (2014). Their study ascertained that in the mid-2000s the spatial pattern of deprivation observed in Glasgow was different to that observed in Liverpool and Manchester. However, rather than supporting McCartney et al.’s (2012a) hypothesis that Glasgow had more concentrated and larger areas of deprivation, Livingston and Lee (2014) found deprivation was more spatially dispersed in Glasgow. They also found a small positive association between mortality in neighbourhoods in Glasgow and levels of deprivation in surrounding neighbourhoods.

To further explore whether the spatial arrangement of deprivation in Glasgow could contribute to its excess mortality a longitudinal analysis of the spatial patterns of deprivation in Glasgow needs to be undertaken and the results compared with other comparable cities. A longitudinal study is necessary given the lag in some causes of mortality, and the rapid changes experienced in the last few decades.

Chapter 3 : Methods

4.1 Introduction

This chapter details the methods employed in this study to ascertain whether the spatial arrangement of deprivation developed differently in Glasgow to that observed in Liverpool and Manchester. It commences by providing the rationale for studying the time period between 1971 and 2011, and the selection of Liverpool and Manchester as comparator cities, before moving on to discuss different ways of measuring deprivation and explaining why particular census data were used to provide an indication of deprivation in this study. Difficulties associated with mapping deprivation, and in particular mapping census data, will then be discussed and it will be shown that a new method was required to do this. The novel method used in this study to map census data using surface mapping will then be introduced, and the decisions relating to how this was achieved discussed.

4.2 Selecting 1971 to 2011 as period of study

The time period examined in this study was from 1971 to 2011. This decision was primarily driven by the literature on deprivation and mortality in Scotland generally, and Glasgow specifically. As discussed in the literature review, the empirical evidence indicates that the mortality gap between Scotland, and England and Wales started to increase during either the 1970s or the 1980s. Campbell et al. (2013), for example, provide evidence that the divergence in these mortality rates commenced in the 1970s. Furthermore, the literature also indicated that around the same time 'excess mortality'[29] levels started to increase in Scotland. Hanlon et al. (2001), for example, argue that the proportion of Scotland's higher mortality levels (relative to England and Wales) explained by deprivation decreased between 1981 and 1991. Meanwhile, Walsh et al. (2010a, 2010b) provide evidence that, relative to Liverpool and Manchester, excess mortality has been increasing in Glasgow since the 1970s. As it appears, therefore, that differences in Glasgow started to emerge in the

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[29] Mortality not directly attributable to deprivation.

1970s, it was logical to examine the development of the spatial arrangement of deprivation from the 1970s.

Practical reasons, did however, also influence this decision. Whilst background research could be (and was) done on the cities to gain an idea of socio-spatial structure of the three cities prior to the 1970s, maps of the same high quality could not be produced for that time using the method adopted by this study. This was for two reasons. First, the method used here is dependent on population weighted centroids; these were not available for the census pre-1971. Second, prior to 1971 the relevant census variables were not available (Norman, 2016).

4.3 Selection of Liverpool and Manchester as comparator cities

To assess if Glasgow's spatial arrangement of deprivation developed differently to elsewhere, comparator cities were required. The rationale for selecting Liverpool and Manchester was twofold. First, as indicated in the literature review, there is already a growing body of literature (Walsh et al., 2010a, 2010b, Livingston and Lee, 2014) comparing health outcomes in Glasgow to these cities. This literature supports the assertion that Liverpool and Manchester are good comparators for Glasgow due to their similar demographic and deprivation profiles. Furthermore, by also using these cities, it is hoped that this research can contribute to this growing body of literature. Second, background research using secondary data sources confirmed the strong similarities between the three cities regarding their demographic profiles, and also that they had very similar socio-economic histories.

4.3.1 Similar demographic and deprivation profiles

As discussed in the literature review, using 2005 data, Walsh et al. (2010a, 2010b) ascertained that Glasgow, Liverpool, and Manchester had almost identical levels of income deprivation (24.8%, 24.6%, and 23.4% respectively) and a very similar distribution of income deprivation across the small areas of each city – as shown in Figure 3-1. Furthermore, as highlighted by Walsh et al. (2010a, 2010b), data from Sheffield University's 'Breadline Britain' study (Dorling et al., 2007) shows that in both 1970 and 2000 the three cities had very similar proportions of their population classified as core poor. Walsh (2014:178:179) demonstrated that:

> "*(a)lthough there were some fluctuation in rates between those years, with slightly higher figures in Glasgow in 1980 and 1990, the differences between the cities over the whole period were slight.*"

This indicates that throughout the time period of interest to this study deprivation levels were very similar in all three cities.

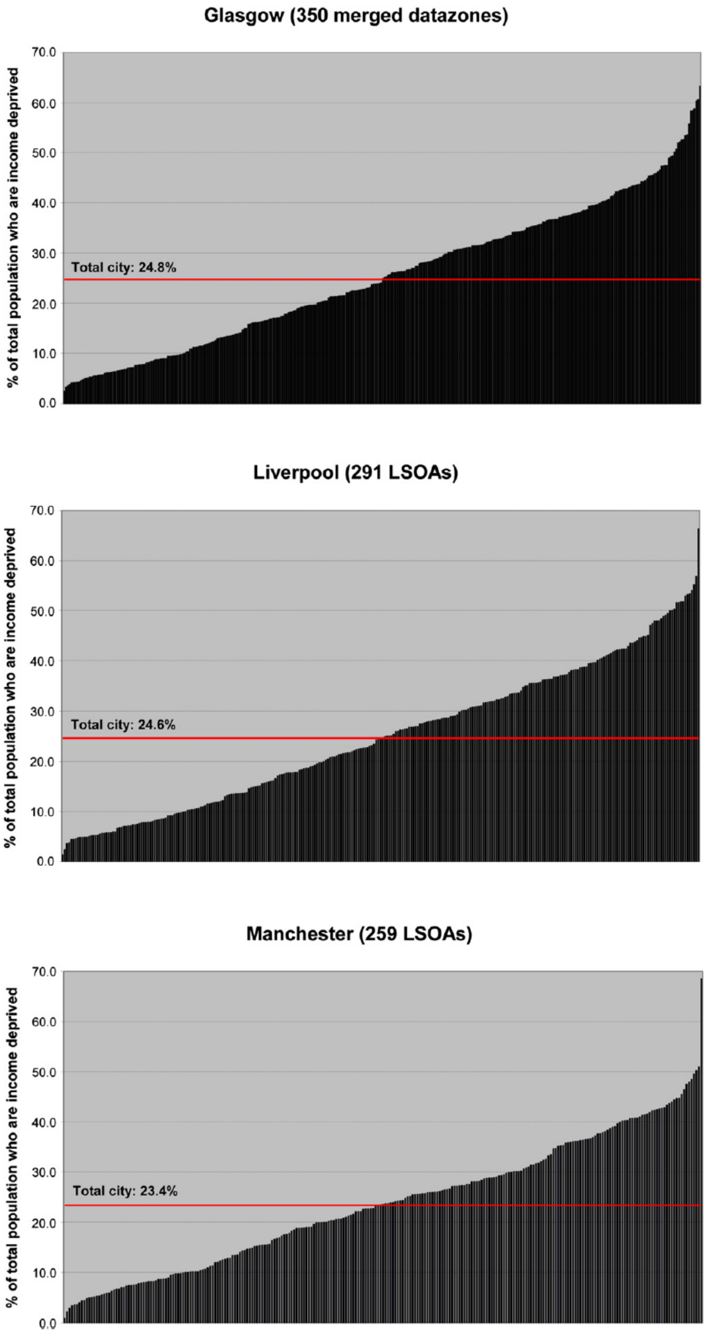

Figure 3-1 Distribution of 'income deprivation' across Glasgow, Liverpool and Manchester, showing the proportion of the total population in each of the cities' small areas classed as 'income deprived'. (Taken from Walsh et al., 2010a: 490)

4.3.2 Similar socio-economic histories

A literature search identified multiple sources detailing development of the individual cities' socio-economic histories and spatial developments. Civic surveys and planning reports for the cities were also consulted as they provided socio-economic and demographic information on the cities at particular time points (and were often the source of information supporting the written city histories). Information from all these sources was used to identify significant events and influences, dating back to the 19th century, which impacted upon the development of the cities. This background research, confirmed the assertions of others (for example Walsh et al., 2010a, 2010b) that the three cities share similar socio-economic histories. In essence it demonstrated that Glasgow, Liverpool, and Manchester each experienced rapid industrialisation and population growth in the 19th century. Changes in technology and the global economy in the 20th century, however, resulted in the decline of industry in all three cities. This process of deindustrialisation was particularly important during the second half of the 20th century and, as can be seen from Figure 3-2, resulted in significant loss of industrial employment.

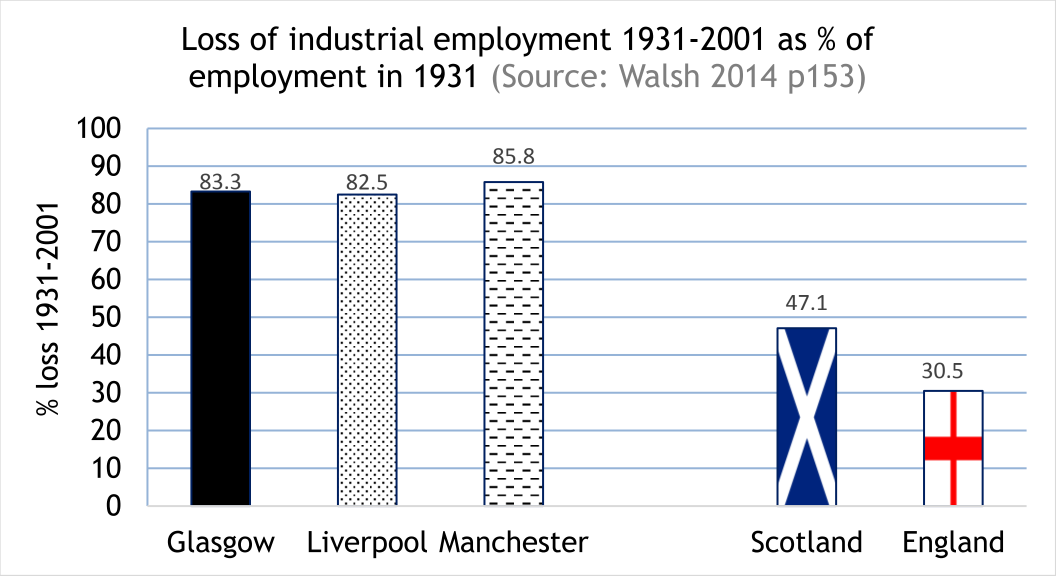

Figure 3-2. Loss of industrial employment 1931-2001 as % of employment in 1931. (Source: data from Walsh, 2014:153.)

It was also evident that Glasgow, Liverpool, and Manchester were all subject to large scale urban change in the 20th century. This involved comprehensive slum clearance schemes and the construction of new housing (on both the land of the former slum housing and in new areas of the cities). This had started in the interwar period and was particularly influenced by the interwar Housing Acts. The 1919 ‘Housing of the Working Classes’ Act (known as the Addison Act), for example, placed a duty on local authorities to consider housing needs and gave financial incentives from central government to local authorities to build subsidised housing (Pooley and Irish, 1984). However, the scale of urban change was most dramatic in the second half of the 20th century and involved the comprehensive redevelopment of large areas and the movement of people to newly built housing schemes both within the cities, as well as out of the cities in new towns or overspill developments (Checkland, 1976, Markus, 1999, Pacione, 1995, Sykes et al., 2013, Williams, 1996). Moreover, the three cities all experienced high levels of public sector housing construction between 1945 and 1975 relative to other British cities. Expressed as a rate per 1,000 dwellings in 1951, this figure was 365 in Glasgow[30], 346 in Liverpool, and 338 in Manchester (Taulbut et al., 2016:26).

Background research therefore confirmed the assertions of others (including Walsh et al., 2010a, 2010b) that as well as having similar deprivation profiles, Liverpool and Manchester's similar socio-economic histories make them good comparator cities.

4.4 Selection of city boundaries

As all three cities experienced boundary changes over the time period being studied, it was necessary to select which definition of city boundaries would be used. The local authority boundary for each of the cities at the time of the 2001 census was selected and the rationale for this was two-fold. First, at the time work commenced on this study, the most recent available census information was for 2001. It was therefore logical to use the boundaries which matched the data. Furthermore, a comparison of the 2001 and 2011 boundaries revealed that Liverpool and Manchester's boundaries had not changed between these times; Glasgow's boundary had been slightly altered, but the impact of this was likely to be minimal and not affect the results of the study[31]. Second, this was the

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[30] Using the post-1974 boundary (which is larger than the 2001 boundary used in this study) and includes the towns of Rutherglen and Cambuslang (which are not within the 2001 boundary). If Rutherglen and Cambuslang are excluded the figure for Glasgow rises to 387 per 1,000 (Taulbt et al., 2016).

[31] The largest change to Glasgow's boundary was the loss of an area about 2km^2 at the western edge of the south bank of the River Clyde which is the location of the Braehead Shopping Centre.

same boundary definition used by Walsh et al. (2010a, 2010b) in their work identifying the presence of excess mortality in Glasgow, rendering this analysis directly relevant to their work.

4.5 Measuring deprivation

Before deprivation can be mapped it has to be measured. A number of different methods have been used over the years to gauge levels of affluence and deprivation at both individual/household and area level; some of these have been single variable measures, whilst others have been multivariate. Exploring these measures of deprivation led to the conclusion that a measure of deprivation which incorporated a variety of indicators was preferable, such a measure also needed to be comparable between the three cities, show spatial patterns, and be valid over time. Ideally indicators of deprivation would have been obtained for each household in each city at each time point, as this would have enabled a very detailed, house by house, street by street, assessment and mapping of deprivation. As such data are unavailable an alternative was required; the alternative selected was census data. This section discusses the available options for measuring deprivation, and justifies both the use of census data in this study and the specific census variables used.

4.5.1 Established measures of deprivation

4.5.1.1 Occupational class

Occupational class has been used for over a century in the UK as a measure of poverty, particularly in studies related to public health and health inequalities. Chadwick, for example, used occupational class to compare health outcomes of different groups in society in his 1842 report “The Sanitary Condition of the Labouring Population”. In a similar vein (albeit it much more developed), occupational category was used in The Black Report and the Acheson Report (amongst others) as an indicator of socio-economic position. Doing so enabled these reports to highlight socio-economic health inequalities. Using occupational groups as an indicator of socio-economic position is, however, subject to criticism. Such criticisms include the theoretical basis of occupational groupings being subjective, and for not accounting for temporal changes in occupational structure (such as increases in the number of women working and increases in service sector employment (Galobardes et al., 2006)). For the purposes of this study, occupational groups were not used as a) the study is looking over time, and it was not clear how era-appropriate occupational groups could be constructed, and b) they were also not felt to capture additional important aspects of individual deprivation.

4.5.1.2 Income thresholds and poverty lines

The use of income thresholds and "poverty lines" are another well-established method of using a single variable to define whether or not both households and areas are poor. In the late 19th and early 20th century Rowntree, for example, (as highlighted in the literature review) pioneered the use of a poverty threshold to identify households in absolute poverty. He estimated the cost of a nutritionally adequate diet and the cost of clothing and rent, and those with an income less than this value were defined as being in primary poverty (Ruggeri Laderchi et al., 2003). More recently it has become common place for governments to measure relative deprivation by setting a poverty line which "*is a fixed fraction of the central tendency of the income distribution*" (Niemietz, 2011:41). The poverty line can therefore fluctuate depending on the incomes of others. The European Union and the UK government use such an income threshold approach to define who is/is not in poverty and thus likely/unlikely to be deprived, setting this threshold at 60% of median household income (Dorling and Ballas, 2008; Kangus and Ritakallio, 2007). Whilst this 60% is an internationally recognised threshold, it is arbitrary; consequently who is defined as being in or out of poverty is also arbitrary. Further, using just income as a measure of deprivation is also problematic as it does not take into account other assets or debts that households might have, both of which impact on whether or not a household is living in deprivation. It is possible for people to have a low income but have a high levels of assets (such as housing). Rowlingson (2008) explains that this is often referred to as being "*asset-rich but income poor*" and particularly applies to some retired households[32]. Using an income threshold alone such people could be classified as deprived.

Income has also been used in some studies to measure *area* deprivation. Studies (such as the 2010 Marmot Review and Fone et al., 2007) have used "neighbourhood income deprivation" – measured by the percentage of households in a neighbourhood who have low incomes – to gauge area deprivation. Whilst using income deprivation is an established method of gauging area deprivation, income alone is somewhat limited as it does not take into account other aspects of area deprivation, such as crime and education, which are also (as detailed in the literature review) important components of area deprivation.

Despite these criticisms of income based measures of deprivation, they are reputed to be the best single measure of deprivation and have been shown to be highly correlated to multi-variate measures (discussed below) in both Scotland and England (Livingston and Lee, 2014, Walsh et al., 2010b). Such an approach could not, however, be used in this study due to the total absence of fine scale, geographically comprehensive data describing the spatial distribution of deprivation over time, across the three cities.

4.5.1.3 Multi-variate measures

Over the last 40 years several different measures have been developed which examine *area* deprivation from a broader perspective. These include the Carstairs Index, the Townsend Index, Scottish Index of Multiple Deprivation (SIMD), and the English Indices of Multiple Deprivation (IMD). Carstairs and Morris (1989, 1991) developed an area based index of relative deprivation using small area census data on low social class, lack of car ownership, overcrowding, and male unemployment. By doing so they produced scores (at the small area level) reflecting material resources which provided access to "*those goods and services, resources and amenities of a physical environment which are customary in society*" (Carstairs and Morris, 1991). Their index, known as the

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[32] A retired couple, for example, may have paid off their mortgage (and thus own their house outright) and/or have savings (so be asset wealthy), yet their pension income could be low.

Carstairs Index, has been widely used and until recently was the principal measure of deprivation utilised in Scottish epidemiological analyses (Walsh, 2014) and was used in some of the studies discussed in the literature review, including Hanlon et al. (2001, 2005) and Leyland et al. (2007).

A similar method of measuring area deprivation was developed by Townsend et al. (1988). The Townsend Index incorporates four variables – unemployment (as a percentage of those who are economically active), households not owning a car, households not owning their house, and household overcrowding – to ascertain whether an area is deprived relative to other areas. This method was used in Norman et al.'s (2011) study, discussed in the literature review. Just as the Carstairs Index was widely used in Scottish epidemiological analyses, the Townsend Index was widely used in English epidemiological analyses.

A limitation of both the Carstairs Index and Townsend Index is that both used census data and so could only be updated decennially. However, multivariate measures of deprivation have significantly evolved over the last decade with the development of multivariate indices (the SIMD in Scotland, and the IMD in England). These are not reliant on census data and can be updated at regular intervals. As well as providing information at a smaller spatial scale than was done by previous indices, they include a greater number and variety of indicators. For example, the first SIMD (published in 2004) brought together 31 different indicators across 6 domains: income, employment, health, education, housing, and access (Scottish Executive, 2005). The most recent (2012) SIMD has 38 indicators across 7 domains: income, geographic access to services, education, housing, crime, employment, and health (Scottish Government, 2014). Similarly, the most recent IMD (2015) used data on 37 different indicators across 7 domains: income deprivation, employment deprivation, health deprivation and disability, education skills and training deprivation, crime, barriers to housing and services, and living environment deprivation (Department for Communities and Local Government, 2015). The SIMD and IMD's use of this range of variables recognises that that deprivation is a multi-dimensional concept and provides a more comprehensive picture of area level deprivation.

Regular measuring of deprivation using the SIMD and IMD has greatly enhanced the ability to compare maps of deprivation temporally. However, as the first

SIMD and IMD were undertaken in 2004 and 2007 respectively, the information they provide is currently only available for a short timeframe. They are, therefore, not suited to longer timeframes of study, something which would be pertinent to understanding the origins of Glasgow's excess mortality. Furthermore, differences in content and component weighting mean they are not directly comparable (Livingston and Lee, 2014) and therefore not suitable for comparing deprivation between Scotland and England. The SIMD and IMD were, therefore, not suitable sources of deprivation information for the purposes of this study.

4.5.2 Census data

Although limited by only being available every ten years, the only spatially comprehensive and comparable data source extending back to the last century is the UK decennial census. Whilst the UK census does not directly identify who is and is not deprived, indicators of social profile provided by the census can be used as proxy measures (Slogget and Joshi, 1998). As was discussed above, variables within it have been reliably used to indicate deprivation, for example the Carstairs and Morris Index (1989). Norman (2010) also used census data to compare area level deprivation over time. Census based measures of deprivation can also be advantageous as census questions remain relatively consistent over time and across constituent parts of the UK, thus enabling temporal and spatial comparisons (Allik et al., 2016).It was therefore decided that census data would be used as indicators of deprivation to identify areas where there were high levels of households experiencing deprivation.

4.5.3 Selection of census data

It was important to select appropriate census variables which would be valid indicators of deprivation, and, to ensure temporal consistency, be available at all time points from 1971 onwards. Among existing measures of deprivation there is a general consensus that they should include indicators of:

> "*(un-)employment, material wealth such as car ownership or income, indicators of socioeconomic position, particularly education and occupation, and housing conditions such as overcrowding, home ownership or renting from a public authority*" (Allik et al., 2016:123).

Therefore, informed by the literature, and specifically following others (Carstairs and Morris, 1991; Townsend 1989; Norman, 2010; Mitchell et al., 2000), four census variables were selected as indicators of household deprivation:

- male unemployment;
- households without a car;
- overcrowded households; and
- socially rented households.

Below, each indicator is justified in more detail.

4.5.3.1 Male unemployment

The relationship between unemployment and deprivation has been well established. Pacione (1989:102), for example, argues that unemployment "*has been identified as the single most important cause of poverty*" and goes on to cite Hasluck's (1987:3) observation that:

> "*as unemployment rises, not only does poverty and individual misery increase, but the capacity of the local community to maintain the physical and social infrastructure is reduced.*"

More recently 1999/2000 statistics showed that 77% of unemployed people were at risk of poverty (Howard et al., 2001). Furthermore, Bailey (2006) argues that UK governments view unemployment as negatively impacting upon individuals due to reduced income increasing the risk of impoverishment. This established relationship between deprivation and unemployment, the use of unemployment data in other measures of deprivation, and the availability of unemployment data at all five time points, meant that unemployment data were selected to be one of the indicators used in this study.

Male unemployment was used rather than general or female unemployment. This was because societal and labour market changes have occurred over the last 40 years resulting in more women being economically active. The Office for National Statistics, for example, reports that between 1971 and 2011 the percentage of working women age women who were not economically active fell from 44.5% to 29.3% (Spence, 2011). Such changes are likely to have had a knock on effect on female unemployment figures, making it difficult to assess whether falls or rises in female unemployment were a consequence of changes in levels of deprivation or labour market. For purposes of temporal consistency, it was considered more robust to use male unemployment.

Whilst there is a well-established link between unemployment and both social and material deprivation (Howard, et al., 2001), there are some limitations regarding the use of unemployment as an indicator of deprivation. It has been suggested that, particularly in the 1980s, both economic and political pressures prompted some out of work people to change their status from unemployed to permanently sick (Beatty and Fothergill, 2005). Over the last decade there has also been increasing awareness of people being deprived, despite being in work. MacInnes et al. (2013), for example, found that (when using the income threshold approach to measure poverty) in 2011/12 of the 13 million people in poverty in the UK, more than half (51.5%) were in a family where someone worked; the remaining 48.4% being in workless or retired families. Furthermore, they highlighted that this figure of 51.5% had substantially increased over the preceding 15 years, having been 34% in 1996/1997. Whilst acknowledging these limitations, it was still felt that male unemployment was a useful indicator of deprivation.

4.5.3.2 Households without a car

Car ownership is a commonly used surrogate for income/wealth (Johnson et al., 2010, Townsend et al., 1989, Allik et al., 2016), with the assumption being that households without cars are likely to have lower incomes than those with one or more cars. Studies which have used households without a car as an indicator of households with low income include those by Townsend, and Carstairs and Morris. Correlations between income and car ownership support this surrogacy (Johnson et al., 2010, Hine and Mitchell, 2001, Townsend et al., 1989) and can be seen in Figure 3-3. In addition, Hine and Mitchell's (2001) study examining the influence of transport on social exclusion in Scottish urban areas, found that not having access to a car could limit people's ability to access services and participate in normal day to day activities (which, as described above, is a feature of deprivation). Figure 3-4 indicates a similar situation in England, with households without cars reporting considerably higher difficulties in accessing essential services than households with cars.

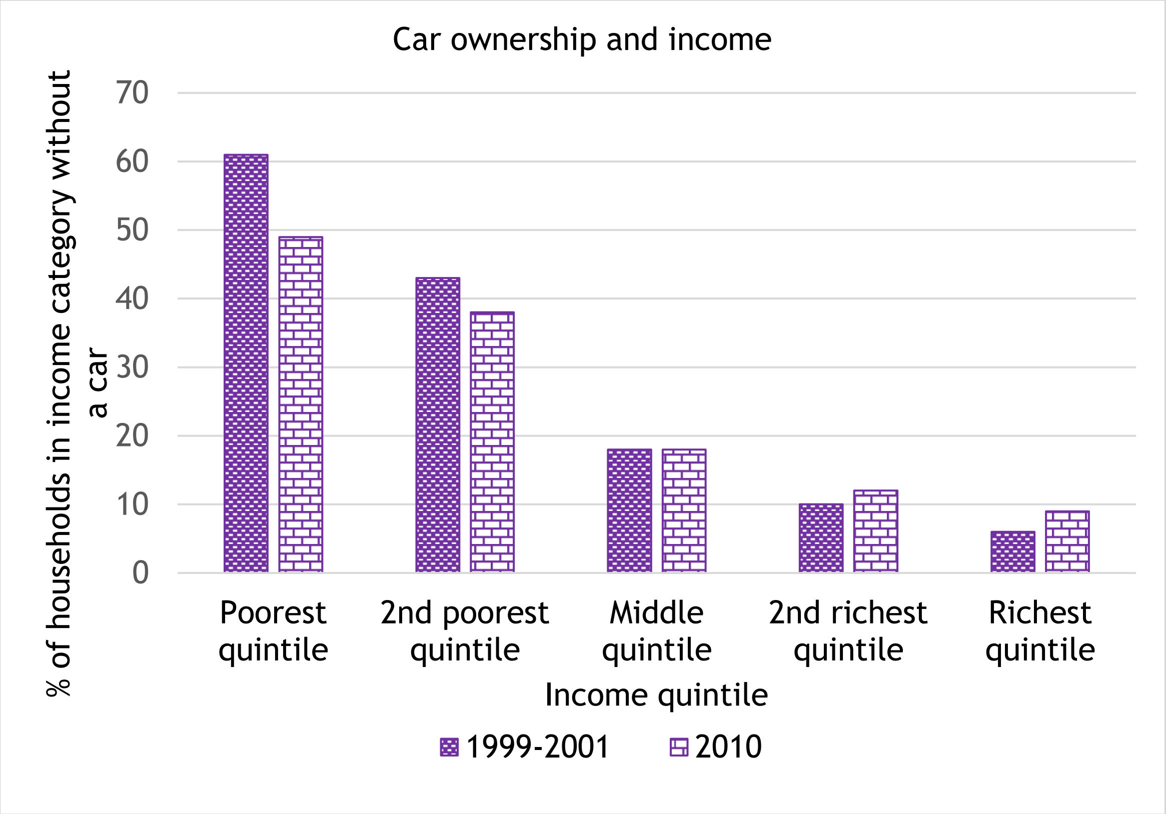

Figure 3-3 Car ownership and income in Great Britain 1999-2001 and 2010 (Source: data from Department for Transport's (2011) National Travel Survey cited in Palmer, 2011.)

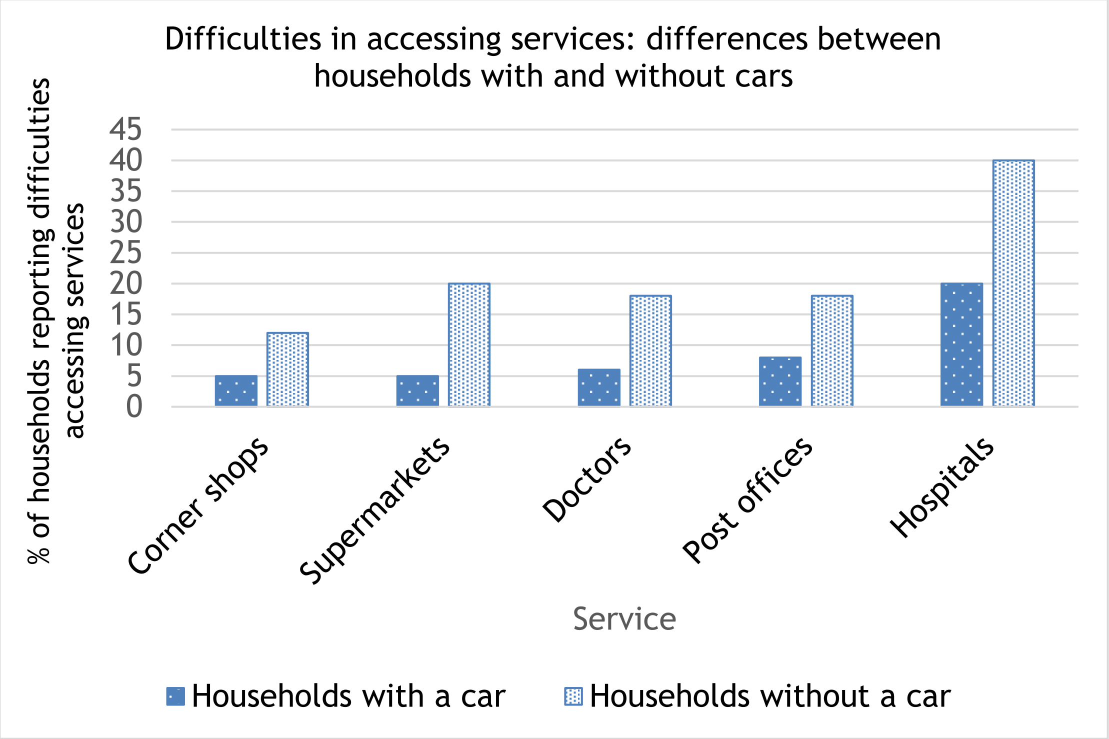

Figure 3-4 Reported difficulties in accessing essential services: differences between households with and without a car in England (Source: data from Survey of English Households 2007/2008 published by the Department for Communities and Local Government and cited in Palmer, 2011).

There are, however, limitations associated with using lack of car ownership as an indicator of low income. The relative costs associated with car ownership have decreased over time (Glaister, 2002) which might have implications for temporal comparability. Furthermore, as can be seen in Figure 3-3, whilst there is a relationship between income and car ownership, not all low income households are without access to a car; indeed between 1999-2001 and 2010 there was a decrease in the proportion of low income households not owning a car. Car ownership is a lifestyle choice for some, and can be influenced by access to public transport and parking facilities (Focas, 1998). The converse can also be true; where public transport is poor and travel distances are long, owning a car can be a necessity and prioritised by those in adverse economic situations.

4.5.3.3 Overcrowded households

Galobardes et al. (2006:9) state that:

> *"(h)ousing is generally the key component of most people's wealth, and accounts for a larger proportion of the outgoings from income."*

As such, housing characteristics provide an indication of material circumstance. Overcrowding is one such characteristic, providing an indication of housing conditions and living circumstances (Townsend et al., 1989). It has been used in a number of deprivation indices, including those by Townsend (1987), Carstairs and Morris (1991), the SIMD (2004, 2006, 2009), and the IMD (2015). It is therefore another well-established indicator of deprivation. Indeed, Dorling et al. (2007) highlight that analysis of the 1999 Poverty and Social Exclusion survey indicated that 57.6% of overcrowded households were classified as "breadline poor.[33]" As with all the indicators, there is not a perfect correlation between household overcrowding and deprivation. People might elect to live in a household defined as overcrowded for cultural reasons, for example. It also does not capture individuals who live by themselves but might be experiencing deprivation. Despite these limitations, however, overcrowded households remains an established indicator of deprivation.

The definition of overcrowding varies between censuses. For the purpose of consistency, the 2001 census definition of overcrowded households was applied to all five time points. The measure of overcrowding used in 2001 census was occupancy rating. The rating assumes that all households require a minimum of two common rooms (excluding bathrooms) plus one bedroom for each couple, any other person aged 16 or over, and each pair of same sex children aged 10-15 years (Office for National Statistics, 2004). Households with less than this were identified as being overcrowded.

4.5.3.4 Socially rented households

In the UK, the overwhelming majority of households fall into one of three tenures (Figure 3-5): owner occupation (owned outright or with a mortgage); private renting; and renting from a local authority or housing association (social

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[33] Referred to in this study as relative poverty.

renting). The dominant tenure is owner occupation, whilst non-owner occupation, Townsend et al. (1988) states, is an indicator of lack of wealth and income. Tenure is, therefore, another housing characteristic which provides a proxy for material circumstance and, hence, is commonly used as an indicator of socio-economic position (Galobardes et al., 2006). Townsend (1987), for example, used the percentage of private households not owner-occupied in his index of deprivation (and thus included both private rentals and social rentals). In this study only social renting was used as an indicator of deprivation; people rent privately for a variety of reasons and this often reflects the point at which they are in their life course rather than lack of income. Young professionals, for example, often rent for a period of time while saving for a mortgage deposit. Renting from a local authority or housing association (social renting), however, is associated with lack of income and therefore an indicator of deprivation. Indeed Dorling et al. (2007) highlight that analysis of the 1999 Poverty and Social Exclusion Survey indicated that 35.7% of social rented households were classed as “breadline poor”.

Mitchell et al. (2000) note that the suitability of census variables as indicators of deprivation is sometimes period specific. Social renting is such a variable because whilst it is currently a good indicator of deprivation, this was not always the case. Prior to the Right to Buy[34] initiative, introduced in 1980, social tenancy was widespread in Britain and not necessarily strongly and consistently associated with deprivation; indeed in 1980 it accounted for almost a third of British households (Jones and Murie, 2006), and 54% of Scotland’s housing stock (Stephens et al., 2003). Consequently, it was decided that it was only appropriate to use social renting as an indicator of deprivation from 1991 onwards.

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[34] Right to Buy, introduced by the Conservative government in 1980, was a policy of privatising social housing. Unlike other privatisation policies, which sold public assets to private companies, Right to Buy sold social housing directly to the public. The policy gave occupants of socially rented housing the legal right to buy their house at a discounted rate (Jones and Murie, 2006; Sprigings and Smith, 2012).

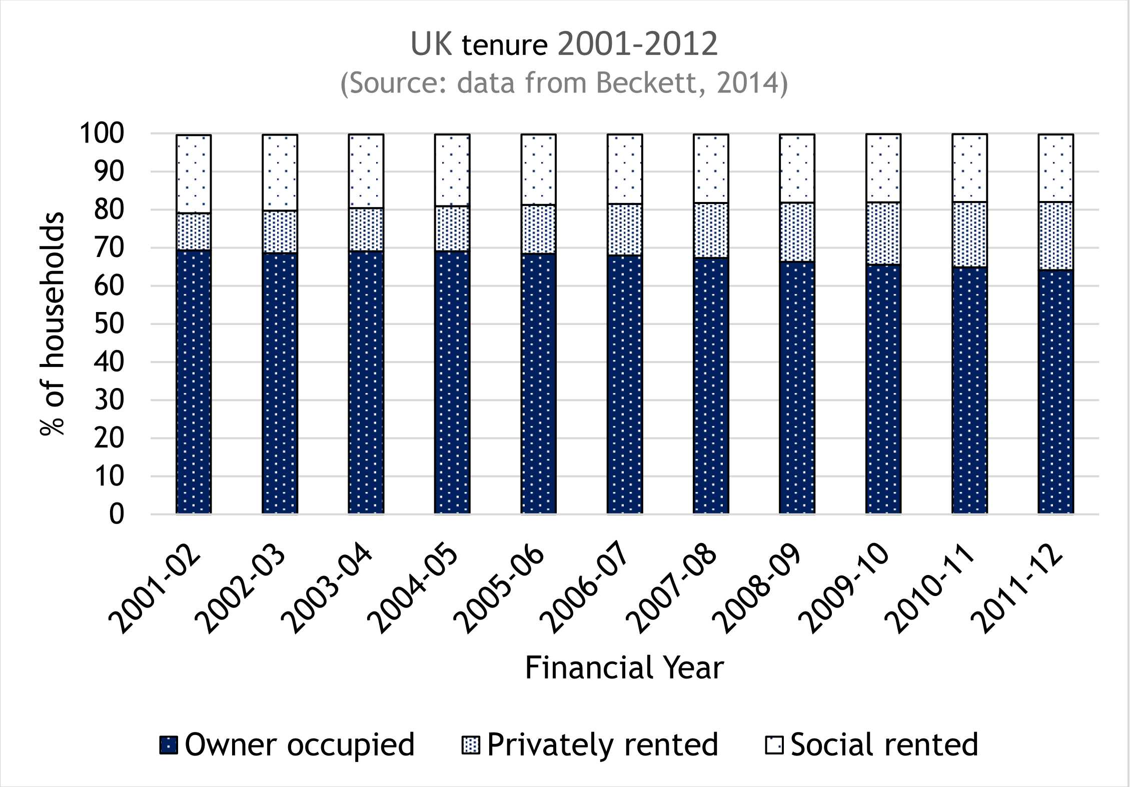

Figure 3-5 UK housing stock by tenure financial years 2001-02 to 2011-12 (Source: data from Beckett, 2014)

4.5.3.5 Census variables not used

A number of other census variables have been used as indicators of deprivation in other studies, but which were not used in this study. These include social class, and amenities. Low occupational social class was used by Carstairs and Morris (1991), for example. However, it was not deemed appropriate in this study because only a 10% sample of this data was available for the 1971 to 1991 censuses. The 10% availability would have been a particular problem as the aim was to map deprivation at a fine a spatial scale as possible, making the small numbers in a 10% sample of the census a potential problem.

Access to household amenities (such as lack of indoor toilet or central heating) has also been used in the past as an indicator of deprivation. However, such indicators have been shown to no longer be representative of poor housing (Townsend et al., 1989). Galobardes et al. (2006:9) suggest that a better housing indicator of deprivation is the “broken windows’ index” which has been used in the USA and provides a measure of “*housing quality, abandoned cars, graffiti, trash, and public school deterioration*”. While such a measure would have been useful in this study, relevant information is not available from the UK census, or any other source in a consistent manner, over time.

4.5.4 Summary

This section has provided the rationale for the use and selection of census variables used in this study as indicators of deprivation. The next section focuses on why a new method of mapping these census variables was required.

4.6 The need for a new mapping methodology

This section explores previous attempts at mapping deprivation over time and, through doing so, explains why a new method of mapping census data that enables temporal and cross-city comparisons is required.

4.6.1 Mapping deprivation over time: how it has been done before?

Producing maps of poverty/deprivation is not new. As detailed in the literature review, in the UK maps of poverty date back to Booth's maps of London and Rowntree's map of York at the end of the 19th century/beginning of the 20th century. Making temporal comparisons of maps of poverty of the same city has also been done before. Dorling et al. (2000), for example, compared 1991 poverty maps of London with those of Booth's at the start of the twentieth century. The authors were able to do this because Booth had produced maps of London. Unfortunately such maps do not exist for Glasgow, Liverpool, or Manchester at the start of the 20th century and so Dorling et al.'s (2000) method could not be replicated for these cities.

Pacione (2004) does provide maps (Figure 3-6 and Figure 3-7) showing what he terms "the geography of disadvantage" in Glasgow at four time points: 1971, 1981, 1991, and 2001. These maps used census information for the smallest census geography at the time (enumeration districts for 1971 and 1981, output areas for 1991 and 2001) to identify which had the highest levels of multiple deprivation relative to the rest of Glasgow. The most deprived 0-1%, 1-5% (and for 1971 and 1981 5-10%) enumeration districts/output areas were then plotted on a map (Figure 3-6 and Figure 3-7). However, rather than showing the exact area covered by these enumeration districts or output areas (the spatial extent of which varies as they were designed to be of similar population size rather than similar spatial extent), each of the most deprived enumeration districts/output areas was marked with a symbol – all identically sized; furthermore, the symbols used vary between the maps. Consequently, his maps do not lend themselves to gauging the spatial extent of deprivation. Although there are further limitations (discussed below) associated with Pacione's (2004) maps, and he does not provide a quantitative/objective comparison of them, they do provide a starting point to exploring the spatial arrangement of deprivation in Glasgow. They indicate three relevant points about the geography of deprivation in Glasgow over the 30 year period between 1971 and 2001:

- The most disadvantaged enumeration districts/output areas are often clustered together; however, clusters are themselves dispersed across the city;
- Some areas of the city appear to persistently contain enumeration districts/outputs areas with the highest levels of multiple deprivation;
- Change can be seen over time, and out of the four time points, the most deprived output areas are least clustered together in 1991.

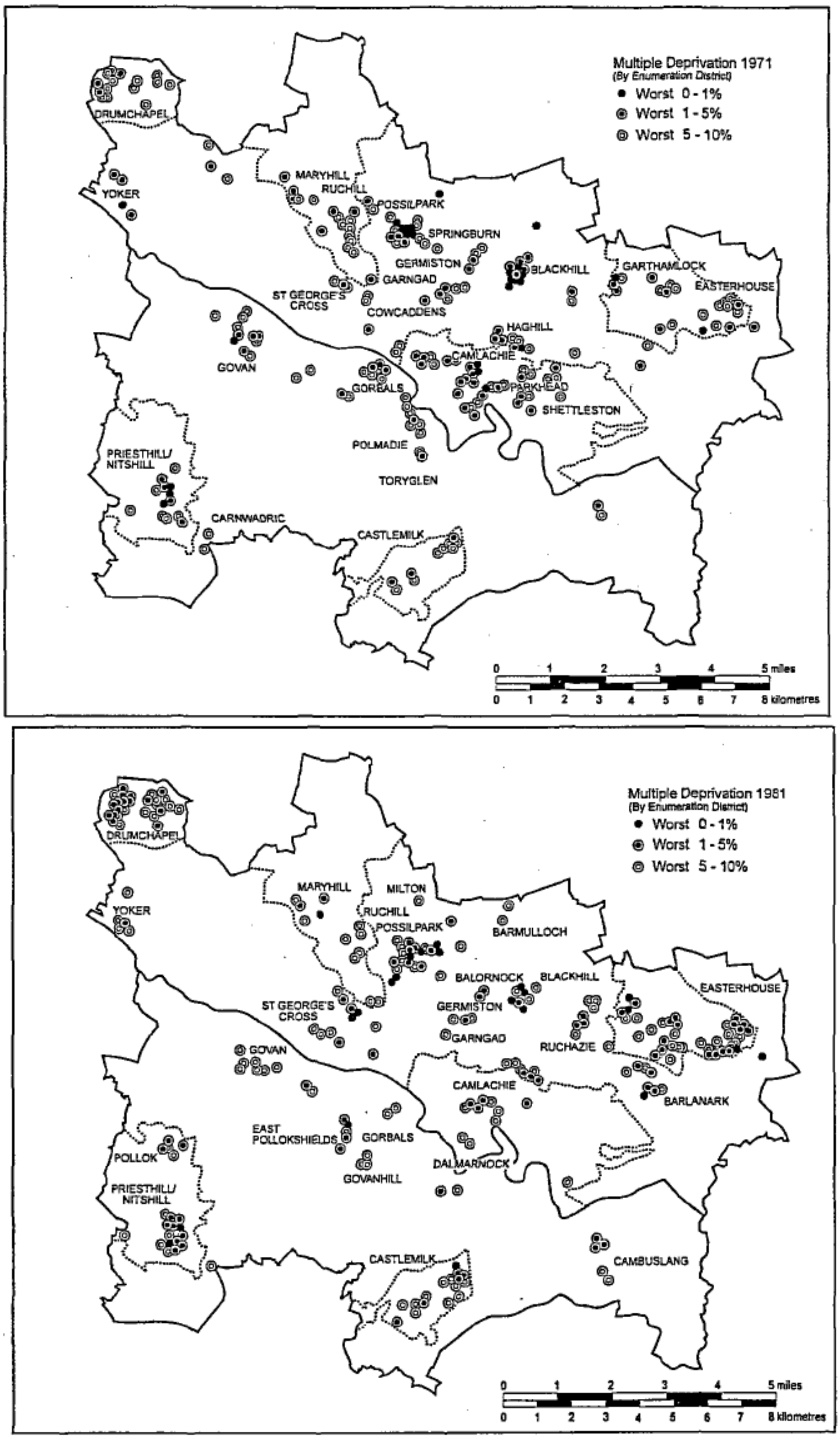

Figure 3-6 Pacione's (2004) maps of the "geography" of disadvantage in Glasgow 1971 and 1981. (Taken from Pacione 2004:123)

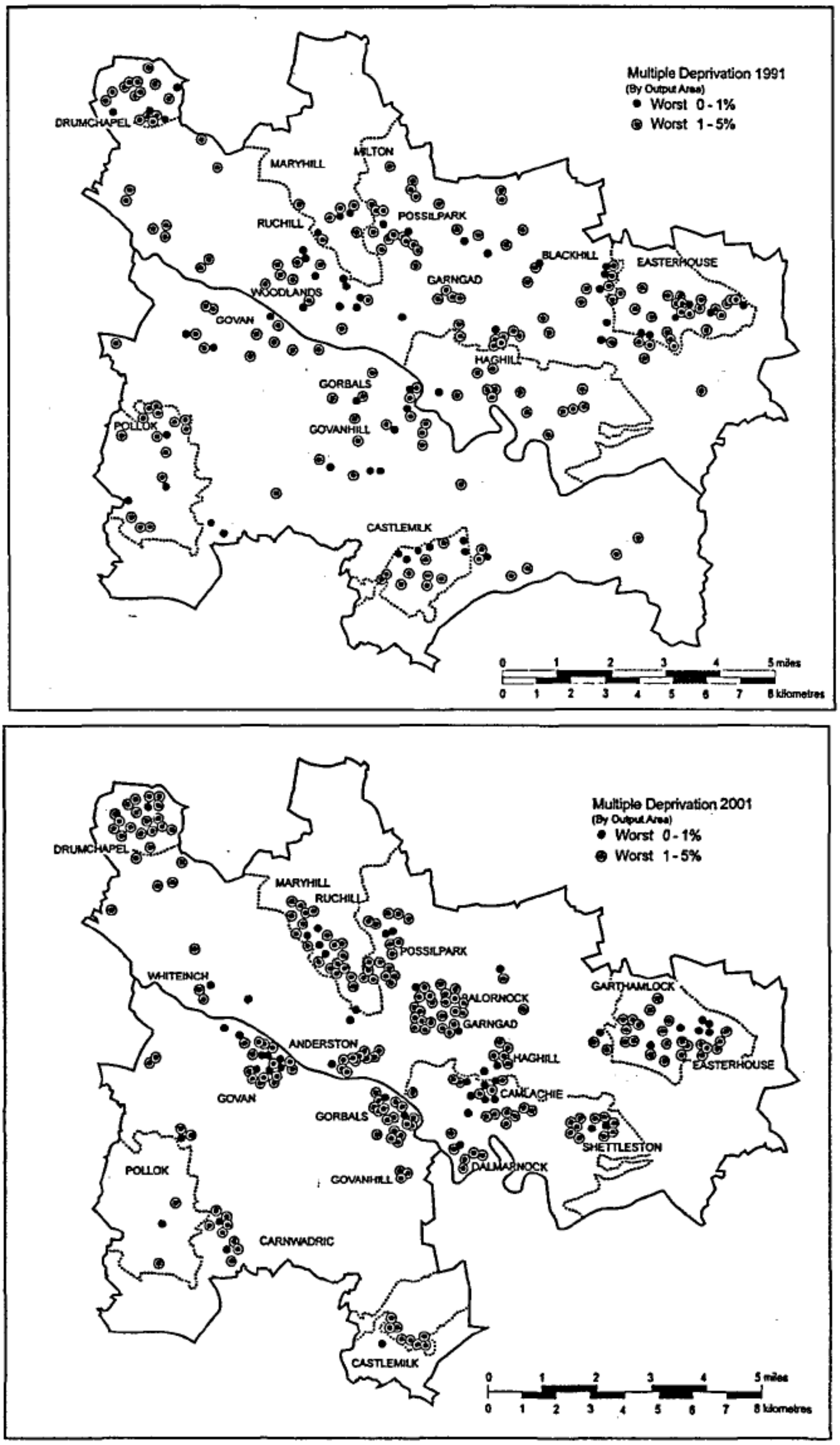

Figure 3-7 Pacione's (2004) maps of the "geography of disadvantage" in Glasgow 1991 and 2001. (Taken from Pacione, 2004:127)

Although Pacione's (2004) maps provide some indication of the spatial arrangement of deprivation in Glasgow between 1971 and 2001, he does not provide a formal, objective assessment of the pattern over time, and a number of limitations with his methods mean that replicating his maps for other cities is not desirable. First, whilst he makes it clear that he uses census information to construct a measure of deprivation, it is not apparent which census information was used or how it was weighted. Thus replicating his work would be problematic. Second, the boundary for Glasgow was significantly changed in 1996, with the difference apparent in the maps in Figure 3-6 and Figure 3-7. Consequently the area used in 2001 differs to that of earlier years, making any quantitative assessment of the maps particularly vulnerable to the modifiable areal unit problem (MAUP). Third, Pacione's (2004) technique of marking enumeration districts/output areas with symbols, rather than mapping the boundary of the output area, is also problematic. In some instances several of the symbols are on top of each other (where there is a clustering of small enumeration districts/output areas identified as containing high levels of multiple deprivation). Whilst this does indicate areas where there is a clustering of multiple deprivation, it also makes the maps harder to decipher. The use of three categories of multiple deprivation in 1971 and 1981 further "crowds" the maps and also impedes visual comparison with the maps for 1991 and 2001. Pacione's (2004) method also does not lend itself to gauging the spatial extent of deprivation. Furthermore, Pacione's (2004) method of using symbols means that in areas with a clustering of symbols it is unclear whether the enumeration districts/output area do in fact border one another (thus forming areas of landlocked deprivation), or if they are just close to one another (and therefore indicate islands of deprivation in close proximity to one another). A different method to that of Pacione (2004) was therefore required to compare the development of the spatial arrangement of deprivation across three cities.

