# Briefing: What do 'left behind' areas look like over time?

Developing place-based typologies of left behind areas

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## Take away messages

- Left behind neighbourhoods tend to be found in more peripheral, less dense locations away from employment centres.
- *Noncentral neighbourhoods* and *noncentral mixed neighbourhoods* are the most common land use/cover classes in left behind neighbourhoods, accounting for more than 50% of all neighbourhoods.
- Much of the change in land use and cover mix took place between 2000 and 2006, very little from 2012 to 2018.
- Distinctive patterns of change prevail in pre-existing urban spaces expanding or reducing residential spaces in non-central residential neighbourhoods, developing parks in existing residential neighbourhoods, and repurposing of non-central areas for industrial and commercial use.
- The incidence of transformations taking place in rural space within the left behind areas is greater compared to the top 10% most deprived areas, particularly processes of agricultural diversification and rural urbanisation.
- Localised industrialisation happening at lower rate in left behind areas than seen in 10% most deprived areas.

## Introduction

Research from OCSCI and the Local Trust establishes that relative to other similarly deprived areas, 'left behind' neighbourhoods fare worse on a range of social and economic outcomes, including rates of unemployment, ill health and child poverty. But why is that? Specific to the 'left behind' neighbourhoods are a lack of places to meet, the absence of an engaged and active community, and poor connectivity to the wider economy, both physical and digital (Local Trust, 2019). These characteristics that distinguish 'left behind' neighbourhoods from other similarly deprived areas offer targets for policy interventions to halt any further processes compounding the experience becoming left behind while improving local outcomes.

But this is only part of the picture, a static snapshot of key aspects of left behind neighbourhoods including socioeconomic attributes, community assets and local infrastructure. Though invaluable in distinguishing left behind areas from other similarly deprived places at one point in time, the existing typology lacks temporal detail. It does not reveal the context in which socio-economic processes that lead to an area becoming 'left behind' take shape, nor does it establish whether there are enduring features of place common to 'left behind' areas. To better support policy initiatives working within left behind areas, we need to both understand the nature of the places, and their historical context and developmental path.

Satellite-derived data provides an opportunity to explore and visualise how places have changed over time. When produced consistently, we can see whether and how places evolve, tracking stability and change in the composition of land use and land cover. Land use and cover are important in the context of left behind neighbourhoods as they help identifying shared local features of the built environment and how it is used. For example, satellite technology can help us parse the components of the built environment that enhance

social interaction, better connectivity or higher productivity. It can also be a powerful tool in understanding temporal trajectories that will allow us to design better policies.

Features of the built, physical, social and economic environment coalesce to create the context in which an area either is or is not left behind. The typologies presented here, focussing on the birds-eye view of the built and physical environment afforded by satellite data, offer new insights into what it means to be a 'left behind' neighbourhood, and therefore new evidence to inform policy interventions.

# Methods

We develop two place-based typologies[1]. The first (static typology) classifies areas according to their land use and land cover at four points in time: 2000, 2006, 2012 and 2018. The second (trajectory typology) classifies areas according to how they have changed over time, from 2000 to 2018, building on the first typology. The classifications are developed for lower super output areas (LSOAs) across England. We focus on experiences of the left behind areas, but also draw out commonalities and differences relative to the 10% most deprived areas in England according to the Index of Multiple Deprivation, and England as a whole.

## Data

The typologies are based on satellite-derived data classifying land use and land cover. CORINE, an open data product made available by the European Space Agency, defines a range of 44 land use classes within five broad groups: artificial surfaces; agricultural areas; forest and seminatural areas; wetlands; and water bodies. We used a subset of CORINE, restricted to the types of classes found in England (37 in total). This varies, spanning classes defined by features such as the type and density of buildings present, transport networks, and extent and type of green space. CORINE data are transferred to LSOA geographies for England, creating a table that contains a row for every English LSOA at each point in time, and a column for each land use/cover class observed. The values in the table correspond to the proportion of a given class in each area in a given year.[2] For example, an LSOA might have 20% given over to land use type 1, and 80% to land use type 2, etc.

## Developing a static classification of land use and cover

We used a K-means clustering algorithim to create our static typology of places, a classification of land use and land cover at LSOA level across England. Cluster analysis allows us to group places (e.g. LSOAs) according to specified characteristics (e.g. the mix of land use / cover in that LSOA) such that differences within the clusters are small. The resulting typology identifies 12 clusters that encompass all LSOAs in England over the four periods considered. Each cluster represents a neighbourhood class. We explored different typologies with different number of clusters, using extensive experimentation and clustergrams – a graphical device to help differences within clusters, to establish the most meanginful number of clusters for this typology – before arriving at the preferred solution with 12.

## Identifying representative trajectories

The second typology identifies trajectories of change within LSOAs in England over time using sequence analysis. This captures transitions of LSOAs between the neigbourhood classes identified in the static classification described above (see Appendix E: Sequence analysis for additional details). Sequence analysis seeks to identify similar series of transitions between statuses (e.g. neighbourhood class) by measuring their similarity based on a technique known as optimal matching (we used the Dynamic Hamming Matching algorithm (Lesnard, 2010)). Clustering methods, such as those used to create the static classification, can then be used to group sequences according to how similar they are. Here we used a Partitioning Around Medoids (PAM) clustering algorithm, settling on 11 clusters as the most meaningful way to characterise change in LSOAs land use and cover over time. The sequence analysis was based on a subset of LSOAs (9,136) that changed at least once between land use and cover classes over the four years included in the analysis (i.e. 2000, 2006, 2012 and 2018). LSOAs that remained in the same land use and cover class were excluded to enable identification of patterns of change over time.

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[1] Final typologies and code available here: https://doi.org/10.5281/zenodo.4650398
[2] This table is also available as part of the package of deliverables.

