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The Changing Geographies of Ageing and Age Mixing Across Urban–Rural Areas in Scotland, 2011–2022

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ABSTRACT

Like other high-income countries, Scotland is experiencing rapid population ageing, with evidence of spatial polarisation of age groups. This study uses the Scottish Censuses of 2011 and 2022 to understand patterns and trends in the geographies of ageing and age mixing. With attention to urban-rural differences, we examined, at the Data Zone (neighbourhood) level, spatial age segregation and age mixing using the Dissimilarity Index, cumulative proportion calculations, Simpson's Diversity Index and Global and Local Moran's I. This paper contributes new findings on the spatial and temporal patterns of ageing and age mixing in Scotland, with relevance for broader debates on health and social care provision, housing accessibility and equity, and population sustainability. First, it illustrates the stark sub-national variation in geographies of age segregation; second, it demonstrates the value of an analytical and interpretive framework using concepts of urban hierarchy; third, it causes us to rethink typical understandings of ageing and the urban hierarchy. In particular, the analyses reveal high age segregation and low age diversity in urban areas together with the potential polarisation of older- and younger-age areas in some parts of cities; stable age mixing in rural areas (but with decreasing age diversity); and accessible (town and rural) neighbourhoods exhibiting both increasing age segregation and diversity and acting as the lynchpin for understanding the local dynamics of age mixing over the last decade. Attention to spatial nuance also reveals that change in age diversity is spatially clustered. The paper raises questions about the demographic dynamics and social meaning implied by spatially-varied age mixing, with implications for population and community planning in Scotland and elsewhere.

1 | Introduction

Intergenerational interactions have been identified as important aspects of community cohesion in age-friendly neighbourhoods (Buffel et al. 2014; House of Lords 2019; Sixsmith et al. 2024). However, populations do not age evenly across space: there is evidence for increasing spatial polarisation between generations, which may reduce opportunities for meaningful intergenerational engagement (Hagestad and Uhlenberg 2006). In the context of ageing populations worldwide, where the

proportion of the population aged 65 years and older is steadily increasing, this poses a significant challenge to the demographic and social sustainability of communities which are ageing fastest. Understanding the changing spatial intergenerational divides can be seen as critical to ensuring sustainable communities (Buffel et al. 2014; Kaplan et al. 2017).

Population ageing is often presented as a major challenge for societies, potentially threatening their future economic growth and sustainability (Poston 2019). Although increasing life

expectancy has led to increases in productive economic years of work (and increasing state retirement age), ageing populations raise concerns over dependency ratios and the economic productivity of a country (Jarzebski et al. 2021; Spijker and MacInnes 2013). Increases in the proportion of older people in a country can place greater economic and social pressure on the working age population, and contribute to declining fertility rates (Jarzebski et al. 2021), which in turn intensifies population ageing. Furthermore, population ageing will likely reinforce existing, and create new, socioeconomic inequalities, especially in societies with inadequate social protection systems (Jarzebski et al. 2021).

Scotland, in particular, is ageing rapidly; the percentage of the population aged 65 years and over was 15.9% in 2001 and is projected to rise to 25% by mid-2047 (National Records of Scotland 2014, 2025). The largest projected increase (of 341,000 people between 2022 and 2047) is for those aged 75 years and over (National Records of Scotland 2025). Using Scotland as a case study, this paper examines trends in the local geographies of ageing and age mixing to engage with debates on segregation, social cohesion and community sustainability. Through analyses of census data over two decades for small areas, the paper extends work for other UK nations (e.g. for Wales and England by Sabater et al. (2017) and Sabater and Finney (2023)) with emphasis on how the dynamics of age mixing manifest spatially across (types of) neighbourhood, with implications for community sustainability in the context of population ageing.

1.1 | Desirability of Age Mixing

Segregation research typically focuses on socio-economic status (e.g., Van Ham et al. 2021) and ethnicity and race (e.g., Catney et al. 2023). However, the dimension of age in spatial segregation research has received considerably less scholarly attention, and perspectives on the meaning and desirability of age mixing vary. Over time, spatial polarisation by age may threaten the socio-economic and demographic sustainability of small communities as fewer people of working age living in older-age areas could lead to a reduction of services (e.g. health and social care, supermarkets) and community resources (e.g. swimming pools and libraries) that are important for ageing well (Verma and Taegen 2019). With increased age segregation, there is a risk of social, economic, and digital exclusion for the older population (Fang et al. 2023). Greater geographical distance between age groups could contribute to reduced intergenerational interactions, leading to increased social isolation and reinforcing ageist stereotypes, which may negatively affect the physical and mental health of older people (Andreoletti and Howard 2018; Hagestad and Uhlenberg 2006; Vanderbeck 2007).

These perspectives have been critiqued in two ways. First, they have a tendency to focus on the experiences and benefits of age mix for the 'bookends' of youngest and oldest members of society (Hagestad and Uhlenberg 2006; Vanderbeck 2007). In Riley (1994) model of an ideal age-integrated society, an 'age continuum' replaces stark age division and highlights the 'breaking down [of] structural age barriers' and 'bringing people together who differ in age' as aspects of integration (Riley and Riley 2000). Second, competing views emphasise the benefits of age-homogenous communities, such as in naturally occurring retirement communities (Masotti et al. 2006). Often, age segregation is seen as "natural, inevitable, or unproblematic" (Vanderbeck 2007, p. 206). The notion of age segregation being detrimental is thus contested, akin to Peach (1996) 'good' and 'bad' ethnic residential segregation. Older people's choice of dwelling in retirement communities highlights a desire to reside away from people of other ages (Vanderbeck 2007). Additionally, many young people who attend university live in highly age-homogenous spaces (Smith et al. 2014).

1.2 | Geographies of Age Mixing

Residential age segregation of younger and older people increased between 1991 and 2011 in England and Wales (Sabater et al. 2017), suggesting that there is increasing spatial polarisation between age groups. However, the spatial sorting of age groups varied across urban-rural geographies, with higher segregation in rural areas compared to urban areas, but urban areas saw a greater increase in segregation over time (Sabater et al. 2017). Furthermore, Sabater and Finney (2023) found that increased age segregation was associated with increasing housing unaffordability, especially in urban and least deprived areas in England and Wales. These findings suggest that the changing geographies of age mixing reflect and impact broader social processes, such as housing dynamics and selective migration.

Urbanisation, demographic change and housing tenure are intricately linked. Urban areas tend to be associated with affluence, access to a wider job market, improved health care and education, and access to cultural and behavioural diversity. However, urban areas are also often places of great inequality with high levels of poverty and economic segregation (Bailey et al. 2016; Van Ham et al. 2021). Spaces (e.g., neighbourhoods) that are increasingly socio-economically segregated may also become polarised along generational lines (Moos 2016; Sabater and Finney 2023) as urbanisation is associated with changing social norms, such as delayed marriage and childbearing. Having children increases living costs and put constraints on career progress, especially for women (Jarzebski et al. 2021), which results in reduced fertility rates and smaller urban birth cohorts.

Nevertheless, urban areas are often characterised by the in-migration of younger generations (Plane et al. 2005). Areas near universities and city centres tend to host transient younger populations (Revington 2021). Yet, while employment and social opportunities in urban settings can be a pull for young people, housing choice is often limited and precarious. Young people are increasingly more likely to rent (Hoolachan et al. 2017), priced out of homeownership in the urban centres where they work (Clapham et al. 2010). Gentrifying forces further alter this housing landscape, transforming previously 'undesirable', industrial, and stigmatised areas into spaces of desirability and capital flow (Butler-Warke 2022; Stein 2019). Within such areas, larger homes that are more suited to families may be owner-occupied by older residents who purchased their property decades before (Clapham et al. 2010). Outside urban areas, an important challenge in the context of population ageing is the demographic sustainability of local communities, especially in rural areas and small towns which often have a

higher concentration of older people. These areas may be characterised by a reduction in local services and inadequate accessibility infrastructure and public transportation (Blackstock et al. 2006; Verma and Taegen 2019). Population decline in small towns and rural areas is often driven by the out-migration of younger people seeking education and employment opportunities in urban areas, and may lead to a self-reinforcing cycle where services close and a lack of economic opportunities causes more young people to migrate to larger urban areas (Jarzebski et al. 2021; Verma and Taegen 2019). Within rural regions, most older people either remain in place or relocate only short distances (Elshof et al. 2014), and some wealthier older people may choose to retire to desirable rural areas, compounding the rate of population ageing in these places (Plane et al. 2005).