4.6.2 Issues associated with mapping census data

Having opted to use census variables as indicators of deprivation, a method of mapping these data which enabled objective, accurate temporal and spatial comparisons was required. Two issues need to be addressed, both of which are related to the way in which individual data are amalgamated by the census. First, the census geographies used in Scotland and England have differed over time. In Scotland the smallest geography, the output area, has been used since 1981. In England, however, the output area was not adopted until the 2001 census; instead the larger sized enumeration district was used. Consequently, comparing Liverpool and Manchester with Glasgow within the same time period is problematic as comparisons would be made of maps derived from data at different scales. Furthermore, this raises issues for temporal analysis as observed changes in the patterns of deprivation could be artefactual, that is the result of a change in scale rather than actual change.

The second difficulty which arises when mapping census data is the modifiable areal unit problem (MAUP) (explained in Chapter 3 section 3.4.1) of the literature review). The census aggregates individual data into areal units (for example enumeration districts and output areas), the boundaries for which are often arbitrary and of an irregular shape. Consequently, as Martin (1989:90) explains:

> "*the data values for each zone may be as much a function of the zone boundary locations as of the underlying distribution*".

It is therefore possible that patterns could be identified in the maps which are actually driven by arbitrary boundaries rather than by the data itself. Furthermore, temporal changes in spatial patterning could be identified which are due to changing boundaries rather than actual changes in the spatial patterning of deprivation.

Both problems would be overcome if individual household data were used, as this would enable each household to be mapped. However, for privacy reasons census data are amalgamated so that individuals' census information cannot be identified. For census data to be used to produce reliable maps of deprivation, a method of mapping which attempts to overcome amalgamation issues (such as changing boundaries and scales) was required.

A variety of different approaches have been adopted to adjust small area census and vital statistics data in attempts to overcome issues related to dealing with boundary changes over time. Mennis and Hultgren (2006), for example, advocate the use of dasymetric[35] mapping in conjunction with areal interpolation. Areal

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[35] Mennis and Hultgren (2006:179) define dasymetric mapping as "the use of an ancillary data set to disaggregate coarse resolution population data to a finer resolution."

interpolation is the process of reaggregating spatial data from one set of zones to another (Eicher and Brewer, 2001:126), whilst dasymetric mapping is "*the use of an ancillary data set to disaggregate coarse resolution population data to a finer resolution*" Mennis and Hultgren (2006:179). The ancillary data used in dasymetric mapping is normally land use data, typically remotely sensed satellite images (Holt et al., 2004, Mennis and Hultgren, 2006, Slocum et al., 2009). As a technique, therefore, dasymetric mapping can be used in conjunction with areal interpolation to adjust census data to a common set of boundaries. To do so in this study would, however, require land use data contemporary to each census time point; such data were not available and so consequently rendered such an approach unsuitable to this study. Norman's (2010, 2016) and Exeter et al. (2005) offer alternative approaches to the issue of boundary changes overtime, both of which could be adopted in this study. With the aim of providing output zones of contemporary relevance, Norman (2010, 2016) converts older census data to recent boundaries. To convert between zonal systems he uses the area of population overlap between different boundary systems to apportion data, using weights "*calculated by counting unit postcodes (a proxy for population distribution) which fall in both the source area (the zone in which the data exist) and the target area (the zone the data are needed for)*" (Norman, 2016:200). Disadvantages of this technique include uneven levels of error between any pair of boundary systems (due to some localities experiencing widespread adjustments whilst others experience little or no change), and increasing error over time (1971, for example, will have more differences with 2011 than 1981). Whereas Norman (2010, 2016) focussed on creating contemporarily relevant zones, Exeter et al. (2005) determined coincidences of boundaries to define 'Consistent Areas Through Time' (CATTs) which could be used to compare data from the 1981, 1991, and 2001 census in Scotland. This approach is, however, only feasible in Scotland as it is based on the 1981 census constructing Enumeration Districts from one or more whole unit postcodes (which did not occur in England and Wales). A further disadvantage of Exeter et al's. (2005) technique is that it results in very uneven populations. This is because small areas can be retained where there has been little change to the census geography, but where there has been widespread change boundaries are aggregated into larger areas. For the purposes of this study, a further limitation of both Norman (2010, 2016) and Exeter et al.'s (2005) approach is that they result in the production of choropleth maps and thus retain some of the issues relating to the amalgamation of data as noted above.

Geographical information systems (GIS) literature suggested that these amalgamation problems could, however, be overcome through the use of surface mapping – a technique which will be explained in the next section.

4.7 The use of Surface Mapping to overcome problems associated with mapping census data

Reviewing candidate techniques for a method which goes some way to disaggregating census data, so as to provide more precise maps of the spatial pattern of deprivation, identified surface mapping. This section introduces surface mapping and SurfaceBuilder, the software used in this study to produce surface maps of census variables.

4.7.1 Surface Mapping

Tate et al. (2008:239) state that:

> *"a surface representation is appropriate under any circumstances where the phenomena being modelled can be thought of as varying continuously across space."*

There are numerous examples of phenomena which have been mapped through surface modelling, including land elevation, air pressure, soil pH, and population density (Tate et al., 2008). Martin (1989, 1996) and Martin and Bracken (1991) developed a technique for the purposes of mapping population and demonstrated that this can be done successfully. Following a review of candidate techniques for mapping the spatial distribution of census variables without areal units, Martin's surface mapping technique (Martin 1989; Martin and Bracken, 1991) was selected.

4.7.2 SurfaceBuilder

Martin's technique uses software he developed – SurfaceBuilder – which attempts to recreate the real population distribution across geographical space from a set of aggregated counts attached to population weighted census zone centroids. Whilst much of Martin's work (for example 1989, 1996, and Martin and Bracken, 1991) focussed on using his technique to produce surface maps of population and population change, the technique is readily applicable to other types of population counts. No other accounts of this technique being applied to counts of deprived people were found in the literature.

SurfaceBuilder uses an algorithm to distribute data from each centroid, based on spatial relationships with other centroids and the number of people or households associated with each centroid. Each centroid is examined and the mean inter-centroid distance calculated. The result of this calculation is then used to "*calibrate a distance decay function which assigns weight to the cells of the output grid*" (Martin, 1996:976). Consequently, the cells closest to the centroid are assigned the highest weights and the cells furthest away are assigned the lowest weights. Whilst the main influence on the weightings is a distance decay model, they are also influenced by the local density of centroids (Martin 1989). SurfaceBuilder then uses the weightings to "*redistribute the population count associated with each centroid into the surrounding region*" (Martin, 1996:976) according to a gravity model, thus creating a surface grid.

SurfaceBuilder's method can be seen from the hypothetical example given in Figure 3-8. In this both squares show the same area which is covered by four adjacent output areas, each containing the same population count. If choropleth mapping is used to represent the population distribution, the entire area covered by each output area would a) be shaded and b) be the same colour, denoting the same population count (as is shown in the square on the left). SurfaceBuilder, however, uses the population weighted centroids to allocate the population into small grid cells and estimate the population of each cell. The result can be seen in the right hand square of Figure 3-8, and shows how the cells with, or close to, the centroids, have higher population counts than those further away.

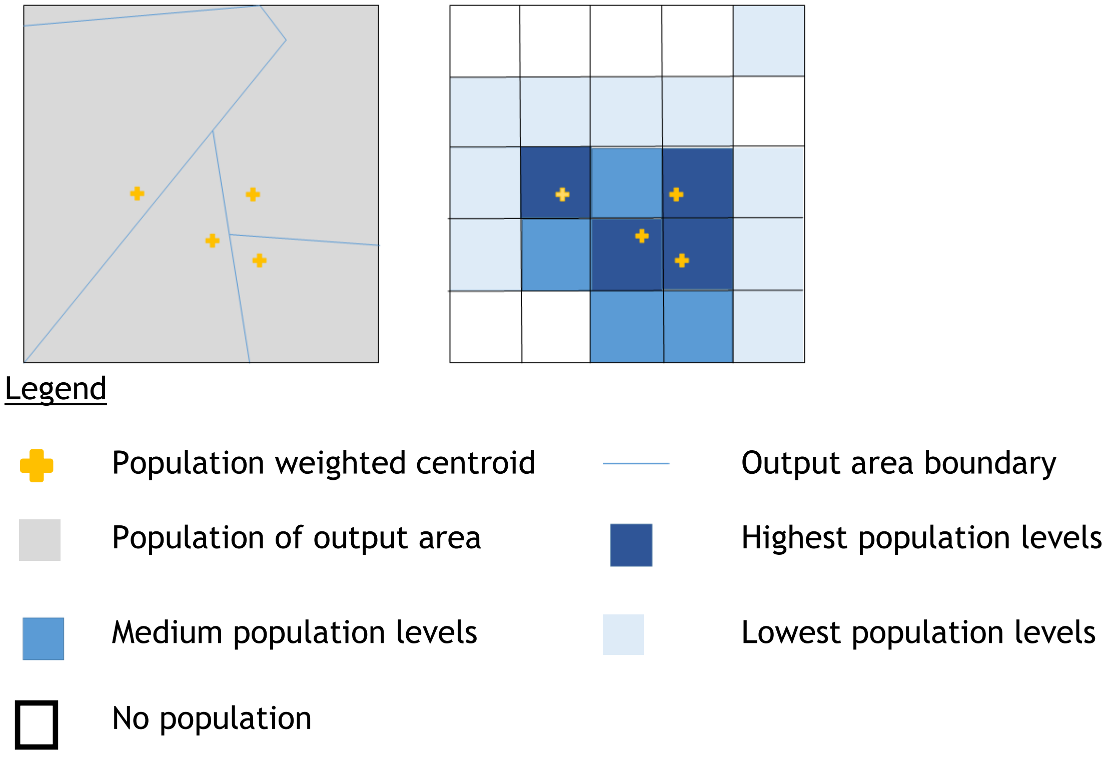

Figure 3-8 Hypothetical demonstration of SurfaceBuilder

The advantages of using population surfaces to map counts of population from census data can be seen by comparing Figure 3-9 and Figure 3-10. Both are produced using the same population data for output areas in Glasgow in 2001. Figure 3-9 is a choropleth map and provides an indication of the population count in each output area. The mosaic pattern of irregular sized and shaped output areas can be seen. Whilst it provides an indication of areas with greater population it conveys the false impression that population is evenly distributed within each output area and the eye is naturally drawn to the physically largest output areas, regardless of their population size; parts of the city without population are not identified. Such issues have been highlighted by cartographers (Dent, 1996; Slocum et al., 2009; and Forrest, 2015) who stress that choropleth maps should not be used to map absolute values; instead the customary advice is that choropleth maps should only use standardised data. A further disadvantage of the choropleth map shown in Figure 3-9 is that parts of the city without population are not identified. Figure 3-10, however, overcomes some of these difficulties. It is a surface map of Glasgow's population created using 2001 census data in SurfaceBuilder showing the estimated number of people in each cell[36] of the map. The map is not subject to the influence of areal unit size and conveys a more accurate and realistic indication of which parts of the city have high, low and no population. Furthermore, unlike the choropleth map in Figure 3-9, it can be more easily and appropriately compared with other maps even if the boundaries of output areas have changed. Whilst boundaries still influence the surface map, as they delineated which parts of the city each census centroid represents, the impact of any changes in boundaries is likely to be "smoothed" out. It could be argued that the use of surface mapping is likely to provide a more accurate representation of the distribution of people across space.

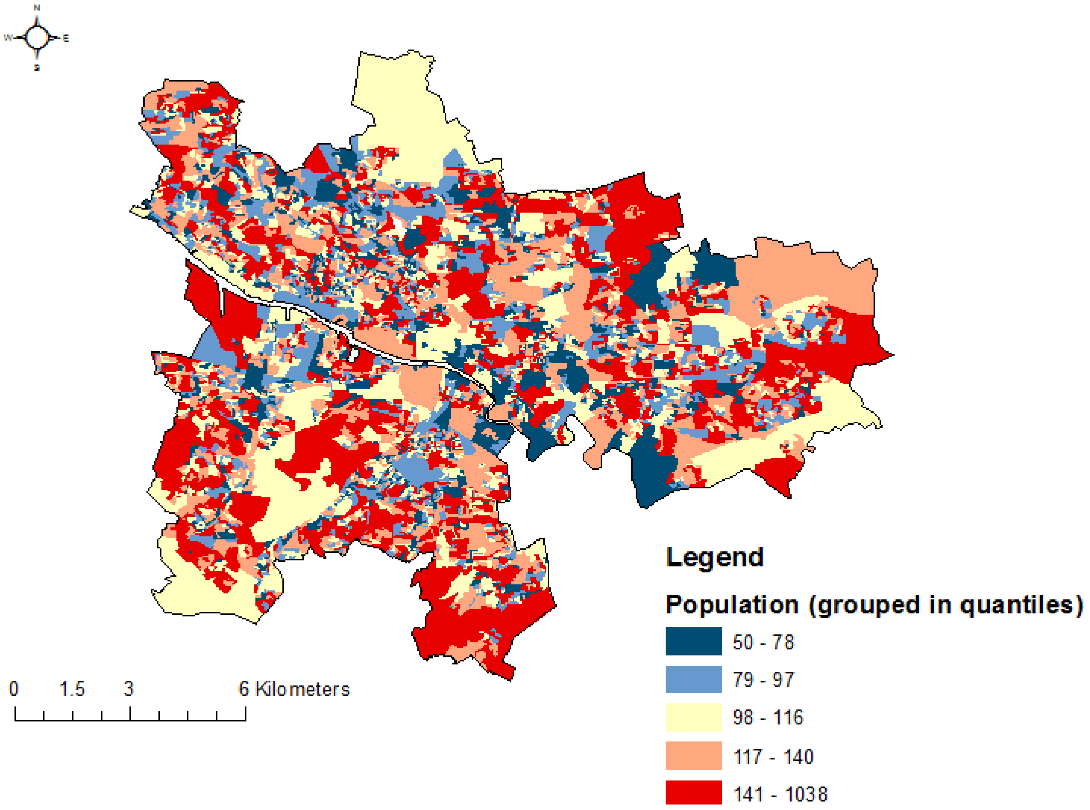

Figure 3-9 Choropleth map of population in Glasgow in 2001 using census output area boundaries (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

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[36] The cell size used in surface maps varies. In this map each cell is 75 metre^2 (for reasons which will be explained in a following section).

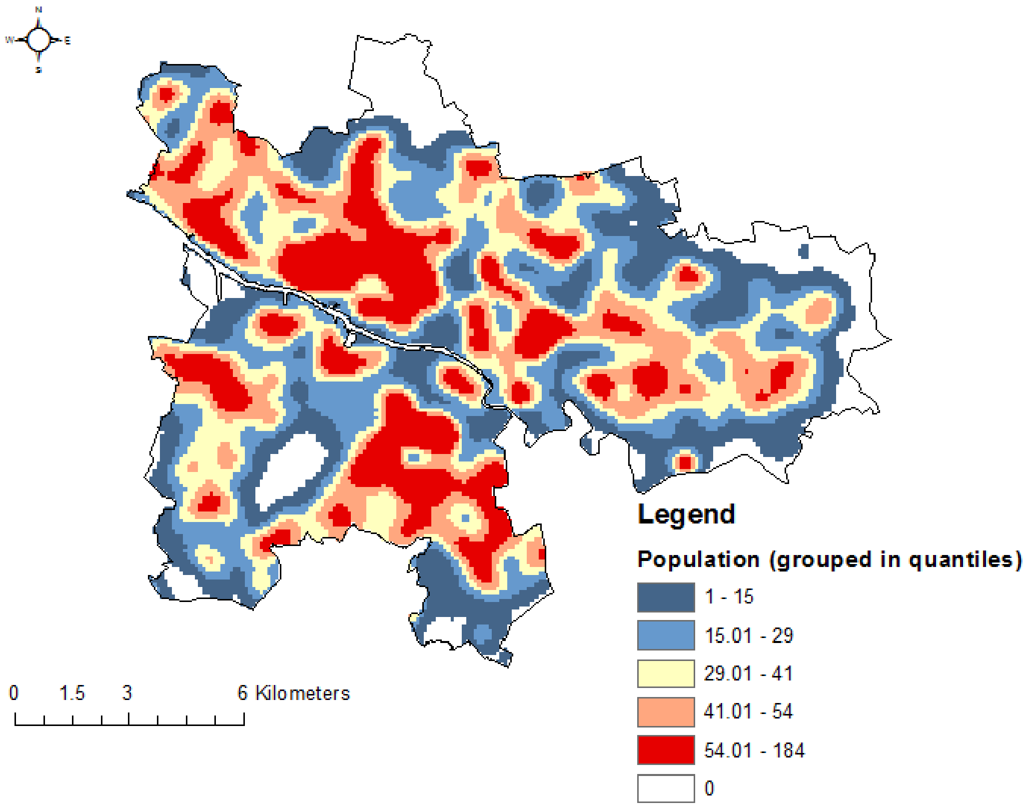

Figure 3-10 Surface map of population of Glasgow in 2001 (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

4.7.3 Summary

This section has introduced surface mapping and demonstrated the advantages of using this approach to produce maps of deprivation for use in this study. The next section details the process followed to produce the surface maps of census indicators of deprivation.

4.8 Making the maps

A summary of the process used to produce the surface maps is shown in the flow chart in Figure 3-11.

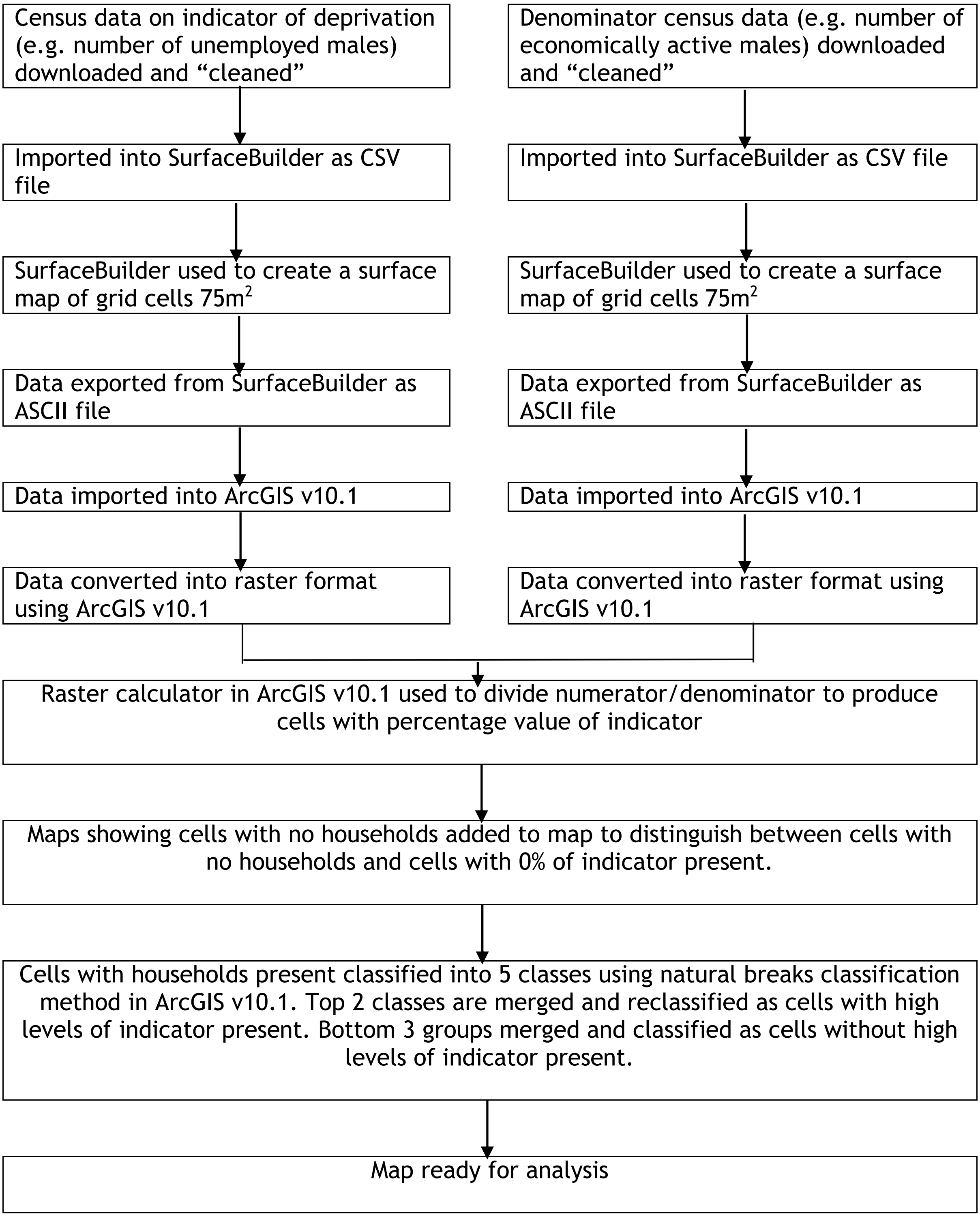

Figure 3-11 Flow chart of map making process

4.8.1 Downloading census data

Census data and population weighted centroids were obtained for the smallest available geographies[37] for each decennial interval from 1971 to 2011. English census data were downloaded from the UK Data Service (via Casweb for 1971-2001, and via InFuse for 2011). 1971 to 2001 census data for Scotland were also downloaded from the UK Data Service (again via Casweb), but from the Scottish Government's website for 2011[38].

These census data were obtained for each of the cities and the areas surrounding them. Even though areas outside of the city boundary were not analysed in this study, it was important that data for the areas surrounding the cities were included due to the way in which SurfaceBuilder calculates the distance decay function. SurfaceBuilder examines all the data for the surrounding centroids, as well as the local density of centroids, when calculating the weighting assigned to each grid cell, irrespective of whether or not there is city boundary. Had data for the areas surrounding the cities not been provided to SurfaceBuilder it would have assumed that there was no proximal population, this could have impacted on the results. This is called an "edge effect" and was important to avoid.

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[37] For 1971 this was enumeration district in both Scotland and England. For 1981 onwards this was output area in Scotland, however, it remained enumeration district in England in 1981 and 1991. From 2001 onwards output areas were also used in England.

[38] The smallest geography at which 2011 Scottish census data are available from InFuse is local authority, hence an alternative source was required to obtain output area data.

The census data obtained were:

- Number of males unemployed/seeking work;
- Number of economically active males;
- Number of households without access to a car;
- Number of households;
- Data[39] on household overcrowding;
- Number of households rented from a Local Authority or Housing Association.

For each of these data sets, comma-separated values (CSV) file were prepared using Microsoft Excel. The CSV files contained the northing and easting of each of the population weighted centroids and the count (for example number of unemployed males) for that population weighted centroid. These files could then be imported into SurfaceBuilder to create population surfaces.

4.8.2 Using SurfaceBuilder

A population surface was made for each of the CSV files using SurfaceBuilder. Surface maps for male unemployment, households without a car, and overcrowded households were created for each of the three cities in 1971, 1981, 1991, 2001, and 2011, and for social rented households in 1991, 2001, and 2011. These surfaces provided a count of either unemployed males, households without a car, overcrowded households, and social rented households in each grid cell. Whilst interesting, this was not particularly informative as they did not indicate what proportion of the total number of people or households this represented. Therefore denominator surfaces were created for each of the indicators so that rates could be calculated. For male unemployment the denominator surface was total number of economically active males, for the other three indicators total households was used. All of these surfaces were

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[39] To account for changes to the definition of overcrowding over time the same definition was used at all time points (see section 4.5.3.3). Raw census data relating to the number of occupants and number of rooms in a household were downloaded so that the number of overcrowded households could be calculated.

exported from SurfaceBuilder in an American Standard Code for Information Interchange (ASCII) format which could then be imported to ArcGIS 10.1.

4.8.2.1 Search radius and cell size

SurfaceBuilder allows the user to select the search radius and cell size used, both of which affect the model of spatial distribution produced. Detailed sensitivity analysis was undertaken to explore the effect of varying these parameters. This sensitivity analysis is discussed in section 4.9.1 and, as shall be seen, justified the decision to use a search radius of 500m and a cell size of $75m^2$.

4.8.3 ArcGIS 10.1

The surfaces produced were imported into ArcGIS 10.1 and converted into a raster format. The raster calculator[40] was then used to divide numerator surfaces by denominator surfaces, and multiply by 100, producing continous, percentage values for each indicator in each cell.

To distinguish between cells with a value of 0% due to no resident population, and cells with a value of 0% because none of the households or people within the cell were classed as deprived, a surface map of count of households in each city was made for each of the time points. The cells in this maps were classified into two groups: those with households present, and those with no households present. This was then incorparated into each map. Using this method, 54 maps[41] were produced showing the percentage values of the indicator in each grid cell.

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[40] The raster calculator is a function within ArcGIS 10.1 which allows mathematical calculations to be made on raster maps.

[41] Male unemployment as a percentage of totally economic active males at each of the five time points in each city (15 maps), households without access to a car as a percentage of all households at each of the five time points in each city (15 maps), overcrowded households as a percentage of all households at each of the five time points in each city (15 maps), social rented households as a percentage of all households for each of the three cities in 1991, 2001, and 2011 (9 maps).

A method of classifying grid cell values was then required so that areas with a high number of deprived people relative to the rest of the city at that time point could be identified. To avoid disrupting the flow of the explanation of how the maps were produced, the rationale for how the cells were classified is given below (section 4.9.2). In the meantime it is sufficient to say that the cells with households present were classified into five classes using the natural breaks (Jenks) classification method, the top two of which were grouped together and classified as cells where there were high levels of an indicator relative to the rest of the city at that time point. For reasons which will also be discussed below (section 4.9.2.6) it was decided to produce maps showing a binary classification of the indicators: areas with high levels of that indicator relative to that city at that time point, and areas without high levels of that indicator. Areas without households were also shown on the map to indicate where the binary classification was not applicable.

4.8.4 Summary

This process was used to produce the (54) maps showing where there were high levels of each of the indicators relative to the rest of that city at each time point. To enhance the temporal analysis, 12 maps were produced identifying areas of each city which had high levels of the individual indicator at all time points, and a further 12 were produced identifying areas of each city which had a high level of the individual indicator at any time point. As was detailed in the discussion of work by those such as Townsend (1979, 1987, 1993) and Bailey et al. (2003) in the literature review, and above in the discussion on measuring deprivation, household deprivation is a multi-dimensional and rarely well-captured by the use of one indicator. To reflect this, as well as analysing the 54 maps, 15 “summary” maps were created for each city and time point which identified cells in which high levels of all the indicators were observed. 15 further maps were created identifying areas of each city at each time point where any indicators of deprivation were present. In total 108 maps were produced.

This section has detailed how these 108 maps were produced. The next section moves on to justify three key decisions made to produce these maps.

4.9 Rationale for key decisions in map making process

The process of producing the maps (detailed above) required three key decisions: what cell size and search radius[42] to use in SurfaceBuilder, and how to classify the cells. This section details the rationale for using a cell size of 75 metre^{2,} a search radius of 500 metres, and using the natural breaks (Jenks) classication method.

4.9.1 Rational for cell size and search radius

As discussed above, SurfaceBuilder requires the user to select cell size and search radius, both of which have implications for the maps produced. Whilst others have tested the accuracy of using different parameters (for example Martin, (1996) and Martin et al. (2011)) it would appear that there is no “ideal” cell size for all purposes. A way of ascertaining which parameters were most suitable was therefore required.

To decide which cell size and search radius to use in this study, 10 surface maps of 2001 census household data for Glasgow were produced using a combination of available options shown in Figure 3-12. The search radius is constrained in SurfaceBuilder by the cell size as the maximum search radius is ten times that of the cell size. These maps were visually examined at two different scales; first, by looking at the whole of the city (as in Figure 3-14), and second, by zooming into an area of Glasgow so that implications of decisions could be seen at a finer detail (as in Figure 3-15). The parameters which produced maps that best reflected the actual distribution of households were then chosen. Glasgow was used for this purpose, as opposed to Liverpool or Manchester, as this study was

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[42] The search radius is the distance from each centroid from which the software incorporates information.

based in Glasgow and (having lived in Glasgow for over twenty years) the researcher was more familiar with land use within the city. The locale examined at a finer scale (Figure 3-13) was selected as it is an established residential area. The type of housing in the area is mixed (ranging from high rise flats to large detached houses); importantly, however, there has been no significant new house building since 2001. It was therefore not an issue that the census data being used were from 2001[43]. The area also contains parks of different sizes. This meant that it was possible to see how accurate the different options were at identifying spaces without households.

		Search radius (metres)			
		250	500	750	1000
Cell size (metres^2)	25	Figure 3-14 & Figure 3-15	Not available	Not available	Not available
	50	Figure 3-16 & Figure 3-18	Figure 3-17 & Figure 3-19	Not available	Not available
	75	Figure 3-20 & Figure 3-23	Figure 3-21 & Figure 3-24	Figure 3-22 & Figure 3-25	Not available
	100	Figure 3-26 & Figure 3-30	Figure 3-27 & Figure 3-31	Figure 3-28 & Figure 3-32	Figure 3-29 & Figure 3-33

Figure 3-12 Cell size and search radius combinations

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[43] At the time this analysis was undertaken 2011 census data were not available.

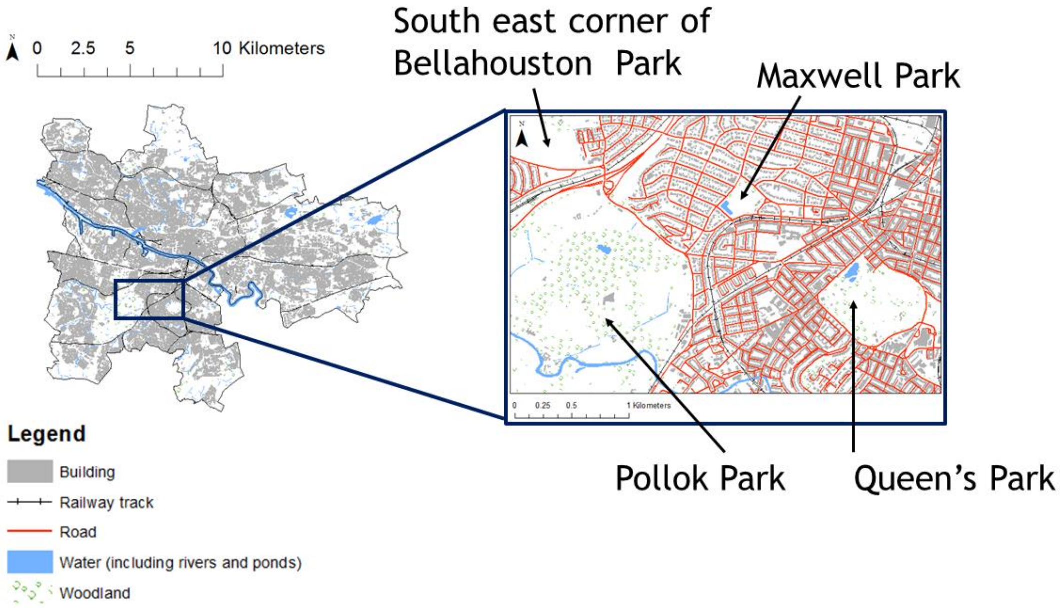

Figure 3-13 The location of the area selected for the purposes of examining the implications of using different cell sizes and search radiuses. (Contains OS Data © Crown copyright and database right 2013)

4.9.1.1 25 metre^2 cells

In Figure 3-14 the areas in black are those where it was identified that there were households when using 25 metres^2 cells and a search radius of 250 metres. The grey areas represent areas where there are buildings. Whilst it would be highly unusual for all the buildings in a city to contain households, it would be expected that more of these buildings were households. It therefore appeared that when using these parameters a considerable proportion of households were not identified. Examining the residential area in Figure 3-15, where it was known that the majority of buildings are residential, confirmed that these parameters did not identify a substantial proportion of households. This was due to search radius being too small to obtain enough information on the area, and thus SurfaceBuilder was only able to identify households close to the the centroid. It was therefore deemed that cell sizes of 25 metres^2 cells and a search radius of 250 metres were too small and led to significant inaccuracies.

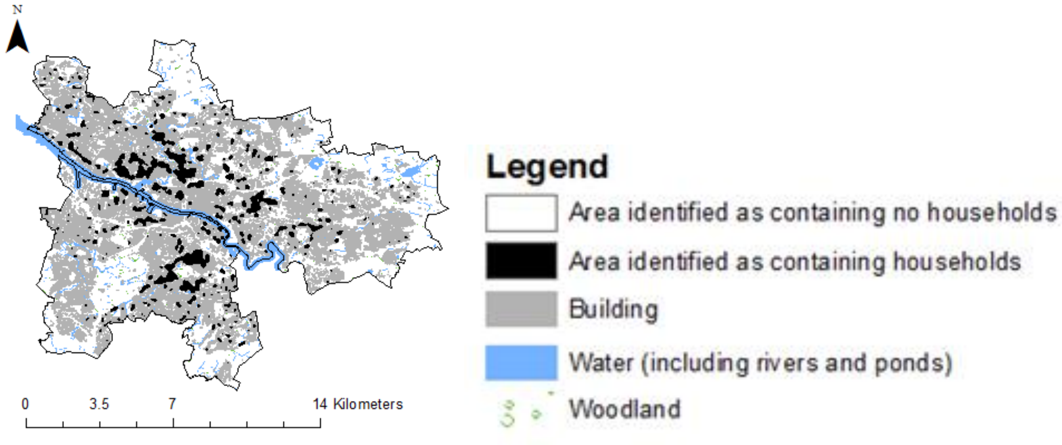

Figure 3-14 Cell size 25 metres2, search radius 250 metres (Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.

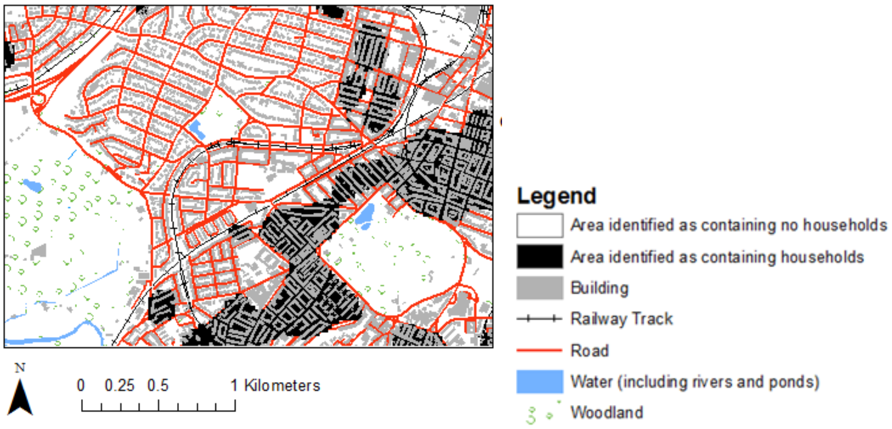

Figure 3-15 Cell size 25 metres2, search radius 250 metres (small area of Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

4.9.1.2 50 metre^2 cells

Increasing the cell size to 50 metres^2 (see Figure 3-16 to Figure 3-19) was an improvement on using a cell size of 25 metres^2 and led to more households being identified (irrespective of the search radius used). However, it was apparent from Figure 3-18 and Figure 3-19 that when these specifications were used a considerable number of households were still not identified. Using grid cells of 50 metres^2 was, therefore, also deemed to be insufficiently accurate for it to be used in this study.

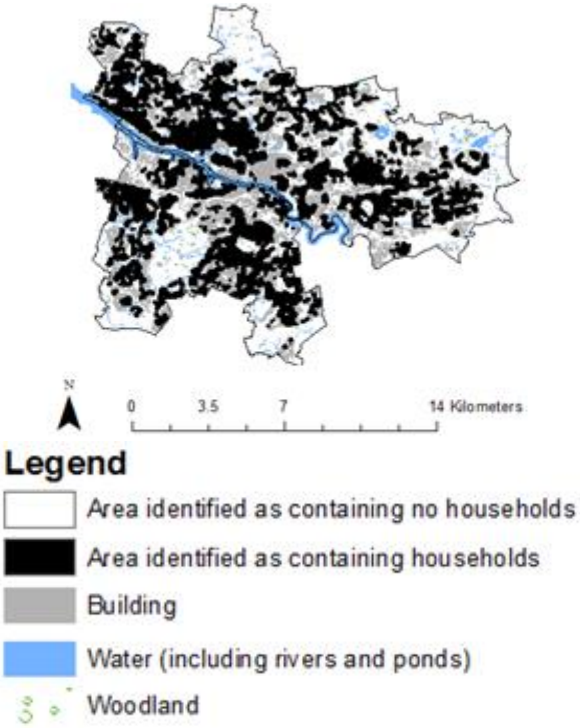

Figure 3-16 Cell size 50 metres^2, search radius 250 metres (Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

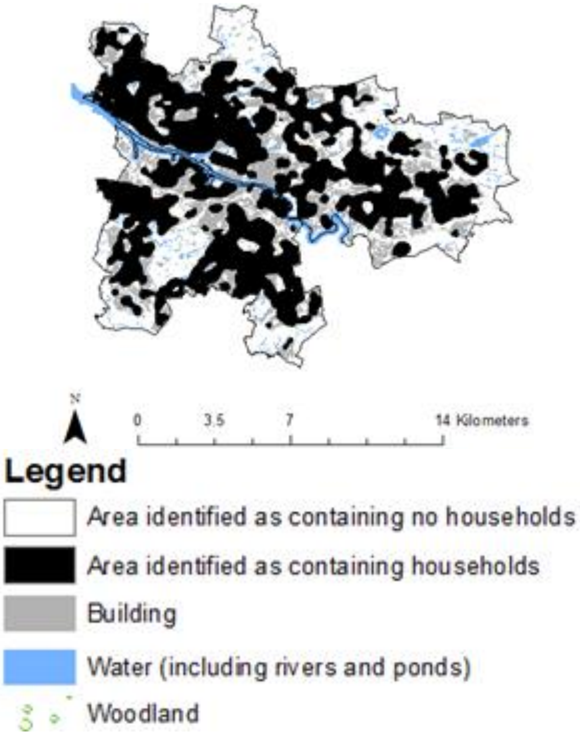

Figure 3-17 Cell size 50 metres^2, search radius 500 metres (Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National

Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

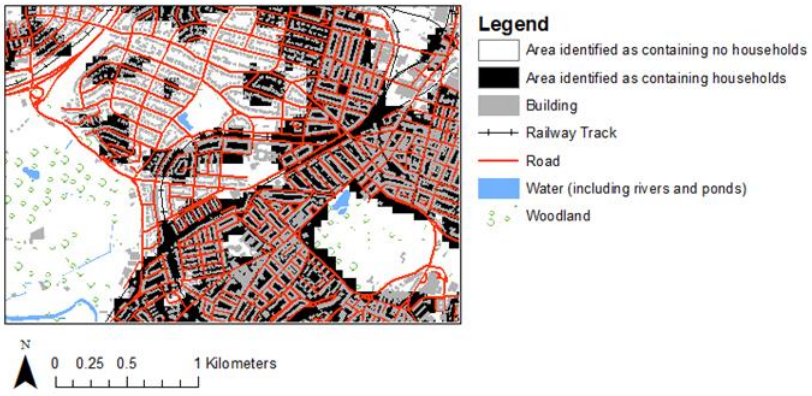

Figure 3-18 Cell size 50 metres^2, search radius 250 metres (small area of Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

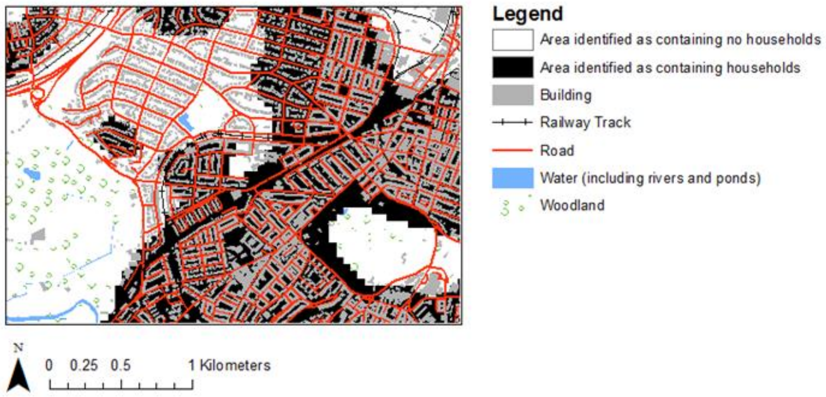

Figure 3-19 Cell size 50 metres^2, search radius 500 metres (small area of Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

4.9.1.3 75 metre^2 cells

Increasing the grid cells to 75 metres^2 (see Figure 3-20 to Figure 3-25) was an improvement on using 50 metre^2 cells. Whilst a 250 metre search radius identified a large number of households, it appeared from Figure 3-20 that some were still not captured using these parameters. This was confirmed from an examiniation of Figure 3-23. Using a search radius of 500 metres (Figure 3-21 and Figure 3-24), did, however, capture the majority of the households that were missing when the smaller search radius of 250 metres was used. Increasing the search radius to 750 metres (Figure 3-22 and Figure 3-25) did capture all of the households; however, in doing so it was also found to encroach more on areas with no households such as the parks. The entirity of Maxwell Park[44], for example, is identified as having households present, as is the majority of Queen’s Park[45]. Using a search radius of 750 metres, therefore appears to be less accurate than using a 500 metre search radius. From this it was decided that a cell size of 75 metres^2 and a search radius of 500 metres led to maps which most accurately dissagregated the data and recreated the actual locations of households.

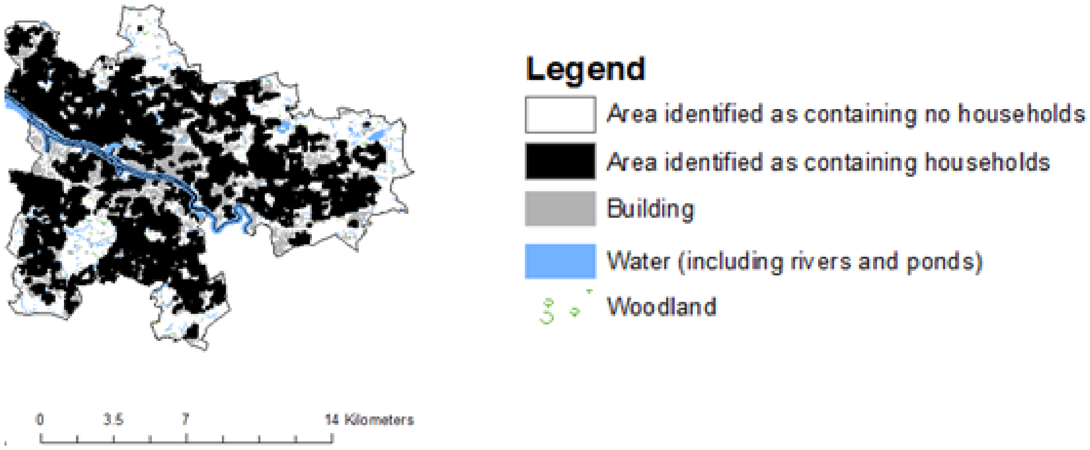

Figure 3-20 Cell size 75 metres2 search radius 250 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

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[44] The location of Maxwell Park is highlighted in Figure 3-13.

[45] The location of Queen’s Park is highlighted in Figure 3-13.

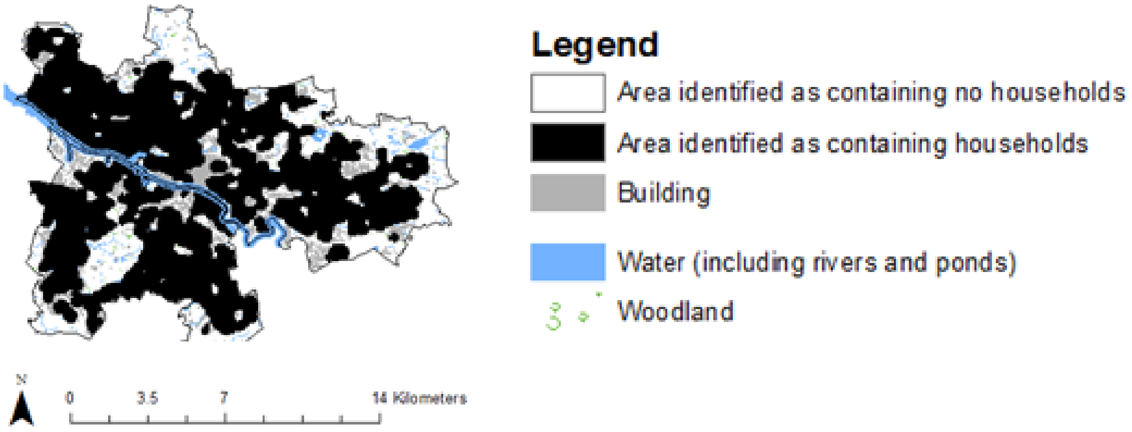

Figure 3-21 Cell size 75 metres^2 search radius 500 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

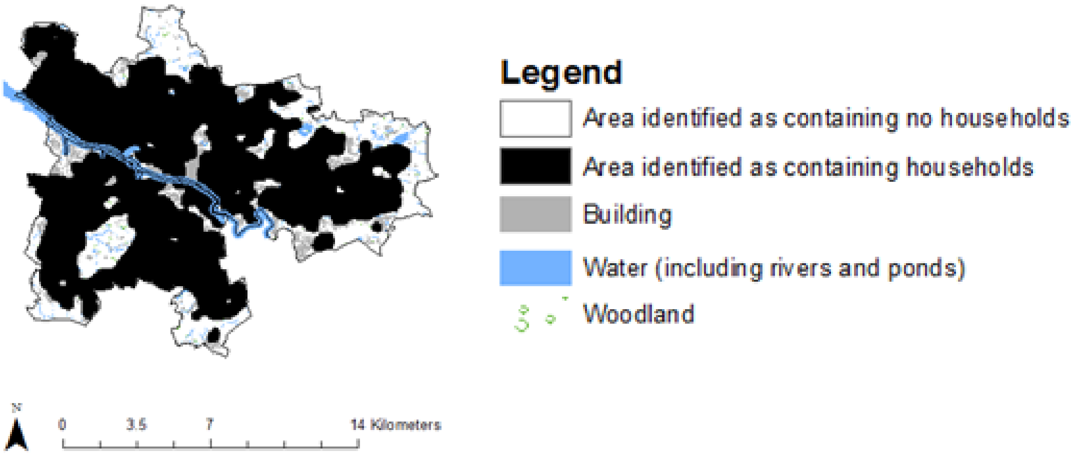

Figure 3-22 Cell size 75 metres2 search radius 750 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

Figure 3-23 Cell size 75 metres^2 Search radius 250 metres (small area of Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

Figure 3-24 Cell size 75 metres^{2,} search radius 500 metres (small area of Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

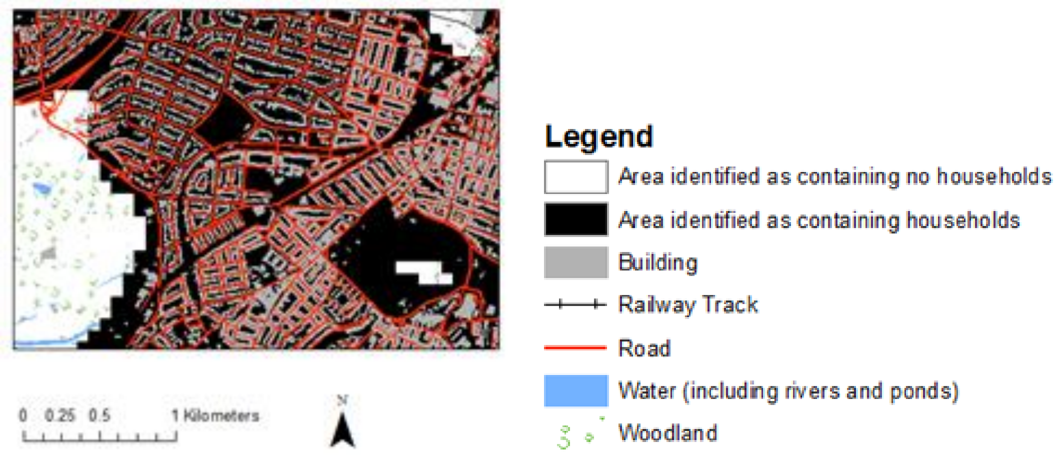

Figure 3-25 Cell size 75 metres2 search radius 750 metres (small area of Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

4.9.1.4 100 metre^2 cells

Figure 3-26 to Figure 3-33 show the results when using 100 metre^2 cells and search radii of 250 metres, 500 metres, 750 metres, and 1000 metres. These were an improvement on using both 25 and 50 metre^2 cells, however, was not felt to be better than the results of using 75 metre^2 cells with a search radius of 500 metres.