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# Results

## Static neighbourhood classes of land use and cover

The (static) classification produced 12 neighbourhood classes that characterise the main trends in land use and cover across all LSOAs in England over the last two decades. An interactive map is provided here which displays the spatial distribution of each of the neighbourhood classes for each point in time. Each class has been assigned a name that represents its most distinctive characteristics, namely: neighbourhoods with parks (3.9% of all LSOAs), neighbourhoods near countryside (5.2%), mixed countryside (3.5%), agricultural land (8.5%), dense central neighbourhood (3%), non-central neighbourhoods (39.7%), industrial and commercial neighbourhoods (4.2%), rural neighbourhoods (4.8%), non-central mixed neighbourhoods (13%), pastures (5.5%), farmlands (6.1%), and neighbourhoods nearby golf and other leisure (2.4%). A detailed description of each neighbourhood class, together with a map of England highlighting its geographical distribution and "sky portraits" (representative satellite images of areas in the class) is available in Appendix A: Static Classification – Pen Portraits. Appendix B: Static Classification – Class proportions, breaks down each of the final clusters according to their composite land use and cover. Table 1 presents the distribution of LSOAs in each class for the four years considered. Appendix D: Static Classification – LSOA Concentrations (discussed below), contains equivalent visualisations considering only the subset of all English LSOAs labelled as 'left behind' and those in the top 10% of deprivation.

*Table 1. Neighbourhood class (cluster) proportions across years for all LSOAs*

| | 2000 | 2006 | 2012 | 2018 |
|---|---|---|---|---|
| Agricultural land | 0.098 | 0.082 | 0.081 | 0.079 |
| Dense central neighbourhoods | 0.027 | 0.030 | 0.031 | 0.031 |
| Farmlands | 0.037 | 0.070 | 0.069 | 0.068 |
| Industrial and commercial neighbourhoods | 0.030 | 0.044 | 0.047 | 0.047 |
| Mixed countryside | 0.062 | 0.026 | 0.025 | 0.025 |
| Neighbourhoods near countryside | 0.047 | 0.055 | 0.054 | 0.053 |
| Neighbourhoods nearby golf & other leisure | 0.021 | 0.025 | 0.026 | 0.026 |
| Neighbourhoods with parks | 0.039 | 0.040 | 0.039 | 0.038 |
| Noncentral mixed neighbourhoods | 0.134 | 0.127 | 0.129 | 0.130 |
| Noncentral neighbourhoods | 0.400 | 0.396 | 0.395 | 0.399 |
| Pastures | 0.061 | 0.055 | 0.053 | 0.053 |
| Rural neighbourhoods | 0.044 | 0.051 | 0.050 | 0.049 |

The class that includes the largest proportion of LSOAs is n*oncentral neighbourhoods*, which covers residential urban areas outside city centres; followed by n*oncentral mixed neighbourhoods*, a similar class located outside centres but still inside cities that also incorporates uses other than residential. The prominence of these classes declines slightly after 2006 but rebounds in the last decade. The third most popular class is *agricultural land*, with a much smaller share of LSOAs which, over time, consistently declines from 9.8% to 7.9%. A number of other interesting trends were identified. First, the consistent increase of *dense central* and *industrial/commercial neighbourhoods*; and second, the apparent jump in *farmlands* from 2006 to 2012, mirrored by drops in *mixed countryside* and *pastures*. Others, such as *neighbourhoods with parks* remain stable over the period considered. The overall picture is one of continuing urbanisation by densification and growth at the edges of cities, converting more previously undeveloped land into developed, either built or used for agriculture.

## Difference and similarity

Table 2 compares the distribution of neighbourhood classes within England (LSOA), left behind neighbourhoods (LBA) and the 10% most deprived areas (IMD). Given the concentration of some left behind areas around the coast, it also compares coastal areas (Coastal) to left behind neighbourhoods on the coast (Coastal LBA). For the purposes of this analysis, coastal areas are defined as those within 10km of the shoreline. The table combines all LSOAs across all time points. Each column reflects the proportion of LSOAs across neighbourhood classes.

*Noncentral neighbourhoods* and *noncentral mixed neighbourhoods* are the most common classes, collectively accounting for more than 50% of all neighbourhoods. For a break down by year, see Tables C.1- C.4 in Appendix C: Static Classification – LSOA concentrations by geography and year.

*Table 2. Neighbourhood class (cluster) distribution within England (LSOA), Left Behind Areas (LBA), 10% most deprived areas (IMD), Coastal areas (Coastal), and left behind Coastal areas (Coastal LBA), 2000, 2006, 2012 and 2018 combined*

| | LSOA (131376) | LBA (5872) | IMD (13132) | Coastal (56132) | Coastal LBA (2820) |
|---|---|---|---|---|---|
| Agricultural land | 0.085 | 0.044 | 0.017 | 0.069 | 0.043 |
| Dense central neighbourhoods | 0.030 | 0.010 | 0.050 | 0.049 | 0.019 |
| Farmlands | 0.061 | 0.017 | 0.004 | 0.050 | 0.023 |
| Industrial and commercial neighbourhoods | 0.042 | 0.057 | 0.084 | 0.041 | 0.068 |
| Mixed countryside | 0.035 | 0.031 | 0.020 | 0.031 | 0.039 |
| Neighbourhoods near countryside | 0.052 | 0.039 | 0.032 | 0.037 | 0.027 |
| Neighbourhoods nearby golf & other leisure | 0.024 | 0.020 | 0.016 | 0.026 | 0.022 |
| Neighbourhoods with parks | 0.039 | 0.061 | 0.062 | 0.043 | 0.054 |
| Noncentral mixed neighbourhoods | 0.130 | 0.162 | 0.165 | 0.124 | 0.165 |
| Noncentral neighbourhoods | 0.398 | 0.486 | 0.516 | 0.450 | 0.483 |
| Pastures | 0.055 | 0.017 | 0.009 | 0.043 | 0.010 |
| Rural neighbourhoods | 0.048 | 0.056 | 0.025 | 0.039 | 0.048 |

Comparing trends for *all* LSOAs to those of left behind neighbourhoods and otherwise deprived areas (Tables D.1 and D.2 in Appendix D) also yields important insights. The first characteristic to note is that, compared to the full set of English LSOAs, left behind neighbourhoods are over-represented in *noncentral (mixed), industrial and commercial and rural neighbourhoods*, as well as those *with parks*; and under-represented in *pastures, farmlands, dense central neighbourhoods* and those with *golf & other leisure* or *near the countryside*. Compared to the 10% most deprived areas, left behind neighbourhoods contain more *rural neighbourhoods*, those *with golf and other leisure, near the countryside, mixed countryside, farmlands, pastures* and *agricultural land*; but notably *less industrial and commercial* and *dense central* neighbourhoods. Overall, the exercise suggests that left behind neighbourhoods tend to be found in more peripheral, less dense locations away from job opportunities.