This paper aims to contribute to these debates on the nature of local population dynamics and age by addressing the following questions:

1. How has the absolute and relative share of older people varied across urban-rural geographies, and over time?

2. How has residential age mixing varied across urban-rural geographies, and over time?

3. How are the changes in age mix and age structure of neighbourhoods over time spatially distributed across urban-rural geographies?

4. To what extent is clustering of neighbourhoods according to changing age diversity observed and how is this spatially patterned?

1.3 | The Scottish Context

These questions are addressed through a focus on the Scottish case. Important challenges for Scotland recently outlined by the Scottish Government (2021, p. 19) include: "maintaining a sustainable total population size; maintaining sustainable age structures within our population; and maintaining a sustainable spatial balance of our population across Scotland's urban, rural, and remote locations". These are challenges common to many other high-income countries with an uneven spatial distribution and ageing of population, including the Nordic countries (Hospers and Reverda 2015). As such, Scotland provides an important case study for understanding spatial age segregation in the context of population ageing and rural population decline.

Our study aims to contribute to understandings of changing age geographies through a detailed, small-scale examination of how local age mixing has evolved over the past decade in Scotland. Understanding the changing local geographies of ageing in Scotland has important implications for the (demographic) sustainability of neighbourhoods in Scotland and broader implications for scholarship on the local spatialities of ageing and their significance for population and community cohesion and sustainability.

Scotland had a population of 5.4 million in 2022 (National Records of Scotland 2025), which is a small rise from 5.2 million in 1975 (Scottish Government 2021). In recent years, Scotland's population growth has been driven primarily by in-migration, as the number of deaths now outweighs the number of births.

Compared to England and Wales, Scotland has seen slower population growth and a faster rate of ageing. Scotland's population is also unevenly distributed geographically, as are its rates of growth and decline. For example, Scottish islands (Scotland has 93 inhabited islands) and remote rural areas have seen a steady population decline over recent years, which is projected to continue (Scottish Government 2023), whereas several cities and accessible rural areas have seen notable population growth.

The population of Scotland is concentrated within settlements in the lowland area of the densely populated central belt, which contains the cities of Edinburgh to the east and Greater Glasgow to the west (see Figure 1). The largest settlement is Greater Glasgow (made up of several localities) with an estimated population of over 1 million in 2020 (National Records of Scotland 2022). The next largest cities are Edinburgh (530,090 people), Aberdeen (220,690 people), and Dundee (158,820 people) (National Records of Scotland 2022).

Scottish small towns (defined as settlements with less than 100,000 people) occupy a unique position between urban and rural spaces, forming a continuum rather than a simple city-countryside divide. Integrated into accessible areas, like the central belt, or functioning as regional centres in remote areas, towns can face similar challenges to cities in terms of deprivation and population decline. Towns in accessible areas close to cities often become commuter towns for families looking for affordable housing options (McCollum et al. 2021). However, less economically affluent towns which have undergone deindustrialisation are vulnerable to population decline and the outmigration of younger people into towns and cities with more economic opportunities (Scottish Government 2024).

The uneven, and changing, geographical distribution and rapid ageing of Scotland's population provide the background context for the current study. The challenge for the analyses is to elucidate the patterns of age mixing in Scotland while taking these trends into account.

2 | Methods

2.1 | Data

The analyses in this paper use data from the 2011 and 2022 Scottish Censuses for Data Zones (2011 boundaries) in Scotland. Specifically, data on all residents, including those in communal establishments, for single years of age, as well as the total population from the Scottish Census in 2011 and 2022 were used. Data Zones have approximately similar populations between around 500 to 1000 people, and there are 7392 Data Zones in Scotland as of 2024 (Scottish Government n.d.). We refer to Data Zones as 'neighbourhoods' throughout the rest of the paper but recognise that Data Zones are statistical geographies and may not be defined as a neighbourhood by the people who live in them.

2.2 | Measures

2.2.1 | Age

Ageing is a dynamic process that varies across individuals, with wide heterogeneity in the pace of biological ageing within
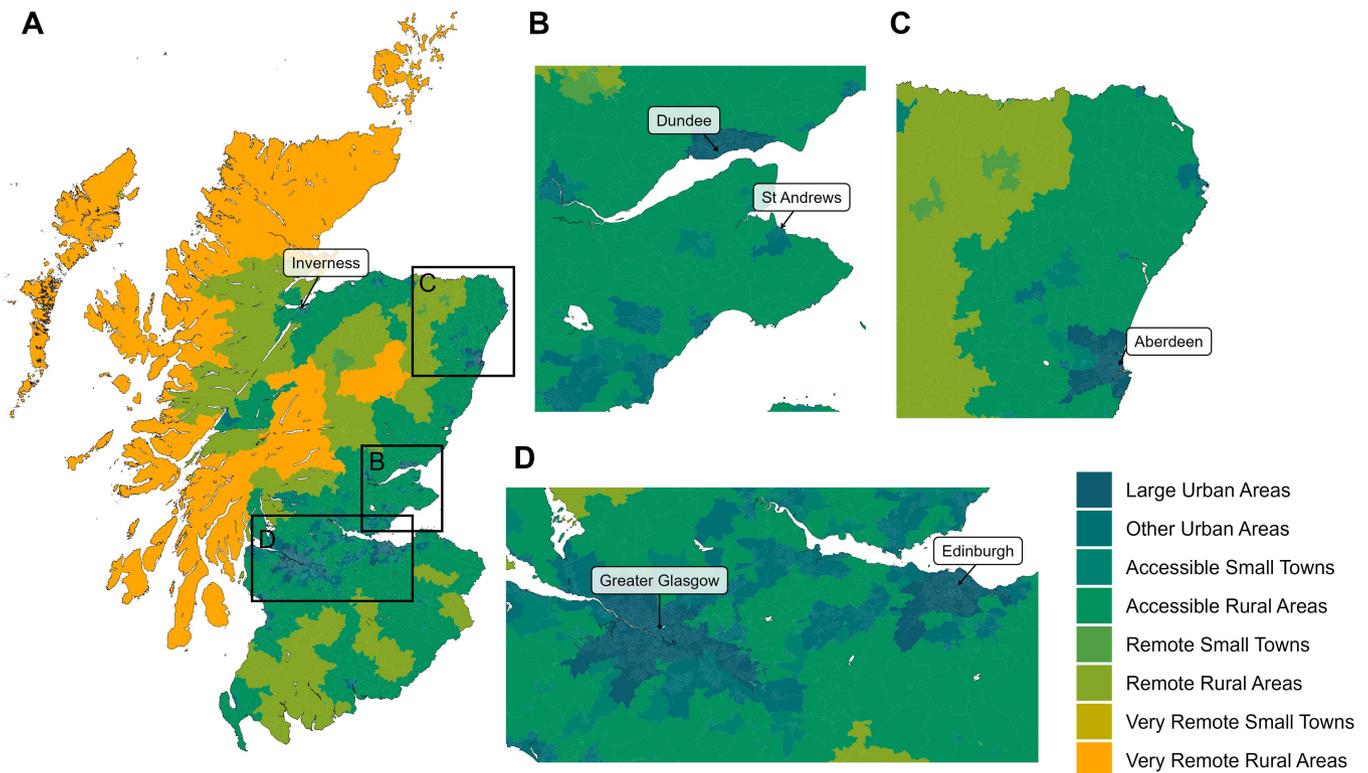
FIGURE 1 | Distribution of urban-rural categories in Scotland. Panel B shows the regions of Fife and Tayside which are composed mainly of accessible small towns and rural areas with a few urban settlements. Panel C shows the county of Aberdeenshire which contains the city of Aberdeen and is predominantly composed of accessible rural areas and remote rural areas. Panel D shows the densely populated central belt, which contains Greater Glasgow and Edinburgh, and is composed of many large and other urban areas and accessible small towns and rural areas.

populations (Crimmins et al. 2009). In particular, disadvantaged populations are more likely to experience earlier onset of age-related conditions (Crimmins et al. 2009; Schrempft et al. 2022). In this paper we use a variety of age categorisations but generally refer to older people or the older population based on a chronological age of 65 years and older. We use this definition as it most closely corresponds to state retirement age and is used in calculations of dependency ratios and conversations around the economic sustainability of populations (although there have been criticisms of this approach, see Spijker and MacInnes 2013). The proportion of the population aged 65 and over is also frequently reported in statistics about population ageing, so using this classification allows for comparisons with other studies.