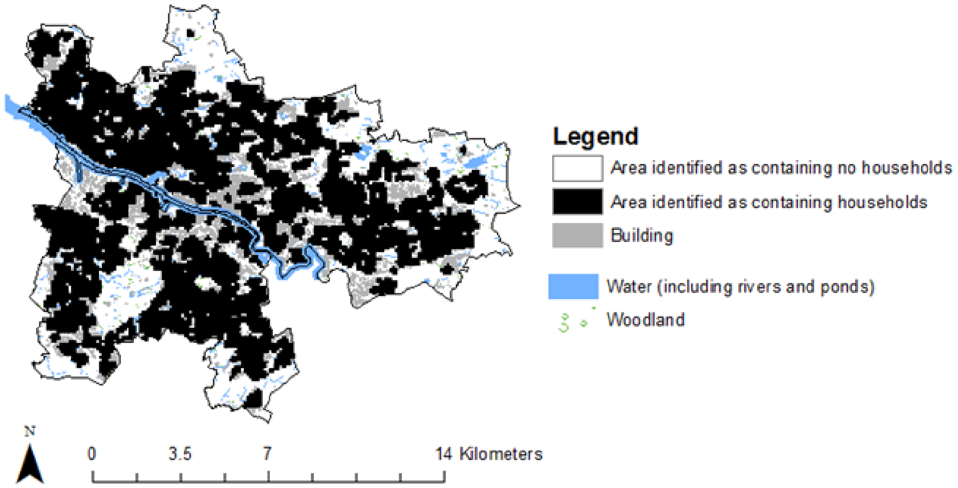

Figure 3-26 Cell size 100 metre^2, search radius 250 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

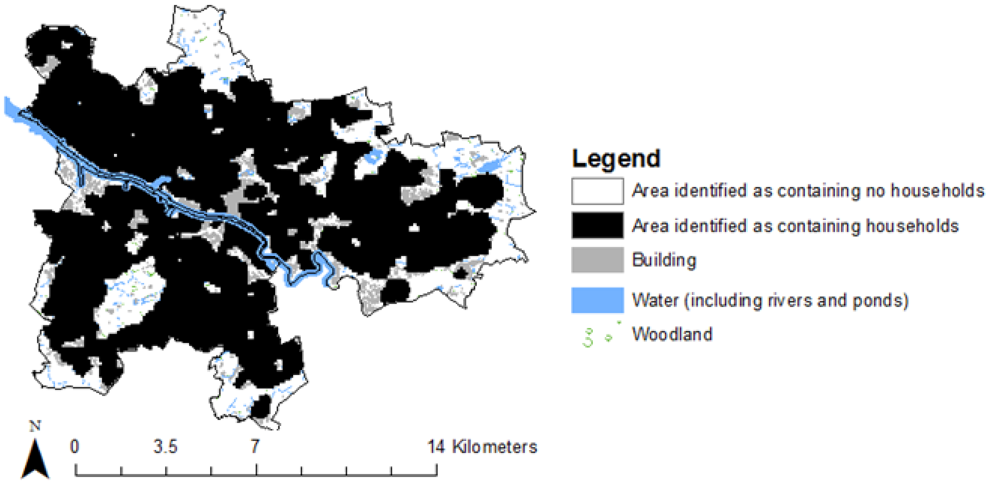

Figure 3-27 Cell size 100 metre^2, search radius 500 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

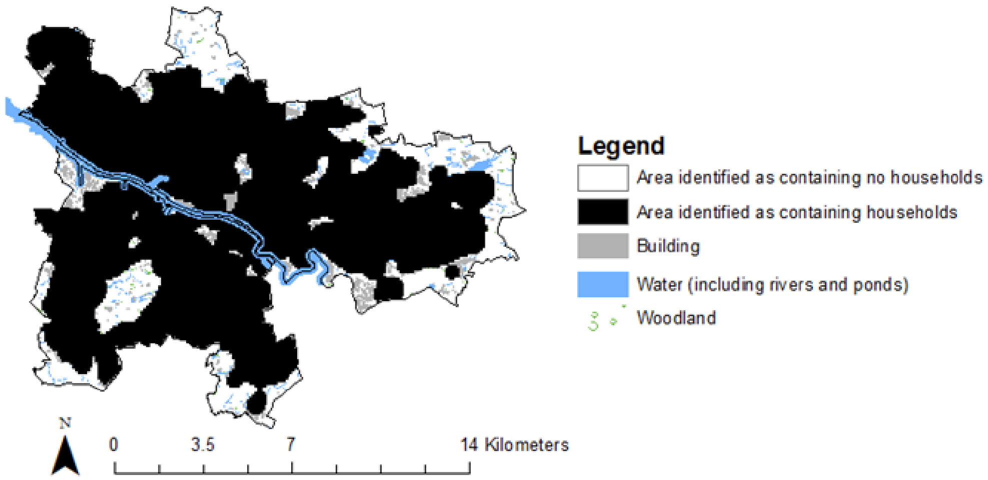

Figure 3-28 Cell size 100 metre^2, search radius 750 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

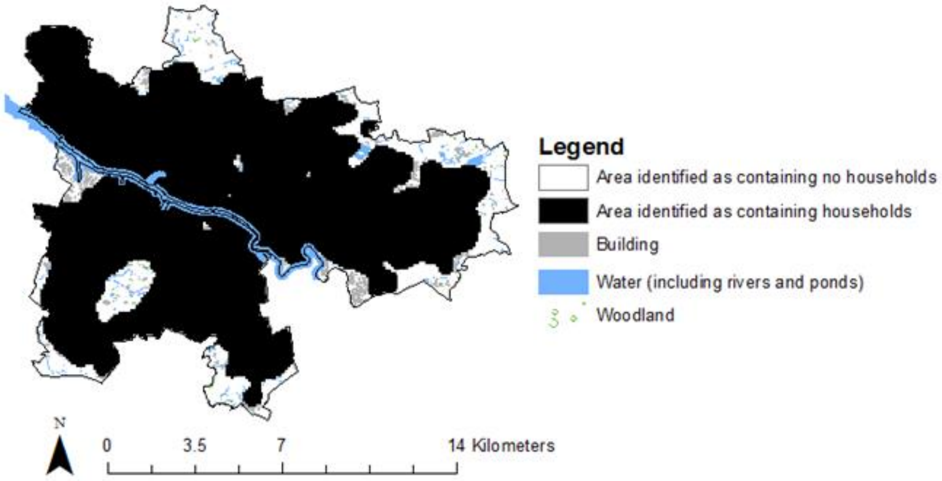

Figure 3-29 Cell size 100 metre^2, search radius 1000 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

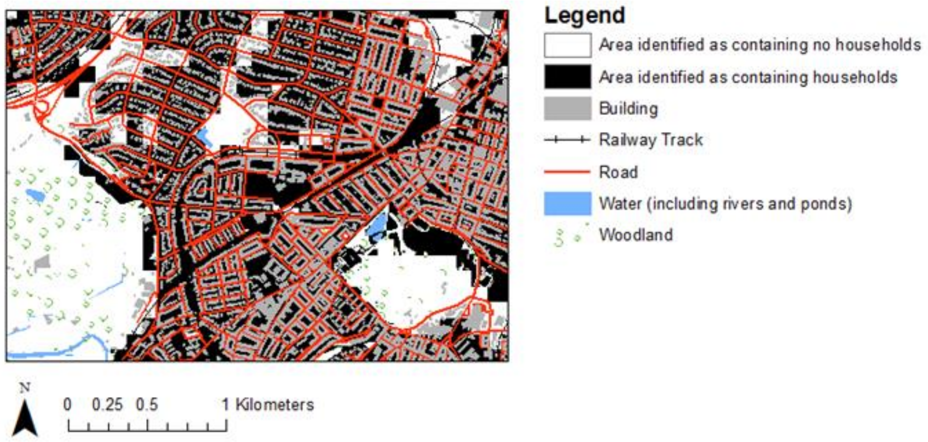

Figure 3-30 Cell size 100 metre^2 search radius 250 metres (small area of Glasgow). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

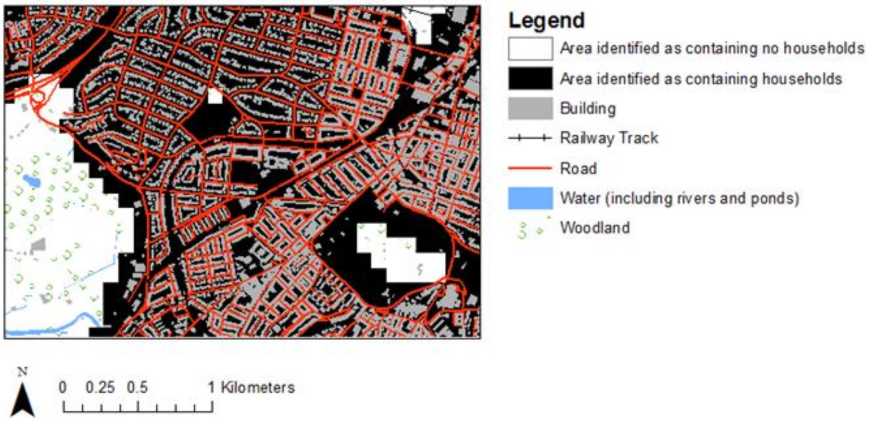

Figure 3-31 Cell size 100 metre^2, search radius 500 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

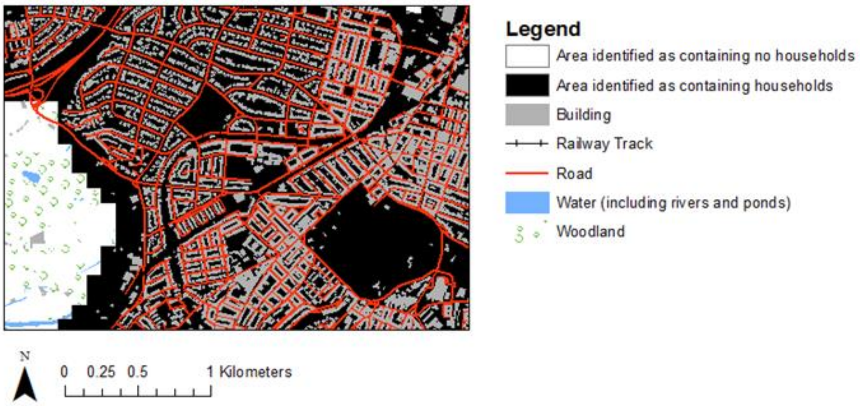

Figure 3-32 Cell size 75 metre^2, search radius 750 metres. (Source:based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

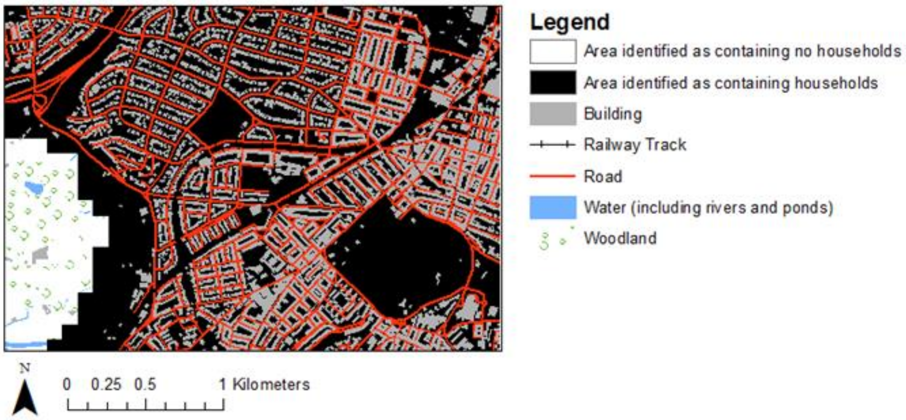

Figure 3-33 Cell size 100 metre^2, search radius 1000 metres. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

4.9.1.5 Selected cell size and search radius

From this analysis it was decided to use a cell size of 75 metre^2 and a search radius of 500 metres. This combination was felt to produce the most meaningful results. It should, however, be noted that this analysis was undertaken on an urban area; it is unlikely that such a combination would consistently produce meaningful results in rural areas with low population densities where output areas are often much larger.

4.9.2 Rationale for classifying the cells

Wyatt and Ralphs (2003:62) state that:

> "*(a) critical choice for the mapmaker is where to define the boundaries between classes that are used when mapping values of a particular variable.*"

This was indeed the case in this study. An advantage of the mapping technique used in this study is that it produces raster maps and therefore every cell in the map has a value. As was detailed in the literature review, this study is interested in relative deprivation, more specifically it aimed to identify which areas of the city have high levels of household deprivation relative to the rest of the city at certain points in time. Consequently, a classification method was required which examined the statistical distribution of the cell values in each map, and then identified which cell values were high relative to the other cells in the same map.

ArcGIS 10.1 provides a number of different classification methods, some of which could classify raster data based on the statistical distribution of cell counts. These are standard deviation, quantiles, natural breaks (Jenks), and geometric intervals. This section will explore these different options and explain why, and how, the natural breaks (Jenks) method was selected to classify cells within each map.

4.9.2.1 Standard deviation

Using standard deviation to categorise data shows how much a cell's attribute value varies from the mean. Class breaks are created with an equal value of ranges that are a proportion of the standard deviation. This method works best if there is a normal distribution curve (Zeiler, 1999). Examining the histograms for cell values revealed that their distribution was often skewed; standard deviation was not an appropriate method of categorising data values in this research.

4.9.2.2 Quantiles

The quantile classification method puts an equal number of cells into each class and class breaks are set in order to accomplish this. Some other studies examining spatial patterns of poverty have used this method for categorising poverty (for example Norman and Boyle (2014) and Gregory (2009) both use quintiles). When quantiles are used, all of the classes are approximately equally represented on the map. For example if the cells were classified into quintiles then it would be expected that 20% of the cells would be in quintile one and therefore occupy 20% of the spatial area of the map; 20% of the cells would be expected to be in quintile two and occupy a different 20% of the spatial area of the map, and so on. This means that quantiles do not necessarily facilitate the comparison of the spatial extent of areas with high levels of households experiencing deprivation. A consequence of the way in which the quantile classification methods groups cells into classes is that values which are close together can be placed in adjacent classes, yet at the same time very different values can be put into the same class. This can result in class boundaries which are not particularly meaningful or revealing in terms of data distribution, and can therefore lead to the production of misleading maps. As this study is interested in ascertaining which areas of a city have a high number of deprived households relative to the rest of that city at that point in time, using quantiles is not a reliable method of classifying cells in this study. A further disadvantage of quantiles is that it works best with linearly distributed data (Zeiler, 1999). Not all data are necessarily going to be linearly distributed (and an examination of the histograms of cell value distribution revealed that this was usually not the case in this study) and so it is possible that gaps occurring between the observations might lead to an over-weighting of some outlying observations.

Thus, whilst there was a precedent for using quantiles (specifically quintiles) to classify cells, their use was not appropriate for this study. There would also be practical difficulties in using quintiles as for some indicators at certain time points the range of cell values was not large enough to form five groups. The biggest disadvantage of using quantiles, however, would have been the potential for there to be a considerable amount of heterogeneity within a class, and at the same time considerable homogeneity between values which just fall either side of the class break.

4.9.2.3 Jenks's natural breaks

Jenks's natural breaks method is widely used in GIS (Henke and Petropoulos, 2013, de Smith et al., 2009) and is a relative classification method based on the distribution of cell counts. It categorises values into different classes by grouping together similar values, and is designed to maximise the variance between classes, and minimise the variance within a class. This means that the class boundaries are more meaningful as they are derived from the distribution itself, and that classes are more likely to contain homogenous values. Using natural breaks (Jenks) therefore leads to maps which stress differences between values (Henke and Petropoulos, 2013).

Using natural breaks to classify the cells in the surface maps means that instead of deciding on an arbitrary value (or proportion of cells) and saying that cells with values above that are classed as “high” and values below that are “not high”, cells are classified into classes in a way which maximises the difference between classes. This is useful for this research because it is attempting to identify areas which vary from other areas by being different in having high numbers of people who are likely to be in deprivation relative to the rest of the city.

4.9.2.4 Geometric intervals

The geometric interval method[46] of classification, which was developed by ESRI[47], was the fourth possible method which could have been used to classify cells. This classification method was developed as a way of classifying continuous data and data containing large numbers of duplicate values. This classification method uses class intervals which have a geometric series to create class breaks. The algorithm used to create these geometric intervals, minimises

> "*the sum of squares of the number of elements in each class*" so that "*each class range has approximately the same number of values with each class and that the change between intervals is fairly consistent.*" (ESRI 2016).

As this study was interested in identifying cells with higher values relative to the other cells in the same map, having a similar number of values within each class, and having consistent interval changes, were not necessarily beneficial.

4.9.2.5 Applying the classification methods to the surface maps

The differences between the way in which the natural breaks (Jenks), geometric intervals and the quantile classification methods categorise values will now be illustrated using surface maps of male unemployment in Glasgow in 2011 as an example. Figure 3-34 to Figure 3-36 are surface maps indicating areas of Glasgow with high levels of unemployment in 2011 produced by classifying cell values into five classes using natural breaks (Figure 3-34), quintiles (Figure 3-35), and geometric intervals (Figure 3-36). Choosing the number of classes to classify data into is frequently an arbitrary decision, and that was the case in this study. To allow meaningful comparisons, it was felt that the cells should be classified into the same number of classes irrespective of the classification method used. As one of the classification methods being tested was quantiles, it was felt that a "typical" quantile such as quintiles, deciles, or virgintiles should

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[46] When this was originally introduced this was termed the smart quintiles method (ESRI, 2016).

[47] The company which developed ArcGIS.

be used. However, both the natural breaks and geometric interval classification method were designed to use fewer than 10 classes[48]. It was therefore decided to use five classes (meaning that the quantile used was quintiles). However, to facilitate a simpler comparison, the maps in Figure 3-34 to Figure 3-36 only show the cells that were classified by the respective classification method into the highest class (that is the class comprised of cells identified as having the highest percentage values of male unemployment).

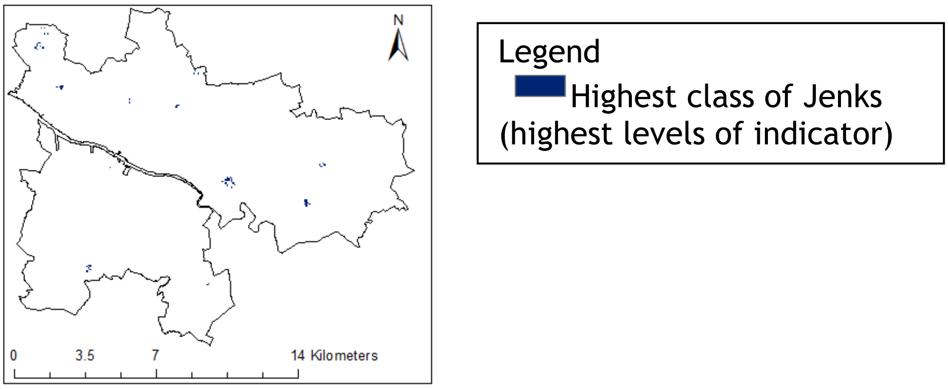

Figure 3-34 Areas with high levels of male unemployment in Glasgow 2011. Cells were classified into 5 categories using natural breaks (Jenks) and the area shown is the top category (highest level of male unemployment). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

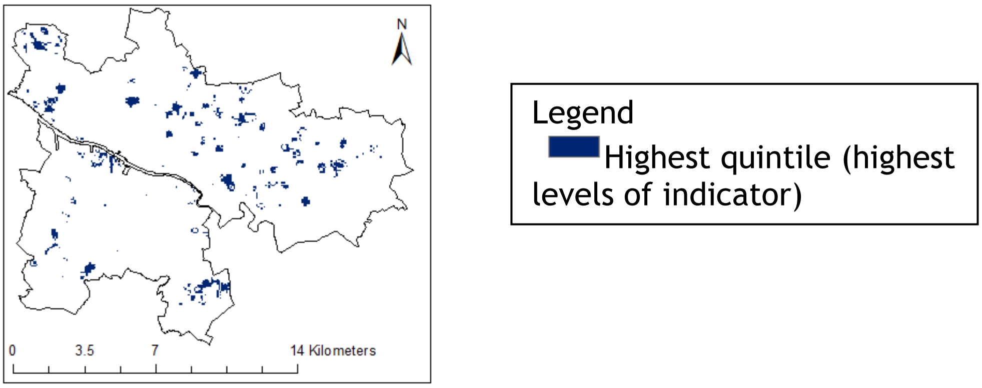

Figure 3-35 Areas with high levels of male unemployment in Glasgow 2011. Cells were classified into 5 categories using quintiles and the area shown is the top class (highest level of male unemployment). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data

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[48] The reason for this being that both the natural breaks and geometric interval classification method were specifically designed for choropleth mapping and it has been proven that it is harder to distinguish between classes and make meaningful sense of maps when there are more than seven classes (ESRI, 2016).

Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

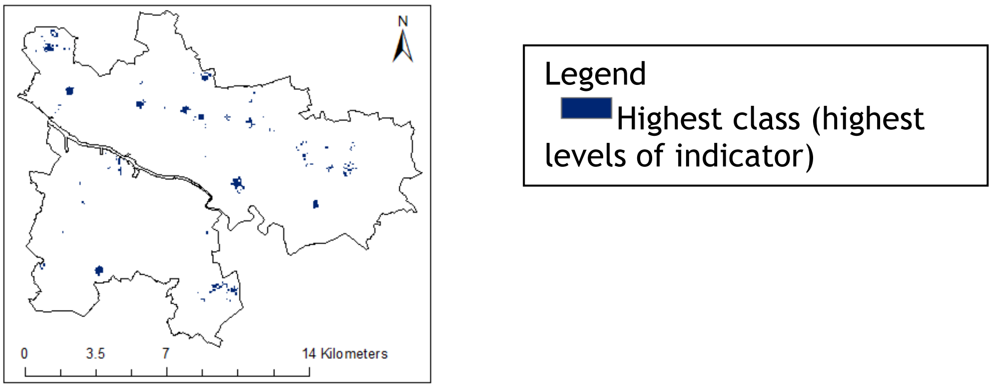

Figure 3-36 Areas with high levels of male unemployment in Glasgow 2011. Cells were classified into 5 categories using geometric intervals and the area shown is top class (highest levels of male unemployment). (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains OS Data © Crown copyright and database right 2013.)

From Figure 3-34, Figure 3-35, and Figure 3-36 it is apparent that categorising cells using quintiles lead to the highest number of cells being categorised into the highest class, and using natural breaks (Jenks) leads to the fewest cells being categorised into the highest group. This is confirmed when looking at Figure 3-37 which shows the number of cells allocated into each class using the three different classification methods. Figure 3-38, Figure 3-39, and Figure 3-40 also show the distribution of cells into classes (through the use of different colours) and indicate which cell values are classified into which class, and the number of cells with each cell value. From these graph the different locations of the class breaks can be seen. Of particular interest is Figure 3-38 as this highlights how the natural breaks classification method puts class breaks in places where there is maximum variation between cell counts.

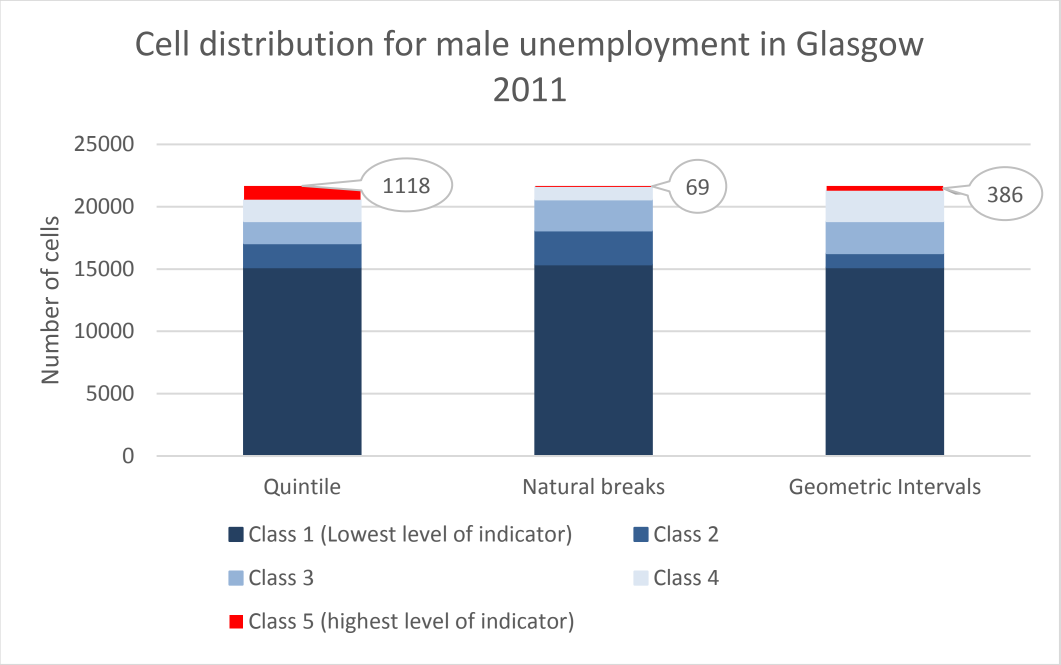

Figure 3-37 Distribution of cells into 5 classes using quintiles, natural breaks (Jenks) and geometric intervals

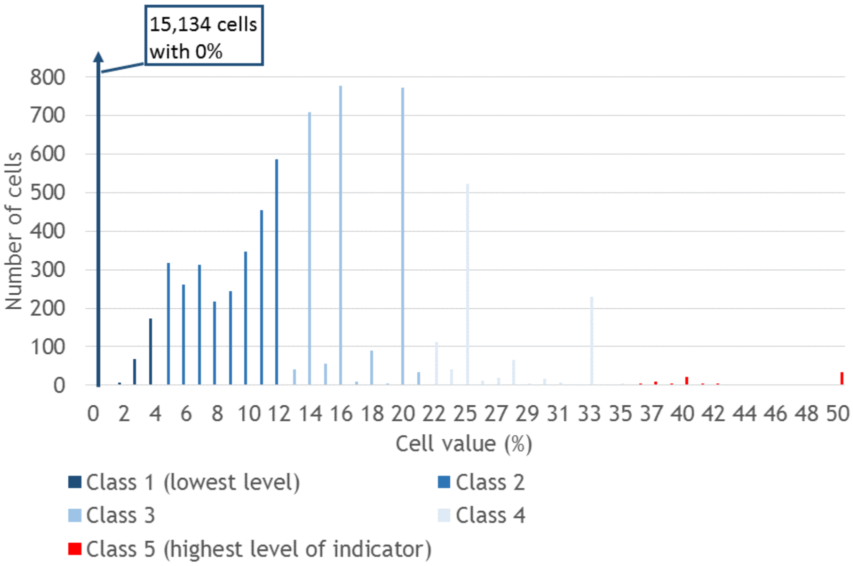

Figure 3-38 Cell value distribution when cell values for male unemployment in 2011 and categorised using natural breaks (Jenks)

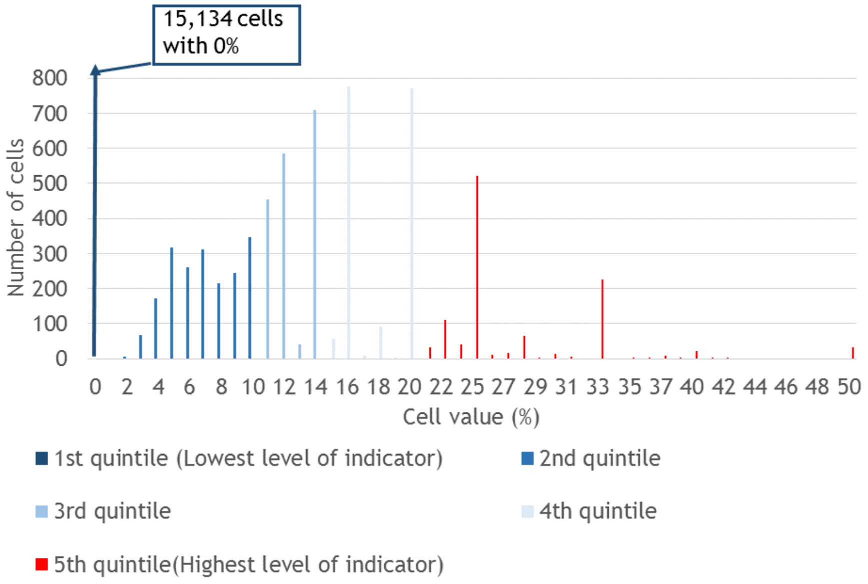

Figure 3-39 Cell value distribution when cell values for male unemployment in Glasgow in 2011 are categorised using quintiles

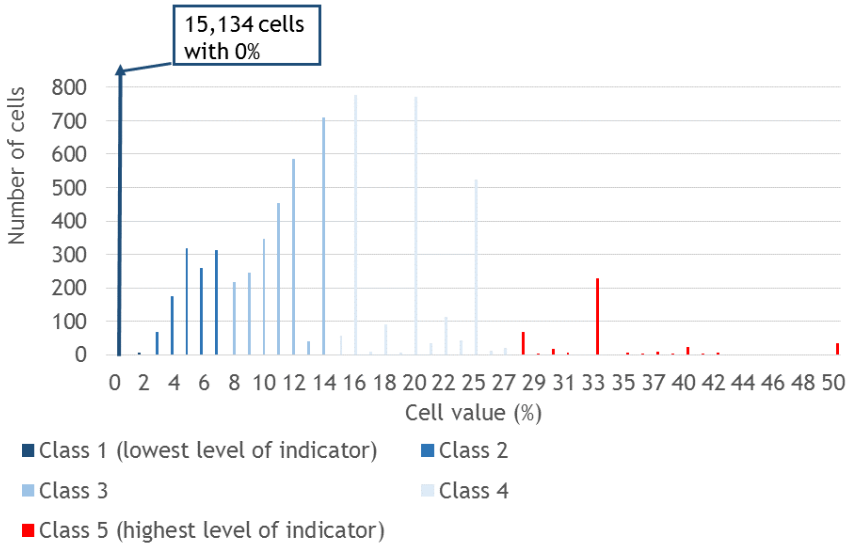

Figure 3-40 Cell value distribution when cell values for male unemployment in Glasgow in 2011 are categorised into 5 classes using the geometric interval method

Having compared the results of using quantiles, geometric intervals, and natural breaks (Jenks) to classify cells, it was decided to use natural breaks. This study is interested in identifying which locations in a city have a high number of deprived households relative to other parts of the same city at the same time period. To do this required a classification method which based the placing of class intervals on the distribution of cell counts, and which maximises differences between classes and minimises differences within classes. The classification system found to most accurately achieved this was natural breaks.

It can be seen from Figure 3-34, Figure 3-37 and Figure 3-38 that when using the natural breaks classification method the class boundary falls in such a position that only a very small proportion of cells are included in it. That is, the cells with cell values which are strong outliers/extreme are included in that group. Using the top category of natural breaks therefore creates a map which shows the cells with just the extreme values. Consequently, cells which still have a high value relative to the rest of the city, but which are not extreme, are excluded. However, looking at Figure 3-38 (and other distribution graphs for other indicators and other cities) revealed that cell values which were high relative to the rest of the city (at that time point), but not extreme enough to fall into the top class, were included if the top two groups of the natural breaks classification were used. It was, therefore, decided that these top two groups would be combined to form the group of cells identified as having high levels of household deprivation relative to the rest of the city.

4.9.2.6 Number of classes examined

Having selected the natural breaks (Jenks) classification method, and having selected how this would be used to define the cells which were categorised as being of high value relative to the rest of the city, a further decision regarding the classification of cells was required: how many of the classes were of interest? It would have been feasible to study the spatial arrangement of all of these classes, and, as these classes would have shown different levels of the indicator, it would have been possible to make comparisons between them (for example to compare the spatial arrangement of areas with the highest and lowest levels of the indicator). However, this study is interested in the spatial arrangement of areas with high numbers of deprived households relative to the rest of the city (at that time point). Consequently what is of interest is the location of areas with high levels of the different indicators. Areas with lower levels of an indicator are, therefore, superfluous to the study's needs[49]. It was therefore decided to produce maps showing a binary classification of the indicators – areas with high levels of a certain indicator relative to that city at that time point, and areas without high levels of that indicator relative to that city at that time point. Areas with no households were also shown on the map to indicate areas where the binary classification was not applicable.

There were two further advantages in using a binary classification. First, as was explained in the discussion above, regardless of the classification system utilised, there will always be a certain level of arbitrariness regarding where class breaks fall. Using natural breaks greatly reduces this; however, class breaks are still somewhat arbitrary. Increasing the number of classes being studied therefore increases the level of arbitrariness in the study. Second, this study is about developing a new method of studying the spatial arrangement of deprivation. To do this, and to test this method, maintaining a level of simplicity was felt to be important. Studying different classes had the potential to overcomplicate the study in a way which would detract from the methods being used and the results.

4.10 Summary

This chapter has detailed the novel methods used to produce 108 surface maps showing deprivation in Glasgow, Liverpool, and Manchester at decennial intervals between 1971 and 2011. The next chapter details the innovative way in which these maps were then analysed.

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[49] This is not to say that the location of such areas are not interesting, they are and could form the basis of further studies, rather they are not of interest to this specific study.

Chapter 4 : Using spatial metrics to analyse the maps

To enable accurate comparisons to be made between the cities over time an objective means of analysing the 108 maps, produced using the methods discussed in the previous chapter, was required. Visual examinations of the maps provided some indication of spatial and temporal differences; this, however, was neither scientific nor rigorous. A method of quantifying the information in the maps was required.

From the literature on map analysis, spatial metrics were identified as a tool which could be used to objectively analyse the maps and facilitate temporal and spatial comparisons. Spatial metrics quantify the structure of a landscape and have previously been used to study urban landscapes (Herold et al., 2002, Herold et al., 2005, Zhao and Murayama, 2011, Geoghegan et al., 1997, Alberti and Waddell, 2000, Wang and Yin, 2011). No evidence, however, was found of previous studies having used them to facilitate spatial comparisons of spatial patterns of deprivation. A further innovation of this study was, therefore, to use spatial metrics to analyse the maps of deprivation in this study.

This chapter discusses the use of spatial metrics to analyse the maps in this study. It commences with an introduction to spatial metrics and a discussion of why their use is both suitable and advantageous to this study, before moving on to discuss how and why specific metrics were chosen to be used in this study.

5.1 Introduction to spatial metrics

Spatial metrics[50] were developed within disciplines (such as ecology) where there is an interest in studying patterns in landscapes. They are defined as "*quantitative indices to describe structures and pattern of a landscape*" (Herold et al., 2002:34). To understand how value is added to this study through the use of spatial metrics, it is first important to have a basic understanding of the concept of "landscape".

Meanings of the term "landscape" vary between academic disciplines and professions (Leitao et al., 2006). Painters and photographers, for example, use the term to describe visual representations of the visible scenery. In human geography landscape can refer to more than just the visible scenery and include the "cultural landscape"; this refers to the way in which individuals and societal groups have modified the land, as well as to the meaning ascribed to the land by individuals and groups (Robertson and Richards, 2003). In ecology, landscapes are understood to be units of space comprised of interacting ecosystems (Leitao et al., 2006). Ecological landscapes can be of any scale, but what is important is that they are spatially heterogeneous. Cities are units of space (sometimes defined by city boundaries) which are spatially heterogeneous both in terms of land use, landforms, and demographics. It is, therefore, reasonable to use this ecological lens and view cities as landscapes. Rather than examining the ecological *ecosystems* making up the urban landscape, the focus is on the mosaic of *neighbourhoods* making up the urban landscape. Viewing the city from a landscape perspective enables the wider context to which city residents are exposed to be studied, without losing the detail that comes from studying small areas or neighbourhoods. It was therefore an ideal approach for use in this study.

Spatial metrics can be used to study any type of landscape, and in recent years there has been growing interest in the use of spatial metrics to analyse whole

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[50] When initially developed spatial metrics were referred to as "landscape metrics" and this continues to be the case in disciplines, such as ecology, where the natural environment is the focus of studies. However, when used to study urban environments the protocol has been to use the term "spatial metrics". Spatial metrics is therefore the term used in this study.

urban environments (Herold et al., 2005, Zhao and Murayama, 2011). Studies which have used spatial metrics to analyse urban environments include: models explaining housing and land values in the vicinity of Washington D.C. (Geoghegan et al., 1997); a framework for modelling how interactions between socio-economic and ecological processes impact upon urban development (Alberti and Waddell, 2000); exploring changes in urban land use (Herold et al., 2002, Wang and Yin, 2011); modelling and analysing urban growth (Herold et al., 2005, Pham et al., 2011, Zhao and Murayama, 2011, Jain et al., 2011, Thapa and Murayama, 2011, Li et al., 2014); and changes in land abandonment in Bucharest (Gradinaru et al., 2013). All these studies examined patterns across whole landscapes rather than between, or surrounding, neighbourhoods. In each case, this approach has furthered understanding of urban environments.

5.1.1 Spatial metrics: patch, class, and landscape

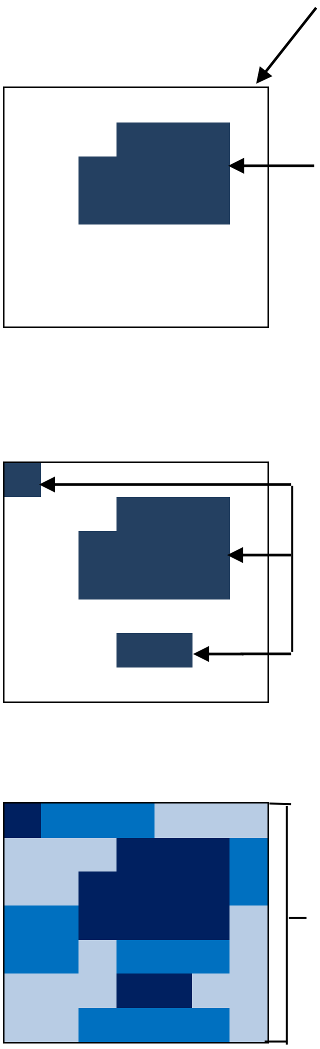
Spatial metrics operate at different levels: patch, class, and landscape, as illustrated in Figure 4-1. A **patch** is an individual homogenous area. It can cover just one cell/grid square or it can be made up of any number of contiguous cells. Patch level metrics describe aspects of individual patches, for example patch size, patch shape, and total edge of a patch. A **class** is made up of all the patches of the same type. Class level metrics measure aspects of a single patch *type* within a landscape. Examples of class level metrics include: the mean patch size of all the patches within the class being analysed, the spatial extent of the area covered by the class, and the number of patches of a particular class within a landscape. In this study, for example, the maps showing high levels of an indicator relative to rest of the city (landscape) at that time point, have three classes:

- Areas with high levels of the indicator

- Areas without high levels of the indicator

- Areas with no households present.

The **landscape** is composed of the mosaic of all the different classes present within a set boundary. Landscape level metrics therefore "*represent the spatial pattern of the entire landscape mosaic, considering all patch types simultaneously*" (McGarigal and Marks, 1995:22)



Landscape boundary.
The landscape boundary defines the area of study. (In this study the landscape boundary for each of the three cities is their city boundary as it was at the time of the 2001 census.)

Patch
A patch is an individual homogenous area within the landscape's boundary. It can be made up of any number of contiguous cells. Patch level metrics quantify aspects of individual patches, for example patch size.

Class
A class is made up of all the patches of the same type. Within this example landscape boundary there are three different patches of the same class. Class level metrics quantify aspects of a class, for example the mean patch size of all the patches within the class being analysed.

Landscape
A landscape is composed of all the different components which are present within the landscape boundary. As such it is a mosaic of all the different patches and classes present. Landscape level metrics quantify characteristics of this mosaic without reference to individual classes or patches, for example at the landscape level mean patch size is the mean size of all patches regardless of class. Landscape level metrics are particularly useful for studying diversity within a landscape. In this example there are 3 classes in the landscape and 12 patches.

Figure 4-1: Levels of study available using spatial metrics

5.1.2 Spatial metrics: composition and configuration

Two fundamental aspects of landscape structure measured by spatial metrics are landscape composition and landscape configuration (McGarigal and Marks, 1995, Leitao et al., 2006). Consequently, the majority of spatial metrics can be grouped into two categories:

- Metrics which quantify and describe compositional aspects of a landscape;

- Metrics which quantify and describe the configuration of a landscape.

Compositional metrics quantify the presence and amount of patches/classes within a landscape (McGarigal and Marks, 1995) and, in doing so, assist in describing and identifying a landscape's pattern (Bolliger et al., 2007). Examples of composition metrics include number of classes, class area, percent of landscape, and the diversity metrics. These metrics are not spatially explicit but do have important spatial effects (Gustafson, 1998, Leitao et al., 2006), or as McGarigal and Marks (1994:9) surmise:

> "*landscape composition encompasses the variety and abundance of patch types within a landscape, but not the placement or location of patches within the landscape mosaic.*"

Configuration metrics are, however, spatially explicit as they quantify "*the spatial character and arrangement, position, or orientation of landscape elements.*" (Leitao, 2006:20). Examples of types of landscape configuration metrics include edge metrics, nearest neighbour metrics, and core area metrics[51].

Understanding the difference between configuration metrics and composition metrics is useful with regards to understanding how they can assist in analysing different aspects of the structure of a landscape. However, not all metrics can be neatly classified into these two categories (McGarigal and Marks, 1995). Two

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[51] These metrics will be explained in further detail later in this chapter.

examples, given by McGarigal and Marks (1995), of metrics which do not fit neatly into either category are mean patch size and patch density. They argue that these:

> "*are not really spatially explicit...because they do not depend explicitly on the spatial character of the patches or their relative location. Moreover, mean patch size and patch density of a particular type reflect both the amount of a patch type present (composition) and its spatial distribution (configuration)*" (McGarigal and Mark, 1995:11).

Whilst neat classification of metrics is not important, it *is* important to be aware that a landscape's structure:

> "*consists of both composition and configuration and that various metrics have been developed to represent these aspects of landscape structure separately or in combination.*" (McGarigal and Marks, 1995: p11).

Consequently, when selecting metrics to study landscapes of deprivation it was important to be aware that some metrics would facilitate an understanding of the composition of the landscape, some would be focused on configuration, and some would facilitate an understanding of landscape structure by combining aspects of both configuration and composition.

5.1.3 Spatial metric software

Metrics were calculated in ArcGIS 10.1 using a freely available extension: Patch Analyst 5.1 for ArcGIS 10 (Rempel et al., 2012). This offers 28 metrics on raster maps. This software was advantageous as it provided a wide range of metrics, and was also used in a number of other studies which used spatial metrics in both ecological studies (Baral et al., 2014, Bourke et al., 2014, Feyisa et al., 2014) and studies of the built environment (Gradinaru et al., 2013).

5.2 Selecting metrics

Herold et al. (2005:78) explain that:

> *"there is no standard set of metrics best suited for use in urban environments as the significance of specific metrics varies with the objective of the study and the characteristics of the urban landscape under investigation."*

Further, spatial metrics have not previously been used to facilitate comparisons of spatial patterns of deprivation. Consequently there was no established, recommended set of metrics to apply.

There was a substantial number and variety of metrics to choose from. To guide choice and to be transparent, criteria for metric selection were established. When devising these criteria, careful consideration was given to whether this study was primarily interested in the configuration or composition of the deprivation landscape, or a combination of both. The study was interested in *both* the spatial arrangement of deprivation (i.e. its configuration) and its composition, necessitating assessment of both configuration and composition metrics. Implicit in the selection criteria was that selected metrics needed either to be available in Patch Analyst 5.1, or easily calculated from the results of other metrics[52]. Also implicit in the selection was an awareness that this study was pioneering the use of spatial metrics in this way and that a smaller, rather than larger, number of metrics might enable more attention to be paid to each one, and make a more manageable task.

5.2.1 Selection Criteria

Seven criteria were used in the selection process. The first four were generic in that they related to the general nature of the metrics, for example that the

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[52] As will be shown below, patch density was a metric used in this study. Patch density is not directly calculated in Patch Analyst 5.1, but is easily calculated by dividing the number of patches by total landscape area (which are both calculated by Patch Analyst 5.1).

metric was appropriate for making cross-city comparisons. The remaining three were specific to the function of the metric; that is, they related to what the metric measured and ensured the selected metrics were pertinent to answering the research questions.

5.2.2 Selection Criteria 1: Must be available at the “class” level

As explained above spatial metrics operate at different levels: patch, class, and landscape. Whilst some metrics are available at all levels, others are only appropriate to specific levels. As the aim of this study was to examine the spatial patterning of deprivation, the interest was in quantifying the spatial arrangement of one particular class: areas with high levels of deprivation. It was therefore appropriate to use class level metrics, making the first selection criteria that metrics had to be available at the class level.

5.2.3. Selection Criteria 2: Must be suitable for cross city comparisons

Some spatial metrics are only meaningful if used to compare landscapes of the same size. Glasgow, Liverpool, and Manchester differ in size[53]. It was therefore essential that the metrics could be meaningfully compared between different sized landscapes. Metrics which do not allow this were therefore not selected.

5.2.4 Selection Criteria 3: Must be suitable for temporal comparisons

As well as comparing the spatial arrangement of deprivation in three cities, this study also compared the *development* of the spatial arrangement of deprivation over time. Consequently, the metrics needed to be suitable for making meaningful temporal comparisons.

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[53] Glasgow has the largest area at 17521.31 hectares, Liverpool is 13355.44 hectares, and Manchester is the smallest as it is 11572.31 hectares.

5.2.5 Selection Criteria 4: Avoid metrics that replicate other metrics

Some spatial metrics essentially duplicate each other and are therefore very highly correlated. As McGarigal and Marks (1995:22) note: "*many of the metrics are partially or completely redundant; that is, they quantify a similar or identical aspect of landscape structure.*" To avoid selecting metrics which quantified the same things, checks for similarity or duplication were made at the end of the process.

5.2.6 Function specific selection criteria

Applying selection criteria 1 to 3 to the spatial metrics available in Patch Analyst 5.1 reduced the number of available metrics by eight (see Figure 4-3), and twenty one remained eligible. The next set of selection criteria was identified by considering the literature on the spatial arrangement of deprivation and health, and visually examining the surface maps produced using the techniques described in the previous chapter.

As was discussed in the literature review, two opposing hypotheses have been postulated regarding how the socio-economic context of surrounding areas – that is the spatial arrangement of affluence and deprivation – might influence health outcomes in an area (Livingston and Lee, 2014). The first hypothesis, based on neo-materialistic approaches (and often referred to as the pull up/pull down hypothesis), is that living in a deprived area surrounded by more affluent areas (islands of deprivation) is more advantageous to health than living in a large concentration of deprivation (landlocked deprivation). The second hypothesis, based on ideas relating to relative deprivation and psycho-social approaches, proffers the opposite perspective: that deprived areas surrounded by more affluent areas will have poorer health outcomes than large concentrations of deprivation, because of the adverse effects of social comparison. Studies which have examined these theories have had mixed and contradictory results; some finding evidence of better health outcomes in islands of deprivations and worse health outcomes in landlocked deprivation, others finding the opposite.

It was, therefore, important to select metrics that would facilitate comparisons of how much of a city’s deprivation (at various time points) was either landlocked, or fragmented to form islands of deprivation. Selecting metrics which quantify the size of patches of deprivation, and levels of fragmentation in the maps was important.

Visually examining the city maps also suggested that there were differences, both between cities and between years, in the proportion of the maps occupied by cells with high levels of deprivation. It appeared that, although levels of deprivation were similar across the city, there were differences in the spatial extent of deprivation across the city landscapes. Selecting a spatial metric which quantified the proportion of the maps covered by areas with high levels of deprivation was therefore also important.

Together these observations suggested that the aspects of the maps which it was important to quantify were fragmentation, patch size, and the spatial extent of deprivation. Consequently the three remaining selection criteria were:

- ***Selection Criteria 5: Provide an indication of fragmentation***
- ***Selection criteria 6: Provide an indication of patch size***
- ***Selection criteria 7: Quantifies the spatial extent of a class***

Metrics which did not do any these were therefore rejected. The, now complete, selection criteria are summarised in Table 4-1.

Selection Criteria 1: Must be available at the class level	Metric must meet all of criteria 1 to 4 and at least one of 5 to 7	Selection criteria 5: Provide an indication of fragmentation
Selection Criteria 2: Must be suitable for cross city comparisons		Selection criteria 6: Provide an indication of patch size
Selection Criteria 3: Must be suitable for temporal comparisons		Selection criteria 7: Quantifies the spatial extent of a class
Selection Criteria 4: Avoid metrics that replicate other metrics		

Table 4-1 Spatial metrics selection criteria

5.3 Applying the selection criteria

The metrics which can be calculated on raster maps using Patch Analyst can be grouped into eight different groups by function, as shown in Table 4-2 to Table 4-9. The eight functional groups are:

- Area metrics
- Patch size and variability metrics
- Edge metrics
- Shape metrics
- Nearest neighbour metrics
- Interspersion metrics
- Core area metrics
- Diversity metrics.

This section discusses the metrics by functional group, and in doing so identifies those which met the selection criteria.

5.3.1 Area metrics

Area metrics quantify the composition of a landscape. As detailed in Table 4-2, three area level metrics can be calculated by Patch Analyst: total landscape area, class area, and percent of the landscape. Total landscape area was immediately discarded as it meets neither selection criteria 1 or 3.

Class area, an absolute metric which quantifies the spatial extent of deprivation, was also discarded as it did not meet the second criteria of being suitable for cross-city comparisons because the cities are different sizes. Percent of the landscape was a more appropriate area metric to use as it quantifies class area in relative terms, thus enables cross cities comparisons (and so meets selection criteria 2). It also met criteria 1 and 3. Percent of the landscape does, however, have some important limitations. As indicated by Figure 4-1, the total area of a landscape is defined by the landscape‘s boundary, which in this study is defined as the city boundary for each of the cities. City boundaries can, however, be somewhat arbitrary when undertaking spatial metrics on the built environment. This is because city boundaries often include natural features (such as rivers or lakes) where it is not possible for people to live. An obvious example of this is provided by Liverpool’s city boundary as this include parts of the River Mersey. This issue means potential problems with the denominator (total land area). However, despite this limitation, it remained a useful metric for comparing spatial patterns of deprivation temporally and spatially, and met the other selection criteria. The percent of the landscape metric was, therefore, selected.