## How have land use and cover changed in neighbourhoods?

We identified 11 main patterns of long-term change between 2000 and 2018, summarised below. Figure 1 shows the ways in which LSOAs have transitioned between neighborhood classes of land use and cover. An interactive map is provided [here](#) which displays the spatial distribution of these trajectories. Appendix E reports the transition rates for each land use and cover between each pair for all LSOAs in England, left behind neighbourhoods and non-left behind neighbourhoods.

**Rural Urbanisation (9.5%):** urbanisation in rural areas. It predominantly involves former areas of agriculture and mixed countryside classes becoming rural neighbourhoods.

**Diversifying Countryside (3.1%):** countryside diversification. Areas in this cluster predominantly transitioned from being a designated agricultural space dominated by pastures to becoming mixed countryside.

**Suburbanisation (10.5%):** urbanisation for areas of, or near to, agriculture or mixed countryside transitioning to residential neighbourhoods. These areas are largely located on the periphery of urban areas.

**Agricultural Diversification (16.6%):** agricultural land use classes in areas of specific agricultural purpose - pastures or non-irrigated arable land - transitioning to areas of varied agricultural usage.

**Leisure Space Creation (3.8%):** designation of leisure space, namely golf courses, in former non-central, residential areas near parks or agricultural land.

**Localised Industrialisation (8.4%):** establishment of industrial or commercial hubs in non-central urban areas.

**Green Urbanisation (5.3%):** transition of non-central urban areas to neighbourhoods near parks. These involve areas with a large share of green urban areas, namely recreational parks or other accessible green spaces.

**Increasing Agricultural Land (5.4%):** the reversal of the "Agricultural Diversification" trajectory. It predominantly involves areas of varied agricultural use becoming specific areas of non-irrigated arable land.

**Diversifying Non-central Neighbourhoods (18.1%):** transition within residential areas outside of city centres. It describes the diversification of such areas, with non-central neighbourhoods becoming non-central mixed neighbourhoods. This pattern tends to represent an expansion of local land use from being mainly devoted to urban fabric uses to incorporate areas dedicated to industrial and commercial, green space and agricultural uses.

**Consolidating Non-central Neighbourhoods (12.6%):** the reverse of the "Diversifying Non-central Neighbourhoods" trajectory: non-central mixed neighbourhoods transitioning to non-central neighbourhoods. This pattern seems to represent an increase of residential land use in non-central urban areas.

**Pasture Intensification (6.8%):** transition of mixed countryside and varied agricultural land to pastures.

The trajectories reflect distinctive patterns in the geographical structure of change in land use and cover across England. First, four representative trajectories of change – *diversifying non-central neighbourhoods, agricultural diversification, consolidating non-central neighbourhoods and suburbanisation* - characterise over 57.7% of all land use and cover across England. Second, the spatial structure of land use and cover seems to have progressed into a spatial equilibrium of stability, with a remarkable incidence of change occurring between 2000 and 2006. The incidence of change has declined over time, with a very small number of transitions occurring between 2012 and 2018.

Third, distinctive patterns of change are observed to prevail in pre-existing urban spaces. These include non-central residential neighbourhoods being repurposed to host a wider set of non-residential activities (i.e. *diversifying non-central neighbourhoods)* as well as the reverse pattern; that is, non-central neighbourhoods becoming increasingly dominated by residential spaces *(consolidating non-central neighbourhoods).* Another pattern taking place in pre-existing urban areas is the addition of parks in existing residential neighbourhoods (*green urbanisation)* as well as the repurposing of non-central areas for industrial and commercial use *(localised industrialisation).*

Fourth, these trajectories taking place in pre-existing urban spaces differ from those which have occurred in pre-existing rural areas. Some of these trajectories featuring prominently in pre-existing rural spaces capture the expansion of existing urban settlements (e.g. *suburbanisation* and *leisure space creation*) or development of new urban spaces (*rural urbanisation*). Others capture the repurposing of pre-existing rural spaces for agricultural activities (*increasing agricultural land*), pastures (*pasture intensification*) or a variety of uses (*diversifying countryside and agricultural diversification*).
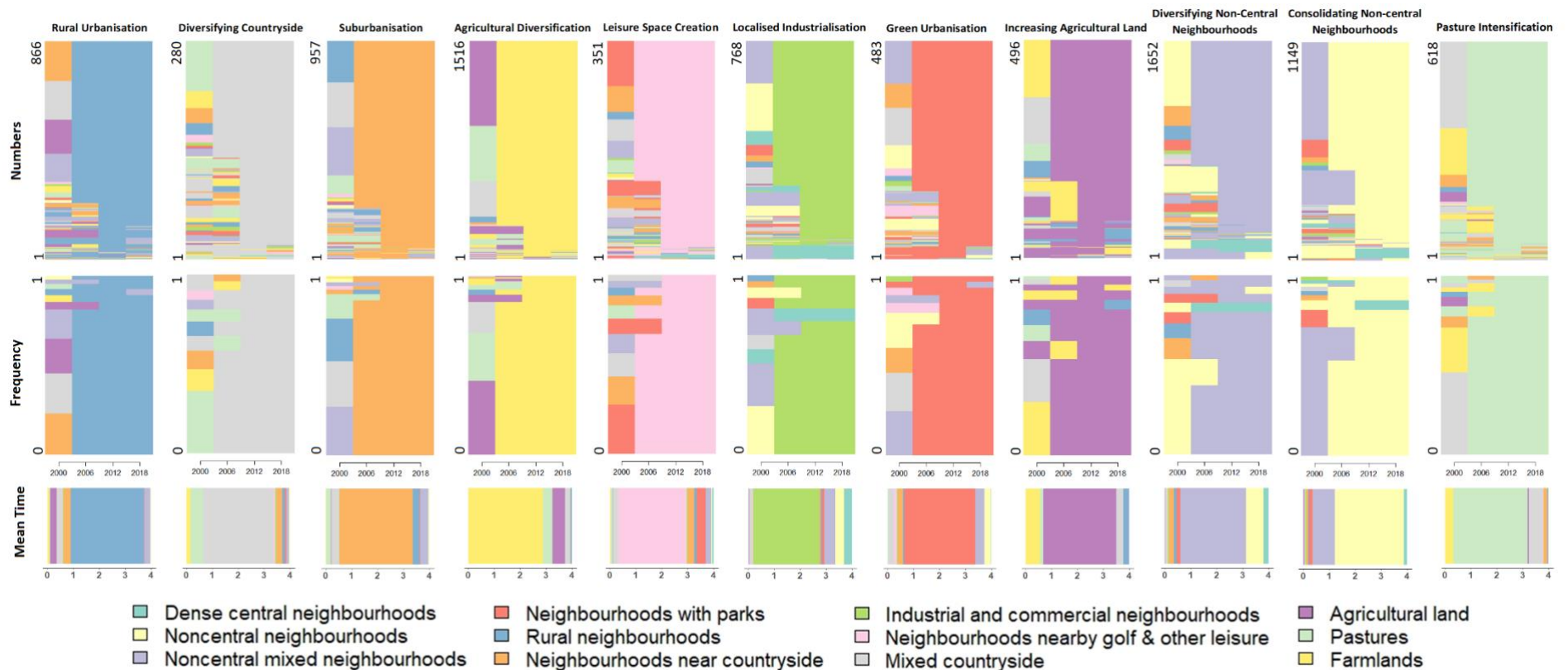
*Figure 1. Representative neighbourhood trajectories*