In addition to classifying older people as those aged 65 and over, we used specific, conceptually informed categorisations of age to examine the age mix of neighbourhoods. First, in the dissimilarity indices, we categorise age into specific intervals to carry out the comparisons between two groups (5-year intervals as well as broader age groups, 24 to 39 *vs.* 65 +). Second, in the calculation of an age diversity index, we use 5-year intervals of age (from 0 to 4 years to 90 years and over). In other analyses, we use a median age of 50 years or more to denote 'older' neighbourhoods and median age below 50 years to denote 'younger' neighbourhoods. The 50 year and older group has previously been used in a strategy set out by Scottish Executive to understand Scotland's changing older population as it marks a point in the life course where life circumstances begin to change for many people (Scottish Executive 2007).

2.2.2 | Urban–Rural Classification

We define urban-rural categories following the 2020 classification published by the Scottish Government (Scottish Government 2022). *Large urban areas* are those settlements with populations of 125,000 or more, *other urban areas* are settlements with populations of 10,000 to 124,999, *small towns* are settlements with populations between 3000 to 9999, and *rural areas* are defined as areas which have populations below 3000. *Accessible areas* are within a 30-min drive time of an urban settlement, *remote areas* have a drive time between 30 and 60 min to an urban settlement, and *very remote areas* are more than a 60-min drive from an urban settlement (Scottish Government 2022). The geographical distribution of the urban-rural categories in Scotland is shown in Figure 1.

2.2.3 | Analysis

First, we examined the changing distribution of the population share aged 65 and over across urban-rural categories in both absolute terms and relative to Scotland. Second, within each urban-rural category, we examined (1) age segregation across neighbourhoods using the Index of Dissimilarity (D), and (2) the cumulative proportions of the population aged 65 and over living in neighbourhoods with differing proportions of people aged 65 and over. Third, we used Simpson's Reciprocal Diversity Index (RDI) to estimate age diversity scores for each neighbourhood across 5-year age groups. Finally, we examined clustering of neighbourhoods according to changing age diversity using Global and Local Moran's I. A summary of metrics

and measures mapped to each research question can be found in Supplemental Table 1.

2.2.4 | Descriptive Analysis: Local Geographies of Ageing

In order to examine how the age composition of Scotland has changed between 2011 and 2022 at the small area level, we calculated the percent change in the total population and the proportion of the population aged 65 and over in each urban-rural category and relative to Scotland as a whole.

2.2.5 | Residential Age Segregation: Index of Dissimilarity

The Dissimilarity index, D, is a common measure of spatial segregation which has been used in many studies to examine segregation (e.g. race/ethnic, socioeconomic, or age segregation) between two population groups (e.g., Sabater et al. 2017; Yao et al. 2019; Catney et al. 2023). The value of D ranges from 0 to 1, with 0 indicating no segregation and 1 representing total segregation, and can be interpreted as the proportion of the population that needs to be replaced by other groups to achieve zero segregation. A standard formula for the dissimilarity index between two groups is:

$$D_{xy} = 0.5 * \sum_i \left| \frac{x_i}{X} - \frac{y_i}{Y} \right| * 100$$

Where x_i and y_i are the population counts in age group x and age group y within neighbourhood i, and X and Y are the total population counts of the two groups in each urban-rural category. We calculated dissimilarity indices between those aged 24 to 39 vs those aged 65 and over across all neighbourhoods within each urban-rural category. We also calculated dissimilarity indices between pairs of age groups in 5-year intervals from 20 to 49 years (younger groups) and 50 years and above (older groups) in 2011 and 2022.

2.2.6 | Experiences of Living in an Older-Age Neighbourhood: Cumulative Proportions

We calculated the percentage of people aged 65 and over living in each neighbourhood and divided the values into five categories (below 10%, 10%–20%, 20%–30%, 30%–40%, and 40% or more). We then calculated the percentage of people aged 65 and over in Scotland who live in neighbourhoods within each category of percentage 65 and over, in 2011 and 2022, for each urban-rural category.

2.2.7 | Residential Age Mixing: Age Diversity

To examine the overall age-mix of the population we used Simpson's RDI, a common measure of species diversity used originally in ecological studies (Jost 2006) and adapted for studies of population mix (e.g., Catney et al. 2023; Hyde 2024). The RDI was calculated across 5-year age groups for neighbourhoods in 2011 and 2022. The possible values of the RDI range from 1 (no diversity, where all members of the population belong to one group) to 19 (the total number of age groups, representing maximum diversity, where all members of the population are evenly distributed across groups). The RDI can be expressed as:

$$S = \frac{1}{1 - \frac{\sum n(n-1)}{N(N-1)}}$$

where n is the number of people in a specific age group and N is the total population count.

To aid interpretation of the RDI, neighbourhoods were ranked from lowest to highest RDI based on 2022 values and divided into quintiles (with each quintile having an approximately equal number of neighbourhoods), where quintile 1 indicates neighbourhoods with the lowest age diversity scores in 2022 and quintile 5 indicates neighbourhoods with the highest age diversity scores in 2022. Neighbourhoods in the first and second quintile (low age diversity) were also divided into 'older' (median age of 50 or above) and 'younger' (median age below 50) neighbourhoods, resulting in seven categories of age mix.

To understand change in age mixing over time, we calculated the change in RDI between 2011 and 2022 for each neighbourhood. Neighbourhoods were divided into quintiles based on the level of change to identify neighbourhoods with increased or decreased age diversity. We defined neighbourhoods with values in the 5th quintile of age diversity change as having increased diversity, and those with values in the 1st quintile of age diversity change as having decreased age diversity. We also calculated change in median age to identify neighbourhoods which are 'becoming older' (increased by > 1 year) or 'becoming younger' (decreased by > 1 year) over time.

2.2.8 | Clustering of Changing Local Age Mix Across Scotland

To understand whether changes in age diversity between 2011 and 2022 are spatially clustered, we used Global and Local Moran's I to identify areas of positive (i.e., clusters) and negative (i.e., outliers) spatial autocorrelation (Anselin 1995). We used a Queen's contiguity matrix which defines neighbours as all Data Zones which share a boundary or corner (Anselin 1995). Further details on the spatial autocorrelation analysis are provided in the supporting information.

Local Moran's I, a type of Local Indicators of Spatial Autocorrelation (LISA) analysis, was performed on values of RDI change between 2011 and 2022. The analysis produced categories based on the value of age diversity change for each neighbourhood and the values of its neighbours, relative to the overall mean. A significance level of $p < 0.1$ was used to identify meaningful clusters and outliers. The 'high-high' cluster indicates a neighbourhood with above-average values of RDI change (i.e. increasing age diversity) surrounded by neighbours with similarly above-average values and the low-low cluster indicates a neighbourhood with below-average values of RDI change (i.e., decreasing age diversity) surrounded by neighbours with similarly below-average values. The 'high–low' outlier indicates a neighbourhood with above-average values of RDI change surrounded by neighbours of below-average values and the 'low-high' outlier denotes a neighbourhood with below-average values of RDI change surrounded by neighbours with above average values.

3 | Results

3.1 | Changing Geographies of Ageing in Scotland

Over the decade 2011–2022, the percent of Scotland's population aged 65 and over increased from 16.8% to 20.0%. While all areas saw increases in the older population, demographic changes are uneven across urban-rural categories, as shown in Figure 2. While large urban areas have seen an increase in total population as well as their share of Scotland's total population, they have experienced a decrease in their share of the older population by 2.1%. Accessible rural areas have seen the largest increase in total population size and a large increase in the population share of older adults relative to Scotland as a whole. Remote and very remote small towns and remote rural areas saw decreases in total population size, and large increases in the older population share.