Area metrics – quantifies the composition of a landscape			
Metric	**What it quantifies**	**Level available at (patch/class/landscape)**	**Unit of measurement**
Total Landscape Area	Total land area within a landscape's boundary	Landscape	Hectares
Class Area	Total land area covered by a specific patch type.	Class Landscape	Hectares
Percent of Landscape (also known as spatial extent)	The percentage of land area within a landscape which is occupied by a specific class. Indicates the spatial extent of a specific class relative to the size of the landscape and in doing so enables meaningful cross city comparisons to be made.	Class	Percent

Table 4-2 Area metrics available to use in Patch Analyst on raster surfaces.

5.3.2 Patch size and variability metrics

At the class level, patch size and variability metrics provide the number of patches, a summary figure of the size of patches, and quantify the variation of patch sizes within a class. As detailed in Table 4-3, the four patch size and variability metrics available were: number of patches, mean patch size, patch size standard deviation, and patch size co-efficient of variation. All four were available at the class level and therefore met the first of the selection criteria.

5.3.2.1 Number of patches and patch density

Number of patches, as suggested by the name, gives the total number of patches of a specified class found in the landscape under examination. In ecology this metric is used as a measure of fragmentation or subdivision in a landscape, with higher numbers of patches indicating a higher level of fragmentation or subdivision. The same principle can be applied when studying spatial patterns of deprivation. Although number of patches quantifies fragmentation, it is not appropriate to use it to compare landscapes of different sizes. The number of patches likely to be present in a landscape is often directly and positively proportional to the size of the landscape[54] (Leitao et al., 2006), making it unsuited to cross city comparisons, and therefore failing selection criteria 2.

In contrast, patch density normalises the number of patches by landscape area, thus enabling city comparisons to be made. Despite being a recognised spatial metric, patch density is not calculated in Patch Analyst. However, as Patch Analyst provides the two figures required to calculate it (number of patches and total landscape area), patch density could easily be calculated. On this basis it was decided that patch density would be selected.

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[54] In this instance therefore it would be expected that Glasgow, having the largest landscape, would have the highest number of patches and Manchester, having the smallest landscape, would have the least.

5.3.2.2 Mean patch size, patch size standard deviation, and patch size coefficient of variation

Mean patch size provides the mean size of all the patches within a specific class. It is one of the metrics which McGarigal and Marks (1995) argue reflects both the composition and configuration of the landscape (see section 5.1.2). As well providing an indication of patch size, it reflects the level of subdivision within a class (Leitao et al., 2006) with a larger figure indicating less subdivision and a smaller figure indicating more subdivision. Mean patch size is different to patch density because it is a function of the number of patches within the class whereas patch density is a function of the total landscape area (McGarigal and Marks, 1995:28). Mean patch size meets criteria 1 to 6 and was selected to be used in this research.

Mean patch size does not, however, convey information regarding variation in patch size. Metrics which provide this information are patch size standard deviation, and patch size coefficient of variation; these measure the difference in size of patches within the same class, giving a sense of how representative the mean patch size is. Patch size standard deviation is an absolute measure, whilst patch size coefficient is a relative measure (it express variability as a percentage of the mean). The principal advantages of patch size standard deviation over patch size coefficient of variation are that standard deviation is more widely used in statistical analysis and so more easily understood, and that it can be used to calculate confidence intervals (which are important when comparing mean values).On this basis patch size standard deviation was selected to complement mean patch size by enabling confidence interval calculation for mean patch size.

Patch size and variability metrics – represent landscape configuration			
Metric	**What it quantifies**	**Level available at (patch/class/landscape)**	**Unit of measurement**
Number of Patches	At class level: total number of patches of each class. At landscape level: total number of patches (regardless of class) present in the landscape.	Class Landscape	None
Mean Patch Size (MPS)	At class level: mean size of patches of a specific class. At landscape level: mean size of all the patches (regardless of class) present in the landscape.	Class Landscape	Hectares
Patch Size Standard Deviation (PSSD)	Standard deviation measures absolute variation in patch size between patches. To be meaningful it needs to be used in conjunction with mean patch size (McGarigal et al., 1994). At class level: standard deviation of patch size of a specific class. At landscape level: standard deviation of patch size of all the patches regardless of class.	Class Landscape	Hectares
Patch Size Coefficient of Variance (PSCoV)	The coefficient of variation of patches. Measures variability as a percentage of the mean and so is a relative measure of variability. Enables more meaningful comparisons of variability across landscapes than PSSD. Formula is (PSSD/MPS) x 100 = PSCoV At class level: relative measure of variability of patch size between patches of the same type. At landscape level: relative measure of variability of patch size between all the patches in the landscape regardless of class.	Class Landscape	Percent

Table 4-3 Patch density, patch size and variability metrics available to use in Patch Analyst on raster surfaces

5.3.3 Edge metrics

Edge metrics quantify the amount of edge or degree of edge contrast present. As detailed in Table 4-4, three edge metrics were available through the use of Patch Analyst: total edge, edge density, and contrasted weighted edge density; all three of which are available at the class level. Total edge is an absolute metric which, at the class level, gives the sum of all the perimeters of all the patches within a class. As it is an absolute measure, McGarigal and Marks (1995:32) note that: "*(i)n applications that involve comparing landscapes of varying size, this index may not be useful.*" Consequently, total edge did not meet the second selection criteria as it was not suitable for cross city comparisons.

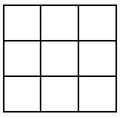
Edge density and contrast weighted edge density are both relative measures of edge and so, unlike total edge, are more suitable for cross city comparisons. These metrics were potentially useful as they provide an indication of fragmentation. Furthermore, if the psychosocial hypothesis is correct and close proximity to more affluent areas can have a negative impact on health outcomes, it would be expected that higher edge densities would be associated with poorer health outcomes (as the interface between the areas of deprivation and areas of more affluence would be greater). Unfortunately, however, perimeters which border the landscape (in this case city) boundary are not included in the metric's calculation. This was potentially problematic as it was feasible that patches of cells with high levels of deprivation might be at the city border, but would be missed in the calculation. Edge metrics were therefore neither spatially or temporally comparable.

Edge metrics – landscape configuration			
Metric	**What it quantifies**	**Level available at (patch/class/landscape)**	**Unit of measurement**
Total Edge	Perimeter of patches, including perimeter of any internal holes. Does not include any parts of the perimeter that surround the landscape boundary or are next to cells classified as no data. At patch level: perimeter of individual patch (including the perimeter of any internal holes that the patch has (e.g. if a doughnut was a patch it would be the sum of the external and internal perimeters). At class level: sum of the perimeters of all the patches of the same type. At landscape level: sum of the perimeters of all the patches in the landscape regardless of class.	Patch Class Landscape	Metres
Edge Density	Relative measure of edge which enable comparisons between landscapes. Edge density is calculate by using the formula total edge/total landscape area = edge density. However, parts of the perimeter that surround the landscape boundary are not included in this calculation. At class level: edge density for each class. At landscape level: edge density for all the edges in a landscape.	Class Landscape	Metres per hectare
Contrasted Weighted Edge Density (CWED)	Standardises edge to a per unit area basis to enable comparisons between different sized landscapes. Measure of edge density with a user-specified contrast weight. CWED equals 0 when there is no edge in the landscape and the value increases as the amount of edge in the landscape increases. As with total edge and edge density, the edges that border the landscape boundary are not included in the calculation. At class level: CWED for each class. At landscape level: CWED for all landscape.	Class Landscape	Metres per hectare

Table 4-4 Edge metrics available to use in Patch Analyst on raster surfaces

5.3.4 Shape metrics

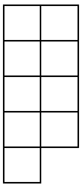
Shape metrics quantify the complexity of shapes of either an individual patch, all the patches within a class, or all the patches within a landscape. In raster surfaces this is calculated by comparing the shape of a patch to a square, with higher figures indicating that patches are less square shaped than patches with lower figures. Figure 4-2 shows how the shape metric is calculated, and how the shape metric increases as the arrangement of cells making up a patch moves further away from being in the shape of a square. As shown in Table 4-5, the four shape metrics available through Patch Analyst which can be calculated on raster surfaces were: mean shape index, area weighted mean shape index, mean patch fractal dimension, and area weighted mean patch fractal dimension. These all met criteria 1 to 3. However, as shape metrics do not provide an indication of fragmentation, patch size, or the spatial extent of areas with high levels of deprivation they did not fit with criteria 5 to 7 and so were not used in this study.



A patch formed by 9 cells arranged in a square. Arranged in this way the shape has the minimum perimeter possible. Shape index therefore = 1.

Shape index =
$$\frac{\mathit{Perimeter\ of\ patch\ \ measured\ by\ number\ of\ grid\ cell\ sides}}{\mathit{minimum\ perimeter\ of\ measured\ by\ patch\ in\ number\ of\ grid\ cell\ sides}}$$

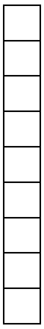
Shape Index = $\frac{12}{12}$ = 1



A patch formed by 9 cells arranged so that the perimeter is 14 grid cell sides. Shape index = 1.17

Shape index =
$$\frac{\mathit{Perimeter\ of\ patch\ \ measured\ by\ number\ of\ grid\ cell\ sides}}{\mathit{minimum\ perimeter\ of\ measured\ by\ patch\ in\ number\ of\ grid\ cell\ sides}}$$

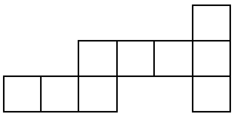
Shape Index = $\frac{14}{12}$ = 1.17



A patch formed by 9 cells arranged in a single file line. Patch perimeter is 20 grid cell sides. Shape Index = 1.67

Shape index =
$$\frac{\mathit{Perimeter\ of\ patch\ \ measured\ by\ number\ of\ grid\ cell\ sides}}{\mathit{minimum\ perimeter\ of\ measured\ by\ patch\ in\ number\ of\ grid\ cell\ sides}}$$

Shape Index = $\frac{20}{12}$ = 1.67



A patch formed by 9 cells arranged so that the patch perimeter is 20 grid cells. Shape Index = 1.67

Shape index =
$$\frac{\mathit{Perimeter\ of\ patch\ \ measured\ by\ number\ of\ grid\ cell\ sides}}{\mathit{minimum\ perimeter\ of\ measured\ by\ patch\ in\ number\ of\ grid\ cell\ sides}}$$

Shape Index = $\frac{20}{12}$ = 1.67
Note that this is the same shape index value as the single file line above.

Figure 4-2 Shape metrics

Shape metrics – unitless metrics which quantify landscape configuration in terms of patch shape complexity			
Metric	What it quantifies	Level available at (patch/class/landscape)	Unit of measurement
Mean Shape Index (MSI)	Shape complexity. Quantifies shape using the mean perimeter-to-area ratio. Calculated by $\frac{\sum of\ all\ patch\ perimetres}{\sqrt{patch}\ area}$ and then adjusted for square standard and then divided by number of patches. Equals 1 when all patches are squares and increases (without limit) with increasing patch shape irregularity. At class level calculated using all the patches of a specific class, at landscape level calculated using all the patches in a landscape.	Class Landscape	None
Area Weighted Mean Shape Index (AWMSI)	Shape complexity adjusted for patch area. Same as MSI but weighted for patch area so that larger patches are given a greater weight than smaller patches. As with MSI, AWMSI equals 1 when all patches are square and increases with increasing irregularity. At class level calculated using all the patches of a specific class, at landscape level calculated using all the patches in a landscape.	Class Landscape	None
Mean patch Fractal Dimension (MPFD)	Uses perimeter-area relationship to quantify shape complexity. Perimeter and area are log transformed. Value approaches 1 when shapes have simple perimeter, and approaches 2 when shapes are more complex.	Class Landscape	None
Area Weighted Mean patch Fractal Dimension (AWMPFD)	Shape Complexity adjusted for patch area. Same as MPFD but weighted for patch area so that larger patches are given a greater weight than smaller patches. As with MPFD value approaches 1 when shapes have simple perimeter, and approaches 2 when shapes are more complex.	Class Landscape	None

Table 4-5 Shape metrics available to use in Patch Analyst on raster surfaces.

5.3.6 Nearest neighbour metrics

Nearest neighbour metrics quantify landscape configuration, and, as their name suggests, measure the distance between patches. As can be seen from Table 4-6 there are two nearest neighbour metrics which were available to use in Patch Analyst on raster surfaces: mean nearest neighbour and mean proximity index. Both of these met selection criteria 1 to 3 as they are available at the class level and suitable for temporal and spatial comparisons. At the class level, mean nearest neighbour is a measure of isolation. It does not, therefore, meet selection criteria 5, 6, or 7. The mean proximity index metric is based on the proximity index developed by Gustafson and Parker in 1992 (McGarigal and Marks, 1995) which "*considers the size and proximity distance of all patches whose edges are within a specified search radius of the focal path*" (McGarigal and Marks, 1995:46). At the class level, the mean proximity index is the mean of all the proximity index scores for patches within the same class. Essentially therefore, it is a measure of the average distance between patches. This figure might be of interest in further studies of the spatial arrangement of deprivation as it would indicate whether patches of deprivation were or were not in close proximity to one another. However, that was out with the realms of this study and the mean proximity index did not meet any of the selection criteria 5 to 7.

Nearest neighbour metrics – quantify landscape configuration			
Metric	What it quantifies	Level available at (patch/class/landscape)	Unit of measurement
Mean Nearest Neighbour (MNN)	Measure of patch isolation. The nearest neighbour distance is defined as the shortest edge to edge distance to another patch of the same type in the defined landscape. The mean nearest neighbour distance is the mean of these distances. Only patches within the defined landscape are included, therefore if there is a closer patch but it is outside the landscape boundary it is excluded. At the class level: mean nearest neighbour distances for specific class within the defined landscape. At the landscape level: mean of all classes nearest neighbour distances within the defined landscape	Patch (not mean) Class Landscape	Metres
Mean Proximity Index (MPI)	Measure of the degree of isolation and fragmentation. The proximity index is calculate using the equation $\frac{\sum patch\ area}{nearest\ edge{-}to{-}edge\ distance\ between\ patch\ and\ focal\ point\ of\ all\ patches^2}$ The mean proximity index is the mean for all of the proximity indexes within the same class or landscape. As with MNN patches outside the defined landscape are excluded.	Class Landscape	None

Table 4-6 Nearest neighbour metrics available to use in Patch Analyst on raster surfaces.

5.3.7 Interspersion metrics

As can be seen from Table 4-7, there is only one interspersion metric available to use in Patch Analyst (Rempel et al, 2012) on raster surfaces: Interspersion and Juxtaposition Index. At the class level, this measures how interspersed patches of a chosen class (which in this study would be areas with high levels of deprivation) are with patches of other classes. This metric is designed for landscapes large numbers of classes; however, the maps of individual indicators only have three classes in total, and the summary maps only have 2 classes. This metric was neither appropriate nor informative in this instance.

Interspersion metrics – quantify landscape configuration			
Metric	What it quantifies	Level available at (patch/class/landscape)	Unit of measurement
Interspersion Juxtaposition Index (IJI)	Measure of patch adjacency. Measures the extent to which patches are interspersed. On a scale of 0-100 with low values when patch types are poorly interspersed and a high value when patches are equally adjacent to one another. At the class level: measure of the interspersion of each class. At the landscape level: measures the interspersion of all the patches in a landscape.	Class Landscape	None

Table 4-7 Interspersion metrics available to use in Patch Analyst on raster surfaces.

5.3.8 Core area metrics

In spatial metrics the core area is defined as the internal area of a patch which is located either equal to, or greater than a certain distance away from, the edge of the patch. Often any cell within a patch totally surrounded by other cells of the same class is used to identify core cells. Core area metrics quantify both landscape configuration and landscape composition, and in ecology they are significant because they are related to edge effects. As can be seen from Table 4-8 there are eight different core area metrics which are available. Of these, total core area was discarded as it was not suitable for cross city comparisons. Some other core area metrics could have been used to quantify “landlocked” deprivation. This might have been useful and potentially could have complemented mean patch size; however, these were not selected; core area metrics would not have greatly assisted in quantifying the spatial extent of deprivation across the landscape, provided an indication of patch size, or provided an indication of fragmentation.

Core area metrics - quantify landscape configuration and composition. Core area is defined as the cells within a patch surrounded by other cells of the same type. A patch can have more than 1 core area.			
Metric	**What it quantifies**	**Level available at (patch/class/landscape)**	**Unit of measurement**
Total Core Area (TCA)	At the patch level: total size of core areas within a patch. At the class level: sum of all the core areas within patches of the same class. At the landscape level: sum of all the core areas within all the patches in the landscape.	Patch Class Landscape	Hectares
Mean Core Area (MCA)	At the patch level: mean size of core areas within a patch. At the class level: mean size of all the core areas within patches of the same class. At the landscape level: mean size of all the core areas within the landscape.	Patch Class Landscape	Hectares
Core Area Standard Deviation (CASD)	At the patch level: measure of the variability of core areas within a patch. At the class level: measure of the variability of all the core areas within all the patches of the same class. At the landscape level: measure of the variability of all core areas within a landscape.	Class	Hectares
Core Area Density (CAD)	Relative number of core areas relative to the class or landscape area. Calculated by $\frac{Total\ number\ of\ core\ areas\ in\ a\ class\ or\ landscape}{Total\ area\ of\ class\ or\ landscape}$	Class Landscape	Number per 100 hectares
Total Core Area Index (TCAI)	Proportion of class/landscape area made up of core. Figure ranges from 0 to 1. Equals 0 when no core area present in landscape and increases as the proportion of core area increases. Calculated by $\frac{\sum Core\ areas\ within\ a\ class\ or\ landscape}{Total\ class\ or\ landscape\ area}$	Class Landscape	Percent
Core Area Coefficient of Variance (CACOV)	The coefficient of variation of core areas. Measures variability as a percentage of the mean and so is a relative measure of variability. Formula is (CASD/MCA) x 100 = CACOV	Class	Percent

Table 4-8 Core area metrics available to use in Patch Analyst on raster surfaces.

5.3.9 Diversity metrics

Diversity metrics quantify landscape composition. Their function is to quantify the level of diversity in a landscape both with regard to the number of classes present and the distribution of these classes. As is shown by Table 4-9 there were three diversity metrics available to use in Patch Analyst on raster surfaces: Shannon’s diversity index, Shannon’s evenness index, and Simpson’s evenness index. These metrics were not included since in this study, only one class is of interest.

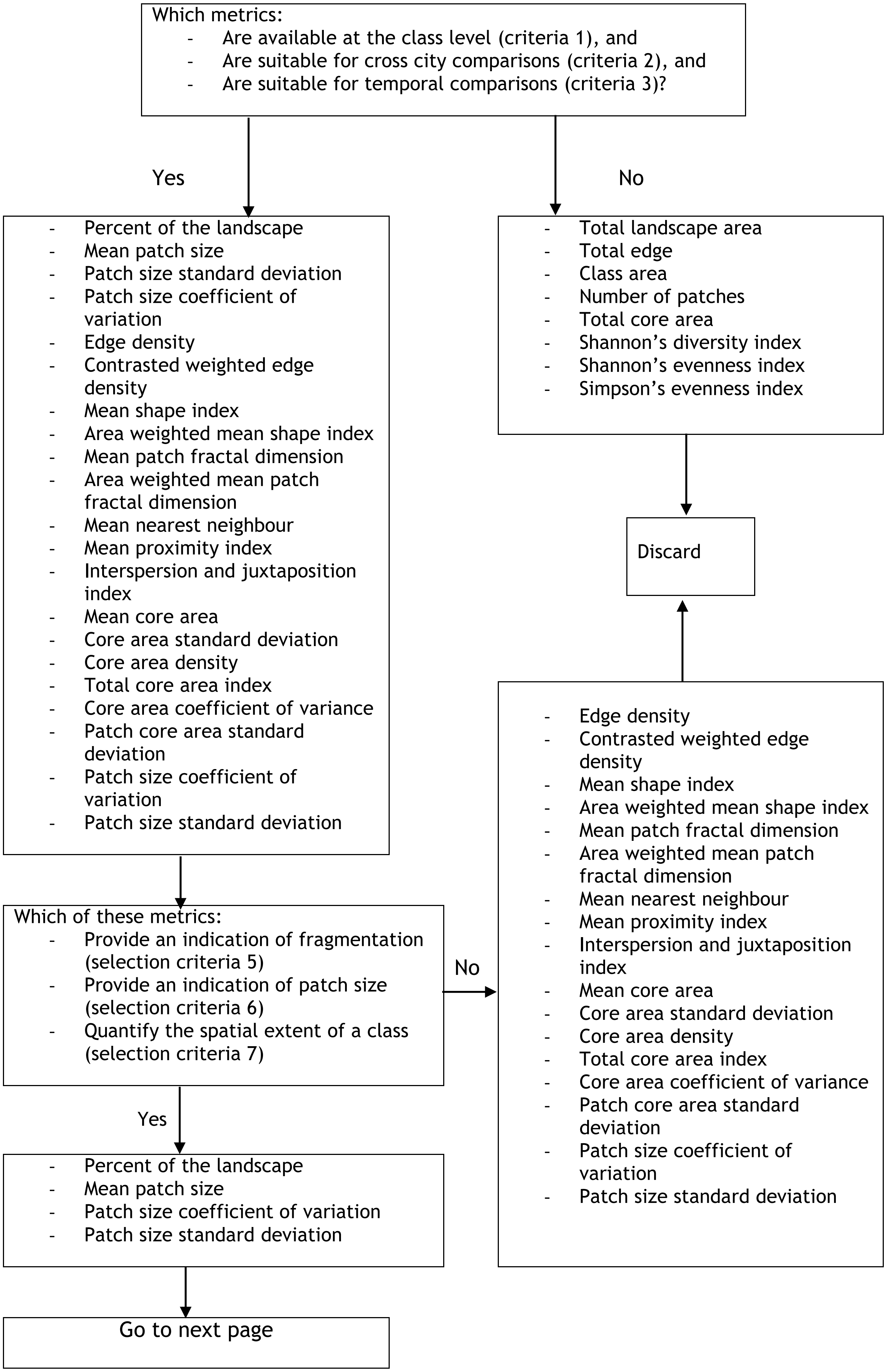
Diversity metrics quantify landscape composition			
Metric	What it quantifies	Level available at (patch/class/landscape)	Unit of measurement
Shannon's Diversity Index	Relative measure of patch diversity. Based on information theory. If the landscape only contains 1 patch the score is 0. The higher the score the higher the number of different patch types and/or the distribution of area among patch types is more even.	Landscape	None
Shannon's Evenness Index	Measure of patch distribution and abundance.	Landscape	None
Simpson's Evenness Index	Measure of the distribution of area among patch types.	landscape	None

Table 4-9 Diversity metrics available to use in Patch Analyst on raster surfaces.

5.4 Summary

Patch Analyst provides a considerable number of spatial metrics with which different aspects of the 108 maps produced in this study could be quantified. Using all of these metrics would have been neither possible or meaningful. A set of seven selection criteria was developed to identify metrics which were suitable for analysing the surface maps of deprivation, and which quantified aspects of the landscape to answer the research questions.

The selected metrics were: patch density, mean patch size, patch size standard deviation, and percent of the landscape (also refered to as spatial extent) (Figure 4-3). The results of their application are presented in the next chapter.



Which metrics:
- Are available at the class level (criteria 1), and
- Are suitable for cross city comparisons (criteria 2), and
- Are suitable for temporal comparisons (criteria 3)?

- Percent of the landscape
- Mean patch size
- Patch size standard deviation
- Patch size coefficient of variation
- Edge density
- Contrasted weighted edge density
- Mean shape index
- Area weighted mean shape index
- Mean patch fractal dimension
- Area weighted mean patch fractal dimension
- Mean nearest neighbour
- Mean proximity index
- Interspersion and juxtaposition index
- Mean core area
- Core area standard deviation
- Core area density
- Total core area index
- Core area coefficient of variance
- Patch core area standard deviation
- Patch size coefficient of variation
- Patch size standard deviation

- Total landscape area
- Total edge
- Class area
- Number of patches
- Total core area
- Shannon’s diversity index
- Shannon’s evenness index
- Simpson’s evenness index

Discard

Which of these metrics:
- Provide an indication of fragmentation (selection criteria 5)
- Provide an indication of patch size (selection criteria 6)
- Quantify the spatial extent of a class (selection criteria 7)

- Edge density
- Contrasted weighted edge density
- Mean shape index
- Area weighted mean shape index
- Mean patch fractal dimension
- Area weighted mean patch fractal dimension
- Mean nearest neighbour
- Mean proximity index
- Interspersion and juxtaposition index
- Mean core area
- Core area standard deviation
- Core area density
- Total core area index
- Core area coefficient of variance
- Patch core area standard deviation
- Patch size coefficient of variation
- Patch size standard deviation

- Percent of the landscape
- Mean patch size
- Patch size coefficient of variation
- Patch size standard deviation

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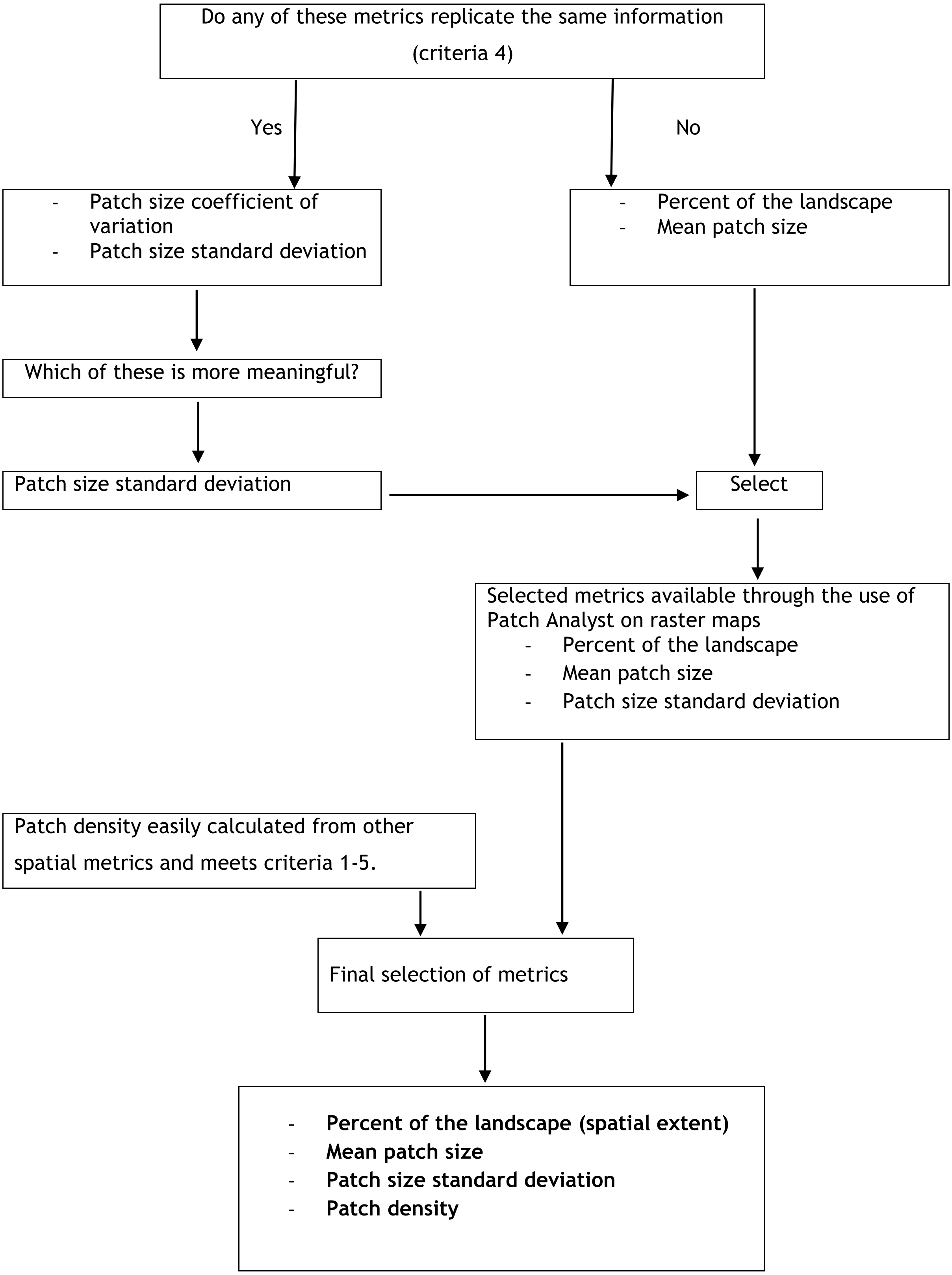

Figure 4-3 Selection of spatial metrics

Chapter 5 Results

This chapter seeks to answer research question 2, namely: “did the spatial arrangement of deprivation develop differently in Glasgow, Liverpool, and Manchester between 1971 and 2011?” This will be done by presenting both the surface maps, and the results of the analysis using three spatial metrics: spatial extent (percent of the landscape), patch density, and mean patch size. A reminder of what these metrics quantify is provided in Figure 5-1. These spatial metrics were used to analyse maps which:

- identified areas with high levels of *all* the indicators[55];
- identified areas with high levels of *one or more* indicator of deprivation present;
- and, identified areas with high levels of *each* of the individual indicators at specific time points, all time points, and any time point.

The results of this analysis will be presented in that order.

Spatial extent (percent of the landscape)

The percentage of the area within a landscape which is occupied by a specific class. Indicates the spatial extent of a specific class relative to the size of the landscape.

Patch density

Normalises the number of patches of a specific class within a landscape by landscape areas to enable meaningful comparisons to be made between landscapes. Provides an indication of fragmentation.

Mean Patch size

The mean size of patches within a specific class.

Figure 5-1 Spatial metrics used in this analysis

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[55] The three indicators used at all of the five time points were overcrowded households, male unemployment, and households not owning a car. A fourth indicator, social rented households was used from 1991 onwards but, as explained in section 4.5.3.4, was not deemed an appropriate indicator of deprivation in 1971 and 1981.

When interpreting these maps it is important to remember that these maps do not show the rates of deprivation or the rates of each of the indicators, instead they show the *residential location* of the most deprived people in a city (relative to the rest of that city) at each time point.

6.1 Areas with high levels of all indicators

The surface maps in Figure 5-2 to Figure 5-4 show the areas identified as having high levels of all the indicators at each of the time periods between 1971 and 2011. From this point on such areas will be referred to as the most deprived areas. These maps reveal four important points. First, both similarities and differences in the spatial pattern of deprivation were observed between the three cities. Second, that the spatial patterning of deprivation in all three cities was temporally fluid; it varied markedly over time. Third, in all three cities the spatial extent of the most deprived areas peaked in 1981, and then steadily decreased to a low in 2011. Fourth, in 1971 Liverpool did not have any areas with high levels of all three indicators. This does not mean that there were not people in Liverpool who were experiencing high levels of deprivation in 1971, instead, it indicates that there were no areas in which all three indicators[56] coincided at a high level. The use of the three spatial metrics - spatial extent, patch density, and mean patch size - enabled these variations to be quantified and compared.

---

[56] The three deprivation indicators used in 1971 were overcrowded households, male unemployment, and households not owning a car. As was explained in the methods section a fourth indicator – social rented households-was used from 1991 onwards, but was not used prior to this as it was not deemed to be an appropriate indicator of deprivation.

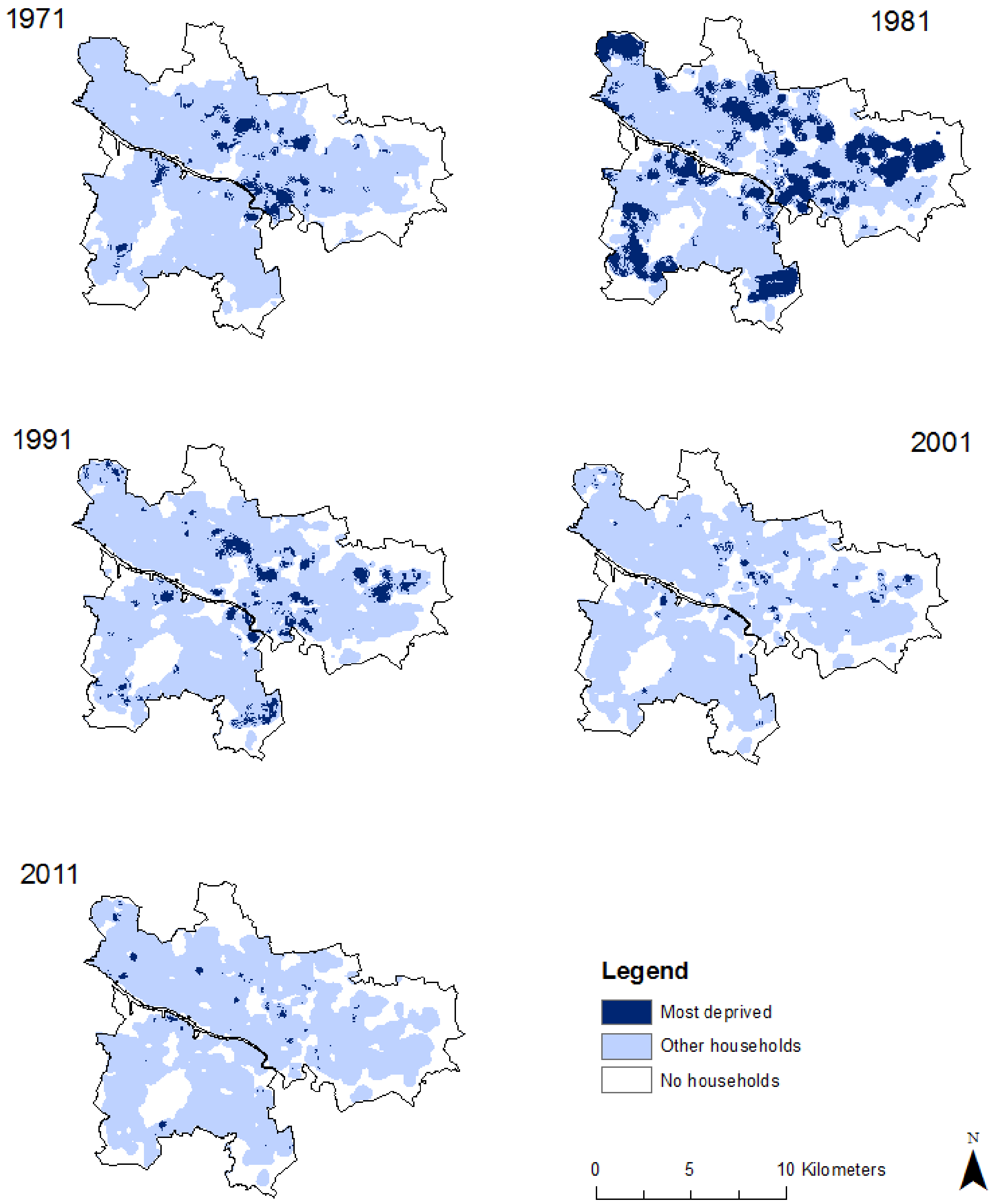

Figure 5-2 Surface maps showing the most deprived areas of Glasgow at decennial intervals from 1971 to 2011. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

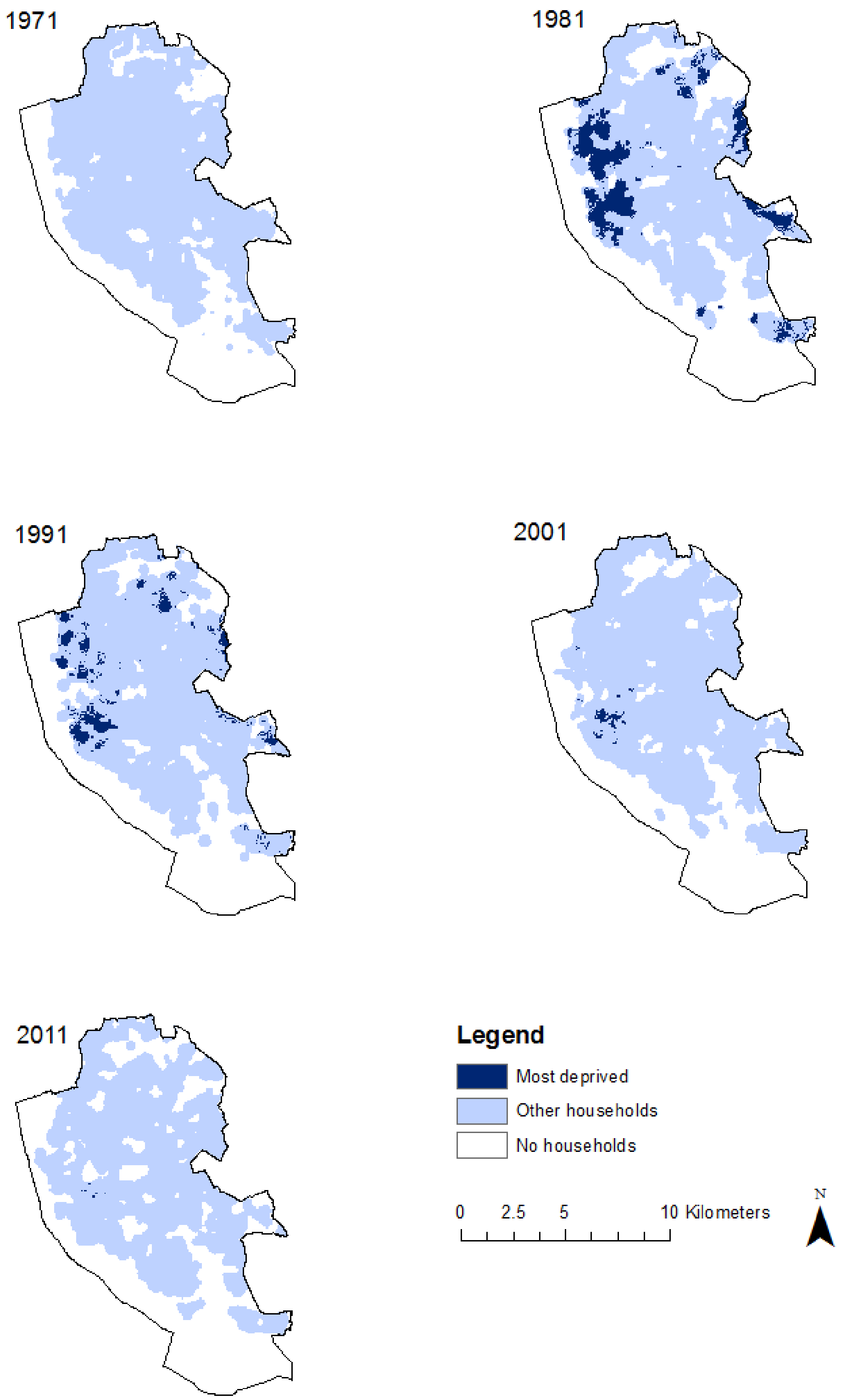

Figure 5-3 Surface maps showing the most deprived areas of Liverpool at decennial intervals from 1971 to 2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

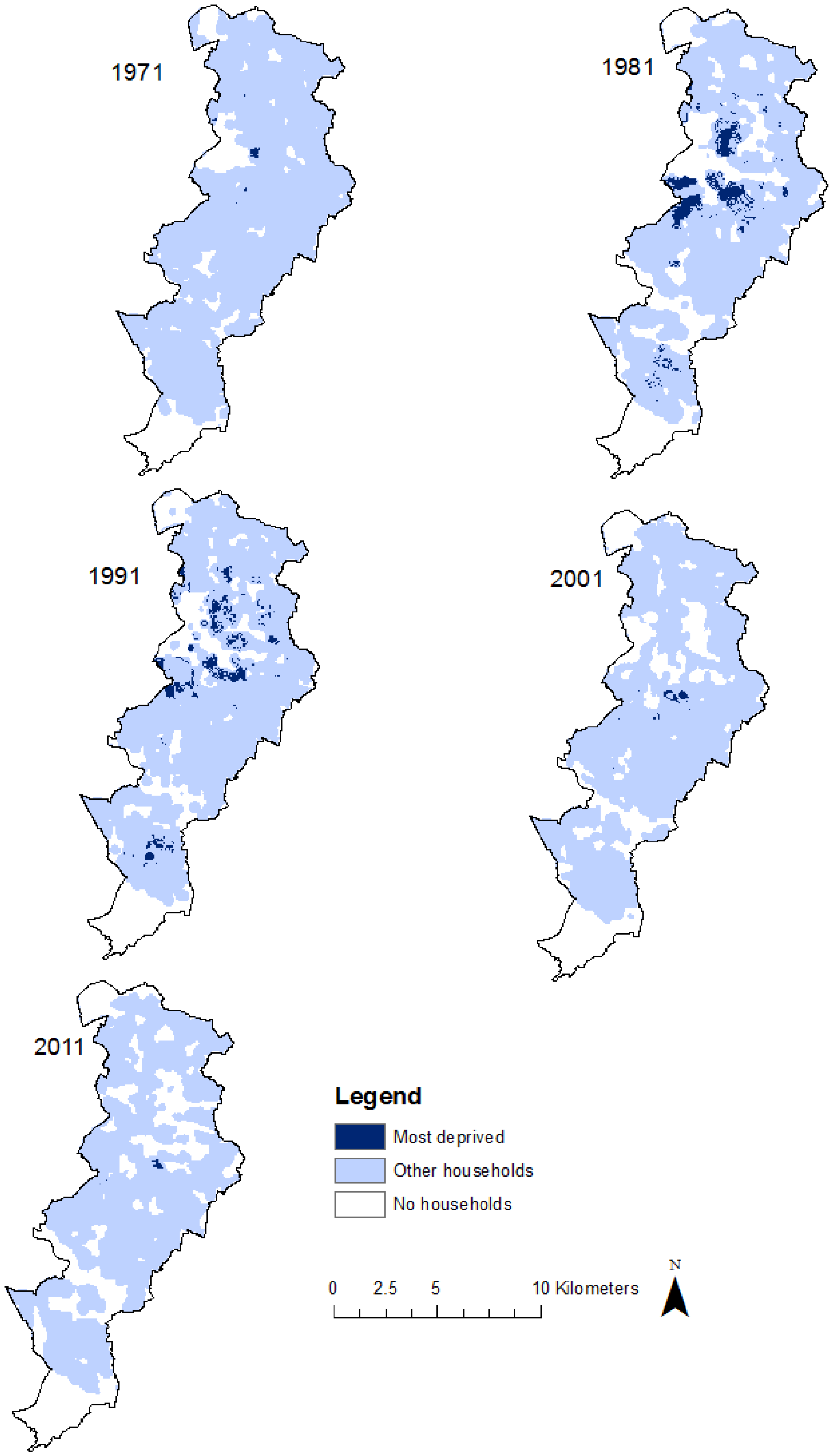

Figure 5-4 Surface maps showing the most deprived areas of Manchester at decennial intervals from 1971 to 2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

6.1.1 Spatial Extent (maximum number of indicators present)

The spatial extent of areas with the most deprived cells (measured using the percent of the landscape metric) varied between the years in all three cities (Figure 5-5), and this confirms the visual impression given in Figure 5-2 to Figure 5-4. All three cities experienced a similar temporal trajectory in the spatial extent of the most deprived areas; a considerable increase between 1971 and 1981, followed by a fall from the peak in 1981 to a low in 2011.

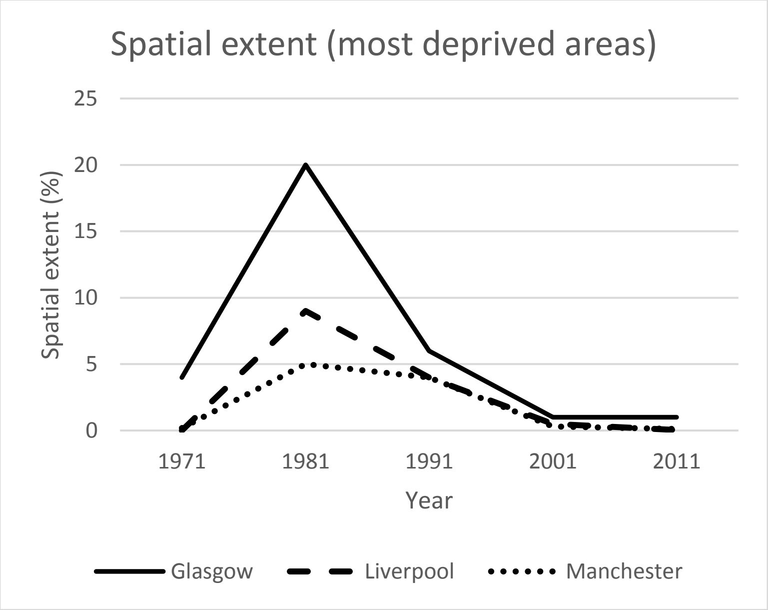

Figure 5-5 Spatial extent (most deprived areas)

From Figure 5-5 it can also be observed that Glasgow had the highest proportion of its landscape occupied by areas classified as the most deprived cells at all time points, but most notably in 1971 and 1981. From 1991 onwards the difference between the cities reduced. Glasgow also had a much more extreme increase and decrease in the proportion of the city classified as being the most deprived.

The percent of the landscape metric was also run using just land with households present as the denominator, rather than all city land. Unsurprisingly the figures were marginally higher; however, the trajectories and inter-city differences were virtually identical. This suggests inter-city differences in spatial extents are not explained by differences in the amount of land which was vacant or used for non-residential purposes.

6.1.2 Patch density (maximum numbers of indicators present)

The patch density for areas with high levels of all the indicators is shown in Figure 5-6. At all time points between 1971 and 2011 Glasgow had the highest patch density, suggesting that Glasgow's most deprived areas were consistently more fragmented than in Liverpool and Manchester; Glasgow, therefore, had (to continue the analogy introduced in chapter 3) more islands of deprivation than the other cities.

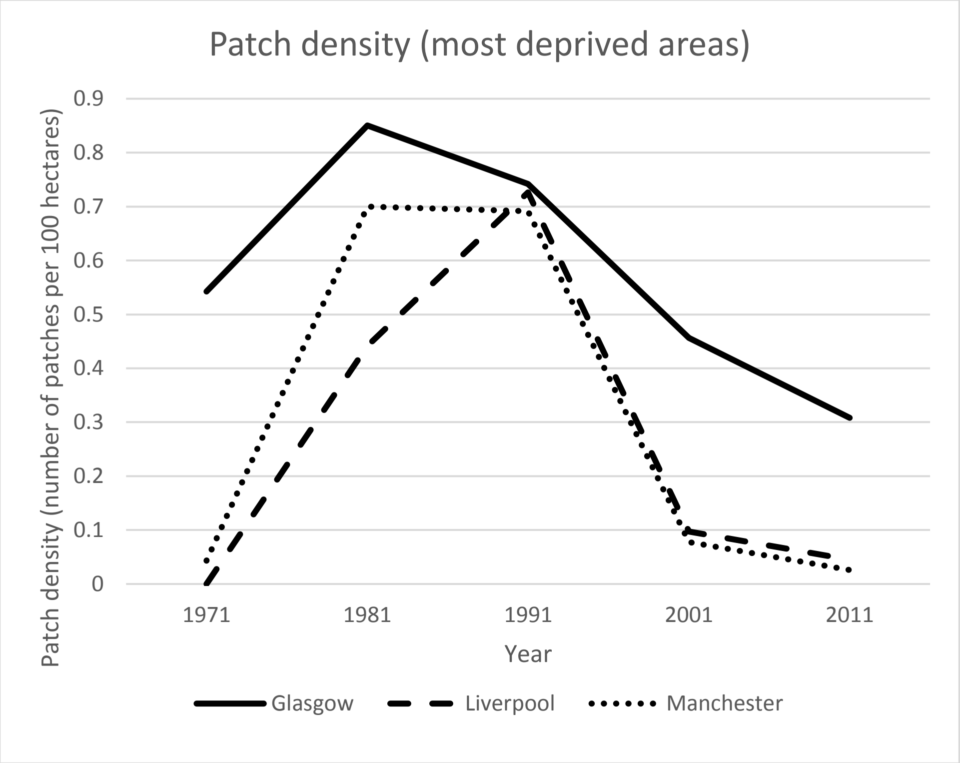

Figure 5-6 Patch Density (most deprived areas)

Temporal changes in patch density were observed for all three cities, with a sharp rise in patch density between 1971 and 1981. This metric peaked in 1981 for Glasgow and Manchester, but in 1991 for Liverpool. In Glasgow, patch density started to fall from 1981 onwards whereas in Liverpool and Manchester levels remained high until 1991, but then fell sharply. There was a striking similarity in patch density across all three cities in 1991, and the trajectory from then on was almost identical in Liverpool and Manchester.

6.1.3 Mean Patch Size (maximum number of indicators present)

The mean patch size metric is shown in Figure 5-7, with confidence intervals in Table 5-1. Glasgow had the highest mean patch size in 1971, 1981, and 1991. Wide confidence intervals meant that there were no significant differences in mean patch size between the cities at any time points when p values were calculated using a non-paired t-test[57]. Considerable variation in patch size, led to high standard deviations and hence, wide confidence intervals. Whilst therefore exercising caution in the interpretation, the trajectories in mean patch size are still interesting. There was a sharp increase in mean patch size for both Glasgow and Liverpool between 1971 and 1981 (clearly visible from the maps in Figure 5-2 and Figure 5-3), but not for Manchester. In Glasgow and Liverpool, this was followed by a significant decrease in mean patch size between 1981 and 1991 (Glasgow p=0.03, Liverpool p=0.04), and a further significant decrease in Glasgow between 1991 and 2001 (p=0.01). The most striking result is the difference in trajectory for Manchester, where the 1981 peak was essentially absent. Aside from 1981, mean patch size was not dissimilar in all three cities. Intra-city variation in patch size was also highest in all three cities in 1981, this is shown by the patch size standard deviation figures given in Table 5-1.