Note: The legend colour scheme identifies 11 representative types of neighbourhoods. Panels from the top to bottom: First panel. Each horizontal line represents an individual trajectory of neighbourhood from 2000 on the left to 2018 on the right i.e., transition between each land use and cover class cluster. The x-axis labels show the years (2000, 2006, 2012 & 2018). Second panel. Each year-specific vertical bar represents the number of areas in each land use and cover class in a given year. Third panel. The bars represent the mean time (or number of years) spent in each land use and cover class cluster.

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Figure 2 displays the incidence of our set of trajectories in left behind neighbourhoods. It reveals that four trajectories prevailed more strongly in the left behind neighbourhoods, accounting for 64.5% of all land use and cover changes in these areas. These trajectories predominantly capture the repurposing of non-central neighbourhoods for residential space (*consolidating non-central neighbourhoods),* a mixed of uses *(diversifying non-central neighbourhoods*) or particularly targeted for industrial and commercial use (*localised industrialisation*) as well as the urbanisation of pre-existing rural spaces (*rural urbanisation*).
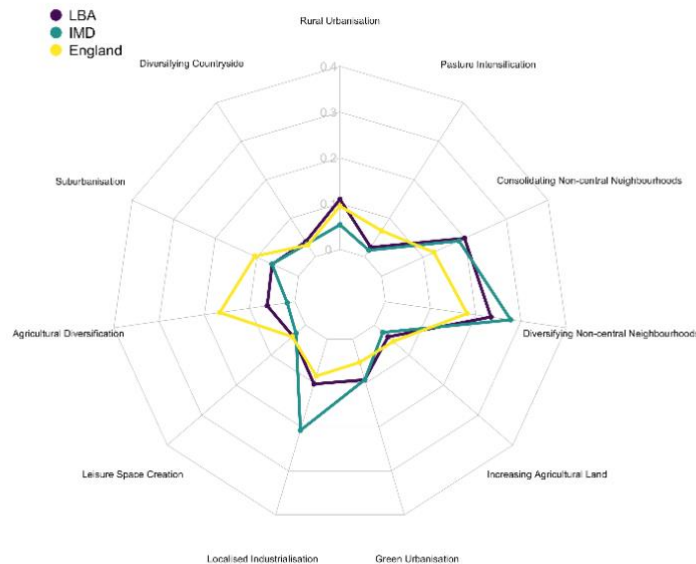


*Figure 2. Share of neighbourhood trajectories by type of area, England, Left Behind Neighbourhoods (LBAs) and Top 10% most deprived areas based on the Index of Multiple Deprivation (IMD)*

Figure 2 also reveals key differences in the incidence of trajectories between left behind neighbourhoods and the top 10% most deprived LSOAs in England. The incidence of transformations taking place in rural space within the left behind areas is greater compared to the top 10% most deprived areas, particularly processes of *agricultural diversification and rural urbanisation.* Left behind neighbourhoods display rates of *agricultural diversification* 3.6 times that of the top 10% most deprived areas. At the same time, while trajectories of *diversifying non-central neighbourhoods* and *localised industrialisation* in left behind neighbourhoods are over-represented in relation to the national average, they feature less prominently than in top 10% most deprived areas. These findings point to a less intensive rate of industrialisation and diversification of land use in pre-existing non-central neighbourhoods across LBAs.

## Concluding remarks

Left behind areas are characterised not only by deprivation, but also by a lack of places to meet, the absence of an active and engaged community, and a lack of connectivity to the digital and physical economy. Though geographically dispersed, the similarities in conditions and outcomes are suggestive of similarities in the processes by which those neighbourhoods are left behind, and indeed the context in which those processes play out. Yet existing typologies used to identify left behind neighbourhoods lack the spatial or temporal detail which would speak to either of those processes or that context.

The context in which people are (or are not) able to meet, in which an active and engaged community might emerge, or which enables connectivity to the economy (digital and physical), results from the interaction not only between the social and economic, but also the physical and built features of a place. We focus on the latter two, developing two place-based typologies to paint a bespoke "birds-eye" picture of the stability and change in left behind neighbourhoods. To be 'left behind' implies a process: drawing out the similarities and differences in the experiences of left behind neighbourhoods relative to elsewhere in England offers critical insights into the

nature of that process. It also supports identification of appropriate policy levers that may prevent other areas becoming left behind, and to , improve local outcomes in areas already classed as 'left behind'.

Our research suggests that, relative to similarly deprived areas, left behind neighbourhoods are urban and residential, yet tend to be found more on the periphery. They are relatively more rural than the 10% most deprived areas with various structures of land use including spaces with golf and other leisure, near the countryside, mixed countryside, farmlands, pastures and agricultural land. This greater degree of rurality may help explain why social, economic and health outcomes are found to vary between left behind neighbourhoods and similarly deprived areas. That left behind areas are relatively more rural than the 10% most deprived areas is suggestive of the importance of differences in connectivity to the economy, whether digital or physical, which may vary depending on the nature of urban areas. This pattern also raises questions as to potential investment in local infrastructure and community assets that may be lacking and thus constraining the emergence of an active and engaged community.