3.2 | Residential Un-Evenness of Older and Younger Populations

For Scotland as a whole, the spatial residential separation of older and younger people across neighbourhoods has remained stable (D for Scotland, for age 24 to 39 vs age 65 and over: 0.28 in 2011, 0.29 in 2022). However, this masks significant geographical variations, as illustrated in Figure 3. In both 2011 and 2022, large urban areas had the highest segregation between the two age groups, and remote rural areas had the lowest segregation between these age groups. Most areas had stable or slightly decreasing segregation levels at both time points; however, accessible rural areas saw a comparatively large increase in segregation, with the index increasing from 0.19 to 0.24 over the study period. D index values for other age group comparisons are shown in Supplemental Figure 1.

An alternative way of envisaging the uneven geographies of population ageing is to consider the age composition of the places in which people live. Figure 4 shows the cumulative proportion of people aged 65 and over who live in neighbourhoods with different proportions of people aged 65 and over, by urban-rural categories and year. Notably, the proportion of older adults living in neighbourhoods with at least 30% of people aged 65 and over increased from 8.3% in 2011 to 22% in 2022. Conversely, the proportion of older people living in areas with less than 20% of people aged 65 and over dropped from 51.7% in 2011 to 33.2% in 2022.

Similarly, all eight urban-rural categories saw an increase in people aged 65 and over living in 'older' neighbourhoods, but the size of the increase varied significantly by geography. The most dramatic increase occurred in very remote rural areas, where the proportion of older people living in older-age neighbourhoods with at least 30% aged 65 and over rose from
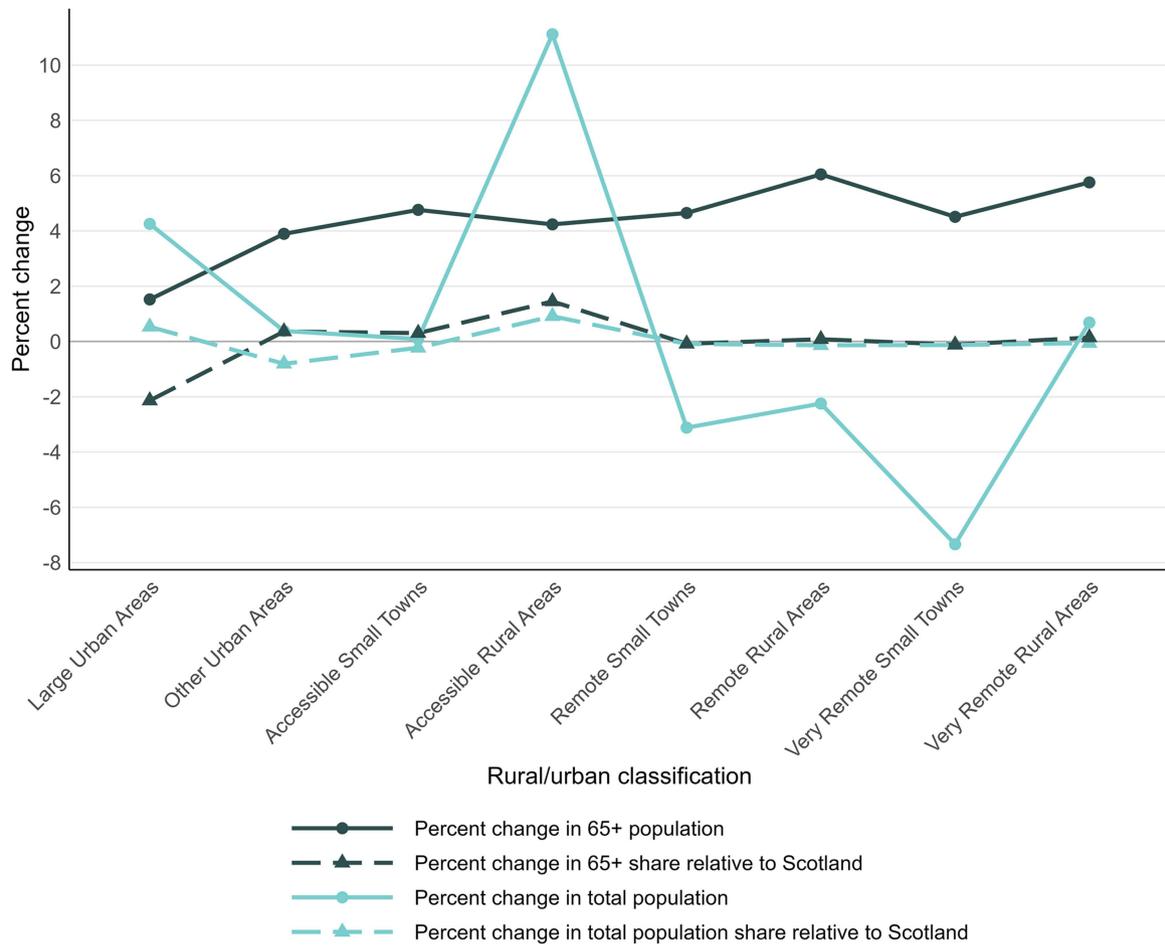

FIGURE 2 | Changes in the total population and in the proportion of people aged 65 and over within urban-rural categories, 2011–2022. Solid lines indicate the absolute percent change in total (blue) and 65+ (black) population. Dashed lines indicate the percent change in total (blue) and 65 + (black) population relative to Scotland.
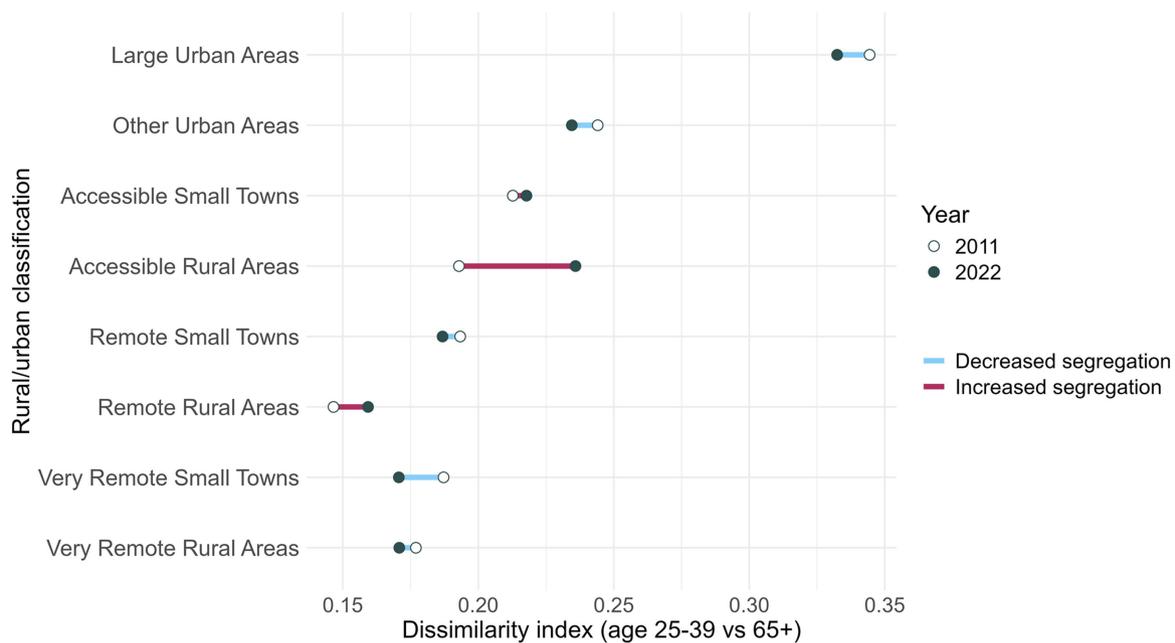
FIGURE 3 | Change in age segregation (age 25–39 years vs. 65 years and over) of Data Zones within urban-rural categories, 2011–2022. Blue lines indicate decreased age segregation, and red lines indicate increased age segregation.