---

[57] (1971: Glasgow-Manchester p=0.78 (not applicable to Liverpool as there were no such areas);
1981: Glasgow-Liverpool p=0.79, Glasgow-Manchester p=0.07, Liverpool-Manchester p=0.09;
1991: Glasgow-Liverpool p=0.37, Glasgow-Manchester p=0.1, Liverpool-Manchester p=0.49;
2001: Glasgow-Liverpool p=0.13, Glasgow-Manchester p=0.42, Liverpool-Manchester p=0.75;
2011: Glasgow Liverpool p=0.22, Glasgow-Manchester p=0.39, Liverpool-Manchester p=0.13).

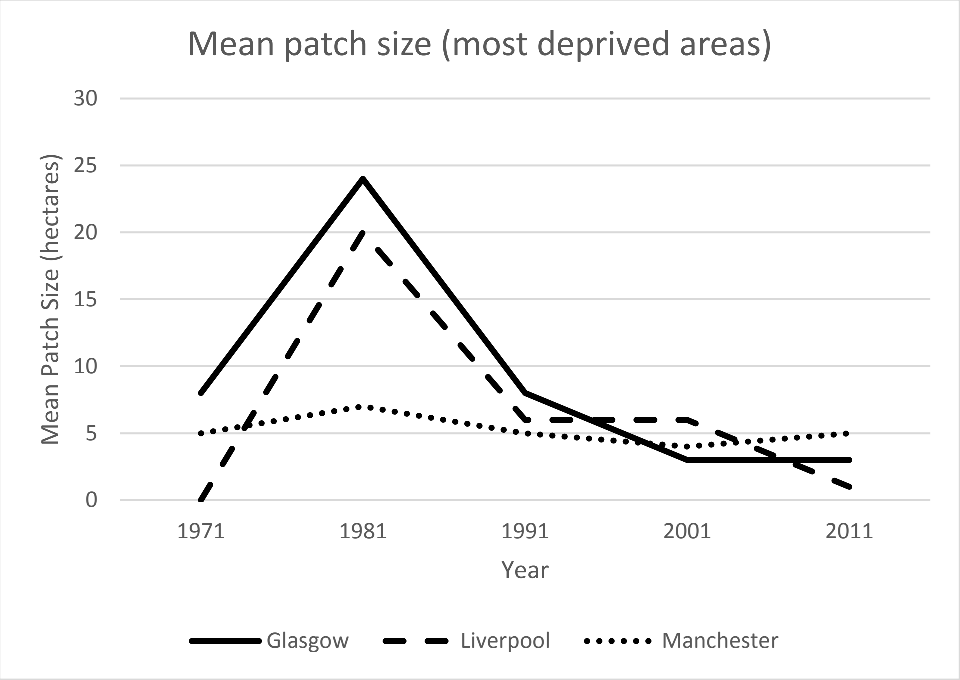

Figure 5-7 Mean Patch Size (most deprived areas)

	Glasgow			Liverpool			Manchester		
Year	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD
1971	**8**	*(3-12)*	23	**0**	*N/A*	0	**5**	*(0-10)*	6
1981	**24**	*(10-37)*	83	**20**	*(3-38)*	68	**7**	*(2-11)*	22
1991	**8**	*(5-10)*	17	**6**	*(2-9)*	17	**5**	*(2-8)*	13
2001	**3**	*(2-4)*	4	**6**	*(0-12)*	10	**4**	*(0-8)*	6
2011	**3**	*(2-4)*	3	**1**	*(0-1)*	20	**5**	*(0-11)*	6

Table 5-1 Mean patch size (MPS), confidence intervals (CI), and patch size standard deviation (SD) for the most deprived areas

The results suggest that there were not enough dissimilarities between Glasgow, and Liverpool and Manchester to argue that patch size was different, or developed differently, in Glasgow.

6.1.4 Summary of the analysis of maps showing areas with high levels of all the indicators

Between 1971 and 2011 there were some differences between the development of the spatial pattern of deprivation in Glasgow, and in Liverpool and Manchester. The spatial extent of areas that were most deprived was higher at all time points in Glasgow than in the other cities, and considerably so in 1971 and 1981. Glasgow also experienced a more extreme increase and decrease in the spatial extent of deprivation over the study period. Higher patch density figures were observed in Glasgow at all time points, indicating a more fragmented spatial arrangement of deprivation. However, whilst the development of Glasgow's spatial arrangement of the most deprived areas exhibited some differences when compared to Liverpool and Manchester, some similarities were also observed. Mean patch size, for example, was largely similar across the cities. Furthermore, whilst there were some differences in values, particularly peak values, the trajectories of change for spatial extent, patch density, and mean patch size were also roughly similar.

6.2 Areas with high levels of 1 or more indicators of deprivation

The next section describes results from spatial metric tests on areas identified as having a high level of one or more indicators present. The surface maps for these are shown in Figure 5-8 to Figure 5-10.

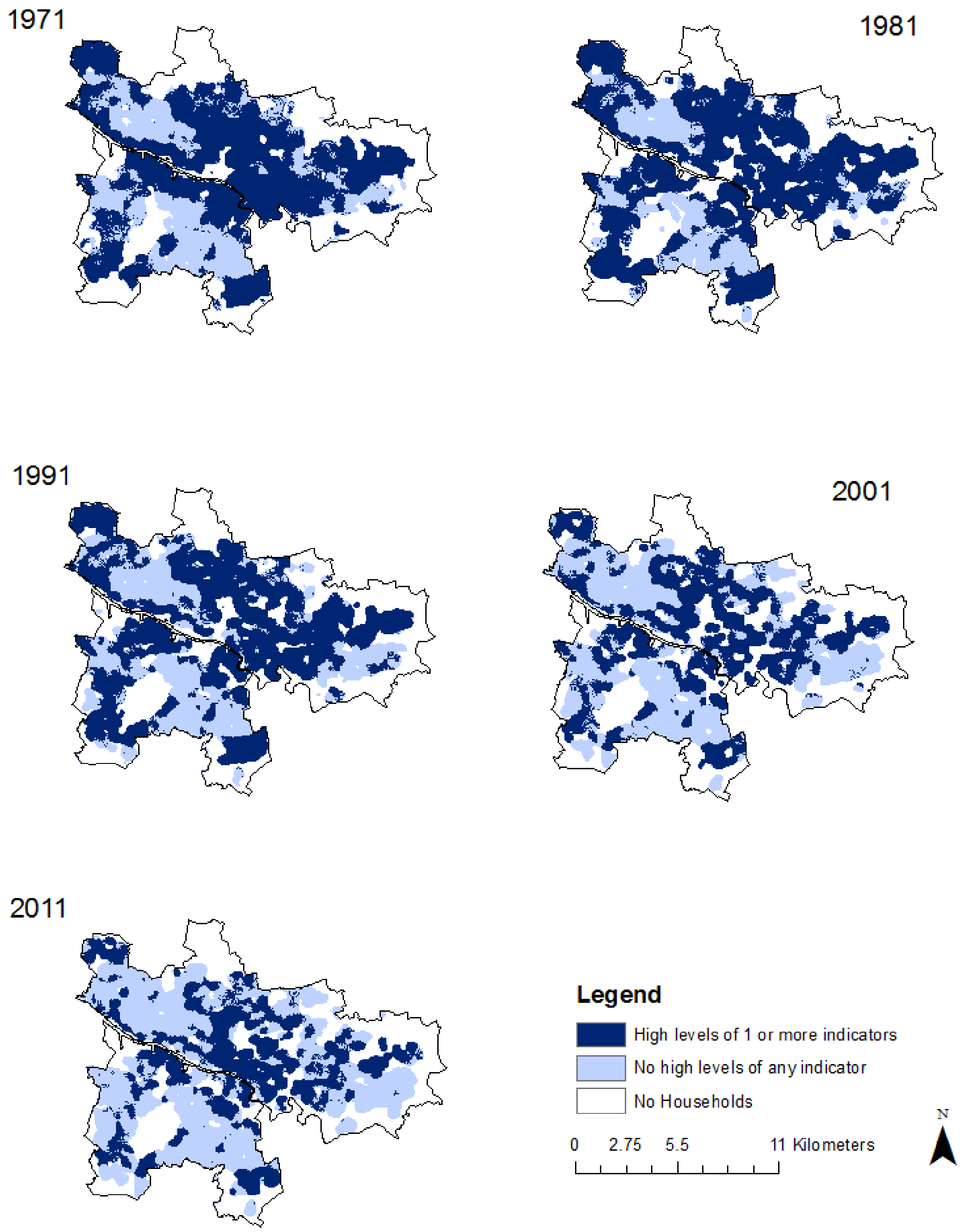

Figure 5-8 Areas in Glasgow with high levels of one or more indicators of deprivation present 1971-2011. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

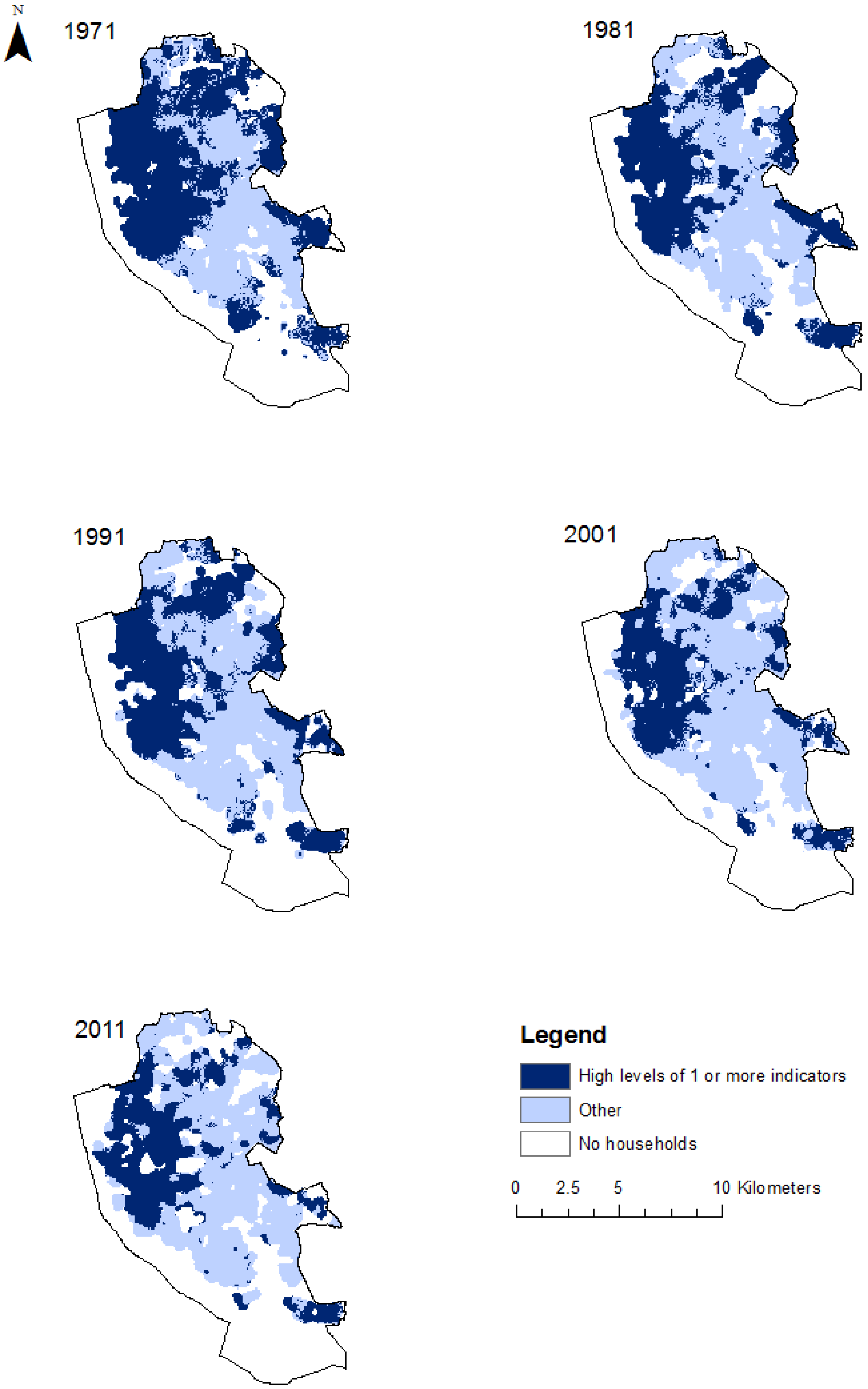

Figure 5-9 Areas in Liverpool with high levels of one or more indicators of deprivation present 1971-2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

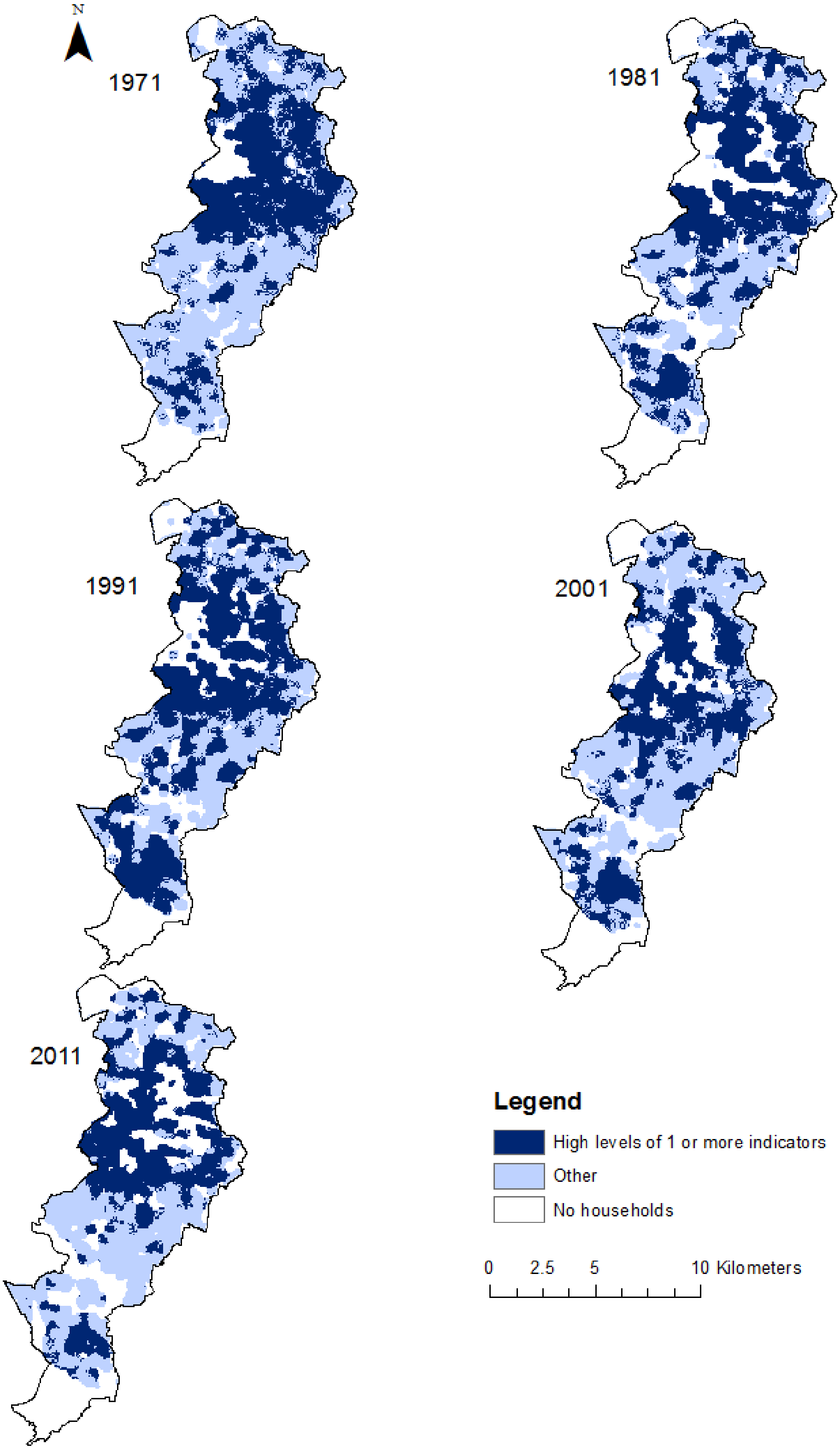

Figure 5-10 Areas in Manchester with high levels of one or more indicators of deprivation present 1971-2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

6.2.1 Spatial Extent (of areas with high levels of one or more indicators of deprivation)

Glasgow had the highest percentage of its landscape occupied by areas with high levels of one or more indicators in 1971 and 1981 (Figure 5-11). The figures for Glasgow and Manchester were identical in 1991 (45%), and virtually identical in 2001 (Glasgow 33%, Manchester 34%); however, by 2011 Glasgow's figure had fallen below that of Manchester's (32%) to 28%, but remained higher than Liverpool (22%). Liverpool had the lowest spatial extent metrics at all time points.

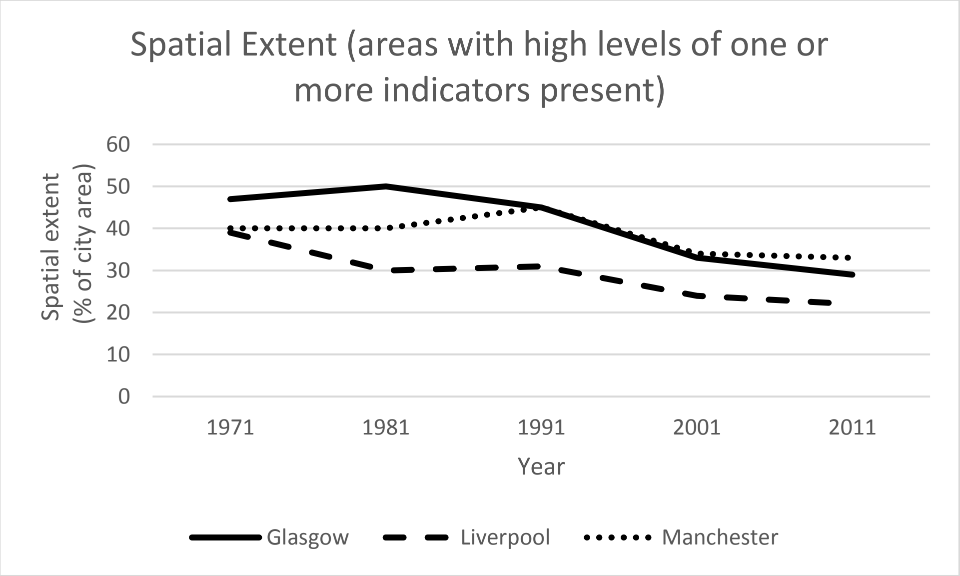

Figure 5-11 Spatial extent (areas with high levels of one or more indicators)

With regard to change over time, there were differences in the spatial extent trajectories of each city between 1971 and 1991[58]; however, from 1991 onwards all cities saw decreases in the proportion of their landscapes occupied by areas characterised as having a high level of one or more of the deprivation indicators. It is worth noting that, in all cities, the spatial extent of such areas was lower in

---

[58] In Glasgow it was observed that the spatial extent of areas with high levels of 1 or more indicators rose slightly between 1971 and 1981 to a peak, and then fell slightly between 1981 and 1991. In Liverpool the peak year was 1971 and there was a decrease from 39% to 30% between 1971 and 1981, and then essentially remained the same in 1991 (31%). In Manchester the 1971 and 1981 spatial extent metric was the same (40%) but had risen to a peak of 45 % in 1991.

2011 than in 1971. Glasgow experienced the largest amount of change with regard to the spatial extent of these areas; however, differences were marginal.

6.2.2 Patch density (areas with high levels of one or more indicators of deprivation)

The results of the patch density metrics for areas with high levels of one or more indicators of deprivation are shown in Figure 5-12. At all the time points between 1971 and 2011 the biggest difference in patch density was between Liverpool and Manchester. The lowest levels of fragmentation were consistently in Liverpool, and the highest in Manchester, with the figures for Glasgow lying in between. Changes over the 40 year period were observed in all three cities. The most dramatic were in Manchester, where patch density fell by almost 50% between 1971 (1.13 patches per 100 hectares) and 2011 (0.62 patches per 100 hectares). By comparison, the changes in Liverpool and Glasgow were relatively small. Levels of fragmentation of areas with one or more indicators of deprivation thus differed between all three cities, but the most dissimilar cities were Liverpool and Manchester.

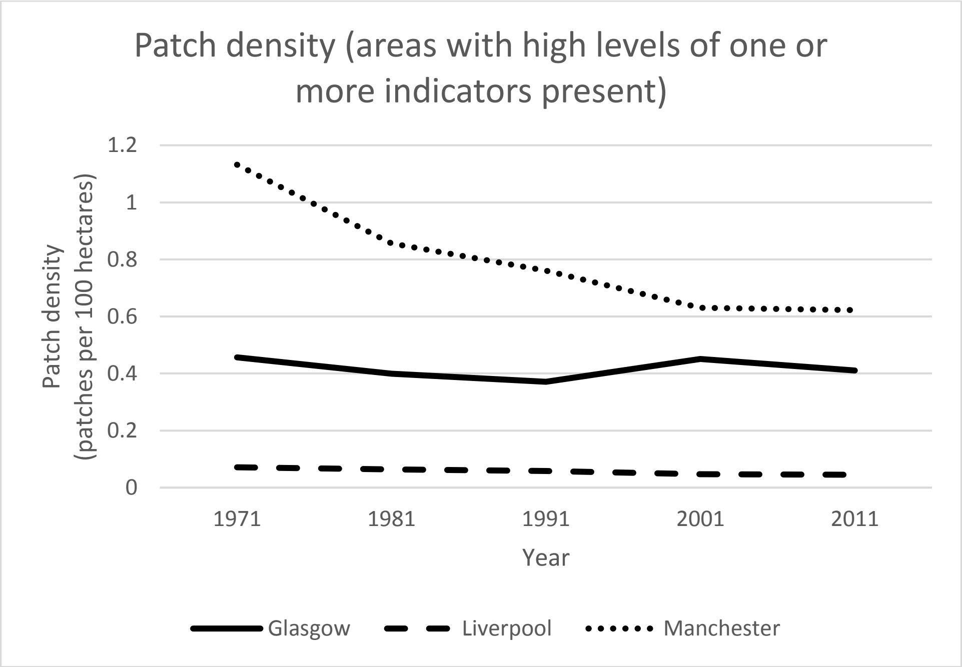

Figure 5-12 Patch density (areas with high levels of one or more indicators present)

6.2.3 Mean patch size (one or more indicators present)

The mean patch sizes for areas with high levels of at least one indicator of deprivation are shown graphically in Figure 5-13, and presented with confidence intervals and standard deviations in Table 5-2. Although these show Glasgow's mean patch size for such areas to be consistently higher than observed in the other two cities, wide confidence intervals meant that there were no statistically significant difference in patch size between any of the cities at any time point[59]. Whilst mean patch size varied in all three cities over time, the greatest variation occurred in Glasgow between 1991 and 2001. However, this too was not statistically significant; indeed, none of the intra-city differences were statistically significant. The patch size standard deviations (shown in Table 5-2) indicate that there was considerable variation in patch sizes in all the cities, however, with the exception of 2011, standard deviation was always highest in Glasgow.

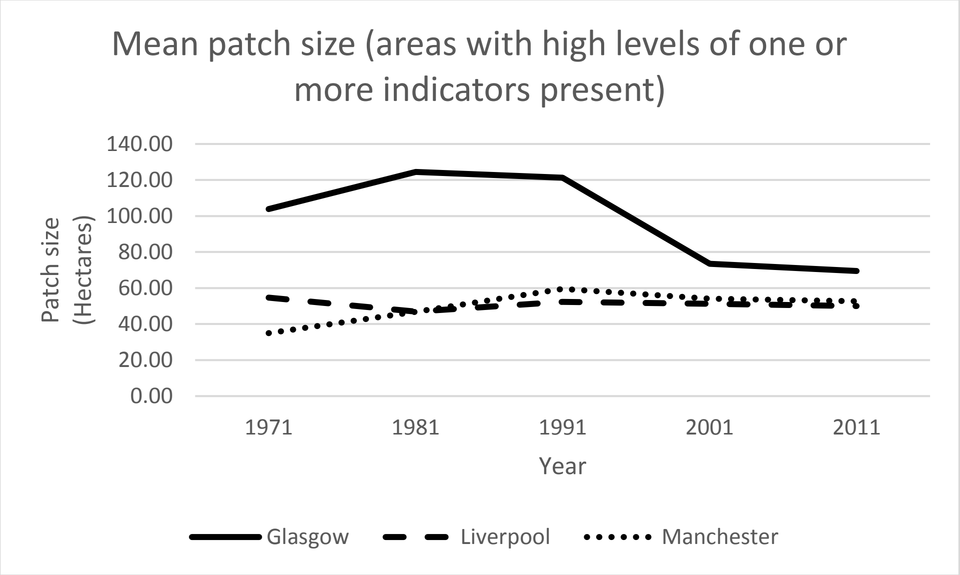

Figure 5-13 Mean Patch Size (areas with high levels of one or more indicators present)

---

[59] (1971: Glasgow-Liverpool p=0.61, Glasgow-Manchester p=0.39, Liverpool-Manchester 0.69;
1981: Glasgow-Liverpool p=0.33, Glasgow-Manchester p=0.33, Liverpool-Manchester p=0.99;
1991: Glasgow-Liverpool p=0.36, Glasgow-Manchester p=0.41, Liverpool-Manchester p=0.89;
2001: Glasgow-Liverpool p=0.69, Glasgow-Manchester p=0.72, Liverpool-Manchester p=0.96;
2011: Glasgow-Liverpool p=0.66, Glasgow-Manchester p=0.73, Liverpool-Manchester p=0.96.)

	Glasgow			Liverpool			Manchester		
Year	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD
1971	**104**	(0-283)	816	**55**	*(0-140)*	426	**35**	*(0-88)*	310
1981	**124**	*(0-283)*	673	**47**	*(0-100)*	248	**46**	*(0-117)*	355
1991	**121**	*(0-259)*	565	**52**	*(0-125)*	326	**60**	*(0-135)*	362
2001	**73**	*(0-154)*	365	**51**	*(0-116)*	260	**54**	*(0-124)*	306
2011	**69**	*(0-127)*	250	**50**	*(0-116)*	260	**53**	*(0-129)*	331

Table 5-2 Mean patch size (MPS), confidence intervals (CI), and patch size standard deviation (SD) for areas with high levels of one or more indicators of deprivation.

6.2.4 Summary of areas with high levels of one or more indicators

When the spatial patterns of areas with high levels of one or more indicators in Glasgow, Liverpool, and Manchester are compared, the development of Glasgow’s pattern does not appear to be markedly different to that observed in Liverpool and Manchester. Since 1991, the spatial extent of such areas was either identical or very similar in Glasgow and Manchester; whilst the largest change in spatial extent over time was observed in Glasgow this was only marginally higher than in Liverpool and Manchester. With regard to patch density, the biggest difference between the cities was in fact observed between Manchester and Liverpool. Despite appearing to have the highest patch sizes of the three cities by a substantial margin (particularly in 1971, 1981, and 1991) this was not statistically significant. Variation in patch size (as measured by patch size standard deviation) was large in all three cities, although, with the exception of 2011, was the highest in Glasgow.

Having presented results for areas with high levels of all of the indicators and areas with one or more indicators present, the results for each of the individual indicators will now be presented.

6.3 Areas with high levels of overcrowded households

Maps showing areas with high levels of overcrowded households are shown in Figure 5-14 to Figure 5-16.

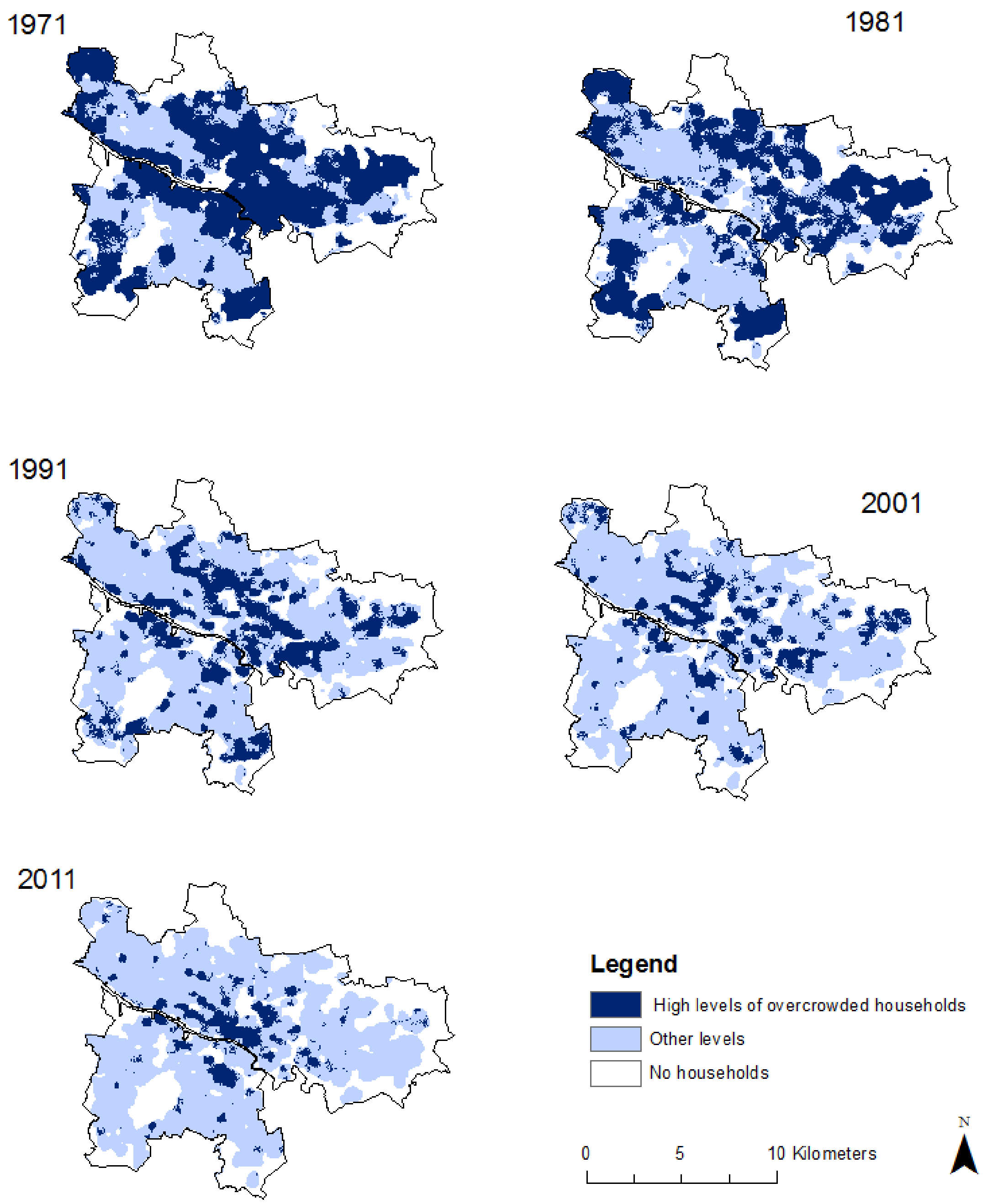

Figure 5-14 High levels of overcrowded households in Glasgow 1971 to 2011 (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

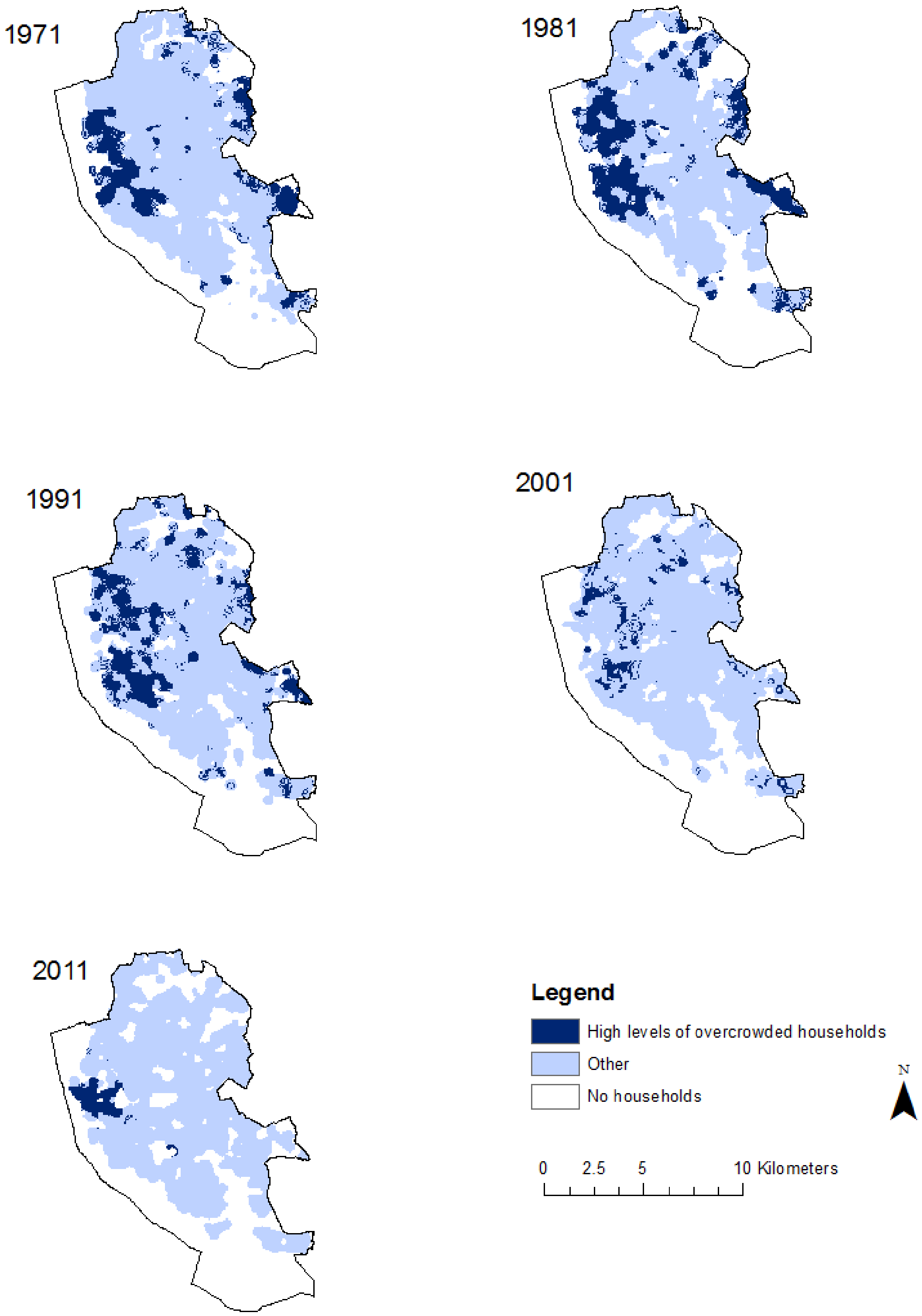

Figure 5-15 High levels of overcrowded households Liverpool 1971 to 2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

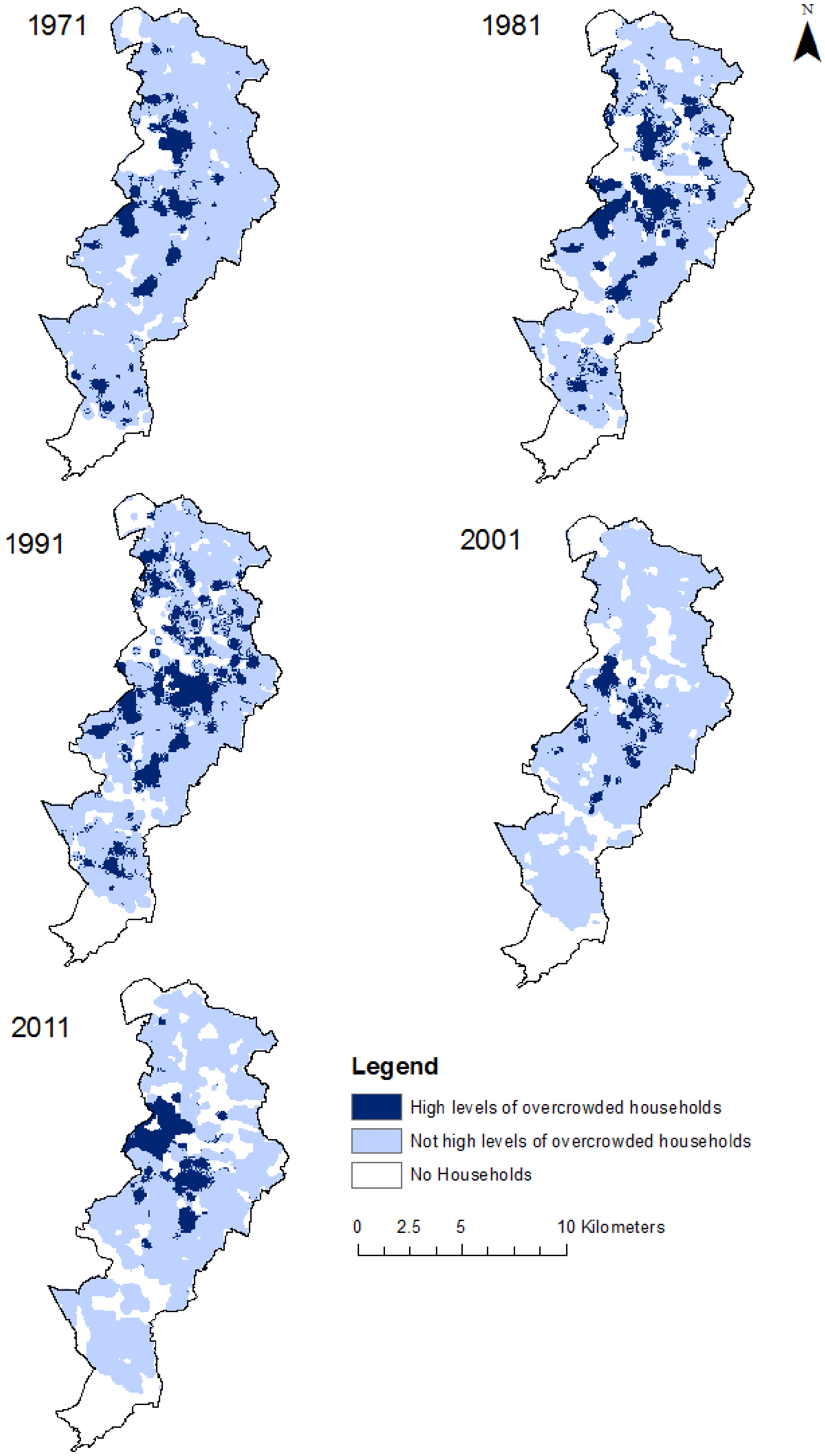

Figure 5-16 High levels of overcrowded households Manchester 1971 to 2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

6.3.1 Spatial extent (overcrowded households)

From Figure 5-17 four notable differences between Glasgow and the other two cities relating to the spatial extent of overcrowded households can be identified. First, in 1971 and 1981 the proportion of Glasgow occupied by areas with high levels of overcrowded households (44% and 36% respectively) was considerably larger than in either Liverpool (11% and 15%) or Manchester (9% and 14%). This is also apparent from the maps shown in Figure 5-14 to Figure 5-16. Although the gap between Glasgow and the other two cities decreases after 1981, with the exception of Manchester in 2011, the spatial extent of areas with high levels of overcrowded households was higher in Glasgow. Third, the temporal trajectories of the spatial extent metric were different in each city. In Glasgow, it continuously fell between 1971 and 2011; in Liverpool there was an increase between 1971 and 1981 and then a continuous decrease; in Manchester it increased between 1971 and 1991, before falling to its lowest level in 2001 and then rising again in 2011. Fourth, the scale of change over the 1971 to 2011 time period was much larger in Glasgow, with substantial difference between the peak and minimum figures.

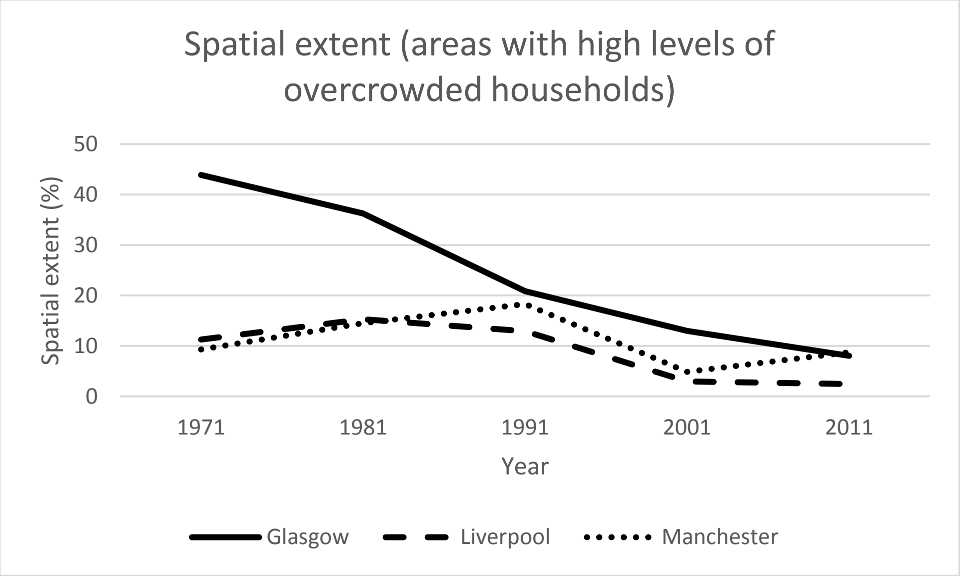

Figure 5-17 Spatial extent (areas with high levels of overcrowded households)

6.3.2 Patch density (overcrowded households)

Patch density for areas with high levels of overcrowded households (Figure 6-18) differed between the cities, both at each time point and with regard to their temporal trajectories. Liverpool consistently had a much lower patch density than either Glasgow or Manchester. In 1971, similar patch density levels were observed in Glasgow and Manchester, however from 1981 onward they were notably different. Whilst patch density increased in both Glasgow and Manchester between 1971 and 1981, the increase was much sharper in Manchester[60]. In Glasgow, the trend was for patch density to increase over a decennial interval, and then fall over the next, and then rise again. In Manchester, however, there was a sharp increase between 1971 and 1981, a very small increase between 1981 and 1991, a sharp decrease between 1991 and 2001, followed by a small decrease up to 2011. There was very little temporal change in the patch density metrics for Liverpool. With regard to changes in patch density, therefore, Manchester saw the most variation. Overall, the pattern of areas with high levels of overcrowded households developed differently in all three cities.

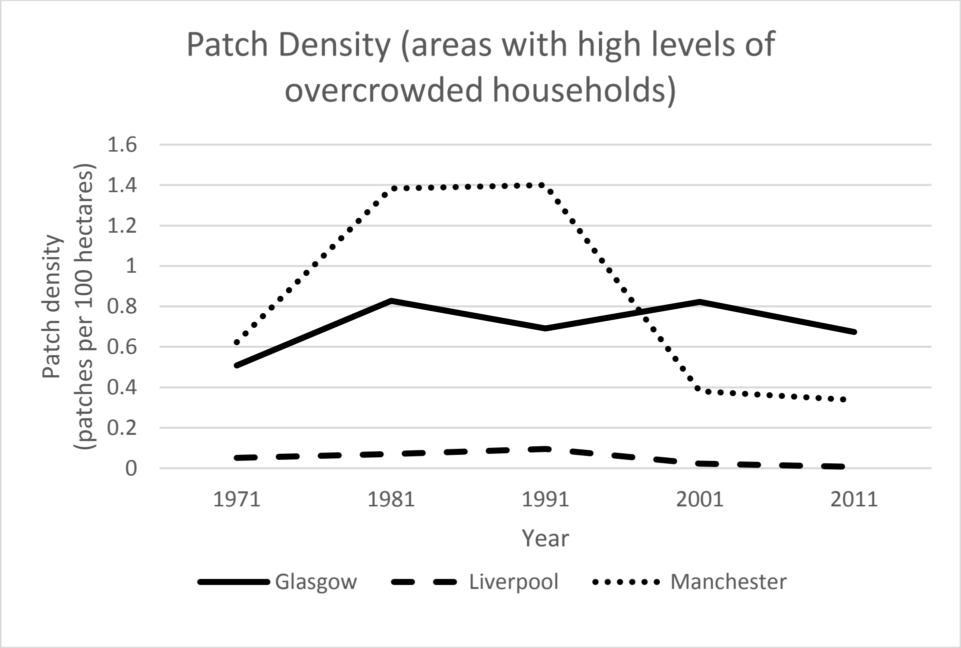

Figure 5-18 Patch Density (areas with high levels of overcrowded households)

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[60] Between 1971 and 1981 patch density in Manchester increased from 0.62 to 1.38 patches per 100 hectares; for the same time period, patch density in Glasgow increased from 0.5 to 0.83 patches per 100 hectares.

6.3.3 Mean patch size (overcrowded households)

Mean patch size of areas with high levels of overcrowded households (Figure 5-19 and Table 5-3) showed both similarities and difference in regard to both specific time points and change over time. It appears from both maps (Figure 5-14 to Figure 5-16) and metrics (Figure 5-19) that mean patch size was similar in Liverpool (22 hectares) and Manchester (16 hectares), but substantially greater in Glasgow (86 hectares) in 1971. However, wide confidence intervals rendered these differences not statistically significant[61] and, as can be seen from the standard deviation figures in Table 5-3, there was a larger variation in patch size in Glasgow compared to the other two cities. So, whilst there were some very large patches, there are also some much smaller ones. Although a substantial decrease in mean patch size was observed in Glasgow between 1971 and 1981, Glasgow continued to have the largest mean patch size in 1981. However, as with 1971, there was no statistically significant difference between the mean patch sizes of any of the cities[62]. In 1991, mean patch size in Manchester was the highest of the three cities, this difference was statistically significant (Glasgow – Manchester p =0.02, Liverpool – Manchester p=<0.01). There was no statistically significant difference between Glasgow and Liverpool (p=0.14). By 2001, mean patch size was similar[63], a situation which continued to 2011[64], at which point Glasgow had the lowest mean patch size of the three cities.

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[61] Glasgow – Liverpool p=0.33, Glasgow – Manchester p=0.26, Liverpool – Manchester p=0.59.

[62] Glasgow – Liverpool p=0.43, Glasgow – Manchester p = 0.06, Liverpool – Manchester p= 0.99.

[63] Glasgow – Liverpool p=0.39, Glasgow-Manchester p=0.3, Liverpool – Manchester p=0.99.

[64] Glasgow-Liverpool p=0.14, Glasgow-Manchester p=0.18, Liverpool-Manchester p=0.75.

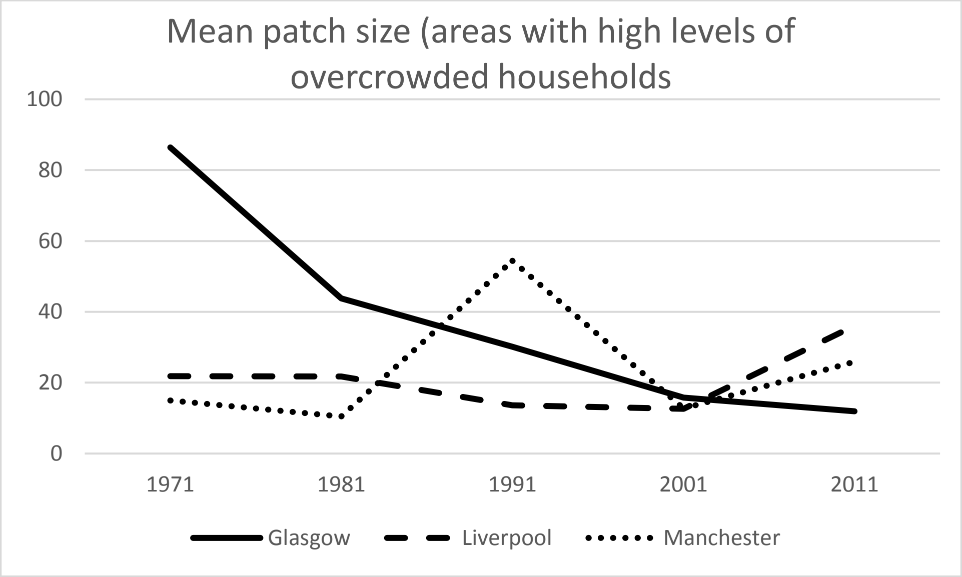

Figure 5-19 Mean Patch Size (areas with high levels of overcrowded households)

	Glasgow			Liverpool			Manchester		
Year	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD
1971	**86**	*(0-198)*	535	**22**	*(0-45)*	99	**15**	*(5-25)*	42
1981	**44**	*(8-79)*	219	**22**	*(5-38)*	84	**10**	*(5-16*	36
1991	**30**	*(11-50)*	110	**14**	*(3-24)*	61	**54**	*(46-63)*	56
2001	**16**	*(9-23)*	45	**13**	*(0-30)*	49	**13**	*(4-22)*	31
2011	**12**	*(4-20)*	42	**36**	*(0-96)*	92	**26**	*(0-53)*	86

Table 5-3 Mean patch size, confidence intervals, and patch size standard deviation (areas with high levels of overcrowded households)

The temporal trajectory of mean patch size trajectory for areas with high levels of overcrowded households differed in Glasgow to that in Liverpool and Manchester. Mean patch size fell at each decennial interval between 1971 and

2011 in Glasgow (Figure 5-19). Although this decrease appears substantial, it was not statistically significant. In Liverpool mean patch size remained the same in 1971 and 1981 and then decreased by 1991. Between 1991 and 2001 there was little change, however between 2001 and 2011 mean patch size more than doubled. As with Glasgow, however, there was no statistical difference between mean patch sizes in Liverpool at any of the time points. Change over time in mean patch size in Manchester was similar to that of Liverpool for between 1971 and 1981, and 2001 and 2011. However, between 1981 and 1991 mean patch size changed in a completely different manner to that experienced in Glasgow or Liverpool; there was a significant increase in mean patch size (p=<0.01). This was mirrored by a significant decrease between 1991 and 2001 (p=<0.01). Manchester therefore stands out as having a markedly different trajectory for this indicator.