As expected, we observed far more stability than change in the land use and cover within places. Places are slow changing entities. Noticeable changes in the physical appearance of places occur over a long sweep of time. Yet, we considered a compressed period of change. Most of the change observed happened between 2000 and 2006, perhaps indicative of the wider socio-economic context and differences in fiscal constraints on planning, development and policy. Of the left behind areas that did see change, the land use and cover trajectories differed from those of the 10% most deprived areas. Left behind rural areas were more likely to see a process of agricultural diversification and rural urbanisation than rural areas in the 10% most deprived of areas. Left behind neighbourhoods in rural areas displayed a less intensive rate of industrialisation and diversification of land use in pre-existing non-central neighbourhoods.

The policy implications of these different experiences of change all point to the importance of evaluating the nature of and access to local labour markets, and the provision of community and social infrastructure within increasingly residential areas. Specifically, our typologies suggest that left behind areas tend to be concentrated in noncentral residential neighbourhoods. This raises questions for their connection and access to employment, as well as access to public transport infrastructure and urban amenities more generally. It is notable that the temporal detail provided in the two typologies presented complement existing work conceptualising 'left behind' areas, drawing out the context in which left behind places may find themselves with fewer places to meet and with fewer opportunities for an engaged and active community to emerge (e.g. noncentral residential areas). Our results are supportive of efforts to move towards a 20-minute neighbourhood mode – where key services and amenities required to meet everyday needs are located within a 20-minute walk, cycle or local public transport trip of their home (Sustrans, 2020). Such an approach would require planning strategies explicitly consider the availability of local services, amenities and transport networks when considering new residential developments. Similarly, the typologies are illuminating as to the context in which connectivity to the wider economy may vary relative to other similarly deprived areas, such as through different paces of localised industrialisation.

The typologies we have created, when combined with existing data on the social, economic and health outcomes of left behind areas, also pave the way for future research. The typologies enable questions like:

- How do health, social and economic outcomes vary within left behind areas by neighbourhood class?
- Are particular land use and land cover trajectories more likely to lead to less or more favourable outcomes?
- Do health, social and economic outcomes vary between left behind areas characterised by change versus stability?
- Are non-left behind deprived areas who change in neighbourhood class at risk of becoming 'left behind'?

Combining the temporal detail provided in the typologies presented here with existing data such as the Community Needs Index will provide the opportunities to address these sorts of questions. This will help establish which kinds of areas need priority intervention; and whether and to what extent different policy responses may be needed in different types of left behind area.

# References

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Code and typologies available here: https://doi.org/10.5281/zenodo.4650398

# Appendix A: Static Classification – Pen Portraits

The following (12) pages present a "pen portrait", an individual description of the most salient characteristics, of each of the 12 clusters developed as part of the static classification. Each pen portrait is laid out as follows: first a short paragraph provides a description of the cluster; then six "sky portraits", satellite images focusing on the extent of representative LSOAs in the cluster and arranged along with a map of England that displays the geographical extent of the areas in the cluster (coloured in red).

# Cluster I - Neighbourhoods with parks (3.9% of all LSOAs)

This class is made up of "discontinuous urban fabric" (51%) and "green urban areas "(42%). It tends to be located in urban areas of larger cities outside their centres. Areas in this class include mostly residential zones with direct access to urban parks. Their distribution closely matches the location of large cities across England.

# Cluster II - Neighbourhoods near countryside (5.2% of all LSOAs)

This class is made up almost exclusively of a "discontinuous urban fabric" (49%) and "pastures" (41%). This represents areas outside cities (villages, small towns) or on their peripheries with direct contact with the countryside. The geographical distribution tends to avoid eastern England due to the smaller proportion of pastures in the area.
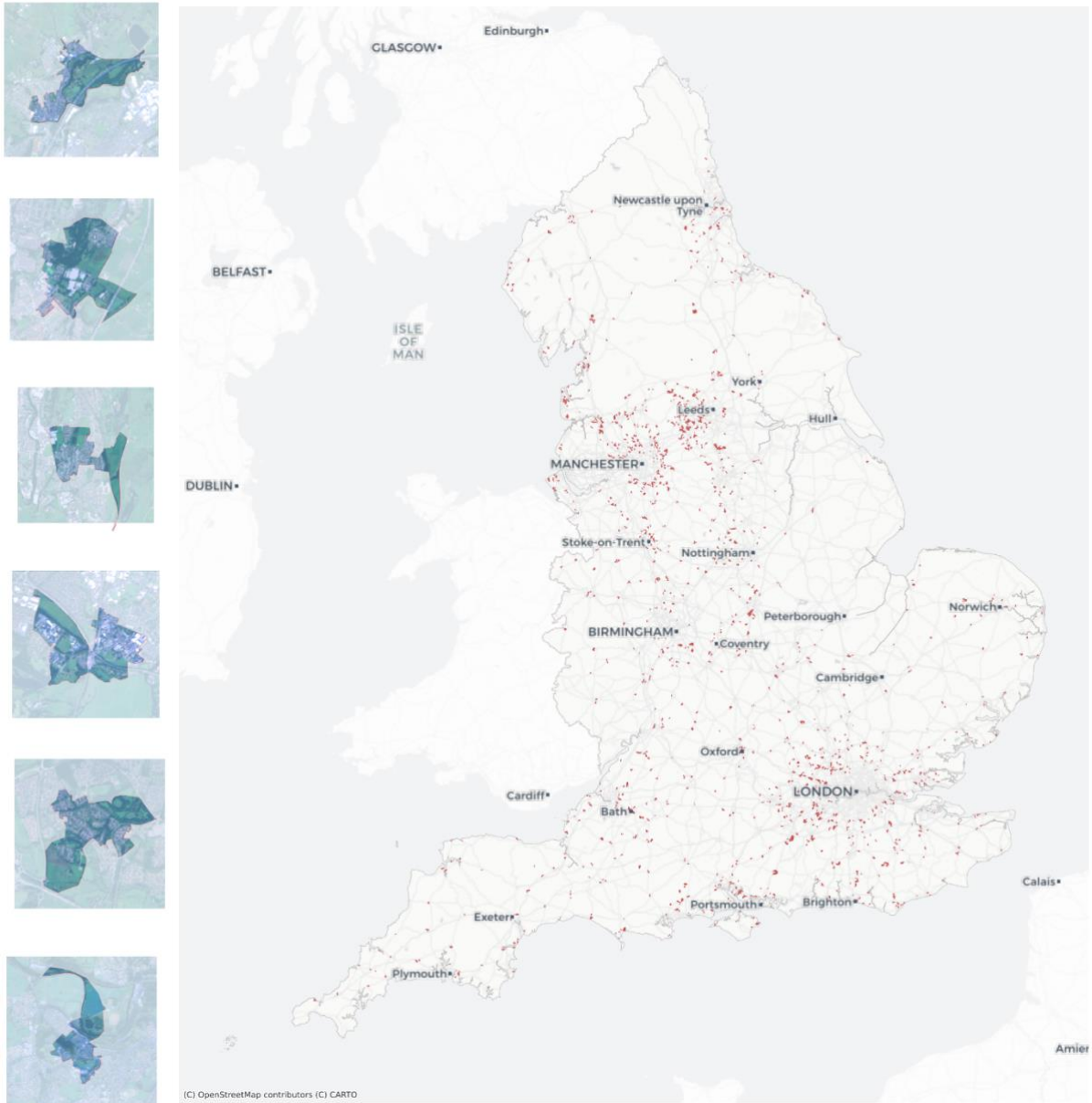
## Cluster III - Mixed countryside (3.5% of all LSOAs)