9.3% in 2011 to 42.5% in 2022. For remote rural areas, this figure increased from 15.1% to 41.6%, and for accessible rural areas, from 4.9% to 21.8%. Among small towns, remote towns saw the largest increase in the proportion of people aged 65 and over living in older-age neighbourhoods; the proportion of older people living in neighbourhoods with at least 30% older residents increased from 18% in 2011 to 38.3% in 2022. While urban areas also experienced a moderate increase in the cumulative proportion of the older population, large urban areas had the smallest proportion of older adults living in 'older' neighbourhoods compared to other urban-rural categories.

3.3 | Local Age Mixing in Scotland

The mean age diversity (RDI) of neighbourhoods in Scotland was 14.9 in 2011 and 15.1 in 2022, indicating a small overall increase in age diversity between the two censuses. However, there was considerable variation in age diversity across neighbourhoods in both censuses (2011: min = 2.33, max = 18.4; 2022: min = 1.7, max = 18.4). The distribution of RDI values in 2011 and 2022 is shown in Supplemental Figure 2. The mean age diversity scores for each urban-rural category in 2011 and 2022 are shown in Figure 5, with the colour of the line indicating an increase (red) or decrease (blue) in mean RDI. There were changes in the diversity index over time for most urban-rural categories: large and other urban areas, and accessible small towns and rural areas saw small increases in mean age diversity, while remote and very remote rural areas saw decreases. The only exception was remote small towns which did not see an overall change in mean age diversity.

The geographic distribution of age mix categories in 2022 across neighbourhoods in Scotland is shown in Figure 6. Rural areas (especially in the north, west, and south) have relatively low age diversity and an older age distribution (median age of 50 or higher). Many urban and accessible

areas (particularly in the central belt and east coast) have low age diversity with a younger age distribution, or high age diversity. Urban and accessible areas tend to be more heterogeneous compared to (very) remote rural areas, while neighbourhoods in (very) remote small towns tend to have relatively high age diversity.

Figure 7 shows the geographic distribution of the change in age diversity scores of Scottish neighbourhoods between 2011 and 2022. Neighbourhoods with decreased age diversity and becoming older are concentrated in (very) remote rural areas (north, west, and south). Urban areas (central belt and east coast) have a relatively high proportion of neighbourhoods that saw decreased age diversity alongside a younger population over time, or increased age diversity alongside an ageing population. Neighbourhoods in some accessible rural areas experienced increased age diversity and a more youthful population distribution over time. The distribution of diversity change categories across urban-rural categories is shown in Supplemental Figure 3.

3.4 | Clustering of Neighbourhoods by Changing Age Mix

Finally, we examined whether neighbourhoods with similar trends in age diversity are geographically proximate to one another using global and local measures of spatial autocorrelation of change in age diversity scores between 2011 and 2022. Moran's I for RDI change was 1.68 ($p < 0.001$), which indicates overall positive spatial autocorrelation, i.e., neighbourhoods with similar values of age diversity change are located near to each other in space. The LISA analysis identified clusters of high or low age diversity change and outliers where neighbourhoods are surrounded by neighbours with different values. Local Moran's I differentiates high and low values of age diversity change as being above or below the mean age diversity
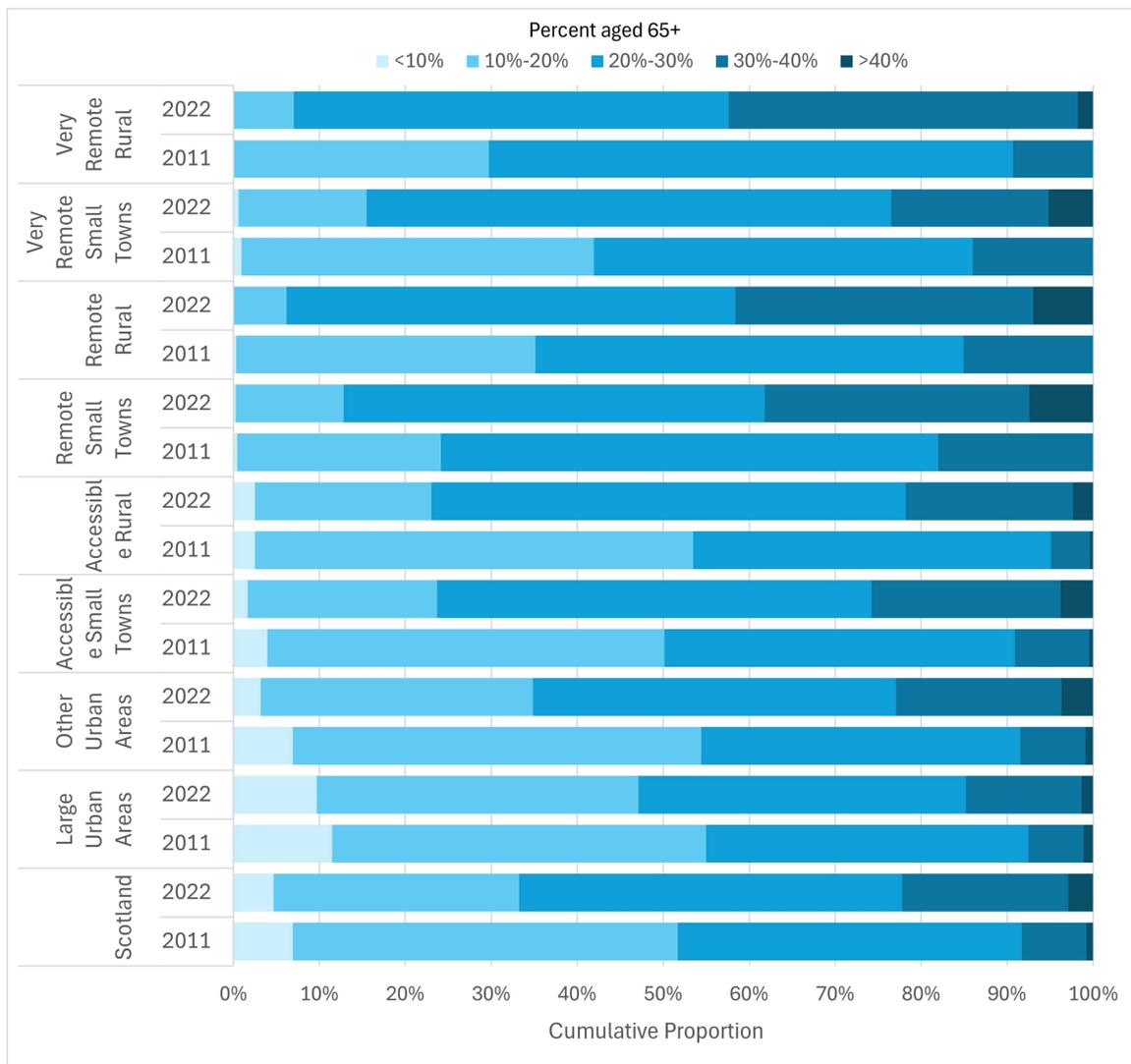
FIGURE 4 | Cumulative proportions of people 65 and over living in Data Zones with increasing proportions of the population aged 65 and over in 2011 and 2022. Darker shades of blue indicate neighbourhoods with higher proportions of the population aged 65 and over.

score (0.19), so the 'low' categories include neighbourhoods with a small increase, or no change, as well as areas with decreased age diversity.

Figure 8 maps the geographical distribution of the Local Moran's I (LISA) clusters, showing a clear urban-rural divide with low-low clusters in the remote and rural areas of the north, west, and south of Scotland, and a mix of clusters and outliers in urban and accessible areas, particularly around the central belt. Urban areas have a larger proportion of neighbourhoods in high–high clusters compared to other areas, especially remote small towns and rural areas which have no high-high clusters. We also see a relatively high proportion of high–low outliers in large urban areas and (very) remote small towns. Remote and very remote rural areas have a relatively high proportion of neighbourhoods in the low-low cluster (35.0% and 23.5%, respectively), suggesting that many remote rural neighbourhoods have experienced decreasing age diversity over time. The distribution of LISA clusters across urban-rural areas is shown in Supplemental Figure 4.