6.3.4 All Years overcrowded

This section presents maps which identify areas that had a high level of overcrowded households at *all* of the time points (Figure 6-20, Table 5-4 Spatial metrics for areas with high levels of overcrowded households at all time pointsTable 5-4). It is apparent that there were two notable differences between Glasgow and the English cities.

Although the proportion of each city with persistent high levels of overcrowded households was low, it is striking that the spatial extent of such areas in Glasgow (2.32%) was more than three times that in Manchester (0.77%), and almost eighteen times that in Liverpool (0.13%). A second notable difference was that these areas were more fragmented in Glasgow, demonstrated by a higher patch density (0.52 patches per 100 hectares) than either Liverpool or Manchester (0.04 and 0.18 patches per 100 hectares respectively). However, mean patch size was similar across the three cities (Table 5-4)[65].

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[65] (Glasgow – Liverpool p=0.74, Glasgow – Manchester p=0.9, Liverpool – Manchester p=0.82)

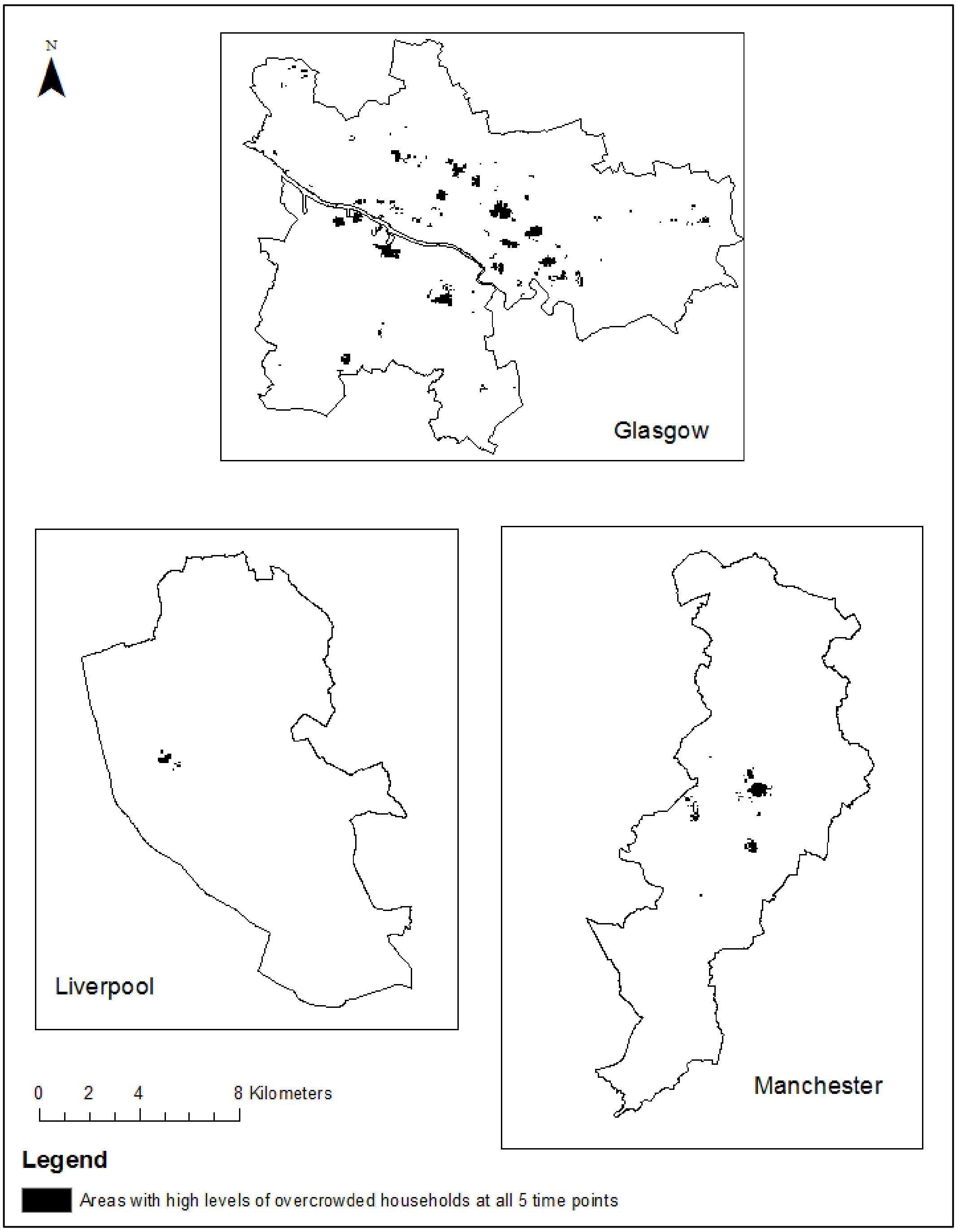

Figure 5-20 Areas in Glasgow, Liverpool, and Manchester which had high levels of overcrowded households at all 5 time points between 1971 and 2011. (Source: based on census data and boundary data provided by General Register Office for Scotland, the National Records for Scotland, the English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey day © Crown copyright and database right 2013.)

Metric	Glasgow	Liverpool	Manchester
Spatial extent (%)	2.32	0.13	0.77
Patch density (patches per 100 hectares)	0.52	0.04	0.18
Mean patch size (hectares) *(Confidence intervals)*	4.47 *(0 – 5.97)*	3.38 *(1.14 – 7.9)*	4.26 *(0 – 7.72)*
Patch size standard deviation	7.32	4.8	8.09

Table 5-4 Spatial metrics for areas with high levels of overcrowded households at all time points

6.3.5 Areas which experienced high levels of overcrowded households at any time point

Areas identified as having a high level of overcrowded households at one or more time points between 1971 and 2011 are shown in Figure 5-21, and their spatial metrics are given in Table 5-5. As with areas identified as having high levels of overcrowded households at all time points, Glasgow had notable differences to the other cities. First, the proportion of Glasgow's landscape identified as having high levels of overcrowded households at one or more time points was much higher than in either Liverpool or Manchester and second, patch density was lower in Glasgow (Table 5-5) (indicating less fragmentation in Glasgow). This was supported by the mean patch size figures (Table 5-5), however differences in mean patch size between the cities were not statistically significant[66].

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[66] Glasgow-Liverpool p=0.38, Glasgow-Manchester p=0.22, Liverpool-Manchester p=0.64).

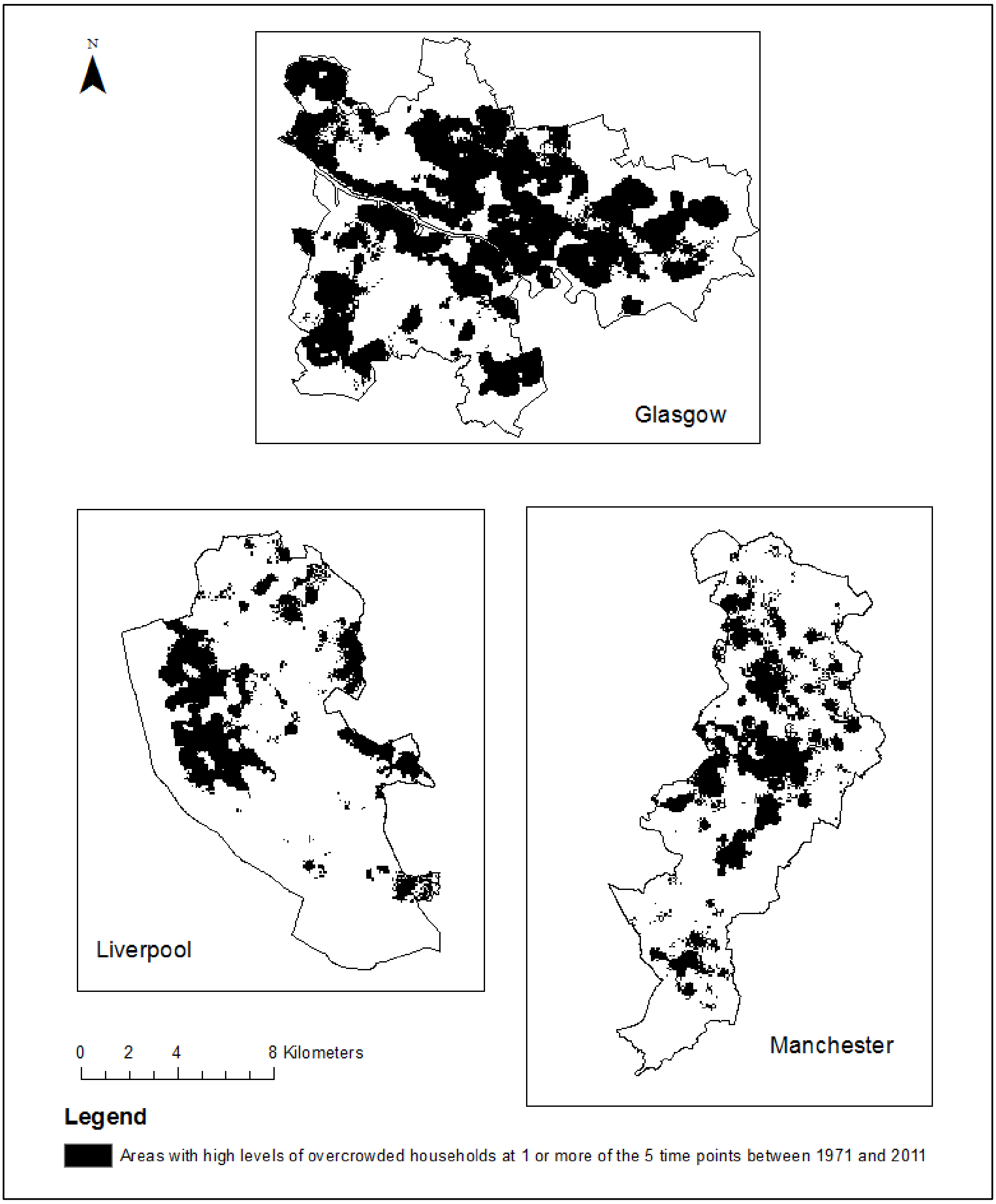

Figure 5-21 Areas which experienced high levels of overcrowded households at 1 or more time points between 1971 and 2011. (Source: based on census data and boundary data provided by General Register Office for Scotland, the National Records for Scotland, the English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

Metric	Glasgow	Liverpool	Manchester
Spatial extent (%)	46	20	25
Patch density (patches per 100 hectares)	0.45	0.64	1.1
Mean patch size (hectares) *(Confidence intervals)*	104 *(0 – 268)*	31 *(0 – 67)*	23 *(4 – 41)*
Patch size standard deviation	740	167	105

Table 5-5 Areas with high levels of overcrowded households at one or more time points between 1971 and 2011)

6.4 Male unemployment

This section presents maps (Figure 5-22 to Figure 5-24) and metrics identifying and describing patterns of areas with high levels of male unemployment and their development.

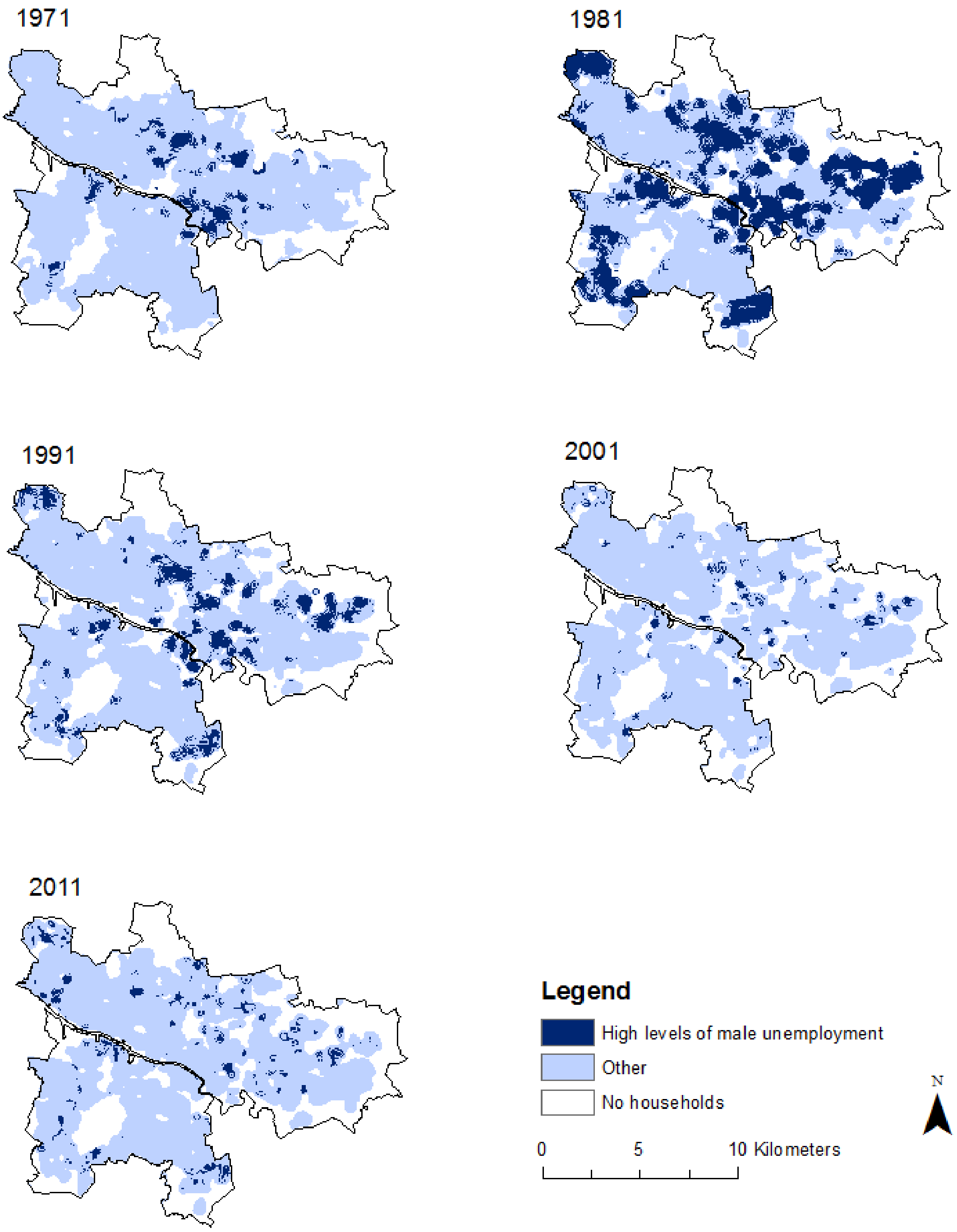

Figure 5-22 High levels of male unemployment Glasgow 1971-2011. High levels of male unemployment Glasgow 1971-2011. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

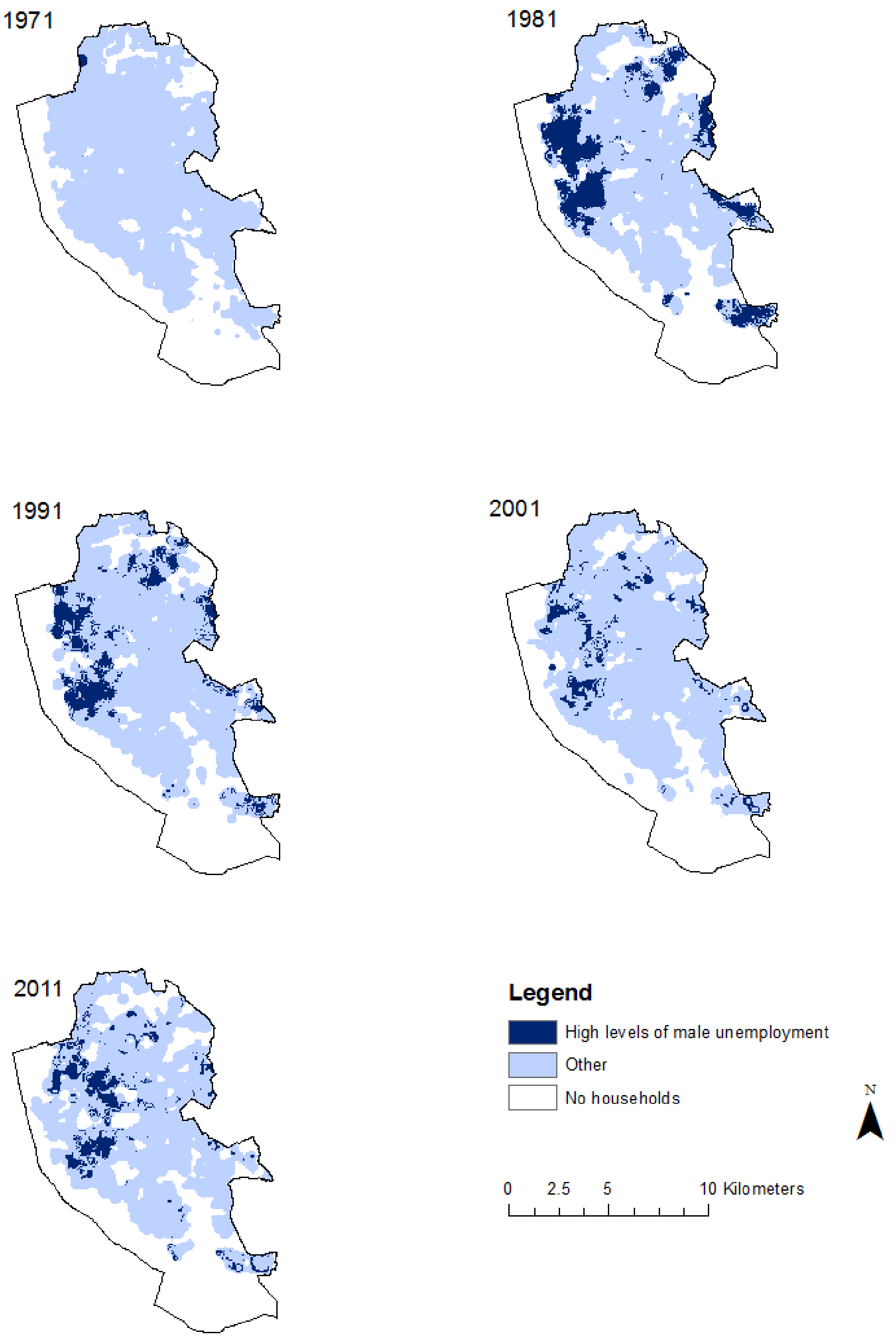

Figure 5-23 High levels of male unemployment Liverpool 1971-2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

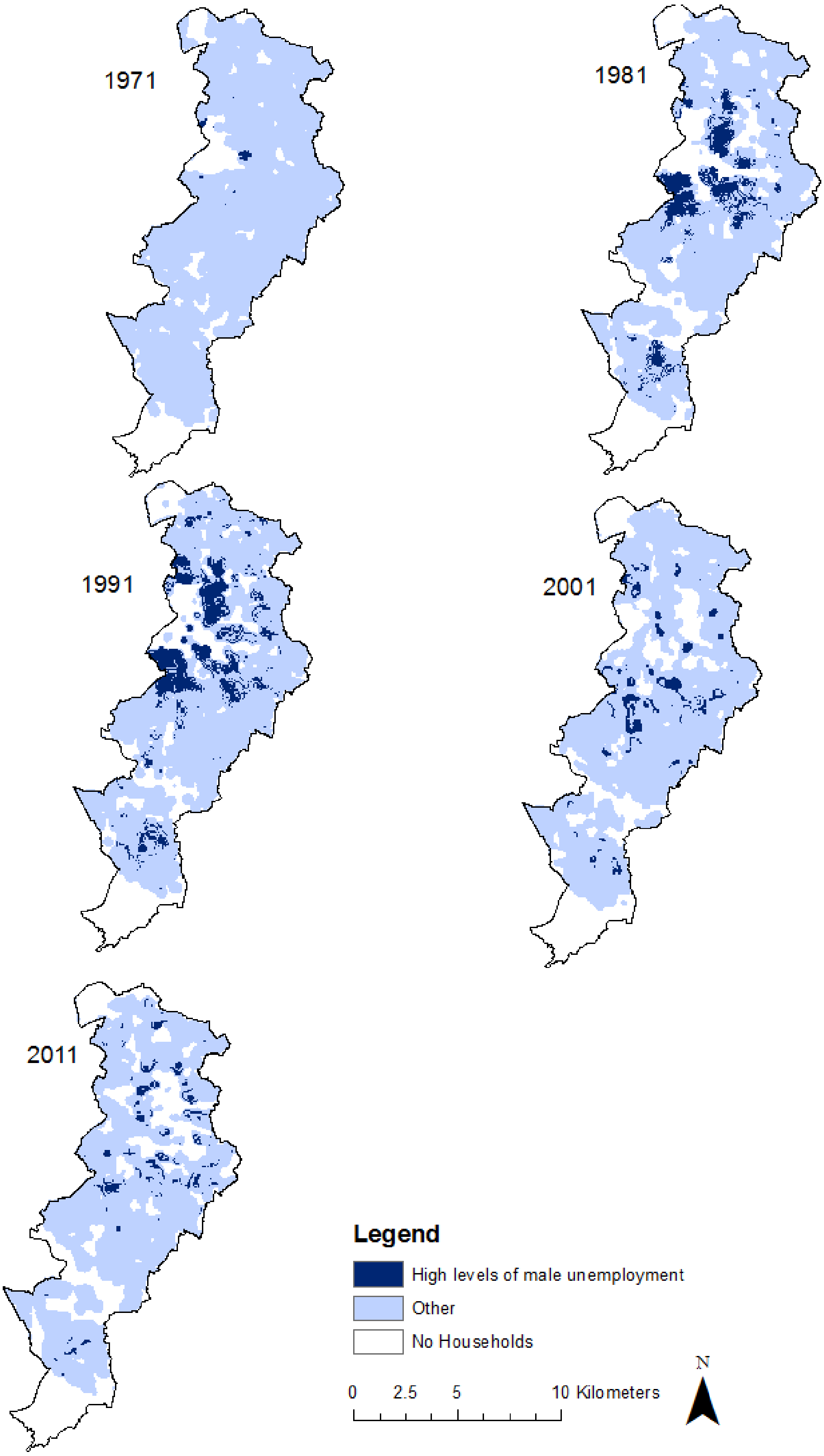

Figure 5-24 High levels of male unemployment Manchester 1971-2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

6.4.1 Spatial extent (male unemployment)

There were both inter- and intra-city differences in the spatial extent of areas with high levels of male unemployment (Figure 5-25). As indicated in Figure 5-22 to Figure 5-24, this figure was very low in Liverpool (0.2%) and Manchester (0.3%) in 1971, but noticeably larger in Glasgow (4.3%). In all three cities there was subsequently a substantial increase, however, Glasgow's (25%) was considerably higher than Liverpool (13%) and Manchester (8%). From 1991 onwards, the spatial extent figures were very similar across the cities. In Glasgow and Liverpool 1981 was the peak year, and the spatial extent metric fell between 1981 and 2001, before increasing slightly in 2011. In Manchester, however, a different trend was observed: spatial extent peaked in 1991, fell between 1991 and 2001, and remained the same between 2001 and 2011.

Glasgow experienced the biggest difference between its peak spatial extent metric (25% in 1981) and its lowest (2% in 2001) (Figure 24). The scale of change over time was, therefore, greatest in Glasgow.

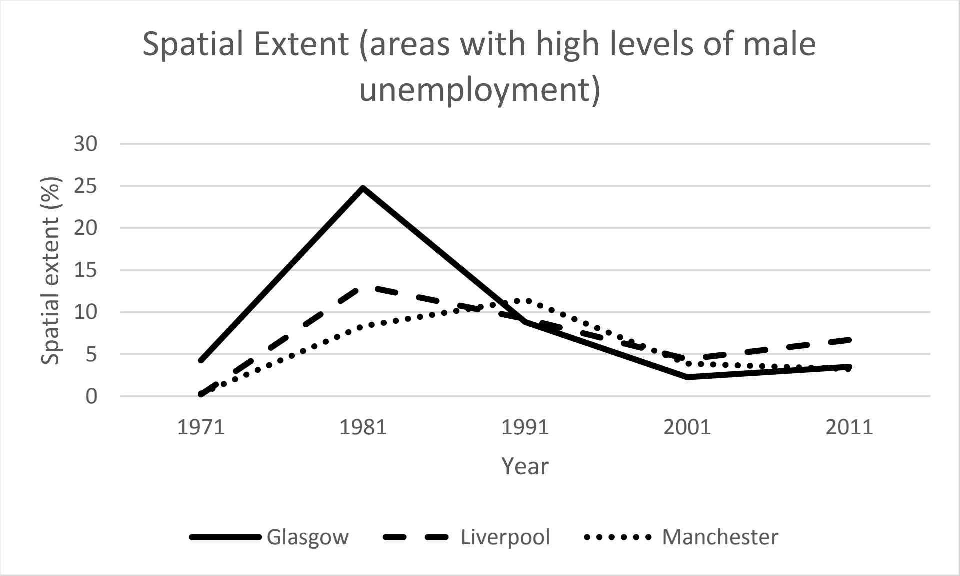

Figure 5-25 Spatial extent (areas with high levels of male unemployment)

6.4.2 Patch density (male unemployment)

The patch density metrics revealed four notable points regarding the fragmentation of areas with high levels of male unemployment between 1971 and 2011 (Figure 5-26). First, in 1971 patch density was considerably higher in Glasgow than in either Liverpool or Manchester (Figure 5-26) indicating much higher levels of fragmentation of such areas in Glasgow. Second, whilst an increase in patch density between 1971 and 1981, and 1981 and 1991 was observed in all three cities, it was much more pronounced in Liverpool and Manchester. By 1981, the highest levels of fragmentation of areas with high levels of male unemployment were observed in Manchester. Third, from 1991 onwards patch density figures in Glasgow and Liverpool were similar, and followed similar declining trajectories to 2001 before increasing again to 2011. Manchester's patch density also fell between 1991 and 2001[67], however, it did so at a much sharper rate, and continued to fall between 2001 and 2011. Fourth, the scale of change overtime in patch density observed in Glasgow was considerably smaller than observed in Liverpool and Manchester.

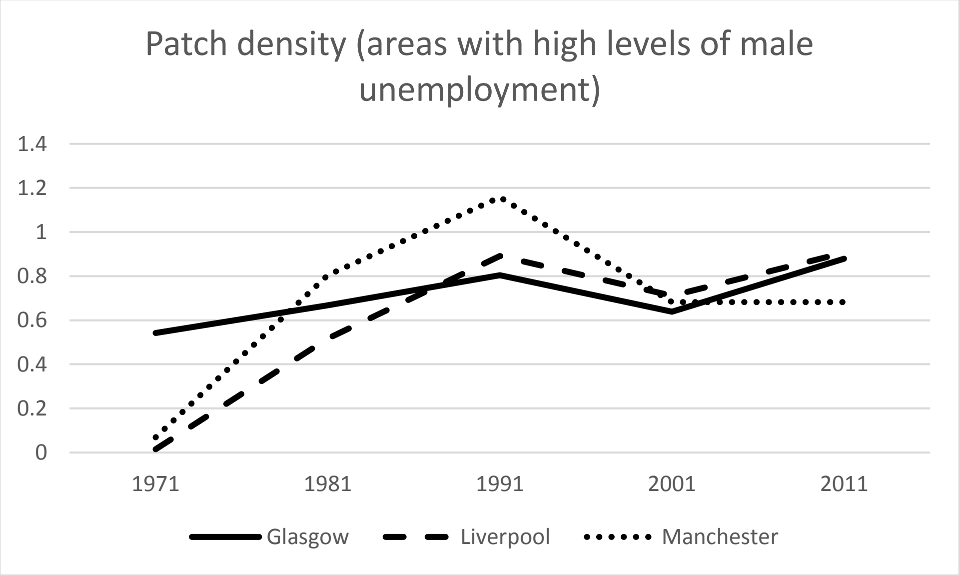

Figure 5-26 Patch density (areas with high levels of male unemployment)

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[67] Indeed, in 2001 patch density was similar across the Glasgow, Liverpool, and Manchester (0.64, 0.71, and 0.68 patches per 100 hectares respectively).

6.4.3 Mean patch size (male unemployment)

Mean patch size metrics are presented in Figure 5-27 and Table 5-6. In 1971 there was no statistical difference between the mean patch sizes of areas with high levels of male unemployment in any of the cities[68]. Whilst In 1981, mean patch size in Glasgow was larger than in Liverpool and Manchester (Figure 5-27, Table 5-6), these differences were, largely, not statistically significant[69]. In 1991, mean patch size was identical in Liverpool and Manchester and very similar to Glasgow, and unsurprisingly, also not significantly different[70]. The similarity continued in 2001, although difference between Glasgow and Manchester did reach statistical significance (p=<0.01). There was no significant difference between Glasgow and Liverpool (p=0.06) or Liverpool and Manchester (p=0.53). In 2011 mean patch size remained similar across the cities, with no statistically significant differences[71].

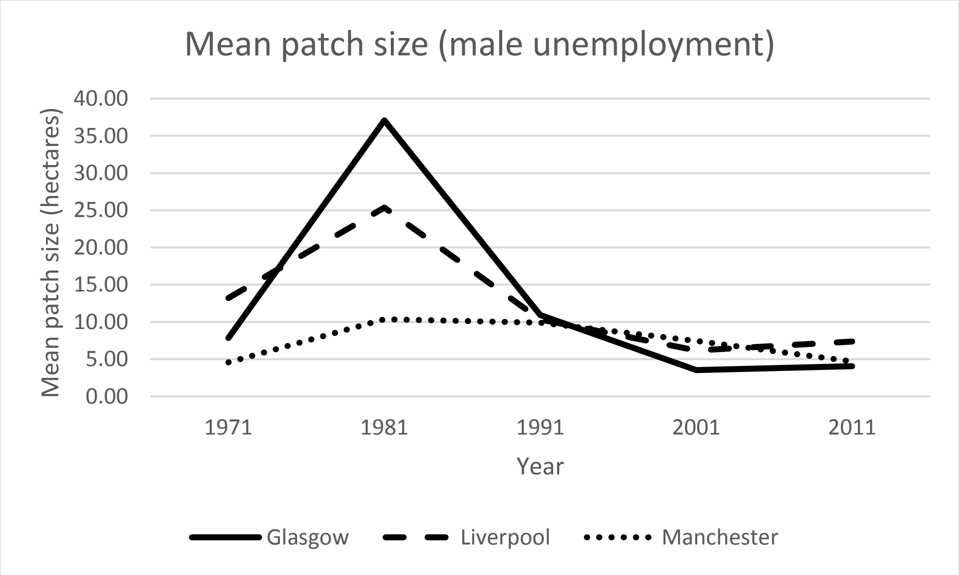

Figure 5-27 Mean patch size (male unemployment)

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[68] Glasgow-Liverpool p=0.74, Glasgow-Manchester p=0.69, Liverpool-Manchester p=0.21.

[69] Glasgow-Liverpool p=0.49, Glasgow-Manchester p=0.05, Liverpool-Manchester p=0.14.

[70] Glasgow-Liverpool p=0.89, Glasgow-Manchester p=0.8, Liverpool-Manchester p=0.94.

[71] Glasgow-Liverpool p=0.14, Glasgow-Manchester p=0.49, Liverpool-Manchester p=0.83.

	Glasgow			Liverpool			Manchester		
Year	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD
1971	**8**	*(3-12)*	23	**13**	*(0-31)*	13	**5**	*(0-10)*	7
1981	**37**	*(14-60)*	126	**25**	*(5-46)*	85	**10**	*(2-18)*	40
1991	**11**	*(6-16)*	28	**10**	*(2-18)*	44	**10**	*(3-17)*	39
2001	**4**	*(3-4)*	5	**6**	*(3-9)*	14	**7**	*(5-10)*	13
2011	**4**	*(3-5)*	7	**7**	*(3-12)*	26	**5**	*(3-6)*	7

Table 5-6 Mean patch size (MPS), confidence intervals (CI), and patch size standard deviation (SD) for areas with high levels of male unemployment.

The trajectory was similar in Glasgow and Liverpool, but between 1971 and 2001 the decennial changes were more pronounced in Glasgow (Figure 5-27). The increase in mean patch size between 1971 and 1981 was significant in Glasgow (p=0.03) but not in Liverpool (p=0.49), the decrease between 1981 and 1991 was also significant in Glasgow (p=0.02) but not in Liverpool (p=0.11), and finally, the decrease between 1991 and 2001 was significant in Glasgow (<0.01) but not in Liverpool (p=0.38). There was little or no change in mean patch size in Glasgow or Liverpool between 2001 and 2011. Whilst mean patch size also fluctuated in Manchester it did so by considerably smaller margins, and none of these changes were statistically significant[72]. These results establish that between 1971 and 2001 changes in mean patch size were significantly different in Glasgow but not in either Liverpool or Manchester.

6.4.4 Areas of the city with high levels of male unemployment at all time points.

Neither Liverpool nor Manchester had any areas which had experienced high levels of male unemployment at each of the time points, but there were a small number of areas in Glasgow (Figure 5-28 and Table 5-7).The proportion of Glasgow covered by these cells was very small, being just 0.03% of Glasgow's

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[72] 1971-1981 p=0.68, 1981-1991 p=0.93; 1991-2001 p=0.59, 2001-2011 p=0.1.

landscape. Patch density was just 0.02 patches per 100 hectares indicating that these patches tended to be grouped together. Even when these cells were not grouped into the same patch, the general trend was for them to be in close geographical proximity to one another (Figure 5-28). Mean patch size was very small, and there was very little variation in patch size (Table 5-7).

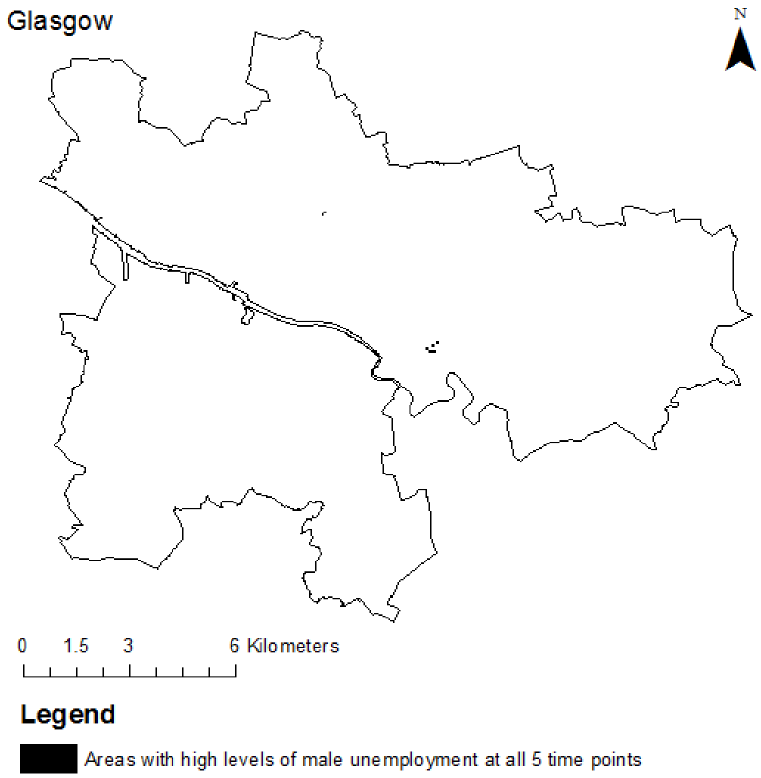

Figure 5-28 Areas in Glasgow with high levels of male unemployment at all 5 time points between 1971 and 2011. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

Spatial extent (%)	0.03
Patch density (patches per 100 hectares)	0.02
Mean patch size (hectares) *(Confidence intervals)*	1.12 0 - 2
Patch size standard deviation	0.69

Table 5-7 Spatial extent metrics for areas in Glasgow with high levels of male unemployment at all 5 time points.

6.4.5 Areas of the city with high levels of male unemployment at any time point

The maps in Figure 5-29 identify which areas of the three cities had high levels of male unemployment at one or more time point between 1971 and 2011. From the spatial metrics (Table 5-8) it is apparent that Liverpool and Manchester had very similar proportions of their landscape occupied by such areas (18% and 16% respectively). This was slightly lower than was observed in Glasgow (24%) but not substantially different. The patch density metrics observed in Glasgow and Liverpool were also very similar but the figure for Manchester was considerably higher (Table 5-8). There were no statistically significant differences between the mean patch sizes of any of the cities[73].

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[73] Glasgow-Liverpool p=0.71, Glasgow-Manchester p=0.09, Liverpool-Manchester p=0.43).

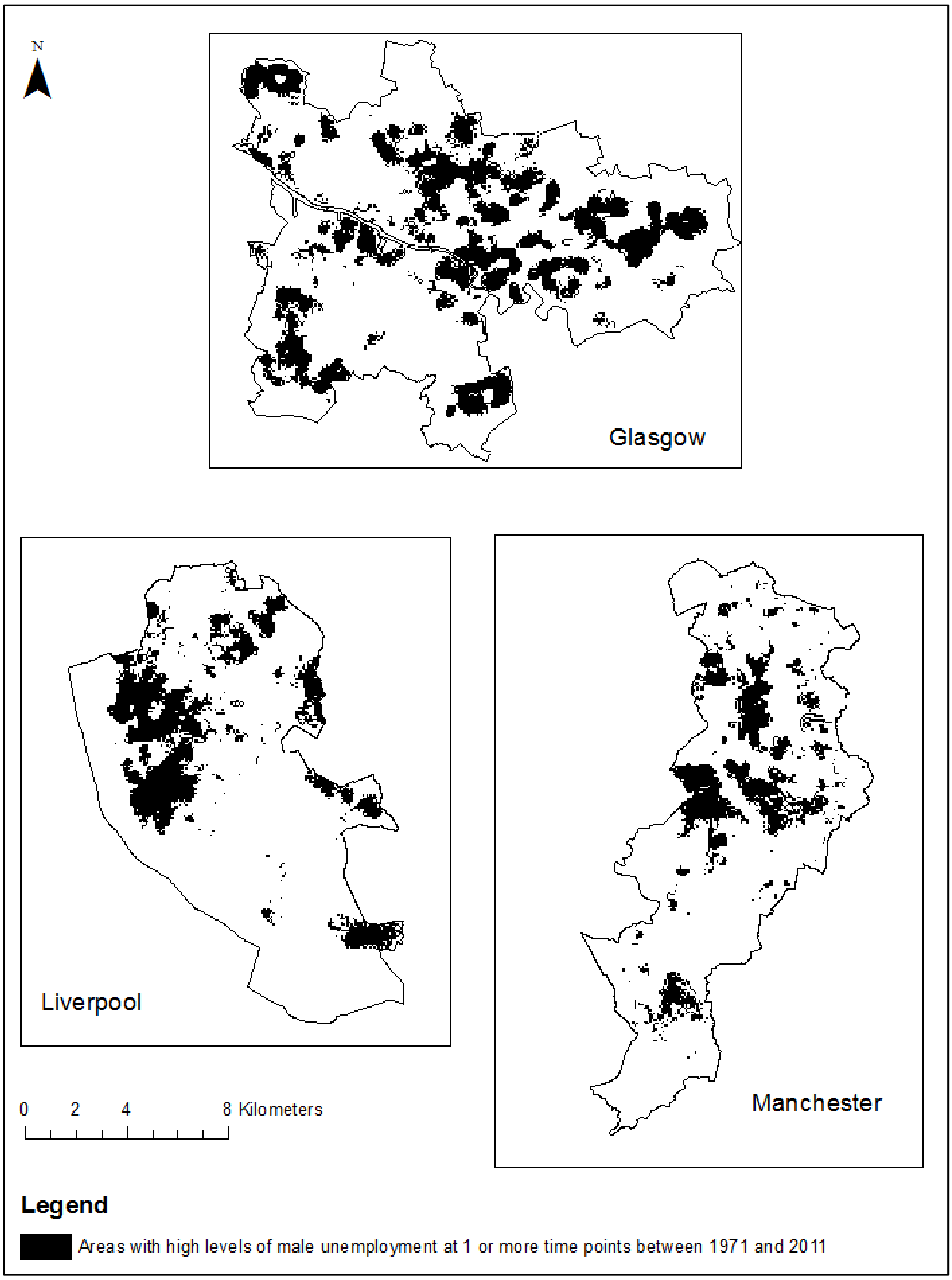

Figure 5-29 Areas in Glasgow, Liverpool, and Manchester which had high levels of male unemployment at 1 or more time points between 1971 and 2011. (Source: based on census data and boundary data provided by General Register Office for Scotland, the National Records for Scotland, the English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

Metric	*Glasgow*	*Liverpool*	*Manchester*
Spatial extent (%)	*24*	*18*	*16*
Patch density (patches per 100 hectares)	*0.72*	*0.67*	*1.08*
Mean patch size (hectares) *(Confidence intervals)*	*33* *(16 – 51)*	*27* *(0 – 57)*	*15* *(4 – 26)*
Patch size standard deviation	*100*	*144*	*63*

Table 5-8 Areas of the city which had high levels of male unemployment at any time point

6.5 Areas of the city with high levels of households without a car

Areas in Glasgow, Liverpool, and Manchester with high levels of households not owning a car at each decennial interval from 1971 to 2011 are shown in Figure 5-30 to Figure 5-32. The results of the spatial metrics undertaken on these maps are discussed in this section.

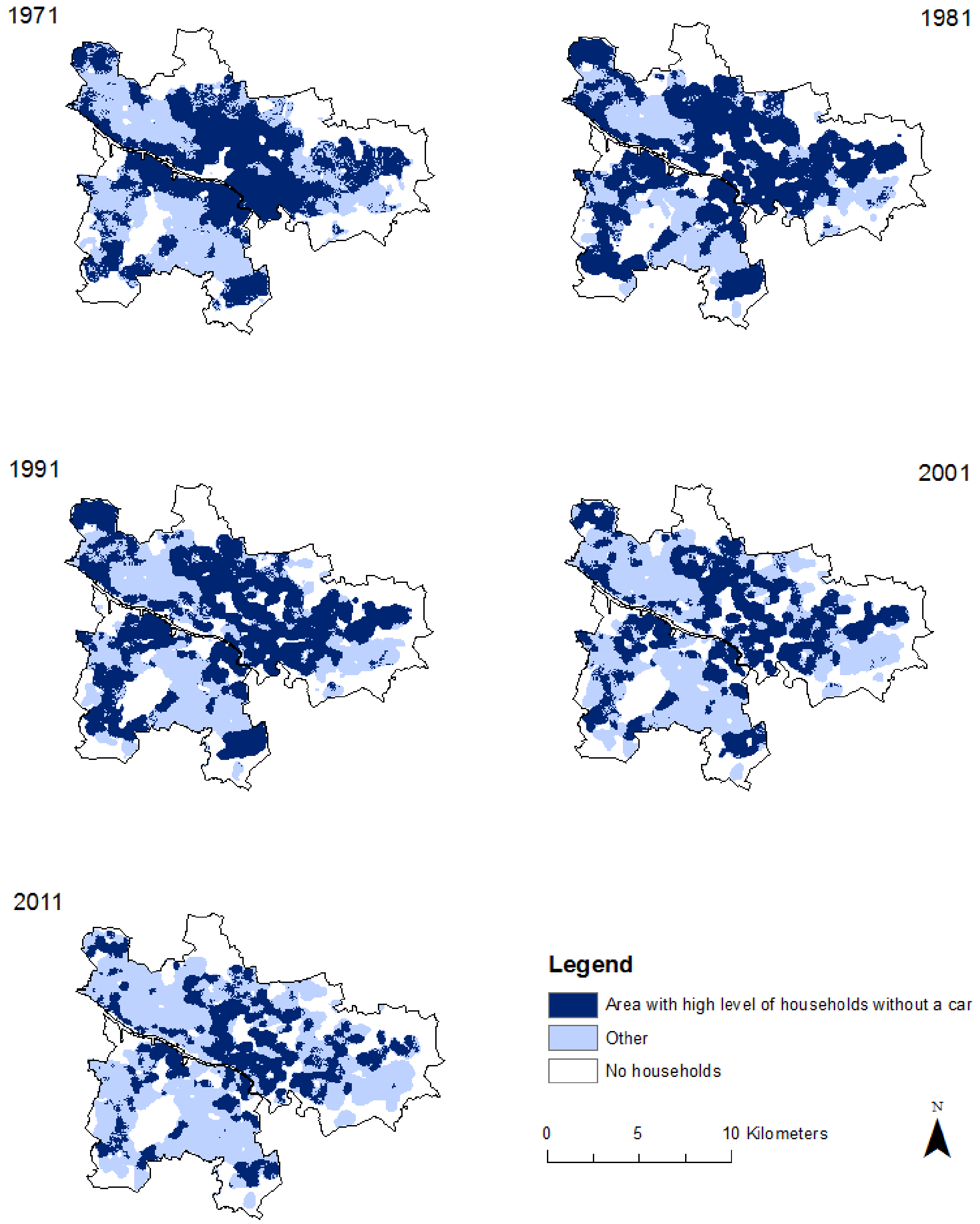

Figure 5-30 Areas in Glasgow with high levels of households without access to a car between 1971 and 2011. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

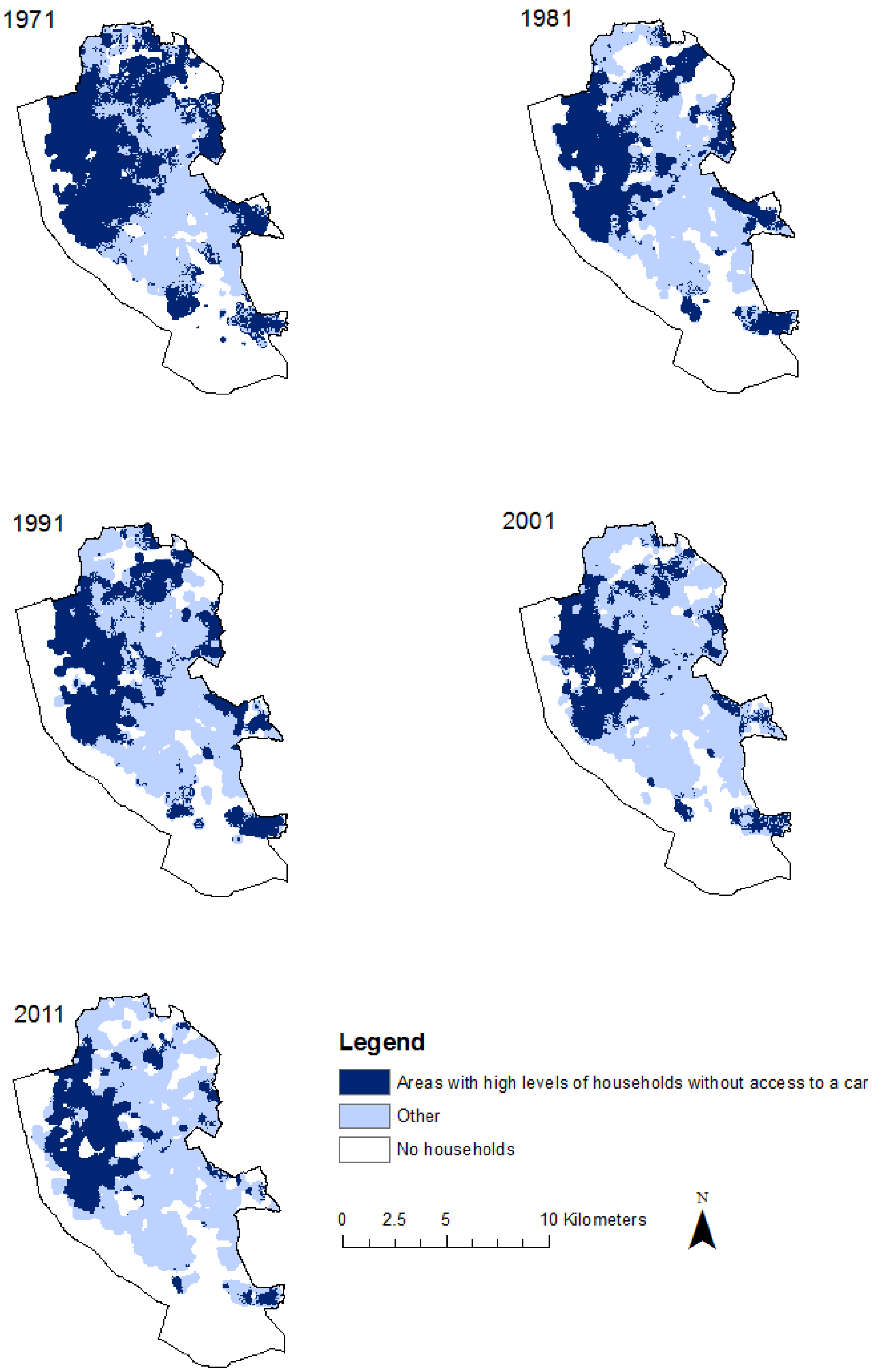

Figure 5-31 Areas in Liverpool with high levels of households without a car 1971-2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

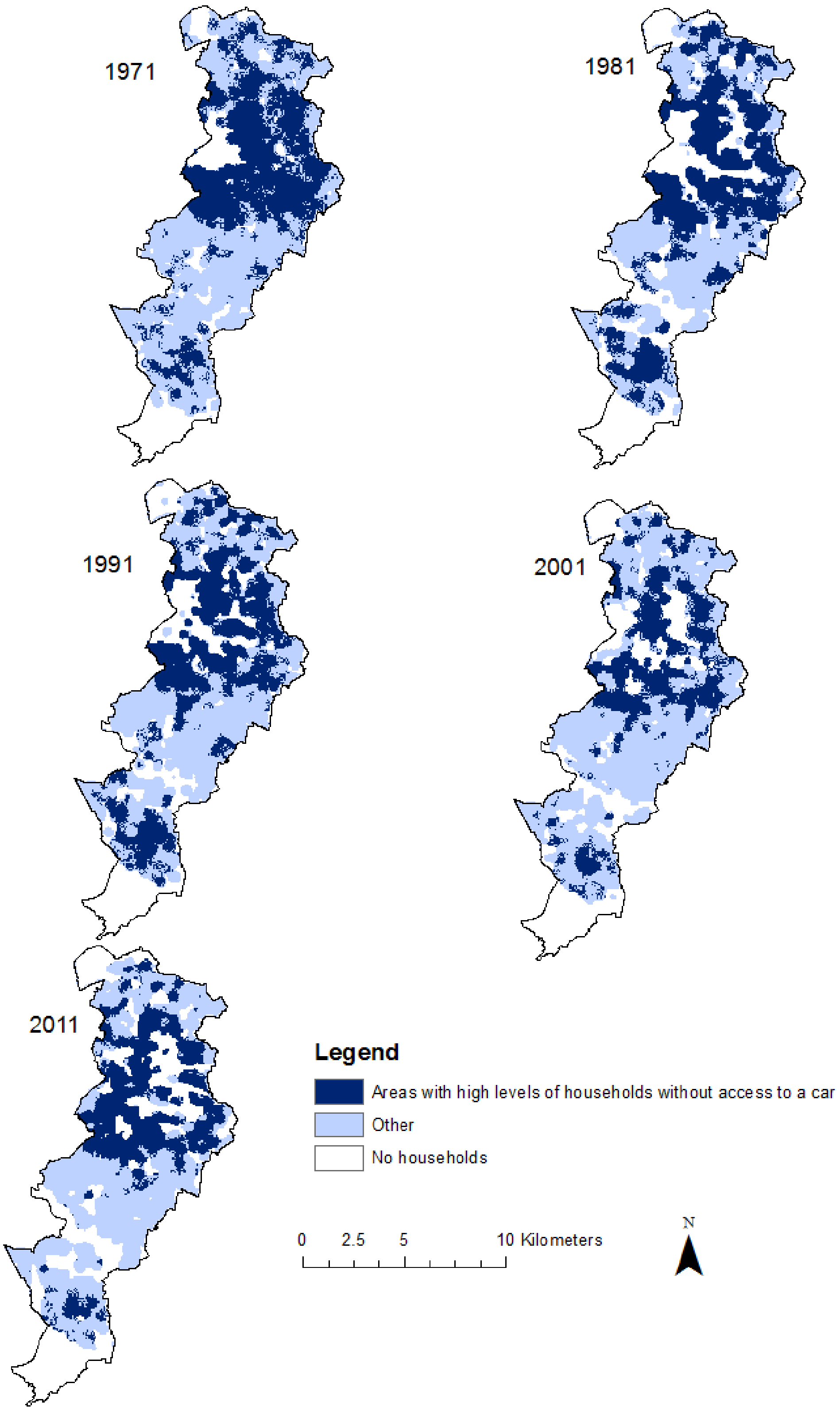

Figure 5-32 Areas in Manchester with high levels of households without access to a car 1971-2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

6.5.1 Spatial extent (households without a car)

Figure 5-33 shows the spatial extent metrics for areas with high levels of households not owning a car and highlights four pertinent points. First, in 1971 the three cities had a very similar proportion of their landscape composed of areas with high levels of households not owning a car. Second, Glasgow’s peak year (1981) was later than that for Liverpool and Manchester (both=1971). Third, there were some important differences in the temporal trajectories across the three cities. In Liverpool and Manchester a decline was observed between 1971 and 1981, and in Liverpool the fall was quite substantial; Glasgow’s figure went up. Between 1981 and 2001, declines were observed in Glasgow and Manchester, and from 1991 onwards in Glasgow and Liverpool. Whilst the spatial extent of areas with high levels of non-car ownership continued to fall between 2001 and 2011 in Glasgow and Liverpool, Manchester saw a slight increase such that, fourth, 2011 was the only year Glasgow did not have the greatest spatial extent of non-car ownership.