This class is made up of a wide variety of natural land uses that don't feature any built environment. It contains one of the lowest proportions of "discontinuous urban fabric" (18%) and non-negligible proportions of uses related to the countryside: "pastures" (13%), "complex cultivation patterns" (8%), "forest" (20%), "grassland" (8%), and "moors" (5%). Because of this mix, it encompasses several natural areas that are protected (e.g. Lake District, Peak District).
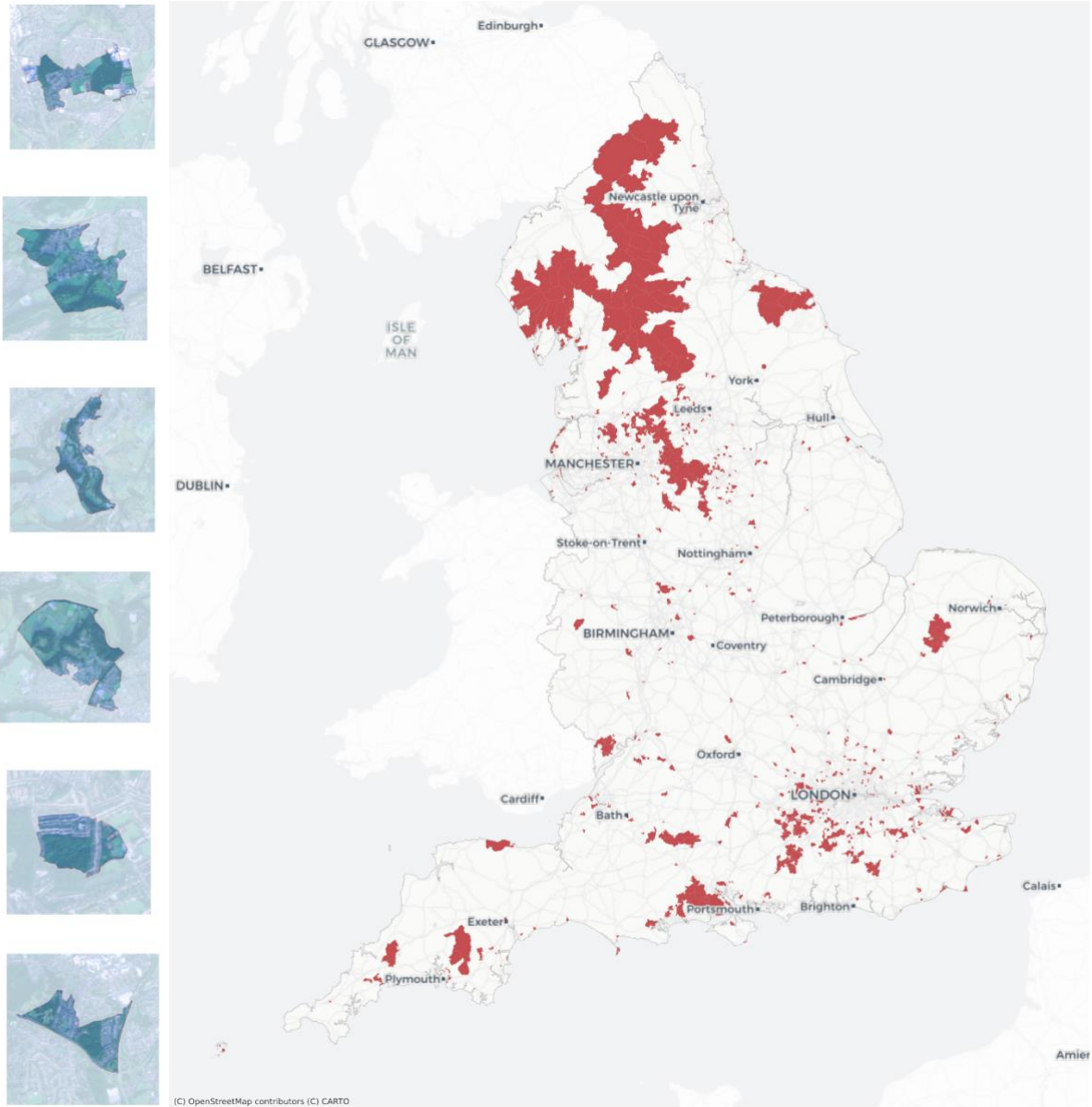
## Cluster IV - Agricultural land (8.5% of all LSOAs)