4 | Discussion

4.1 | Shifting Geographies of Ageing in Scotland: An Overview

Our results have shown how the spatial sorting by age of Scotland's population has changed between the 2011 and 2022 censuses. With regard to our first research question, we found that while most areas are experiencing an increase in the proportion of residents aged 65 and over, the changes in ageing are uneven across urban-rural geographies. As expected, remote and very remote rural areas saw the largest absolute increase in the proportion of the population aged 65 and over. While large urban areas saw a small absolute increase in the proportion of the older population, they also saw a decrease in the proportion of the older population relative to Scotland, suggesting that population ageing is not occurring to the same extent in these areas. These variations suggest a shift in the geographies of ageing. For research questions 2 and 3, using the Dissimilarity Index as a measure of age segregation, we found that age
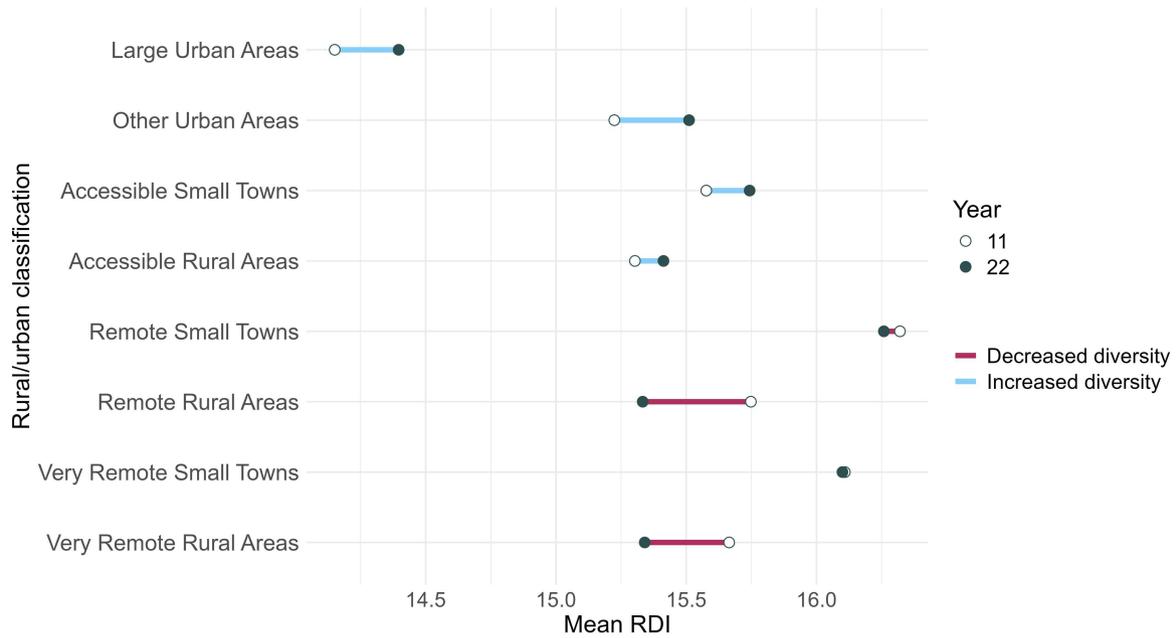
FIGURE 5 | Mean age diversity scores (RDI) of Data Zones within urban-rural categories, 2011–2022. Blue lines indicate increased age diversity, and red lines indicate decreased age diversity.
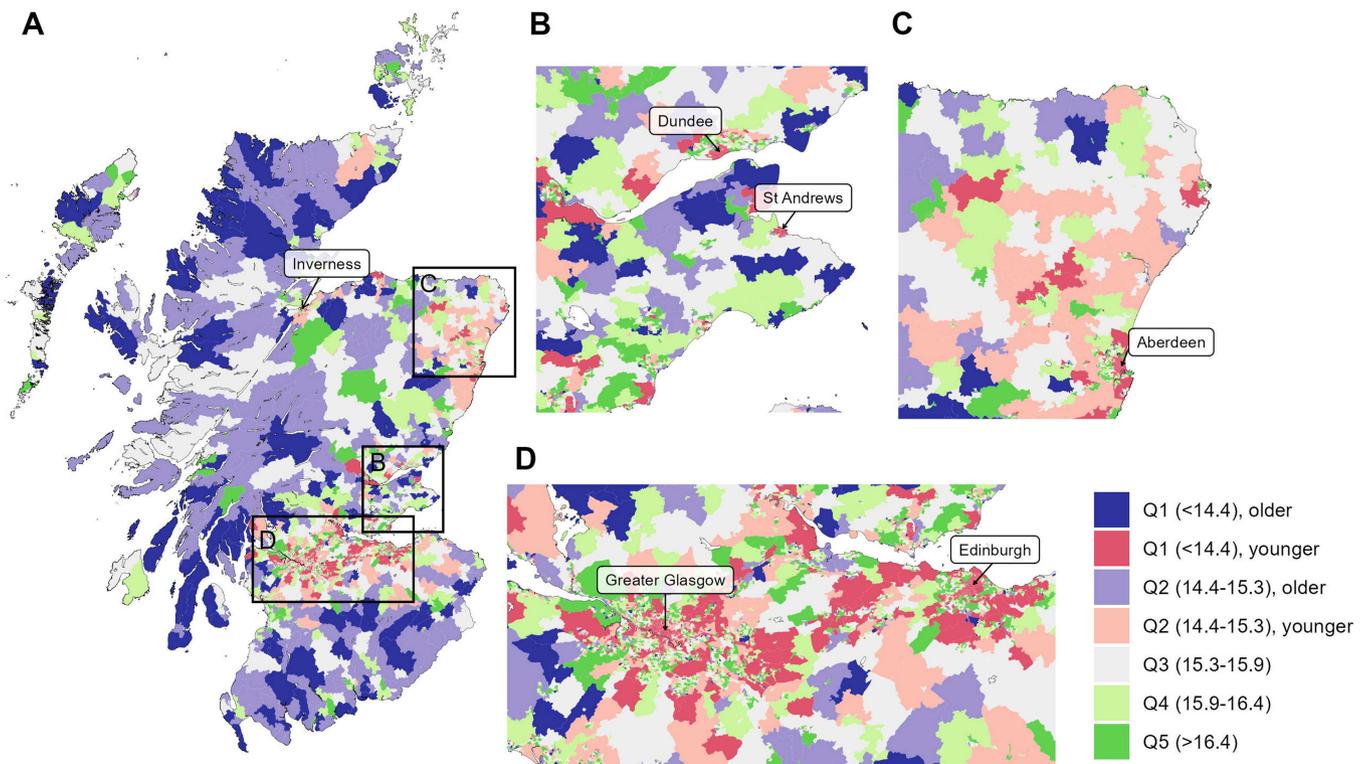

FIGURE 6 | Spatial distribution of age diversity (RDI) across Data Zones in Scotland (A), Fife and Tayside (B), Aberdeenshire (C) and the central belt (D), 2022.

segregation is highest in urban areas and lowest in very remote rural areas. The 'gradient' of age mixing across urban-rural areas is further confirmed by increases in the proportion of people living in 'older' neighbourhoods in all area types with the largest increases seen in (very) remote rural areas and the smallest increases in urban areas. Using the RDI, we found that age diversity is lowest in large urban areas and highest in

remote and very remote small towns, suggesting that people living in (very) remote small towns may experience greater integration across generations.