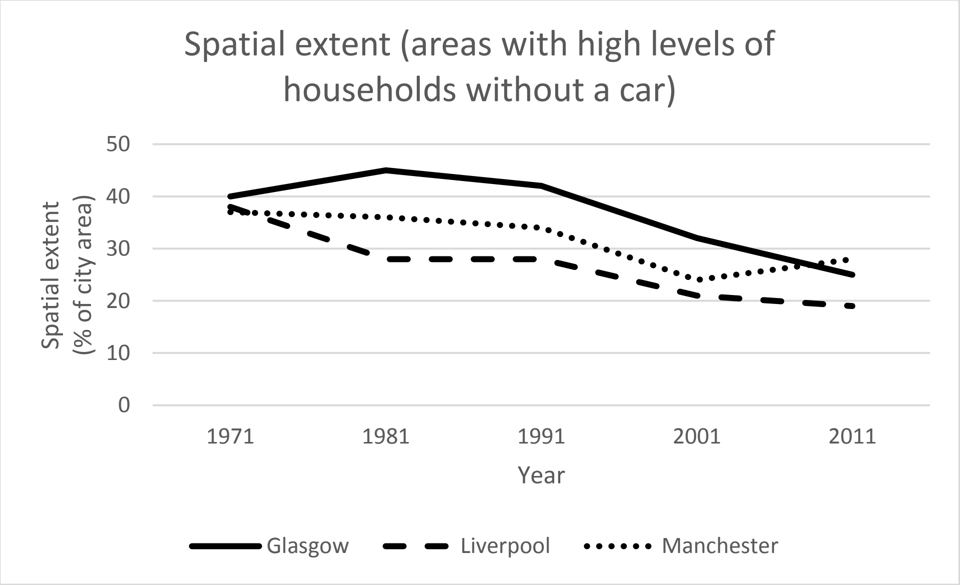

Figure 5-33 Spatial extent of areas with high levels of households without a car 1971 to 2011

6.5.2 Patch Density (households without a car)

Manchester had the highest patch density figures of all three cities at all time points (Figure 5-34) (Liverpool was a close second in 1981). Glasgow had the lowest patch density at all the time points apart from 2011 when Liverpool's value fell narrowly lower. This indicates that in general, Manchester was the most fragmented and Glasgow the least. The biggest difference in patch density between the cities was in 1971, with 0.59 patches per 100 hectares in Glasgow compared to 1.13 patches per 100 hectares in Manchester. The difference was narrowest in 2011. In all three cities patch density peaked in 1971. In Liverpool and Manchester the lowest patch density was observed in 2011, but in Glasgow patch density was lowest in 1981 and 1991 (0.34 patches per 100 hectares at both time points). In terms of temporal changes in patch density of areas with high levels of households not owning a car, Liverpool generally experienced a decline over time, with decline, followed by a rise for Glasgow and Manchester (Figure 5-34).

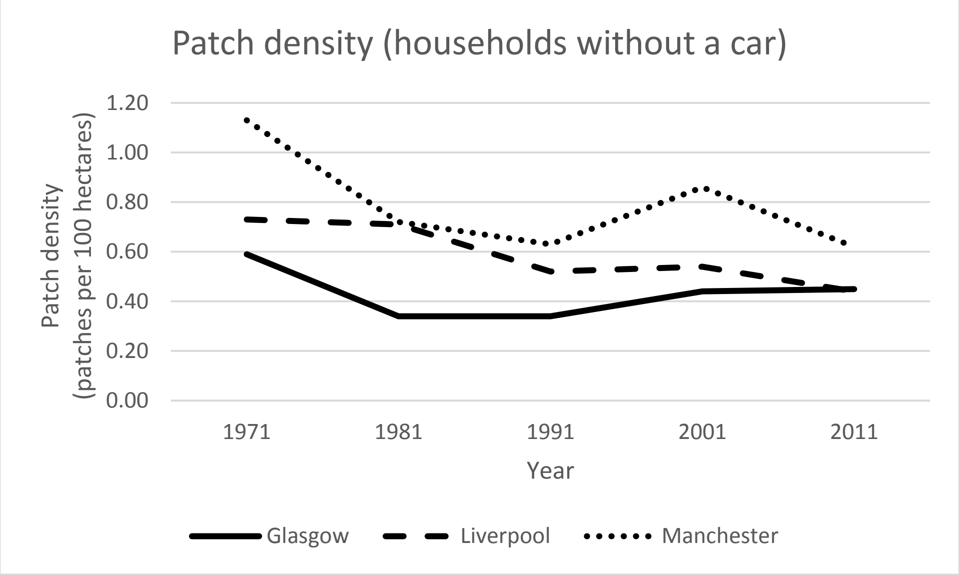

Figure 5-34 Patch Density (households without a car)

6.5.3 Mean patch size (households without a car)

Glasgow had the highest mean patch size at all five time points (

Figure 5-35), though there were no significant differences in mean patch size between the cities at any time points (Table 9)[74]. Considerable variety in patch size (see patch size standard deviation figures in Table 5-9) is likely to explain the wide confidence intervals. Caution is therefore required in interpreting these results, however, it does appear that the temporal change in Glasgow was different to that in Liverpool and Manchester. The two most striking difference are that: first, between 1971 and 1981 a sharp rise in Glasgow's mean patch size was observed, which was not seen in either Liverpool (which fell) or Manchester (where the increase was less steep); and second, whilst there was a decrease in mean patch size in all three cities between 1991 and 2001, this decrease was much more pronounced in Glasgow. However, it is important to note that there was no significant difference, intra-city, over time.

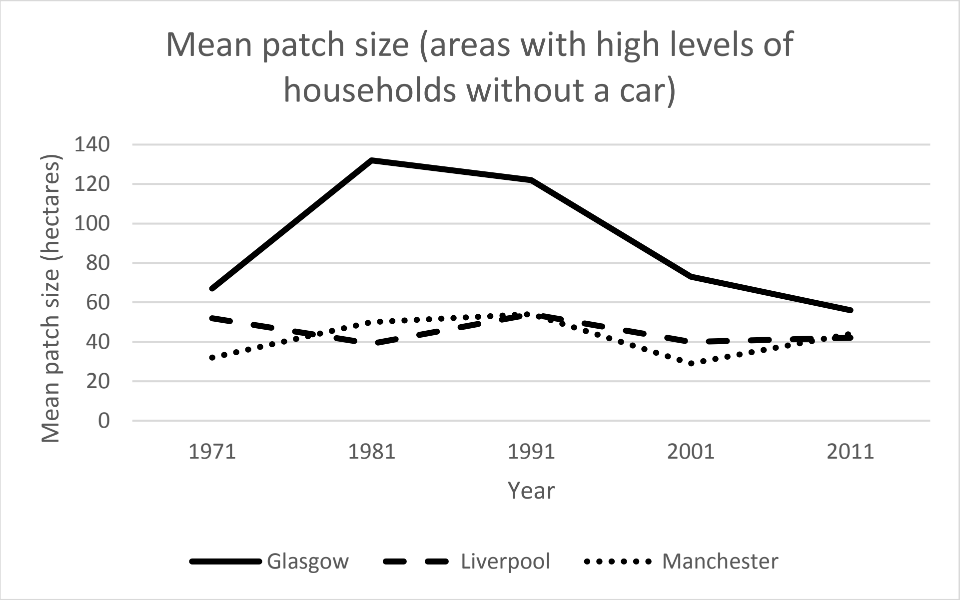

Figure 5-35 Mean patch size (areas with high levels of households without a car)

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[74] (1971 Glasgow- Liverpool p=0.82, Glasgow-Manchester p=0.53, Liverpool-Manchester p=0.68;

1981 Glasgow-Liverpool p=0.21, Glasgow-Manchester p=0.31, Liverpool-Manchester p=0.78;

1991 Glasgow-Liverpool p=0.38, Glasgow-Manchester p=0.34, Liverpool-Manchester p=0.99;

2001 Glasgow-Liverpool p=0.5, Glasgow-Manchester p=0.27, Liverpool-Manchester p=0.7;

2011 Glasgow-Liverpool p=0.72, Glasgow-Manchester p=0.78, Liverpool-Manchester p=0.96)

	Glasgow			Liverpool			Manchester		
Year	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD
1971	**67**	*(0-171)*	536	**52**	*(0-134)*	413	**32**	*(0-84)*	300
1981	**132**	*(0-299)*	658	**39**	*(0-84)*	225	**50**	*(0-112)*	287
1991	**122**	*(0-258)*	541	**54**	*(0-126)*	309	**54**	*(3-106)*	226
2001	**73**	*(0-150)*	347	**40**	*(0-91)*	222	**29**	*(0-60)*	160
2011	**56**	*(12-99)*	196	**42**	*(0-104)*	242	**44**	*(0-112)*	295

Table 5-9 Mean patch size, confidence intervals and standard deviation (areas with high levels of households without a car)

6.5.4 Areas with high levels of households not owning a car at all time points between 1971 and 2011

Figure 5-36 and Table 5-10 show that the spatial patterning of areas persistently classified as having high levels of non-car ownerships was generally similar across the three cities. Liverpool and Manchester both had 13% of their city areas classified in this way, only slightly lower than Glasgow (18%). Patch density was identical in Glasgow and Manchester, and higher than observed in Liverpool. Therefore, it appears that areas with high levels of households not owning a car at all time points were more fragmented in Glasgow and Manchester than in Liverpool. Glasgow and Liverpool had very similar mean patch sizes with Manchester's only slightly lower. There was no significant difference between these mean patch sizes[75].

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[75] Glasgow-Liverpool p=0.92, Glasgow-Manchester p=0.53, Liverpool-Manchester p=0.7.

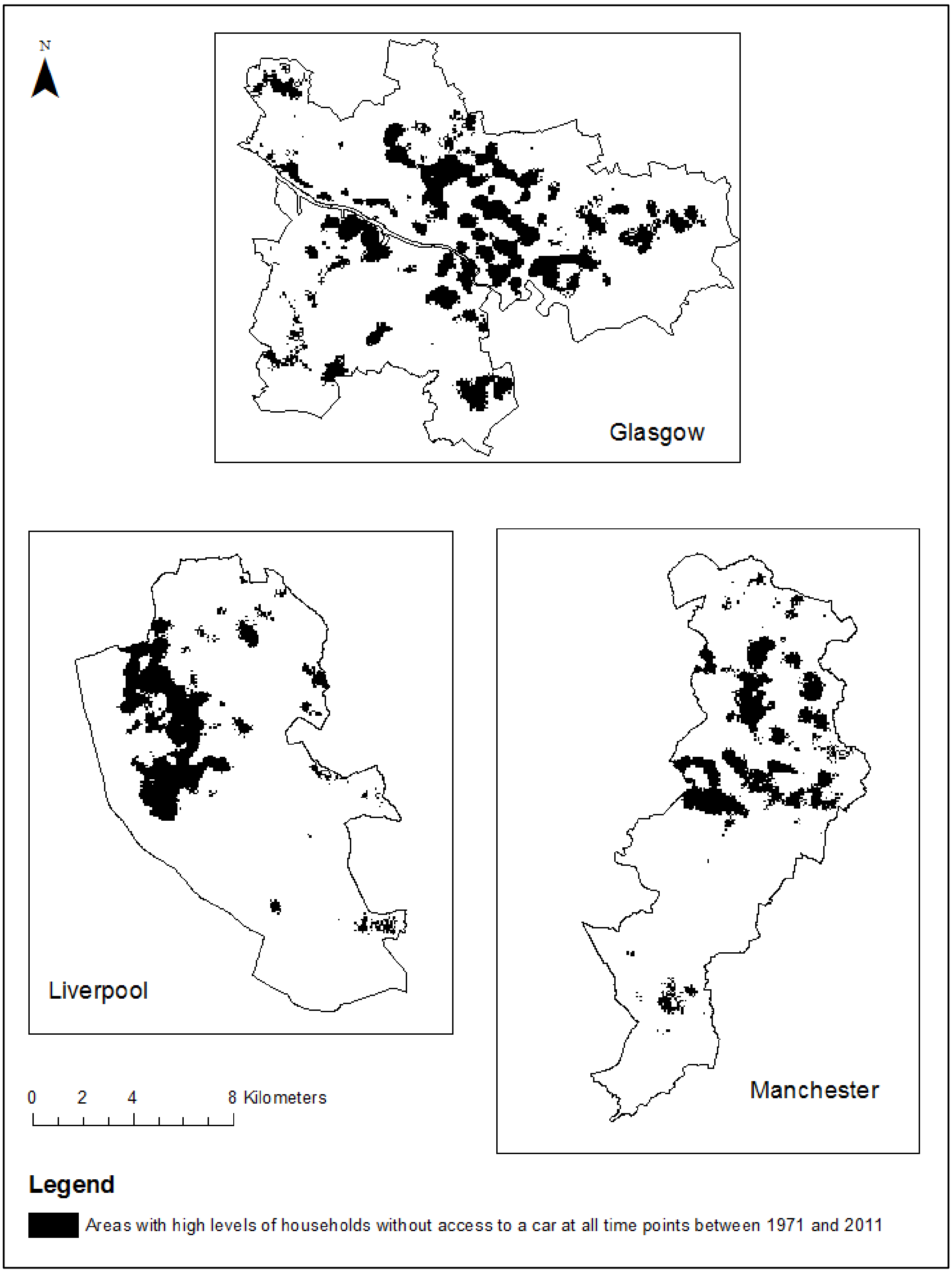

Figure 5-36 Areas with high levels of households without access to a car at all time points between 1971 and 2011 in Glasgow, Liverpool, and Manchester. (Source: based on census data and boundary data provided by General Register Office for Scotland, the National Records for Scotland, the English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

Metric	Glasgow	Liverpool	Manchester
Spatial extent (%)	18	13	13
Patch density (patches per 100 hectares)	0.66	0.45	0.66
Mean patch size (hectares) *(Confidence intervals)*	27 *(13-41)*	29 *(0-72)*	*20* *(5-35)*
Patch size standard deviation	77	171	68

Table 5-10 Spatial metrics for areas with high levels of households not owning a car at all time points between 1971 and 2011 in Glasgow, Liverpool, and Manchester

6.5.5 Areas with high levels of households not owning a car at one or more time points between 1971 and 2011

Figure 5-37 shows areas identified as having a high level of households not owning a car at one or more time point between 1971 and 2011. Glasgow and Manchester had very similar spatial extent metrics (47% and 46% respectably) (Table 5-11). This means that almost half of their landscapes had a high level of households not owning a car at one or more time points between 1971 and 2011. The figure was lower in Liverpool at 36%. The lowest patch density was observed in Glasgow and the highest in Liverpool (Table 5-11). Glasgow had, by some considerable margin, the highest mean patch size (207 hectares), however wide confidence intervals rendered this difference statistically insignificantly[76]. There was considerable variety in patch size in all three cities, but most pronounced in Glasgow (Table 5-11). This variation is likely to explain the high standard deviations and wide confidence intervals.

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[76] Glasgow-Liverpool p=0.48, Glasgow-Manchester p=0.73, Liverpool-Manchester p=0.68.

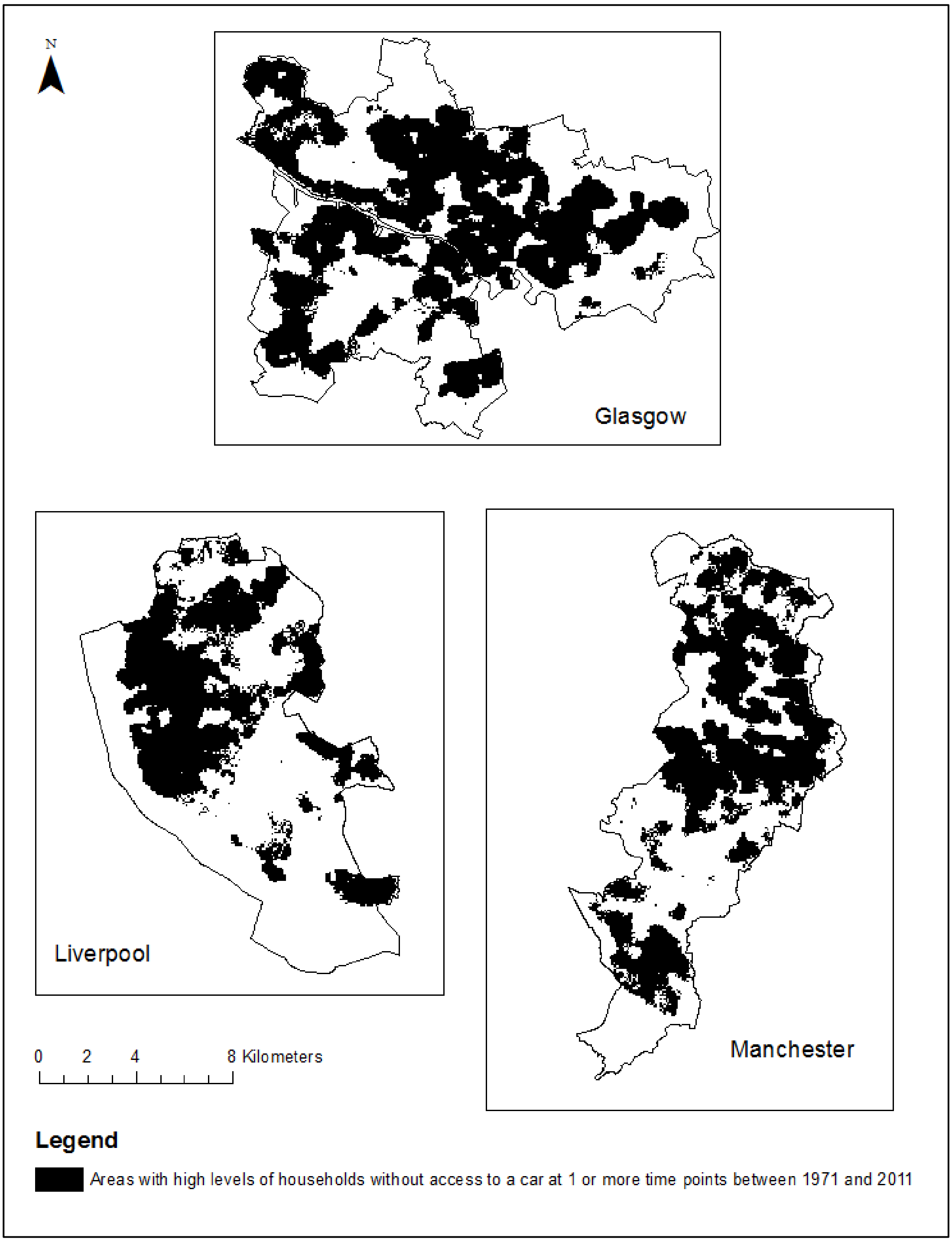

Figure 5-37 Areas with high levels of households without access to a car at 1 or more time points between 1971 and 2011 in Glasgow, Liverpool, and Manchester. (Source: based on census data and boundary data provided by General Register Office for Scotland, the National Records for Scotland, the English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

Metric	Glasgow	Liverpool	Manchester
Spatial extent (%)	47	36	46
Patch density (patches per 100 hectares)	0.23	0.43	0.35
Mean patch size (hectares) *(Confidence intervals)*	207 *(0-580)*	84 *(0-201)*	132 *(0-330)*
Patch size standard deviation	1203	456	637

Table 5-11 Areas with high levels of households not owning a car at 1 or more time points

6.6 Socially Rented Households

Maps showing areas with high levels of socially rented households in each city in 1991, 2001, and 2011 are shown in Figure 5-38 to Figure 5-40. Visually, these suggest that the proportion of the cities composed of such areas decreased over time in all three cities, that the patches "shrank" over time, and that, often, larger patches fragmented into become smaller patches.

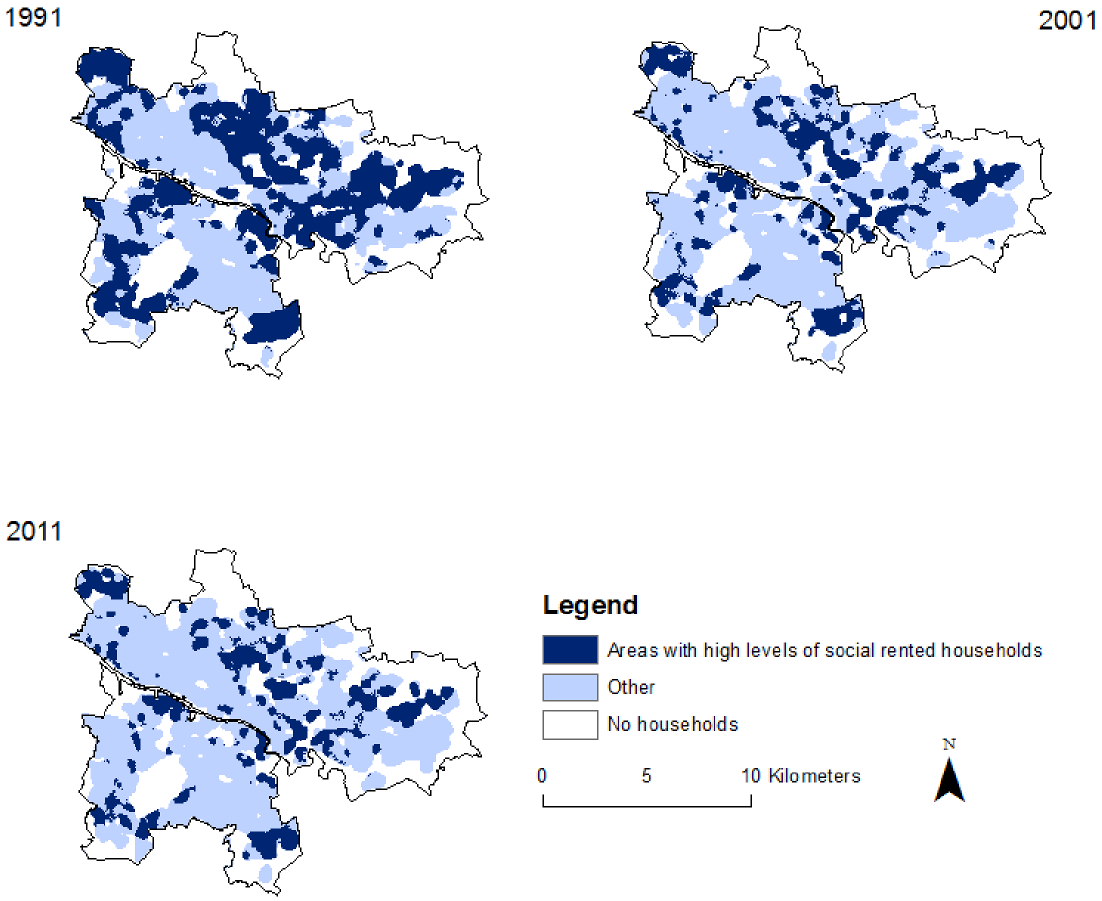

Figure 5-38 Areas in Glasgow with high levels of social rented households 1991-2011. (Source: based on census data and boundary data provided by General Register Office for Scotland and the National Records for Scotland with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

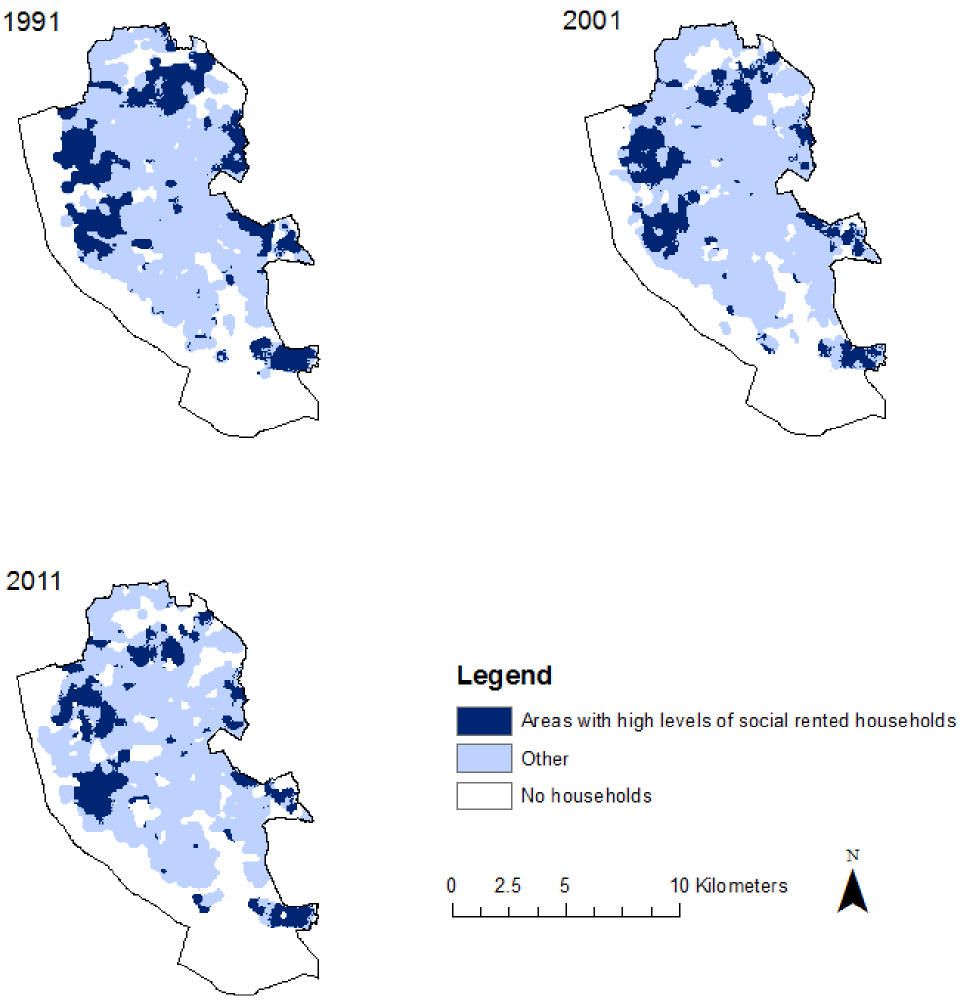

Figure 5-39 Areas in Liverpool with high levels of social rented households 1991-2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

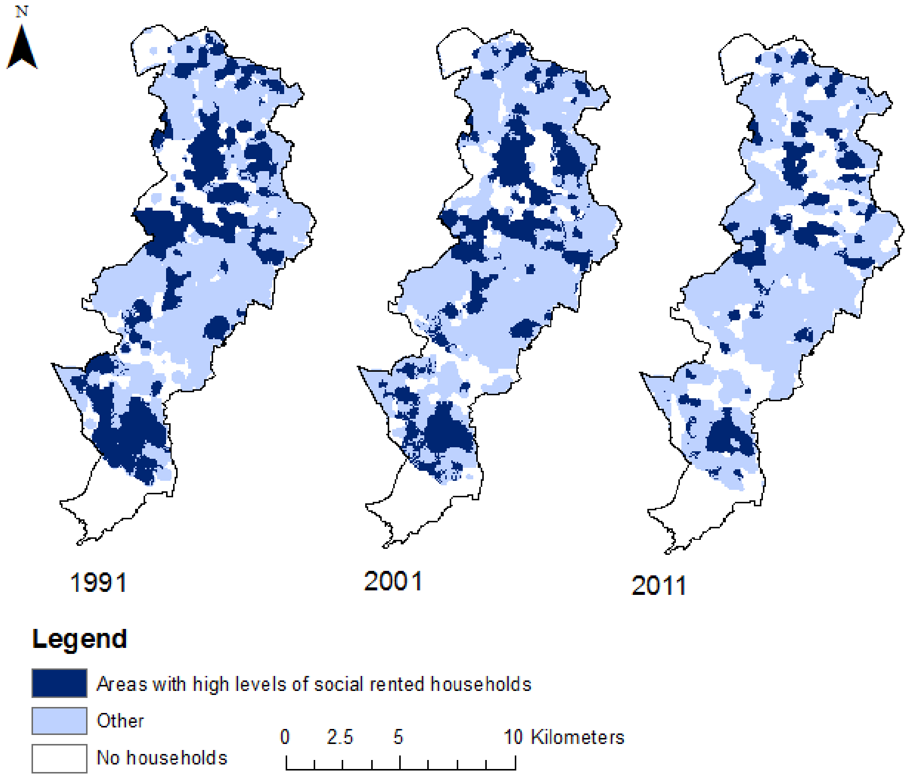

Figure 5-40 Areas in Manchester with high levels of social rented households 1991 to 2011. (Source: based on census data and boundary data provided by English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

6.6.1 Spatial Extent (Socially rented households)

In 1991 and 2011, the proportion of the city made up of areas with high levels of socially rented households was highest in Glasgow (Figure 5-41). In 1991, the figure for Glasgow (35%) was almost double that observed in Liverpool (18%). By 2011, however, the figures were far more similar across the three cities, suggesting a reduction in inter-city difference over time.

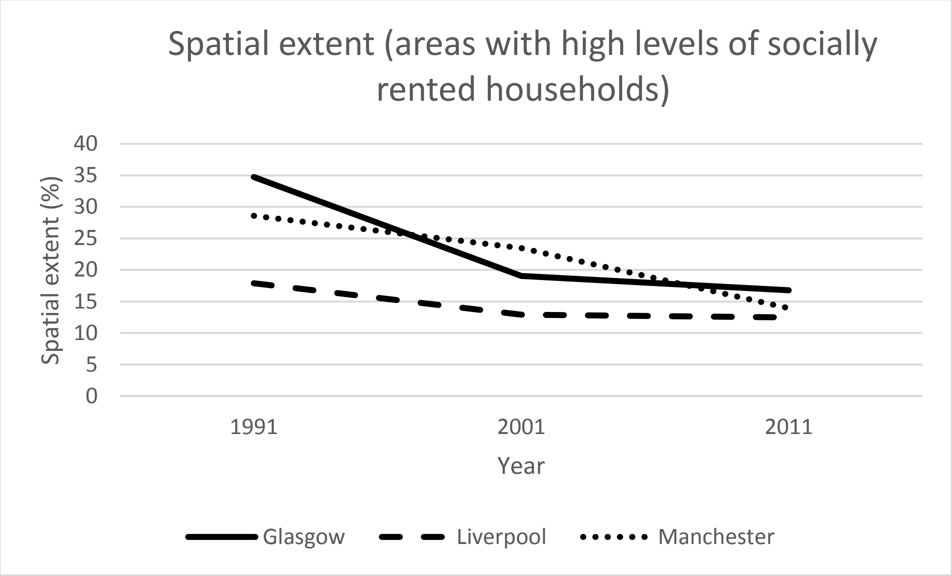

Figure 5-41 Spatial extent of areas with high levels of socially rented households

The spatial extent of areas generally fell over time. In Liverpool and Glasgow the greatest decrease was between 1991 and 2001, whereas in Manchester the biggest change was seen between 2001 and 2011. In this regard, therefore, Manchester differed to Glasgow and Liverpool. Between 1991 and 2011 Glasgow experienced a considerably larger fall in the spatial extent of areas with high levels of social rented households than Liverpool and Manchester.

6.6.2 Patch density (socially rented households)

There was little difference between the cities with regard to the patch density of areas with high levels of socially rented households (Figure 5-42). The temporal trajectory for patch density observed in Glasgow and Manchester was very similar. Both cities experienced an increase between 1991 and 2001, followed by a slight decrease between 2001 and 2011. Liverpool’s temporal trajectory was slightly different as a smaller increase was observed between 1991 and 2001, and that rather than decreasing between 2001 and 2011 (as observed in the other two cities) Liverpool’s patch density continued to increase. However, as the differences in patch density observed between the three cities were so small, Liverpool’s slightly different temporal trajectory is very unlikely to be significantly different to that observed in Glasgow or Manchester.

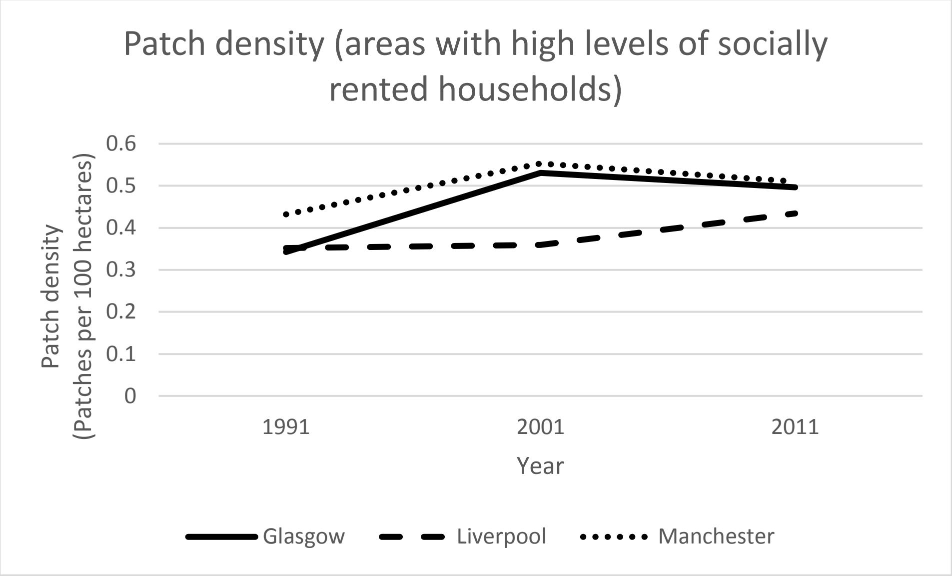

Figure 5-42 Patch density (areas with high levels of socially rented households)

6.6.3 Mean patch size (socially rented households)

In 1991 the mean patch size observed in Glasgow was almost double that observed in Liverpool and considerably higher than observed in Manchester (Figure 5-43, Table 5-12). However, wide confidence intervals meant that these observed differences were not statistically significant[77]. In 2001, Glasgow and Liverpool had identical mean patch sizes (36 hectares), only slightly lower than that in Manchester (42 hectares) and not significantly different[78]. Whilst Glasgow had the highest mean patch size in 2011 again the difference with the other cities was small and not statistically significant[79].

---

[77] Glasgow-Liverpool p=0.29, Glasgow-Manchester p=0.47, Liverpool-Manchester p=0.64.

[78] Glasgow-Liverpool p=1, Glasgow-Manchester p=0.69, Liverpool-Manchester p=0.76.

[79] Glasgow-Liverpool p=0.66, Glasgow-Manchester p=0.45, Liverpool-Manchester p=0.86.

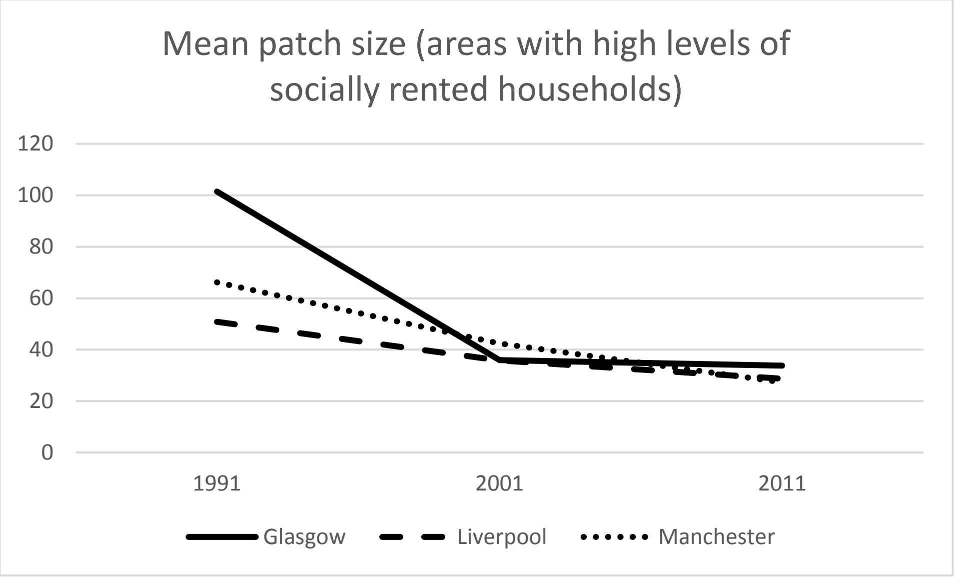

Figure 5-43 Mean Patch Size (areas with high levels of socially rented households)

	Glasgow			Liverpool			Manchester		
Year	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD	**MPS** (hectares)	*(CI)*	SD
1991	**101**	*(25-178)*	302	**51**	*(16-86)*	122	**66**	*(16-116)*	181
2001	**36**	*(21-51)*	76	**36**	*(11-61)*	89	**42**	*(14-70)*	114
2011	**34**	*(21-46)*	60	**29**	*(10-48)*	74	**27**	*(16-39)*	46

Table 5-12 Mean patch size, confidence intervals, and patch size standard deviation for areas with high levels of socially rented households between 1991 and 2011 in Glasgow, Liverpool, and Manchester

The temporal trajectory in all three cities was for mean patch size to fall over time. Glasgow's temporal trajectory did, however, differ somewhat as the scale of the decrease was much greater between 1991 and 2001 in Glasgow. Indeed, there was a statistically significant difference between mean patch size in Glasgow in 1991 and 2001 (p=0.04), but not in either Liverpool (p=0.49) or

Manchester (p=0.39). Although the observed mean patch size also fell in all three cities between 2001 and 2011, this difference was not significant[80].

6.6.4 Socially rented households at all time points

Figure 5-44 identifies the areas in Glasgow, Liverpool, and Manchester which had high levels of socially rented households in 1991, 2001, and 2011. These maps and the spatial metrics (Table 5-13) reveal very little difference between the three cities with regards spatial extent, patch density and mean patch size[81].

---

[80] Glasgow p=0.85, Liverpool p=0.66, Manchester p=0.35.

[81] Glasgow-Liverpool p=0.72, Glasgow-Manchester p=0.48, Liverpool-Manchester p=0.8.

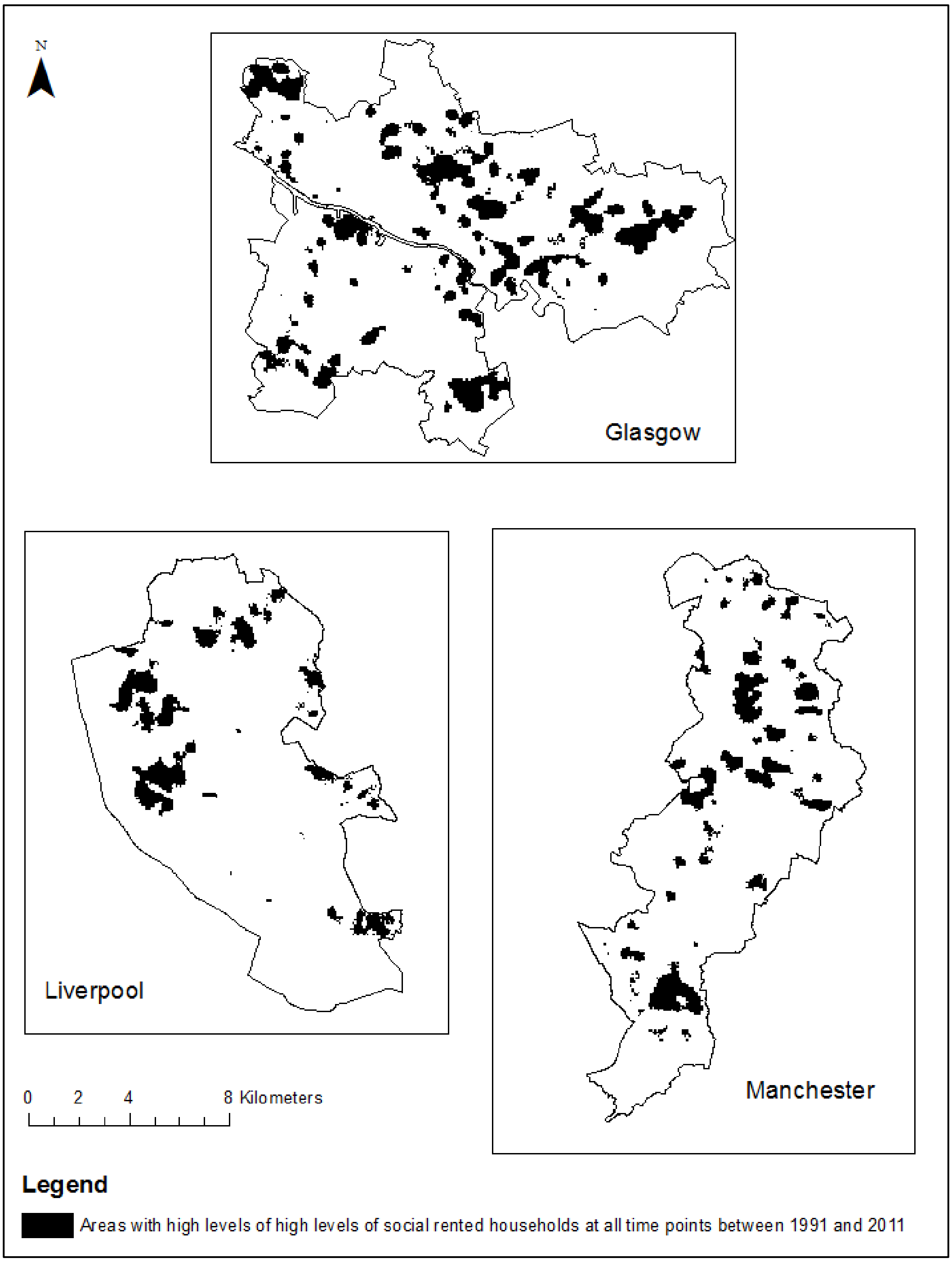

Figure 5-44 Areas in Glasgow, Liverpool, and Manchester with high levels of socially rented households at all time points between 1991 and 2011. (Source: based on census data and boundary data provided by General Register Office for Scotland, the National Records for Scotland, the English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

Metric	Glasgow	Liverpool	Manchester
Spatial extent (%)	15	9	11
Patch density (patches per 100 hectares)	0.5	0.34	0.49
Mean patch size (hectares) *(Confidence intervals)*	29 (18-40)	26 (10-41)	23 (12 – 34)
Patch size standard deviation	51	54	43

Table 5-13 Spatial metrics for areas in Glasgow, Liverpool, and Manchester which had high levels of socially rented households at all time points between 1991 and 2011

6.6.4 Socially rented households at one or more time points

Figure 5-45 shows the areas in Glasgow, Liverpool, and Manchester where high levels of socially rented households were observed at one or more time point between 1991 and 2011. The associated spatial metrics are given in Table 5-14. These reveal that the spatial pattern of high levels of socially rented households was also broadly similar across the three cities.

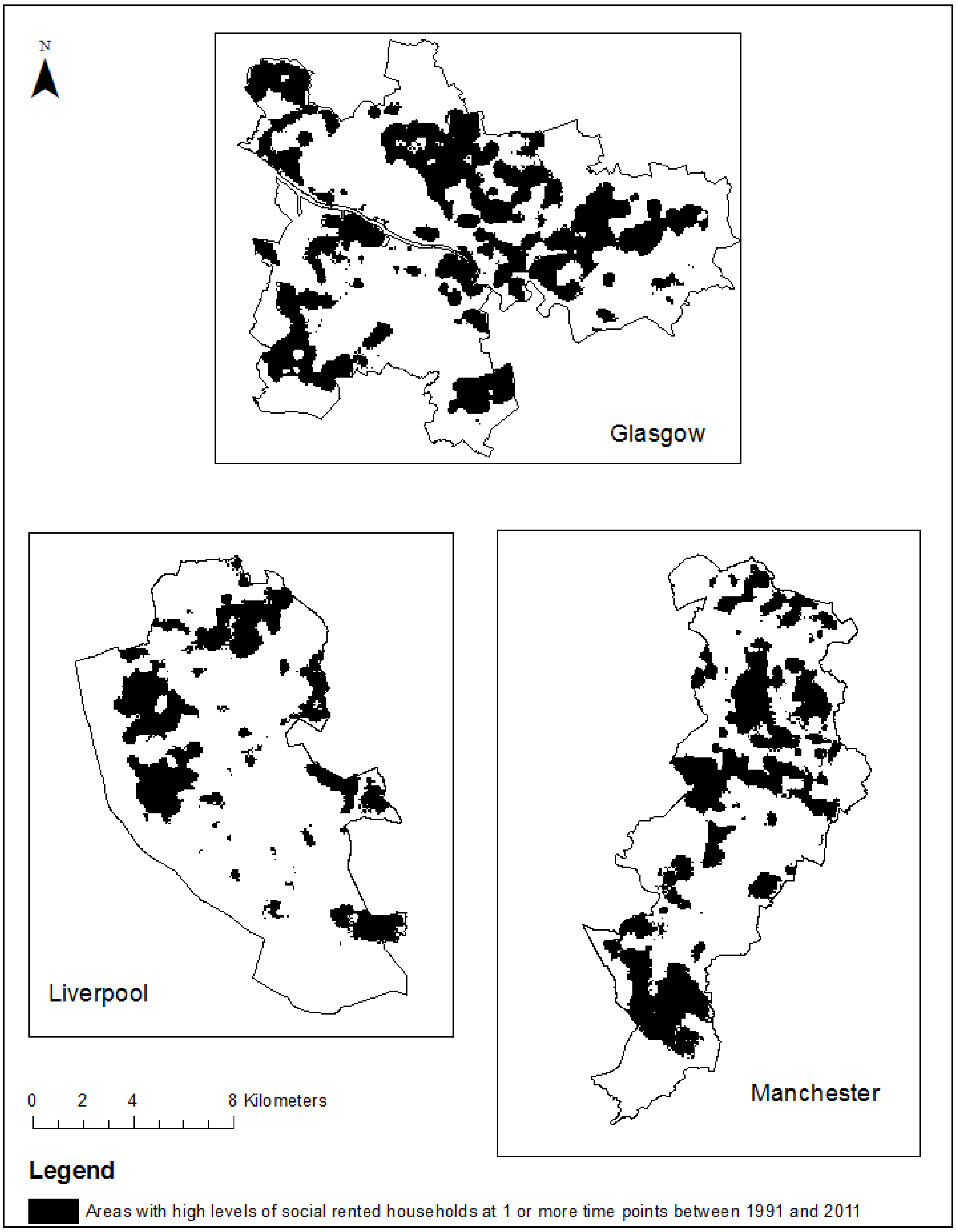

Figure 5-45 Areas in Glasgow, Liverpool, and Manchester which experience high levels of socially rented households at 1 or more time points between 1991 and 2011 (Source: based on census data and boundary data provided by General Register Office for Scotland, the National Records for Scotland, the English Office for National Statistics and Office for Population Census and Surveys with the support of the UK Data Service Census Support. Contains National Statistics data © Crown copyright and database right 2013. Contains Ordnance Survey data © Crown copyright and database right 2013.)