This class is made up of at least three fourths (77%) of "non-irrigated arable land" with a small component of "pastures" (7%). It represents areas outside of cities, beyond their periphery. The overall geographical distribution reflects the topographical characteristics of the English landscape with overconcentration of this class in the eastern part of the country.
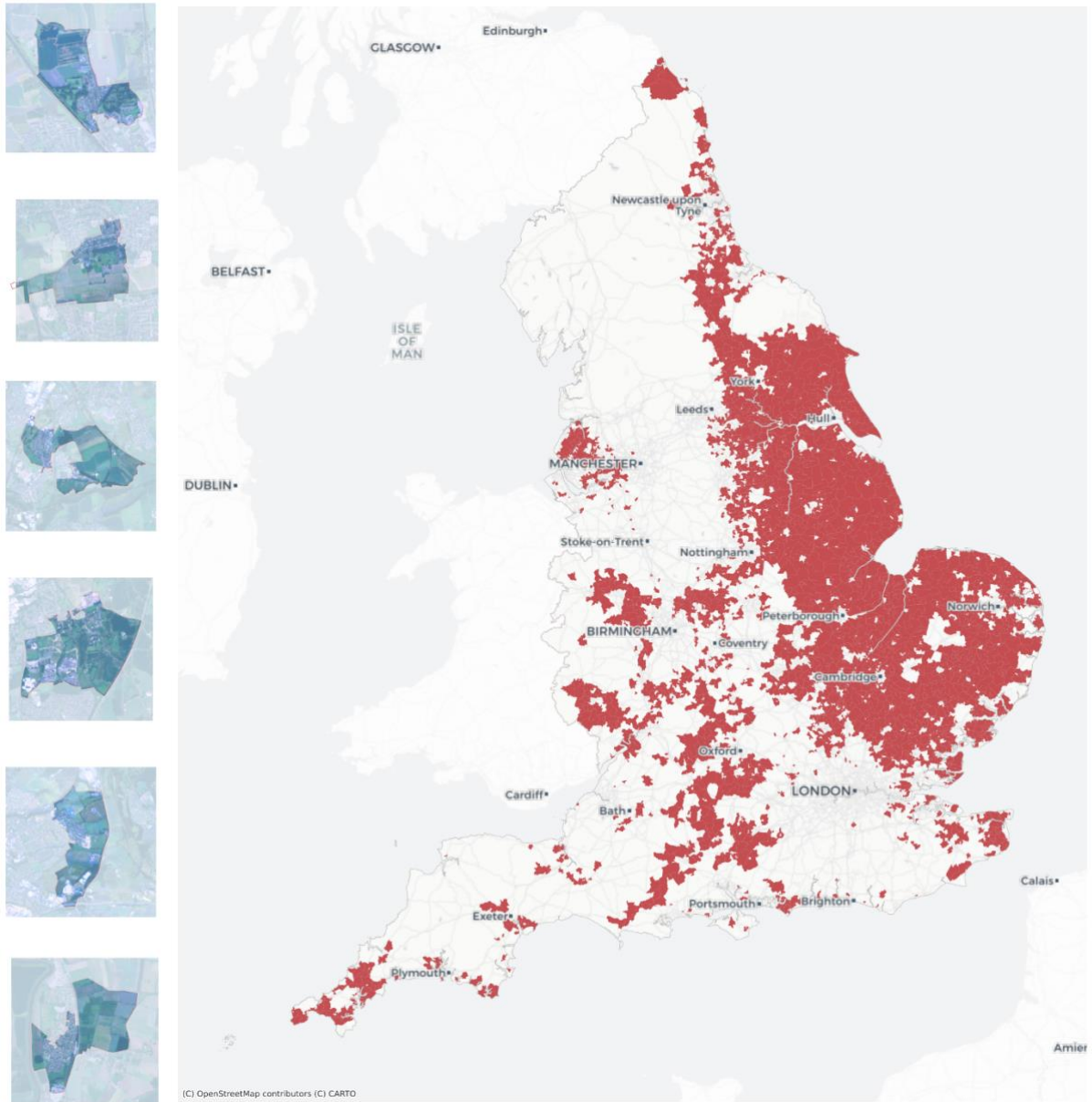
## Cluster V - Dense central neighbourhoods (3% of all LSOAs)

This class is made up almost entirely of "continuous urban fabric" (77%) with bits of "discontinuous urban fabric" (19%). These represent city and town centres. Their distribution is aligned with the overall distribution of cities across England. Within them, these areas represent the most compact and dense parts.
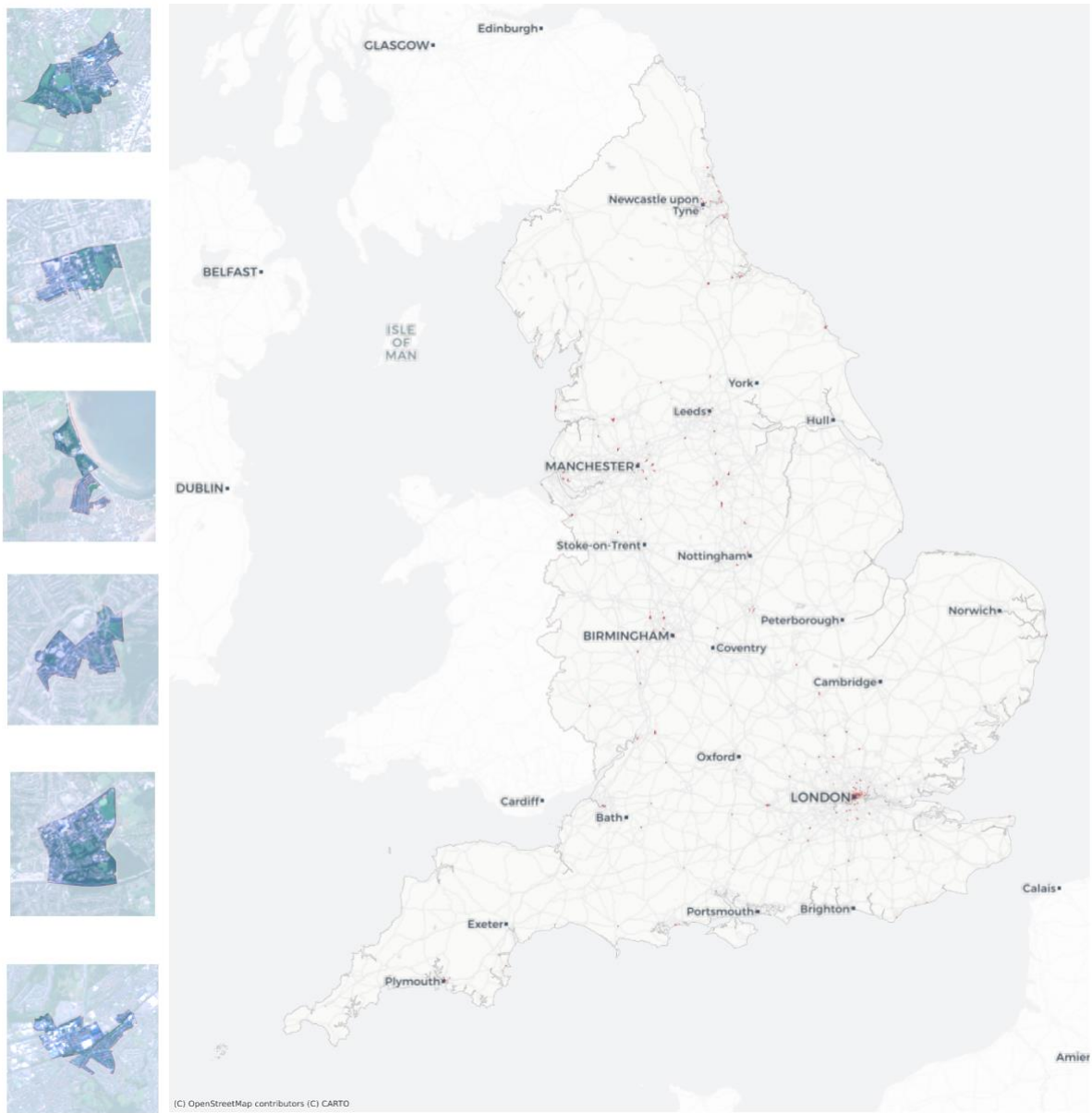
## Cluster VI - Noncentral neighbourhoods (39.7% of all LSOAs)