Our analyses to address research question 4 reveal that, in general, neighbourhoods in Scotland with similar values of age diversity change are located near to each other in space.
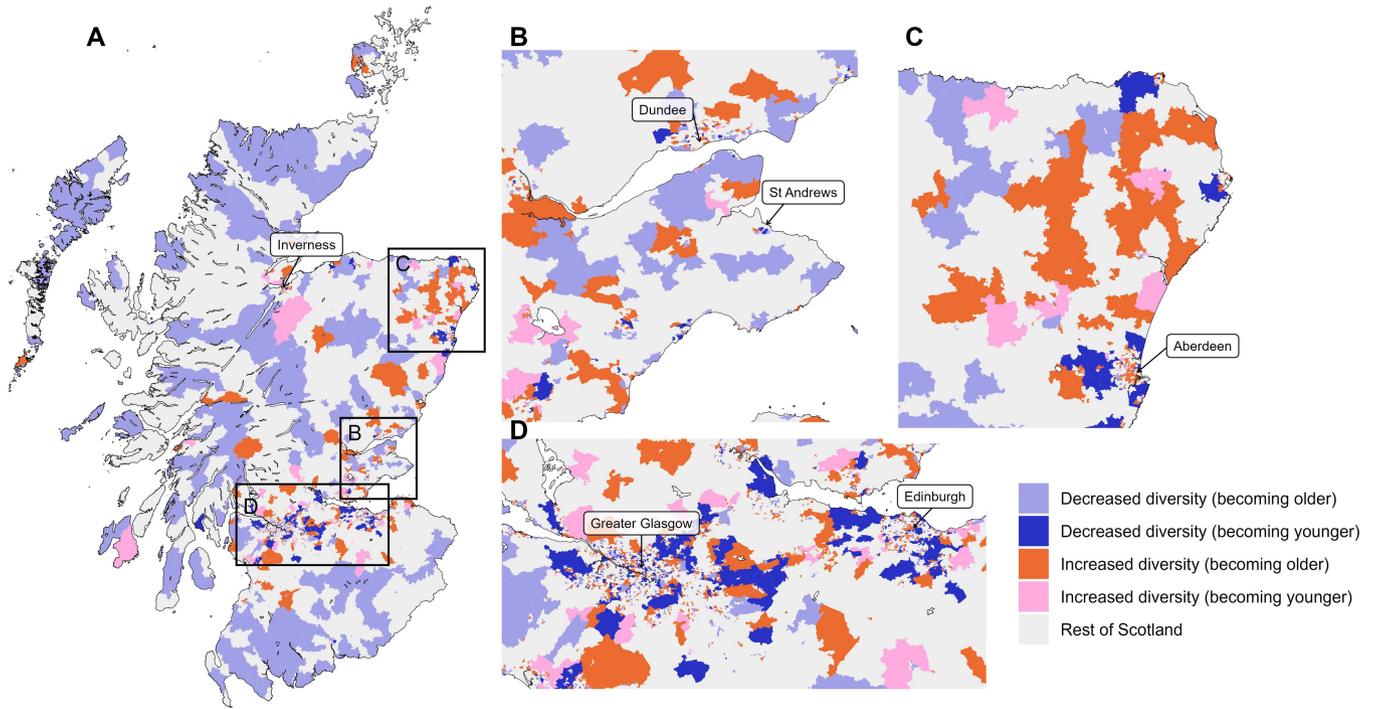
FIGURE 7 | Change in age diversity (RDI) and ageing (change in median age) across Data Zones in Scotland (panel A), Fife and Tayside (panel B), and the central belt (panel C), 2011–2022.
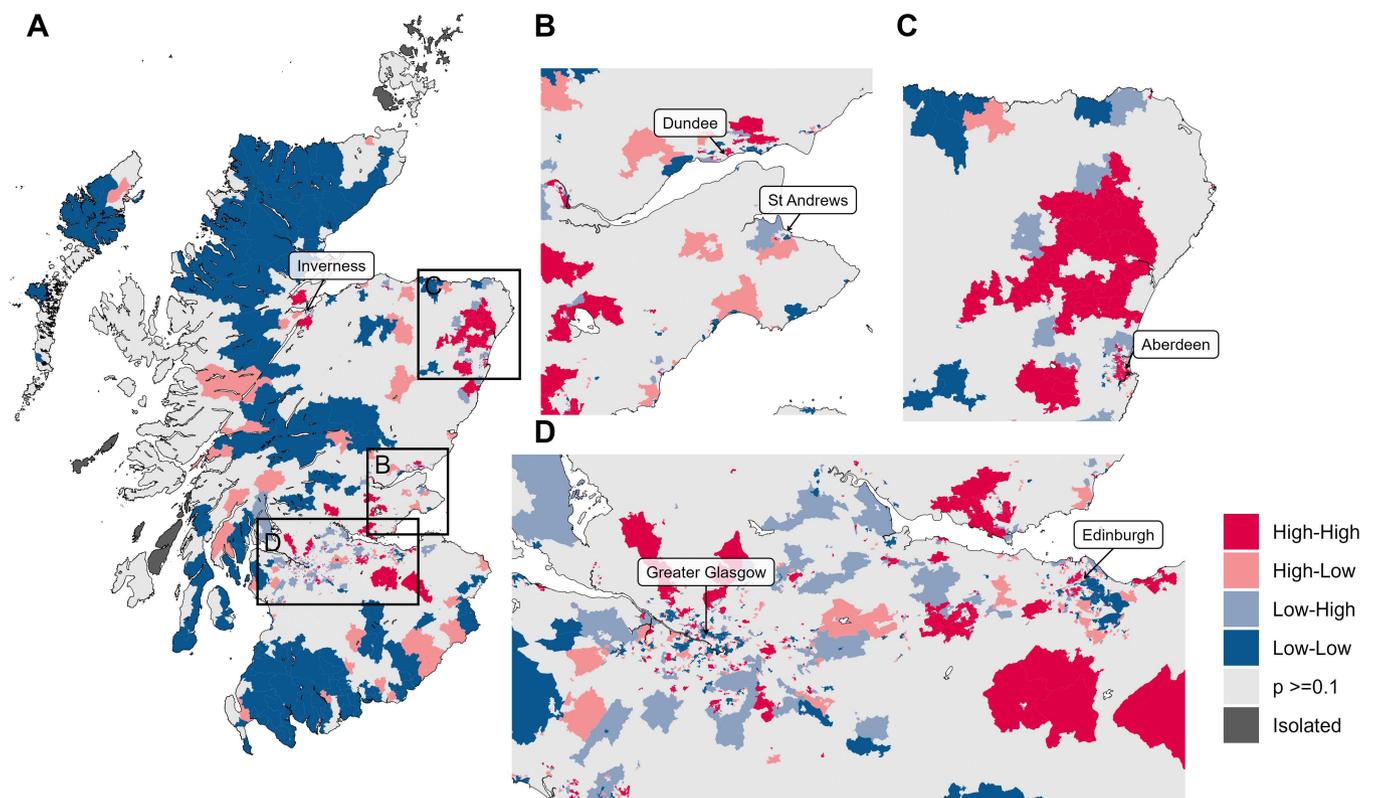

FIGURE 8 | Spatial distribution of local indicators of spatial autocorrelation (LISA) clusters of change in age diversity in Scotland, 2011–2022.

In particular, we see that very remote rural areas have large clusters of areas of decreased age diversity, which has implications for service provision and economic sustainability in these areas. In contrast, urban areas see pockets of decreased age diversity, but also areas with diverging trends compared to neighbouring areas (low-high or high-low), suggesting that these areas may be becoming more age-polarised over time.

4.1.1 | Patterns and Trends in Age Mixing in Urban Areas

Our analyses have shown that, in Scotland, large urban areas have a younger population distribution, higher age segregation, and lower average age diversity compared with other areas. In both large and other urban areas, there were small decreases in age segregation and increases in average age diversity over time. These findings concur with a study of age segregation in the US that found high age segregation in urban areas compared to rural areas which decreased over time (Das Gupta and Wong 2022). Decreasing age segregation and increasing age diversity in many urban areas suggests more opportunities for intergenerational interactions which could contribute to social cohesion and wellbeing in these areas (Buffel et al. 2012; Fang et al. 2023), as well as improving the resilience and sustainability of age-mixed urban communities (Buffel et al. 2014).

While the overall trends show decreased age segregation and increased age diversity over time, we find that there is an unevenness to the geographies of ageing and age mixing within urban areas. For example, a relatively large proportion of neighbourhoods in large urban areas saw decreased age diversity and a shift towards a younger demographic, while others saw increased age diversity and a shift towards an older demographic. These diverging trends suggest a polarisation between 'older' and 'younger' areas in some parts of cities, despite an overall decrease in age segregation. This is underscored by our analysis using local indicators of spatial autocorrelation, which reveal that neighbourhoods with increasing age diversity are often located adjacent to neighbourhoods with decreasing age diversity.