Metric	Glasgow	Liverpool	Manchester
Spatial extent (%)	33	20	33
Patch density (patches per 100 hectares)	0.37	0.36	0.41
Mean patch size (hectares) *(Confidence intervals)*	89 (23 – 156)	57 (18 – 95)	80 (22 – 139)
Patch size standard deviation	275	135	205

Table 5-14 Spatial metrics for areas which experienced a high level of socially rented households at 1 or more time points between 1991 and 2011

6.7 Did the spatial arrangement of deprivation develop differently in Glasgow to that observed in Liverpool and Manchester?

This chapter has presented surface maps and spatial metrics. From these, two general conclusions can be drawn. The first is that there was no consistent and clear difference between the cities in terms of the development of spatial patterns of deprivation; similarities and differences were both observed. The second is that the spatial arrangement of deprivation varied markedly over time; thus confirming assertions made in the literature review that examining the spatial arrangement of deprivation at just one time point is limited, and that making temporal comparisons adds value.

To bring together the results together, this section summarises results by metric.

6.7.1 The spatial extent results

The use of the spatial extent metric quantified the proportion of each city's landscape made up of areas with high levels of deprivation/indicator(s) of deprivation. Three important themes were identified.

First, Glasgow often had much higher spatial extent figures in 1971 and 1981. This was the case for:

- areas with high levels of all the indicators;

- areas with high levels of one or more indicators;
- areas with high levels of overcrowded households;
- areas with high levels of male unemployment.

The extent of areas with high levels of socially rented households was much higher in Glasgow in 1991. Overall, it seems that the spatial extent of deprivation was different in Glasgow, most notably in 1971 and 1981, to that observed in Liverpool and Manchester.

Second, there were some differences relating to the proportion of each city's landscape made up of areas which experienced high levels of the specific indicators at any time point, and all time points. Glasgow was the only city with patches of high levels of male unemployment at all time points. The proportion of Glasgow's landscape which experienced high levels of overcrowded households at all time points or any time point was also substantially higher than in either Liverpool or Manchester. However, there was little difference between the cities regarding households not owning a car and socially rented households.

Third, the scale of change in the spatial extent of deprivation (i.e. difference between the highest and lowest metrics) was largest in Glasgow, often by a considerable margin. This was the case for each of the individual indicators (although marginal for households not owning a car), as well as for areas with high levels of *all* the indicators, and areas with high levels of one or more indicators.

I conclude therefore, that with regard to the spatial extent of deprivation, Glasgow has had a different development from Liverpool and Manchester.

6.7.2 The patch density results

There was considerable variety in results from the patch density metric, which makes identifying trends difficult. For some indicators, patch density was consistently highest in Glasgow (high levels of all indicators of deprivation and overcrowded households for example). For others, however, Glasgow had the lowest patch density and so was the least fragmented of the three cities (high levels of one or more indicator of deprivation, and areas with high levels of overcrowded households at one or more time point for example). Furthermore, for some indicators the city with the highest and lowest patch density fluctuated between the years (as was the case with areas with high levels of male unemployment). In general however, Glasgow and Liverpool's patch density figures were often more alike, with Manchester's being different (as seen in areas with high levels of male unemployment from 1991 to 2011). The scale of *change* in patch density was also often more extreme in Manchester than in Liverpool or Glasgow (for example, for areas with high levels of male unemployment and overcrowded households).

Overall, therefore, I conclude that the development of patch density in Glasgow between 1971 and 2011 was not markedly different to that of Liverpool and Manchester.

6.7.3 The mean patch size results

One advantage of the mean patch size metric was that it was possible to test whether differences were of statistical significance. Those that reached statistical significance were:

- Between 1981 and 1991 Glasgow and Liverpool both experienced statistically significant increase in mean patch size of areas with high levels of all the indicators. Glasgow then experienced a significant decrease between 1991 and 2001.

- In 1991 patches with high levels of overcrowded households in Manchester were statistically significantly larger than in either Glasgow or Liverpool.

- Manchester experienced a statistically significant increase in mean patch size for areas with high levels of overcrowded households between 1981 and 1991, followed by a statistically significant decrease between 1991 and 2001.

- Patches with high levels of male unemployment in 2001 were statistically significantly smaller in Glasgow than in Manchester.

- Glasgow had a statistically significant increase in the mean size of patches with high levels of male unemployment between 1971 and 1981, followed by a significant decrease between 1981 and 1991, and 1991 and 2001.

The majority of the differences between mean patch sizes across the three cities were, therefore, not of statistical significance. However, the mean patch size graphs very often suggested that Glasgow's results were *substantively* different from that observed in Liverpool and Manchester; that is to say, they appeared large and meaningful. That these differences were not of statistical significance was due to the presence of wide confidence intervals, driven by considerable variation in patch size. Instances where mean patch size appeared to be substantively different, but not significantly different were:

- Mean patch size for areas with one or more indicator present appeared to be much larger in Glasgow in 1971, 1981, 1991, and to a slightly lesser extent in 2001 and 2011.

- Mean patch size for areas with high levels of overcrowded households in 1971 appeared to be much larger in Glasgow.

- There appeared to be a substantial decrease in mean patch size for areas with high levels of overcrowded households in Glasgow between 1971 and 1981, and 1981 and 1991.

- Mean patch size for areas where high levels of overcrowded households were observed at one or more time point appeared to be much larger in Glasgow.

- Mean patch size for areas with high levels of male unemployment in 1981 appeared to be much larger in Glasgow.

- Mean patch size for areas with high levels of households without a car appeared larger in Glasgow at all time points, and appeared markedly so in 1981 and 1991.

- A sharp increase between the mean patch size of areas in Glasgow with high levels of households without a car was observed between 1971 and 1981, followed by a sharp decrease between 1981 and 1991.

- Mean patch size for areas with high levels of households without a car at one or more time point appeared much higher in Glasgow.

- Areas with high levels of socially rented households looked to be much bigger in Glasgow in 1991.

This issue of results appearing substantively different but the difference not being of statistical significance will be explored in further detail in the next chapter.

It is also important to draw attention to instances where there were marked similarities between the cities. The most notable were:

- The mean patch size for areas with high levels of overcrowded households at all time points was very similar across the cities.

- The mean patch size for areas with high levels of households not owning a car was very similar across the cities.

- The mean patch size for areas with high levels of socially rented households was very similar across the cities.

Overall, mean patch size was not consistently different enough in Glasgow relative to Liverpool and Manchester to argue that it developed differently. I therefore conclude that the development of mean patch size in Glasgow was not markedly different to that observed in Liverpool and Manchester.

6.8 Summary

This chapter has detailed the results of the spatial metrics and identified both similarities and differences in the development of Glasgow’s spatial arrangement of deprivation relative to that observed in Liverpool and Manchester. The most pronounced finding being that the spatial extent of deprivation was found to be much larger in Glasgow in 1971 and 1981, and that changes in the scale of the spatial extent observed in Glasgow was much larger. The next chapter provides a discussion of these findings as well as an analysis of how successful this new method of mapping the spatial arrangement of deprivation is.

Chapter 6 : Discussion

The purpose of this study has been to ascertain whether Glasgow's spatial landscape of deprivation developed differently between 1971 and 2011 to that observed in Liverpool and Manchester, and, if it did, ascertain whether these differences could plausibly contribute to Glasgow's excess mortality. To facilitate this, this thesis sought to answer three research questions:

Research question 1: What techniques best facilitate comparisons of the development of the spatial arrangement of deprivation?

Research question 2: Did the spatial arrangement of deprivation develop differently in Glasgow, Liverpool, and Manchester between 1971 and 2011?

Research question 3: If the spatial arrangement of deprivation did develop differently in Glasgow, could these differences be a plausible contributor to Glasgow's excess levels of mortality?

This chapter will provide a brief recapitulation of the study, discuss the results, examine the strengths and weaknesses, offer the definitive "answers" to the research questions, and consider the implications of the findings, before moving on to and examining further ways in which this research could be developed.

7.1 Study recapitulation

7.1.1 Reasoning and Background

The literature review highlighted that the spatial arrangement of deprivation can influence health outcomes. It revealed that spatial arrangements of deprivation are often broadly categorised in to two groups:

- small areas of deprivation surrounded by more affluent areas (islands of deprivation); and

- areas of deprivation surrounded by other areas forming a large spatial concentration of deprivation (landlocked deprivation).

Two seemingly opposing hypotheses have been postulated regarding how health outcomes could be affected by residence in islands of deprivation or in landlocked deprivation. The relative deprivation hypothesis is based on psycho-social interpretations of health outcomes. It suggests that health outcomes will be worse in islands of deprivation due to the adverse effects on stress levels of the population comparing themselves to more affluent people living nearby. The pull up/pull down hypothesis, however, postulates that health is likely to be worse in large concentrations of deprivation. This is due to such areas often being spaces of underinvestment with worse access to physical and social infrastructures which aid health. The pull up/pull down hypothesis suggests, therefore, that the collective resources of islands of deprivation are “pulled up” by being in close proximity to more affluent areas, whilst the collective resources of large concentrations of deprivation are “pulled down”. Furthermore, this hypothesis also suggests that health outcomes in more affluent areas will be worse than expected (again “pulled down”) when surrounded by deprived areas. These hypotheses have been tested by others, and whilst precise direction and magnitude of effects seems to vary, it is clear that health outcomes *are* influenced by spatial arrangements of deprivation.

Glasgow is a city notorious for poor health and high levels of mortality; outcomes which were traditionally attributed to the city’s high levels of deprivation (Carstairs and Morris, 1989). Recent studies, however, have suggested that this might only be a partial explanation (Walsh et al., 2010a, 2010b). In particular, comparisons with Liverpool and Manchester, two cities with very similar levels of income and employment deprivation to Glasgow, have shown mortality rates to be higher in Glasgow. Based on these comparisons, it has been identified that Glasgow has an “excess” of mortality over and above that which would be expected for a city with its age, gender, and demographic profile (Walsh et al., 2010a, 2010b). These studies argued that this excess mortality has persisted and grown since the 1970s. An abundance of hypotheses have been proffered to explain Glasgow’s excess mortality. One hypothesis is that the spatial *pattern* of deprivation contributes to Glasgow's high mortality levels.

Cummins (2007:355) argues that many studies looking at relationships between deprivation and health have tended to view small areas, or neighbourhoods, as the "*only meaningful unit of interest*", something my literature review confirmed. Such studies have failed to account for the wider spatial and temporal contexts to which people are exposed, and which are likely to have an impact on health. This issue could be addressed by using larger spatial units; however, the accompanying loss of detail can be hugely problematic. A perspective which enables a wider context to which people are exposed to be studied, but which does not entail losing the detail that comes from studying small areas, is therefore required. Viewing the city from a landscape perspective provides such an approach and was used in this study to compare the development of the spatial arrangement of deprivation in Glasgow, Liverpool, and Manchester between 1971 and 2011.

7.1.2 Methodological Innovation

Since there was no established method of conducting such an examination, a substantial part of this study involved developing a technique which would facilitate it and permit inter-city and temporal comparisons. The ideal way of doing this would have been to obtain deprivation data (which were comparable over time and between cities) for each household in each city at each time point, as this would have enabled a very detailed, house by house, street by street assessment and mapping of deprivation. Such data were (and remain) unavailable. Consequently, an alternative approach was required. The development of a methodology to map, and then quantify the maps, formed the bulk of this study. I mapped data from the census (which provided an indication of individuals/households likely to deprived) in a way which enabled accurate temporal and spatial comparisons to be made. Mapping was achieved through the use of surface maps, made with SurfaceBuilder software. Using surface mapping in this way is a novel contribution of the thesis. Spatial metrics were then used to quantify the landscapes and enabled thorough comparisons and analysis of the maps. Again, no record of using spatial metrics to quantify the spatial arrangement of deprivation was found in the literature.

7.1.3 Results

The use of these innovative techniques revealed that there were both similarities and differences in the way the spatial arrangement of deprivation developed in Glasgow, Liverpool, and Manchester between 1971 and 2011. The spatial extent metric revealed that Glasgow often had a larger proportion of its landscape occupied with areas of deprivation, and that this was particularly prominent in 1971 and 1981. The scale of change in the spatial extent of deprivation over the time period was also greatest in Glasgow. From this it was concluded that, overall, the spatial extent of deprivation developed differently to that observed in Liverpool and Manchester.

Drawing clear conclusions from the patch density metrics was more problematic. For some indicators (such as areas with high levels of all indicators, areas with high levels of one or more indicator, areas with high levels of overcrowded household in any year) the results were different across the three cities. For others (such as areas with high levels of socially rented households at each time point, all time points, and any time point), results were very similar across the cities. There was a lack of consistency between indicators, and often there were temporal fluctuations. The scale of change in fragmentation was often more extreme in Manchester than observed in Glasgow or Liverpool; indeed Glasgow and Liverpool’s patch density figures were often more alike. It was therefore concluded that Glasgow’s patch density did not have a markedly different development to that of Liverpool and Manchester.

Differences in mean patch size were often not statistically significant, but did appear substantively interesting. Statistical significance was elusive due to considerable variations in patch size which resulted in large confidence intervals. This will be discussed in further detail in a later section. Glasgow did have a significantly smaller mean patch size both in terms of areas with high levels of overcrowded households in 1991 relative to Manchester, and areas with high levels of male unemployment in 2001 relative to Manchester. There were also a number of marked similarities, notably for areas with high levels of overcrowded households at all time points, areas with high levels of households not owning a car, and areas with high levels of socially rented households. Overall, mean patch size was not consistently different and did not develop differently in Glasgow relative to the other cities.

In summary, this study found that the spatial extent of deprivation developed differently in Glasgow relative to that observed in Liverpool and Manchester, but patch density and mean patch size did not.

7.2 Could differences in the development of Glasgow's spatial arrangement of deprivation be a plausible contributor to its excess mortality?

One research question now remains unanswered: could differences relating to the spatial extent of deprivation contribute to, or even explain, Glasgow's excess mortality?

Before discussing this, an important caveat is required; no health data were examined as part of this study. In the early stages it had been anticipated health data would be examined in relation to spatial arrangement of deprivation, however, the thesis necessarily evolved into a methodological study and this focus left no capacity to develop and carry out a formal analysis of health. Thus the focus of this section is to assess the results of the analyses in light of what is already known in the research literature, and thus seek a plausible answer rather than a definitive one.

7.2.1 Could differences in the spatial extent of deprivation contribute to Glasgow's excess mortality?

The focus of the literature regarding how spatial arrangements of poverty affect health has been whether health is better in islands of deprivation or landlocked deprivation. The findings of the patch density and mean patch size metrics in this study indicate that overall, relative to Liverpool and Manchester, levels of fragmentation in the landscape of deprivation were not different in Glasgow. This implies that the presence of islands of deprivation or large concentrations of deprivation was not different in Glasgow, thus suggesting that Glasgow's excess mortality is unlikely to be explained by a substantially different level of "islands" or "landlocked" deprivation.

Even if differences regarding this aspect of pattern of deprivation had been identified, it is unclear from the literature what proportion of the 4,500 excess deaths which occurred in Glasgow between 2003 and 2007 this could explain. Whilst the literature is helpful in that it identifies differences in health outcomes between islands of deprivation and areas of landlocked deprivation, there is ambiguity regarding the scale of effect and how many of Glasgow's excess deaths this could account for. This ambiguity is partly due to contradictory findings of studies, but also because very few studies went as far as to explicitly quantify the relationship they identified[82].

The spatial extent metric did suggest differences between the cities over time. Glasgow frequently had greater spatial extent of deprivation, particularly in 1971 and 1981. About 20% of Glasgow's area was classified as having the maximum number of indicators present in 1981, more than double that observed in Liverpool (9%), and four times that observed in Manchester (5%). In the same year, 50% of Glasgow's landscape was composed of areas with high levels of one or more indicator of deprivation. In other words, half of Glasgow's land area had high levels of one or more indicator of deprivation in 1981. The peak figures for this in the other two cities were lower (Liverpool 40% in 1971 and Manchester 45% in 1991). The spatial extent of areas with high levels of overcrowded households and high levels of male unemployment was also observed to be substantially higher in Glasgow in 1971 and 1981 relative to Liverpool and Manchester. It appears, therefore, that in 1971 and 1981 deprivation was substantially more spatially prevalent in Glasgow.

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[82] Two studies, both interested in mental health, were an exception to this. Pearson et al. (2013), for example, found that treatment for anxiety/mood disorders were 50% higher in islands of deprivation in New Zealand than in landlocked deprivation. Astell Burt and Feng (2015) found that the odds ratio for psychological distress was 5.83 for deprived people living in deprived areas, this was significantly higher than for deprived people living in non-deprived areas.

What does this mean for health? We need to consider the metrics together; spatial extent of deprivation was greater in Glasgow, but its fragmentation and arrangement was similar to the other cities. If a greater proportion of a city is composed of deprived areas it is plausible that the whole city's population has a greater chance of exposure or, "witnessing" deprivation. Whilst the precise arrangement and size of the deprived areas did not appear markedly different in Glasgow, the metrics tell us that deprivation was more spatially ubiquitous. In turn, this suggests that there was a greater interface between affluence and deprivation; in Glasgow, it would be harder to go anywhere without experiencing or seeing deprived areas.

The analysis also revealed a temporal sequence to Glasgow's greater spatial extent of deprivation; it has waned over time. However, an effect on health today is still plausible. The delayed consequences of exposure to social and environmental harms in a previous period of a person's life is common and well documented in epidemiology (Rachet et al., 2003). The length of this lag effect varies. It has, for example, been shown that blood pressure in adulthood is influenced by a foetus's intrauterine environment (Barker et al., 1989), and also by the mother's intrauterine environment (Barker et al., 2000). If the spatial extent of deprivation does influence health outcomes, therefore, it is possible that differences between the cities in 1971 and 1981 still influence health outcomes today. Many city residents who grew up in the 1970s and 1980s will still be in the city, and are now at an age where premature mortality risk is highest.

How well does the literature support this hypothesis? Although there is not a large quantity of evidence, what does exist is supportive. Sridharan et al.'s (2007) study of mortality in Scotland (discussed in the literature review), for example, found that deprivation in one area negatively influenced mortality in proximal neighbourhoods. With a greater spatial ubiquity of deprivation in Glasgow, it follows that there will also be more areas of the city which are proximal to deprived areas. From Sridharan et al.'s (2007) findings we would expect such areas to have higher mortality levels than those areas not in proximity to deprivation. Whilst Sridharan et al.'s (2007) finding do not help explain why mortality levels are higher in Glasgow's deprived areas when compared to Liverpool and Manchester, they still provide a useful insight into Glasgow's high mortality levels among the more affluent, relative to elsewhere in the UK. As was shown in the discussion of Walsh et al.'s (2010a, 2010b) findings in the literature review (section 3.3.3), although Glasgow's excess mortality figures are highest amongst the most deprived deciles, there is an excess of mortality across all deprivation deciles. Perhaps the spatial ubiquity of deprivation affects everyone in the city.

There is also other evidence supporting this idea. Cox et al.'s (2007) study on deprivation inequality and Type 2 diabetes in Tayside, for example, found that less deprived areas surrounded by more deprived areas had higher than expected incidence of the disease. They therefore argued that, with regard to Type 2 diabetes, health was "pulled down" in areas surrounded by more deprived areas. This suggests that greater exposure to deprived areas can impact upon health outcomes. Again however, this evidence does not explain why health should be so much worse in Glasgow's *deprived* areas than in those in the other cities. In this regard Zhang et al.'s (2011) study is more helpful. Their study found that islands of deprivation had higher mortality levels than areas of landlocked deprivation, a finding echoed by Pearson et al. (2013) and Allender et al's (2012). The literature focuses little on the spatial extent of deprivation *per se* as an element of spatial arrangement. The nature of the interface between more and less deprived does seem important and, for the health of the deprived, their exposure to the more affluent especially so.

In chapter 3 it was argued that studies examining the influence of the spatial pattern of deprivation on health behaviours and/or outcomes tend to fall into what Cummin's (2007:355) terms "the local trap" by regarding small areas as "*the only meaningful unit of interest*". The focus on examining health differences between areas of landlocked deprivation and islands of deprivation, is a prime example of this. Through the use of a landscape perspective, this study has adopted a different approach to analysing the spatial arrangement of deprivation. This perspective has enabled the arrangement of deprivation across cities to studied. Consequently the scale of analysis used in this study differs to that used by most of the literature. Whilst the findings of the literature on relationships between health and the spatial arrangement of deprivation remain pertinent, they may not, therefore, be directly applicable to landscapes of deprivation.

In summary, the literature does not offer clarity as to whether the health of those living in deprived areas can be negatively influenced only if that area is *surrounded* by more affluent areas, or whether other kinds of proximity are sufficient. There is almost no consistent information about the effect of size on mortality rates, or other measures of health. Further, the metrics used in this study offered relatively little clarity on the proximity and interface between more and less deprived. Whilst the patch density metric provides an indication of fragmentation, it does not provide an indication of how isolated patches of deprivation are from other patches of deprivation. These sources of uncertainty are problematic when attempting to assess the plausibility of an argument that attributes some of Glasgow’s excess mortality to spatial arrangement of poverty. Given that the spatial extent of deprivation was larger in Glasgow relative to Manchester (particularly in 1971 and 1981), that patch density and mean patch size metrics were similar, this can be interpreted as indicating that deprivation was spatially more ubiquitous in Glasgow. Consequently, it would appear plausible that exposure of more affluent and deprived people to each other was greater in Glasgow (particularly in 1971 and 1981) and that subsequently, this may have adversely affected mortality rates.

7.3 Evaluating the method used in this study

This thesis has made an original contribution by developing a technique which enables the landscape of deprivation to be mapped and objectively analysed at decennial intervals from 1971 onwards. Whilst surface mapping and the use of spatial metrics to analyse landscapes are already well established techniques, they have not been used to map or analyse landscapes of deprivation before.

Inevitably, methodological innovation leads to reflection on the strengths and weaknesses of the new techniques. It is important to acknowledge the strengths, but also consider the limitations and how they might have impacted on the results. This will be done by considering the stages in this study in turn and highlighting strengths and limitations of these.

7.3.1 Using census data to measure deprivation: strengths and limitations

Four census variables were used as indicators of deprivation in this study. Census data was the only viable option for measuring deprivation, but doing this is an established technique (Allik et al., 2016, Carstairs and Morris, 1989, Carstairs and Morris, 1991, Norman, 2010). Census data enabled indicators of deprivation to be mapped over a longer time period than was possible via other measures of deprivation (such as the Scottish Index of Multiple Deprivation). Furthermore, although there are some changes to census questions over time, as Allik et al (2016:122) note, the questions remain relatively consistent over time and across the constituent parts of the UK. This was advantageous as it meant that the maps produced from the census data were comparable both temporally and spatially. Such comparability is not readily achieved with other deprivation measures (Allik et al., 2016). Further, every household in the UK is legally required to complete the census; it should, therefore, "*cover the entire population without exception*" (Cabinet Office, 2008:77). Total population coverage means, in theory, the avoidance of bias that can be associated with sample survey data.

There are, however, some limitations associated with using census data to provide information on deprivation. Pacione (2004) highlights three main limitations:

- the UK census does not include direct measures of income or wealth;
- risk of ecological fallacy;
- as the census is only carried out every 10 years information from it may become outdated as the inter-census period progresses.

All three are valid criticisms; however, they also all have counter-arguments. A counter-argument to the first limitation (the significance of which Pacione

(2004:120) argues is “*often overstated*”), for example, is that census data are collected on a variety of topics which can be used as indicators of low income. Ecological fallacy is primarily an issue when using aggregate counts from the census, but the techniques used in this study attempt to disaggregate the data and replicate something closer to individual or household level information. However, SurfaceBuilder still works with cells which are, in effect, areal units and the ecological fallacy therefore remains an issue. For the purpose of this study, census data becoming outdated over the inter-census period was not of relevance. This was because census data were being used to provide an indication of which areas were likely to have high numbers of deprived people residing in them in census years.

The choice of census variables in this study was also a potential weakness. Whilst the study had a clear rationale for the four census variables chosen as indicators of deprivation, all four variables had limitations (as was also discussed in the methods chapter in section 4.5.3). However, the variables did provide data on unemployment, material wealth, and housing conditions – all of which have been shown to indicate whether or not households are likely to be experiencing deprivation. Allik et al. (2016:123) state that there is a general consensus among existing measures of deprivation that they should include indicators of:

> “*(un)employment, material wealth such as car ownership or income, indicators of socioeconomic position, particularly education and occupation, and housing conditions such as overcrowding, home ownership or renting from a public authority.*”

A possible limitation, therefore, of this study is that it did not include a variable which provided an indication of socio-economic position; this was due to data availability. As discussed in the methods chapter, low social class was not used due to it only being coded for a 10% sample for the 1971, 1981, and 1991 censuses. Data on educational qualifications was also only available for a 10% sample, and the information recorded changed in both 1981 and 1991 (Dale, 2000). Small numbers in a 10% sample was potentially problematic given that the aim was to map census variables at as fine a spatial scale as possible.

It should also be noted that this study was potentially limited by not weighting the census variables used to reflect their relative importance in capturing deprivation. This was not done for two reasons. First, and most important, there was a lack of information regarding what weight to assign to each variable and what a weighting scheme would be trying to achieve. Weighting schemes of this kind are almost always arbitrary, which lead to the second reason. Any weighting scheme would have required extensive sensitivity analysis and, since the study was innovative in the way in which it mapped deprivation, it was felt to be important that the development and testing of the techniques be kept as simple as possible.

7.3.2 The maps of deprivation: strengths and limitations

A key achievement of this study has been to produce 108 maps showing the landscape of deprivation in Glasgow, Liverpool, and Manchester at decennial intervals between 1971 and 2011. Using Martin's (1989, 1996) and Martin and Bracken's (1991) approach to spatially disaggregate census counts, maps were produced which offered a more realistic and arguably more accurate representation of the distribution of deprived populations across each city than previous approaches using other techniques (such as choropleth mapping). This, in itself, is a key strength of this study and one of the ways in which an original contribution has been made. It also enabled a whole landscape approach to the assessment of deprivation distribution, enabling the wider context to which people are exposed to be studied without loss of the finer detail that accompanies studying smaller areas. The approach overcomes issues inherent with using fixed areal units, and has enabled the production of temporally and spatially comparable maps. It provided one direct answer to Cummins' critique that many studies examining relationships between place and health have tended to view small areas or neighbourhoods as the "*only meaningful unit of interest*" (Cummins, 2007:55).

Attention should, however, be drawn to the fact that the maps produced were only models which attempted to recreate the spatial distribution of people and households with high levels of each census variable. Whilst care was taken to ensure that the models were as robust as possible, they are just models and therefore will contain error. Detailed sensitivity analysis (described in the methods chapter) was undertaken to ensure that the most appropriate parameters (such as radius and cell size) were used to produce the maps that seemed to best replicate the location of households. However, the models could not be ground truthed for each of the indicators of deprivation. Specific issues requiring attention relate to three decisions made in the production of these models: the use of Jenks's natural breaks classification method, the use of a binary classification system, and presumptions made regarding SurfaceBuilder.

As detailed in section 4.9.2, Jenks's natural breaks method was used to classify the cells in order to identify which cells had values that represented high levels of household deprivation relative to the rest of a specific city at a certain time point. This method was chosen, because unlike the other available techniques, Jenks's natural breaks is designed to group together similar values, and maximise variances between classes whilst minimising variance within a class. Consequently class boundaries are more meaningful as they are derived from the distribution of cells. As explained in section 4.9.2.3, classifying cells in a way which maximises differences between classes was viewed to be advantageous in this instance as the focus of this research was on identifying cells with values which were high relative to the rest of the city at that time point. An issue with this method, which could potentially have influenced the results, is that when using the natural breaks classification method the actual class values are relative to the distribution specific to that map, and hence potentially different for each map. Consequently, a value which is classified as deprived in one map might be classified as non-deprived in another. For example, in a map of overcrowded households in Glasgow in 1971 a value of 40% might be classified as being high, but potentially not at other time points or in other cities or for different indicators. A further issue relating to the Jenks's natural breaks method is that as it looks for clusters in the data/breaks between clusters, classes can vary much more with small changes in the dataset than would be the case with quantiles or equal intervals. Both issues suggest that drawing meaningful comparisons of maps between cities and time points is problematic. It should, however, be highlighted that (as discussed in section 4.9.2) there is no ideal classification method as they all have issues and limitations associated with them. Furthermore, as the purpose of the maps was to highlight areas with high levels of an indicator in a city at a specific time point relative to the rest of that city at that time point, the use of the Jenks's natural breaks classification method remains a valid in this study.

The decision to dichotomise cells into 'deprived' and 'non-deprived', as detailed in section 4.9.2.6, was based on the aim of this study being to develop a technique which enabled analysis of the spatial arrangement of areas with high levels of deprived households, relative to the rest of the city as specific time points. As such it was the location of areas with high levels of different deprivation indicators that was of interest, and a binary classification was justified. Further, for the purposes of methodology development, additionally identifying cells or areas with relatively lower or higher levels of deprivation could have potentially overcomplicated matters. In hindsight, rather than overcomplicating the analysis, employing a binary classification adversely limits it. The dichotomy lacks sufficient detail about relative deprivation to explore in depth the pull up/pull down hypotheses proposed to explain why spatial arrangement of deprivation might affect health. It is, for example, possible that the spatial gradient of deprivation is different in Glasgow to that found in other cities. It might, for instance, be that in Glasgow areas with high levels of deprivation tend to be in very close proximity to areas with very high levels of affluence, whereas in Manchester or Liverpool the trend might have been for the most deprived areas to be surrounded by slightly less deprived areas and for the levels of deprivation to gradually decrease whilst levels of affluence gradually increase. According to both the relative deprivation hypothesis and the pull up/pull down hypothesis such spatial arrangements would have implications for health. Using a binary classification, might therefore, have been too crude-a-technique to ascertain meaningful differences/similarities between the cities. As is discussed in section 7.6.1.2 expanding the number of classes used is an avenue for further research.

SurfaceBuilder was developed to model population and household surfaces and so the spatial gravity parameters it uses presumably reflect this purpose. The presumption in this study is that these will be valid for modelling the spatial distribution of specific types of people and household characteristics. It is feasible that this might not be the case because the influences determining spatial location of deprived people or households, in relation to each other, could be different from those affecting people more generally. For example, perhaps the “spreading out” of deprived people between census centroids via a gravity model should be less even than for the whole population. A limitation of this study is, therefore, that the accuracy of the maps is unknown. Despite this, however, it should be noted that the same techniques and parameters were used in all three cities and at all five time points. Assuming errors in the replication of the true patterns of deprivation were not location or time dependent, comparison of the maps between cities and over time should still be valid.

7.3.3 Analysing the maps using spatial metrics: strengths and limitations

This is the first study to have used spatial metrics to analyse landscapes of deprivation. Their use was a key strength as it enabled the maps to be objectively analysed in a manner suitable for making temporal and spatial comparisons. The use of three spatial metrics meant that different qualities of the spatial distribution of poverty could be assessed. Visual examinations of the maps suggested differences and similarities between cities and over time, but without spatial metrics, objective quantification would not have been possible.

Although the metrics were very useful with regard to quantifying patterns in the landscape, there were some challenges associated with their use, particularly with regard to interpretation. As this was the first time spatial metrics had been used to quantify patterns of deprivation, there was no guidance as to what the results of the metric tests actually meant. It was, for example, unclear what constituted a high or low patch density figure, and sometimes whether variations between figures represented substantive differences or not. In theory this was less of a problem for mean patch size as differences could be tested for statistical significance. In practice, however, apparently substantive differences in mean patch size were found not to be statistically significant. This was due to most of the deprivation landscapes being characterised by considerable variation in patch size, variations which led to the presence of wide confidence intervals.

The approach to calculating confidence intervals around the mean patch size and hence statistical significance was very basic. It is possible that more robust and appropriate tests could be devised, which might narrow confidence intervals. However, this was beyond the scope of the thesis. The ability to calculate confidence intervals for one metric, but not the others, was also problematic. Had it *not* been possible to determine whether or not differences in mean patch size were significantly different, it is conceivable that different conclusions could have be drawn. Comparing the results of the metrics for which there was no statistical test (both between cities and years) was somewhat subjective.

Despite an element of ambiguity in interpreting the results, the spatial extent metric was useful and revealed some important differences between the development of the landscape of deprivation in Glasgow compared to Liverpool and Manchester. By quantifying the proportion of the landscapes occupied by areas with high levels of an indicator (or indicators), the spatial extent metric revealed that even where levels of deprivation overall were similar across cities, there were differences regarding how much of the land of the city is occupied by areas of deprivation.

A key feature of the literature on the relationship between health and the spatial arrangement of deprivation (regardless of the hypothesis being tested) is the comparison of health outcomes in deprived areas surrounded by other deprived areas (landlocked deprivation), with deprived areas surrounded by more affluent areas (islands of deprivation). The patch density metric, therefore, was important because it provided an indication of whether a city's deprivation landscape is more likely to be made of islands of deprivation or landlocked deprivation (with a higher patch density indicating more islands and vice versa); a direct quantification of something referred to by competing hypotheses. However, the information provided by the patch density metric was also somewhat limited. It would have been useful to know more about the spatial arrangement of the patches, such as whether or not the patches were in close spatial proximity to one another. Perhaps a better understanding of the "patchiness" of the landscape, and the spatial arrangement of islands of deprivation, would have been gained if other metrics had been used in addition to the patch density metric. This is expanded on in the “Future research” section below.

Mean patch size also provided useful information on the spatial arrangement of deprivation of the landscapes being studied. By providing an idea of the size of individual areas of deprivation within a landscape it complemented the information provided by the patch density metric. The size of individual areas is important for two reasons. First, it supplements the information provided by the patch density regarding the identification of whether a landscape is mostly composed of landlocked deprivation or islands of deprivation (with larger mean patch sizes indicating the former, and smaller mean patch sizes indicating the latter). Second, if a landscape is characterised by large concentrations of deprivation it provides an indication of the size of these concentrations.

7.3.4 General approach: strengths and limitations

The above has detailed the strengths and limitations of specific aspects of the methods used to generate the findings of this study. The discussion here shall move to an examination of the strengths and limitations of the general approach used in this study; that is the use of a landscape perspective and a temporal approach to compare Glasgow’s spatial arrangement of deprivation with that of other cities.

Using a landscape perspective to compare the spatial arrangements of deprivation in Glasgow, Liverpool, and Manchester was a key strength of this study. As has already been mentioned, a weakness of many studies examining the arrangement of deprivation is that small areas or neighbourhoods are often viewed as the quintessential unit of interest (Cummins, 2007). By doing so such studies have failed to account for the wider spatial and temporal contexts to which people are exposed to. By adopting a landscape perspective the wider context to which people are exposed to can be studied in a manner which does not lose the detail associated with studying small areas. Another key strength of this study, therefore, has been its use of a landscape perspective.

Using a temporal perspective and studying the development of the spatial arrangement of deprivation between 1971 and 2011 was a further strength of this study. As was discussed in the literature review, studies examining the spatial arrangement of deprivation and health have all been cross-sectional. Whilst a cross-sectional approach to exploring the spatial arrangement of deprivation is useful, such an approach only provides detail for one specific point in time. Cities are, however, dynamic environments subject to changes in both their social and physical structures; although they are often built in stone, the socio-spatial structure of a city is not set in stone. Therefore the spatial arrangement of deprivation at one point in time is not necessarily the same as at a previous or future point in time. A key finding of this study was that the spatial extent of deprivation observed in Glasgow did differ to that observed in Liverpool and Manchester, and that this was particularly evident in 1971 and 1981 but not in the latest available data. Had a temporal approach not been adopted in this study differences between Glasgow and the other cities would not have been identified. This is also of particular relevance when there is an interest in identifying relationships between the spatial arrangement of deprivation and health outcomes, because of the possible lag effect between exposure and the onset of disease (Rachet et al., 2003).

A limitation of this study, however, is that it was only possible to map deprivation in the three cities from 1971 onwards. As it was established that the spatial arrangement of deprivation does change over time, it would have been advantageous to have covered a longer time period. Whilst doing so was not feasible due to data availability, this study is limited by only going back to 1971.

Liverpool and Manchester were selected as comparator cities to Glasgow due to having similar levels of deprivation. This was advantageous as it reduced the possibility of differences in the levels of deprivation driving differences in the spatial arrangement of deprivation. A limitation, however, was that only two comparator cities were used. Although Liverpool and Manchester have lower mortality rates than Glasgow, relative to other cities in England they also have high mortality rates. Had more comparator cities been used, however, it would have been useful to include cities which have high levels of deprivation but better than expected health outcomes; this would potentially have shed light on what a “healthy spatial arrangement of deprivation” might look like.

7.4 Research questions

This section summarises the key findings of this study by directly addressing the research questions.

7.4.1 Research question 1: what techniques best facilitate comparisons of the development of the spatial arrangement of deprivation.

Using surface mapping techniques to map census data relating to deprivation produced maps showing the landscape of deprivation in Glasgow, Liverpool, and Manchester at decennial intervals between 1971 and 2011. The innovative use of spatial metrics quantified patterns within these landscapes. These methods enabled the development of the spatial arrangement to be mapped and analysed in a way which enabled inter-city and temporal comparisons to be made from a landscape perspective.

7.4.2 Research question 2: did the spatial arrangement of deprivation develop differently in Glasgow to that observed in Liverpool and Manchester between 1971 and 2011?

Using the method outlined above, it was identified that there were both similarities and differences between the development of Glasgow’s spatial arrangement of deprivation and those of Liverpool and Manchester. It was concluded that patch density and mean patch size did not develop differently in Glasgow relative to the other cities. The spatial extent of deprivation did, however, develop differently in Glasgow between 1971 and 2011, with deprivation being more spatially ubiquitous in Glasgow – most prominently so in 1971 and 1981.

7.4.3 Research question 3: If the spatial arrangement of deprivation did develop differently in Glasgow, could these differences be a plausible contributor to Glasgow’s excess levels of mortality?

It is plausible that the Glasgow’s greater spatial extent of deprivation could contribute to Glasgow’s excess levels of mortality. However, if this is the case, it is likely that it only accounts for a small proportion of Glasgow’s excess mortality.

7.5 Implications

A number of implications can be drawn from the findings of this study. It appears clear from the literature that the spatial arrangement of deprivation can influence health behaviours and health outcomes. Examining this literature revealed, however, that the causal pathways driving this relationship are not well understood. The first implication, therefore, is that further research is required if we are to adequately understand relationships between the spatial arrangement of deprivation and health. Suggestions for such future research is given below in the section 7.6.

The second implication relates to the success of the methods used in this study. I have successfully demonstrated the validity of adopting a landscape perspective and utilising surface mapping techniques to map landscapes of deprivation. Surface mapping is a tool which could be used in further studies of deprivation, as well as in other studies where disaggregating data aggregated by geography would be useful. As such this study has reasserted the usefulness of surface mapping. Furthermore, this study has demonstrated a reliable means of quantifying and analysing such maps through the use of spatial metrics. Having demonstrated the usefulness of these techniques, the implication is, therefore, that these methods are valid and could be used in other studies.

The third implication relates to the census. This study was based on the use of data from both the most recent census and previous censuses. Without that data it would not have been possible to produce maps showing the development of the spatial arrangement of deprivation from 1971 onwards, nor would it have been possible to produce comparable maps of cities in England and Scotland. Consequently, the understandings gained by conducting this analysis would not have been possible had it not been for census data. This study has, therefore, reaffirmed the utility of the census for research purposes. It has now been confirmed that there will be another UK census in 2021, however, concern remains that that could be the last census. The third implication of this study is, therefore, that the census is of immense value to research and gaining understandings of society; it should therefore be continued.

The above implications have been spatially general; the final implications, however, expressly concern Glasgow. Whilst I have demonstrated that it is plausible that the development of the spatial arrangement of deprivation might contribute to Glasgow's excess mortality, further research is required to ascertain whether this is indeed the case. If the spatial arrangement of deprivation does contribute to Glasgow's poor health outcomes, it is unlikely to account for all of the excess. This implies that other explanations need to be examined if we are to gain more insight into why Glasgow has an excess of mortality. If the spatial arrangement of deprivation is found to categorically contribute to Glasgow's excess mortality this would have implications for policy. It would most likely become a "wicked" problem without easy solutions, not least because it might be seen as implying that different spatial arrangements of deprivation should be aspired to. This, however, would not be easy to achieve as there are also likely to be some benefits to Glasgow's spatial arrangement of deprivation. One of the key findings of this study was that deprivation was more spatially ubiquitous in Glasgow in 1971 and 1981 relative to Liverpool and Manchester. If this is found to be a contributing factor to Glasgow's present day excess mortality then it is clear that (as is common in epidemiology) there is a lag effect, the length of which remains unknown.

7.6 Avenues for further research

There are a number of exciting ways in which the research presented in this thesis could be furthered. These broadly fall into two categories:

- Ways in which the methodology could be developed further to study more aspects of landscapes of deprivation.

- Ways in which the impact of the spatial arrangement of deprivation on health outcomes could be studied.

7.6.1 Further development of the methodology

This study pioneered both the use of surface mapping techniques to map the landscape of deprivation, and the use of spatial metrics to analyse these landscapes. As part of the methodological development, the study was kept as simple as possible. Having now shown that these techniques work, there are a number of ways in which they could be further developed and which might overcome some of this study’s limitations.

7.6.1.1 Expand the number of spatial metrics used to analyse the landscapes of deprivation

The first would be to expand the number of spatial metrics used to quantify the arrangement of deprivation in the landscape, in particular the use of nearest neighbour metrics, edge metrics, shape metrics, and core metrics. As identified in the limitations section, it was not possible to distinguish between landscapes where the patches were in close proximity to one another and those where they were further apart. As discussed above, the spatial relationships between more and less deprived areas may be implicated in their health effects. It is possible for landscapes to have identical patch density metrics but different configurations of islands of deprivation, with some being more isolated than others. Nearest neighbour metrics could enable comparisons of the isolation of patches of deprivation to be made and would be a useful addition to the work presented in this study.

Edge metrics were not used in this study due to limitations associated with the way they are calculated in Patch Analyst 5.1 (Rempel et al., 2012) which renders them neither spatially or temporally comparable. If this could be overcome, for example through the use of different software, edge metrics would be highly advantageous. Based on assumptions relating to findings regarding the spatial extent of deprivation, this study has concluded that Glasgow has a larger interface between deprived and less deprived areas. The use of edge metrics would, therefore have been very useful in this study as it would have provided an accurate measure of the interface between more deprived and less deprived areas, thus confirming whether this assumption was correct. Further research into comparing the edge density figures for the landscapes of deprivation in Glasgow, Liverpool, and Manchester would therefore be useful.

7.6.1.2 Expanding what is studied

To keep the study as straight-forward as possible, the maps produced employed a binary classification of levels of the indicators. Having shown that both the mapping technique and method of quantifying the results works, it would be interesting to expand the number of classes used (for example most deprived, deprived, not deprived, least deprived). It would then be possible to compare landscapes to see if the spatial arrangement of different levels of deprivation varies between Glasgow, Liverpool, and Manchester. It is, for example, feasible that the spatial gradient in deprivation is steeper in one city than in the others. That is, it could be that in Glasgow very affluent areas are located very close to very deprived areas, whilst in Manchester and Liverpool the most deprived areas are surrounded by slightly less deprived areas, which are surrounded by non-deprived areas etc. Both the pull up/pull down hypothesis and the relative deprivation hypothesis imply that such gradients could have an influence on health outcomes.

Studies examining relationships between health and the spatial arrangement of populations within an area have focussed on the spatial arrangement of deprived areas. Given the well-established relationship between health and deprivation this is entirely understandable; indeed this study has focussed on mapping the spatial arrangement of deprivation. What is therefore missing from the literature is an exploration of relationships between the spatial arrangement of affluence and health. The techniques used in this study could be used to map analyse the spatial arrangement of affluence, and in doing so facilitate such an exploration.

7.6.2 Ways in which the impact of the spatial arrangement of deprivation on health outcomes could be studied

Whilst it appears that some aspects of the spatial arrangement of deprivation did develop differently in Glasgow to that observed in Liverpool and Manchester, and evidence from the literature indicates that this could plausibly contribute to Glasgow's excess mortality, it remains unclear whether spatial arrangement did actually influence health. An obvious area for further research, therefore, would be to test this relationship rigorously.

Comparisons of the spatial arrangement of deprivation with the spatial arrangement of mortality, for example, would help reveal whether or not the development of Glasgow's landscape of deprivation contributed to Glasgow's excess mortality. Such research might not, however, reveal the mechanisms by which the spatial arrangement of deprivation actually influences health. Further investigation of the two principal hypotheses identified in the literature review for *how* the spatial arrangement of deprivation could influence health behaviours and health outcomes would enhance understandings of the relationship between the spatial arrangement of deprivation, and could have important policy implications.

I argue that further research into these hypotheses should focus on their assumptions, rather than solely on comparing areas with high levels of concentrated deprivation (landlocked deprivation) with areas where there are small pockets of deprivations amidst more affluent areas (islands of deprivation). The pull up/pull down hypothesis is primarily based on a collective resources approach and, at a very basic level, argues that residents of islands of deprivation benefit from greater collective resources and thus have better health outcomes than residents of landlocked deprivation. It would therefore be useful to ascertain the following:

- Do residents of "islands of deprivation" actually have better access than residents of landlocked deprivation to resources that are likely to promote health (for example: such as health services, facilities such as parks, employment opportunities and "healthier" social models of health behaviour). This could be explored by mapping the spatial landscape of deprivation, identifying islands of deprivation and landlocked deprivation, locating such resources and comparing whether the proximity of these between islands of deprivation and landlocked deprivation. A city such as Glasgow which has both large concentrations of deprivation, and small pockets of deprivation surrounded by more affluent areas, would be ideal for such a study.

- Do residents of islands of deprivation have better health *behaviours* than residents of landlocked deprivation? Investigations might draw on linking respondents from population health surveys, such as the Scottish Health Survey, to their spatial location within (or not) islands of deprivation or landlocked deprivation.

The relative deprivation hypothesis is based on three (interrelated) assumptions:

- Less affluent people compare themselves unfavourably to more affluent people.

- This unfavourable comparison results in low level stress.

- Deprived people residing in islands of deprivation have greater exposure to more affluent people than those living in landlocked deprivation.

Further research into the relative deprivation hypothesis, therefore, requires investigation into these three assumptions. Reliably ascertaining the extent to which more deprived people unfavourably compare themselves to others in society is likely to be methodologically challenging. A very simple study design would be to recruit participants from four groups of people:

- Deprived people living in an area identified as an island of deprivation;

- Deprived people living in an area identified as landlocked deprivation;

- Affluent people living in an areas identified as an island of affluence;

- Affluent people living in an area identified as landlocked deprivation.

A common means of measuring stress in a non-invasive and physiological manner, and which does not require the researcher to be present, is to collect and then test salivary cortisol (Inder et al., 2012). Participants from these groups could then be asked to take saliva samples over a period of time and either take a note of their location or also carry a global positioning system (GPS) recording devise with them. If the relative deprivation hypothesis is correct it would be expected that the participants categorized as deprived and living in a deprived area would have the highest stress levels. Furthermore, plotting the GPS traces of participants onto maps showing the landscape of deprivation would enable analyse to be undertaken on where participants felt the most and least stressed, as well as the exposure participants of the different groups had to more or less affluent areas.

Another way in which the biological reactions of people to different levels of affluence could be tested would be to adopt an approach used in the “Mobility, Mood and Place” study. An innovative feature of this study is to use mobile neural imaging methods to record participant’s responses to different environments. In the Mobility, Mood and Place study participants wear a GPS recorder and an Electroencephalography (EEG) Neuro-headset, information from which can be used to gauge emotions, and asked to walk a set route. Their interest has been focused on examining the impact of urban and natural landscapes on the brain. It would, however, seem feasible that such techniques could be used to examine the reactions people from different socio-economic groups have when encountering differently affluence areas. Such an approach could further understandings of the relative deprivation hypothesis.

7.7 Final thoughts

In the four year period between 2003 and 2007 there were 4,500 excess deaths in Glasgow; that is, 4,500 more people died than would be expected given Glasgow’s age, gender, and demographic profile (Walsh et al., 2010a, 2010b). If, as is likely, this trend has continued, then it would be expected that there have been 4,500 excess deaths (of which 2,090 would have been under the age of 65) during the four years it has taken to complete this thesis. Whilst this study has found that Glasgow’s spatial arrangement of deprivation could plausibly be contributing to these deaths, it is unlikely that this is explains all of Glasgow’s excess mortality. It remains unclear, therefore, why more people are dying in Glasgow than would be expected, and why so many of these people are under the age of retirement. What is clear, however, is that this is a life and death matter. It is therefore imperative that further research into Glasgow’s excess mortality is conducted.

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