4.2 | Patterns and Trends in Age Mixing in Accessible Areas

The geographies of ageing of Scotland's urban areas must be interpreted in relation to their hinterlands; we suggest that it is the change in the accessible rural areas proximate to cities that is the lynchpin for understanding the local dynamics of age mixing in Scotland over the last decade. It is these areas in which age segregation is increasing most. Over the 2011–2022 decade, accessible rural areas saw a large increase in their share of Scotland's total population as well as a growing older population, suggesting a shift in migration dynamics into these areas. Accessible rural areas and small towns also saw small increases in age diversity over time, along with a decline in the proportion of neighbourhoods characterised by low diversity and younger age profiles. Interestingly, they also had the largest proportion of neighbourhoods that saw an increase in age diversity and became younger over time. However, there is a spatial mismatch between both measures in accessible rural areas: while these areas saw relatively small increases in age diversity, they also saw increases in age segregation, with accessible rural areas seeing the largest relative increase.

4.3 | Patterns and Trends in Age Mixing in Remote Areas

Small towns in remote and very remote areas have the highest age diversity levels of all urban-rural categories and were relatively stable between 2011 and 2022, suggesting that these towns have the least polarisation between young and old, which has not changed substantially over time, despite ongoing concerns regarding depopulation. Remote small towns also had lower age segregation levels compared to urban areas and accessible areas and saw small decreases in age segregation over time. However, although average trends in age diversity and age segregation are stable, many remote towns are experiencing significant population ageing and population decline, with many neighbourhoods seeing increased age diversity *and* increased median age between 2011 and 2022, which may be a result of lower fertility rates, changing migration patterns, and natural ageing in previously 'young' places (Jarzebski et al. 2021).

In contrast, many remote and very remote rural areas saw a decrease in age diversity in combination with an increase in median age, suggesting that the population of these areas has increasingly lower proportions of younger people and higher proportions of older people. People living in remote areas are more vulnerable to the effects of poverty or ill health due to poorer infrastructure (including public transportation) and services and increased risk of social isolation for people without community ties (Shucksmith et al. 2021). Furthermore, in areas that are losing population as a result of mortality and outmigration, shrinking of social networks and declines in service provision could increase the risk of frail older people becoming socially isolated (Abramsson and Hagberg 2018; Verma and Taegen 2019).

While remote and rural populations are experiencing significant population decline and ageing, they are also often areas of social cohesion and community belonging (Abramsson and Hagberg 2018). Despite our findings of decreasing age diversity in many rural areas, recent evidence suggests that older people living in remote rural areas in Scotland have a significantly higher age diversity in their social networks compared to older people living in urban areas (Long et al. 2024). Furthermore, people living in remote rural areas are less likely to report poor general health and loneliness compared to people living in urban areas, despite less frequent social interactions (Long et al. 2024).

4.3.1 | Demographic Drivers of Changing Geographies of Ageing

The complex patterns and trends of changing age geographies in Scotland that have been elaborated in this paper invite reflection on the demographic and social drivers of this population change. What is evident is that the interactions of the demographic drivers of neighbourhood population change – mortality, fertility and migration – interplay dynamically across the urban-rural system so as to shape new geographies of age and ageing. Scotland's distinctive population distribution with contrasting size and age structures of settlements in relatively close proximity provides an opportunity to reconsider models of population change with regard to age. It is beyond the scope of this paper to empirically investigate the causal drivers of changing geographies of ageing, but we recommend this for the focus of future research and offer some speculative interpretations as a starting point.

Scotland's changing geographies of ageing might be interpreted as a story of a lack of economic and social opportunities for

young people and families in remote areas driving out-migration with associated reduced fertility that consolidates population ageing. Additionally, retirement migration to affluent rural areas will compound the rate of population ageing in other remote areas (Stockdale and MacLeod 2013). Meanwhile, nearby remote small towns are maintaining their age structure and relative age diversity intergenerationally, replacing populations lost via out-migration through corresponding in-migration and family building. In contrast, accessible rural areas – those relatively proximate to major urban centres – are highly dynamic with changing age structures that point to new age-selective geographies of internal migration.

In many accessible areas, our findings suggest that increasing in-migration of younger people has resulted in neighbourhoods becoming younger with increased age diversity, while other areas with lower migration are becoming older with decreased age diversity, which would explain our findings of increased age segregation in these areas. This is supported by the LISA analysis, which found that a relatively high proportion of areas of increasing age diversity sit next to areas of decreasing age diversity in accessible rural areas. It may be that migration of younger adults and families into accessible rural areas is driven by rising housing unaffordability in desirable urban centres (Bailey et al. 2025). Increased internal migration to accessible rural areas, within commuting distance to many urban areas, may also reflect counterurbanisation trends post-Covid 19 (Halfacree 2024). Furthermore, the substantial rise in both population and age segregation in these accessible rural areas between 2011 and 2022 could be explained by new housing developments (Scottish Government 2025), which may attract mobile younger families seeking more space and affordability (Kulu and Milewski 2007).

Urban areas have similarly seen an uneven geography of age mixing over the last two decades that, despite decreasing age segregation overall, suggests a polarisation between 'older' and 'younger' areas in some parts of cities. We might interpret the hotspots of younger, older, and more/less age diverse neighbourhoods in urban and accessible areas as a form of hetero-localism (Zelinsky and Lee 1998). An outstanding question for research is how and why age-selective migration is creating these uneven geographies and spatial polarisation in urban and accessible areas, and how this reflects broader socio-spatial processes of urbanisation, gentrification, housing unaffordability, and cultural shifts in family structures (Bailey et al. 2017; Hochstenbach 2019; Moos 2016; Sabater and Finney 2023).

5 | Conclusion

This paper has addressed questions on the changing geographies of ageing and age mixing in Scotland using a variety of methods. The paper adds spatial nuance and a focus on ageing and age mix across urban–rural areas to the existing literature. Our results have demonstrated the spatial unevenness of ageing and age mixing which has implications for the demographic and social sustainability of communities in Scotland. Fang et al. (2023) highlighted the importance of co-creating sustainable intergenerational communities which reduce social distance across generations, encourage intergenerational knowledge

exchange to enhance social and economic sustainability, and enhance wellbeing by reducing loneliness and isolation within communities. Kaplan et al. (2017, p. 2) stated that "strong intergenerational relationships are not only at the root of healthy and productive aging; they are also an important component of sustainable and liveable societies." Additionally, young people who reside in rural areas are, like older residents, affected by the withdrawal of services, social stereotyping and, depending on the specific geography, social isolation and poverty (Glass et al. 2020). However, it is important to note that measuring the age-mix of local neighbourhoods does not tell us about the quality or quantity of intergenerational interactions; intergenerational communities emphasise the interactions between generations rather than solely living in proximity to one another (Kaplan et al. 2017). Future research, especially qualitative research, is essential for understanding how generations interact – the lived experience of age mixing – in neighbourhoods across urban–rural areas.

Our measures of population ageing and age diversity are based on chronological age and do not take into account the heterogeneity of ageing populations: many people in their 60 s and 70 s are healthy, active members of society, while others, especially within deprived populations, experience premature ageing at younger chronological ages (Crimmins et al. 2009; Yang and Lee 2010). Despite concerns about population dependency and economic and demographic sustainability, ageing populations do not necessarily imply lack of sustainable development and can represent a valuable social resource. Many older people contribute actively to their communities, including through volunteering activities (Matthews and Nazroo 2021; Yarker et al. 2020). However, there are also many groups of older people, particularly those living in deprived areas, who age at a faster rate and may be less able to engage in their communities and sustainability initiatives. This raises concerns about addressing inequalities in ageing and demographic change in deprived communities.

Despite these limitations, this paper reveals spatial patterns that cause us to rethink typical understandings of ageing and the urban hierarchy, particularly high age segregation in urban areas, age mixing in rural areas, and mixed findings in accessible areas. For population sustainability, it is very rural areas that are of concern: despite being relatively age-mixed the trend is for decreasing diversity, demographic ageing, and ongoing population decline. To promote age mixing and social sustainability, it is the urban areas and (pockets within) their hinterlands that need attention due to high levels of age segregation. Further work needs to understand the drivers of these demographic dynamics particularly in terms of age-selective internal migration patterns and housing dynamics, as well as undertaking research that explores the value of intergenerational communities in terms of health and wellbeing and lived experiences of intergenerational interactions.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Scottish census data from 2011 and 2022, and 2011 Data Zone boundaries are publicly available from the UK Data Service (https://statistics.ukdataservice.ac.uk/).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.
Supporting Information