This class is made up almost entirely of "discontinuous urban fabric" (98%). These are urban areas located within city boundaries that are outside city centres. Their nature is predominantly residential and thus constitutes the class where most of the population lives.
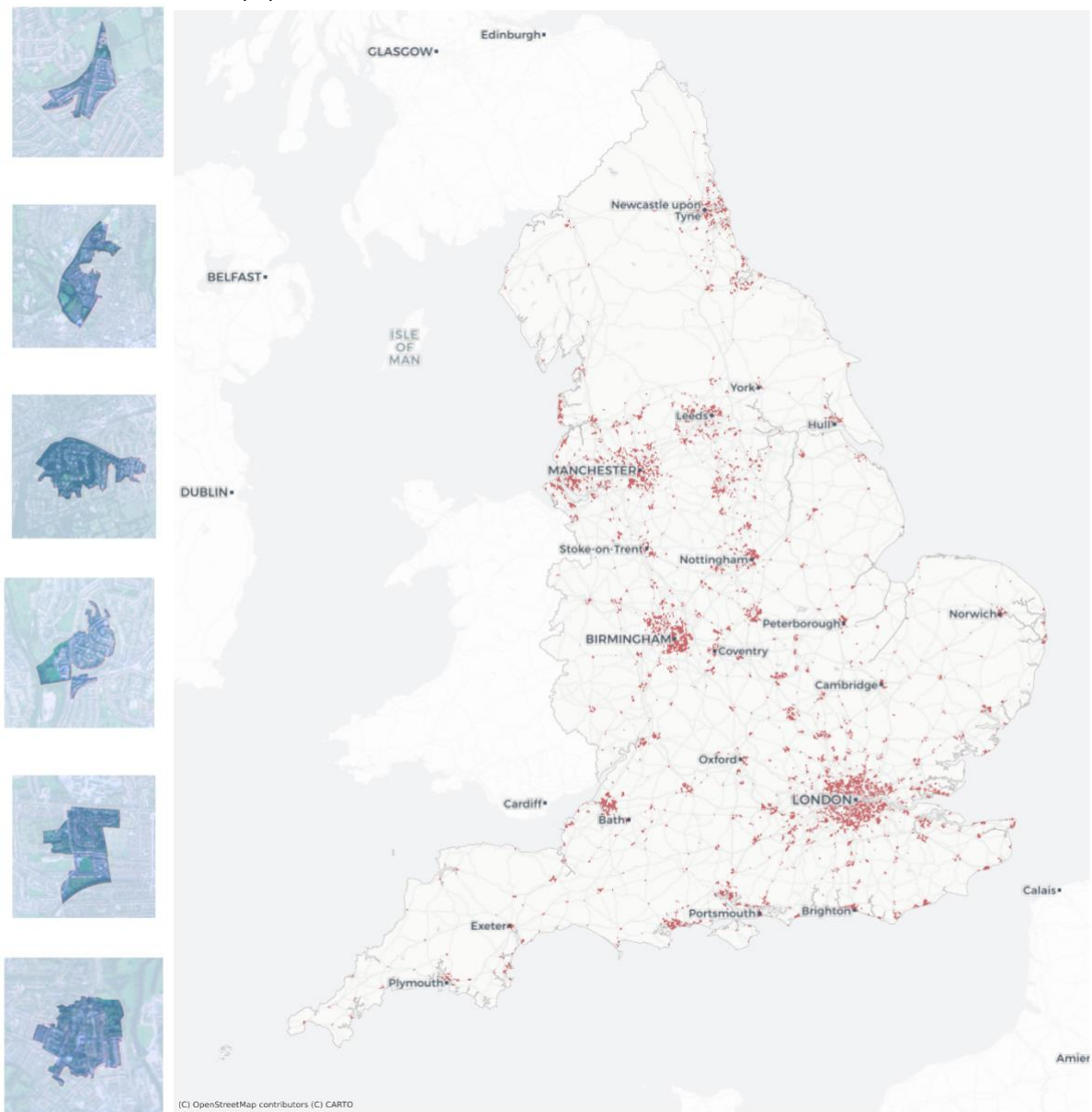
# Cluster VII - Industrial and commercial neighbourhoods (4.2% of all LSOAs)

This class is made up of "industrial and commercial units" (53%) and "discontinuous urban fabric" (32%). These areas represent major industrial hubs and commercial areas composed of large buildings located on peripheries of cities along the main transport corridors or port areas. These areas are found in most cities across England with no further specific pattern.
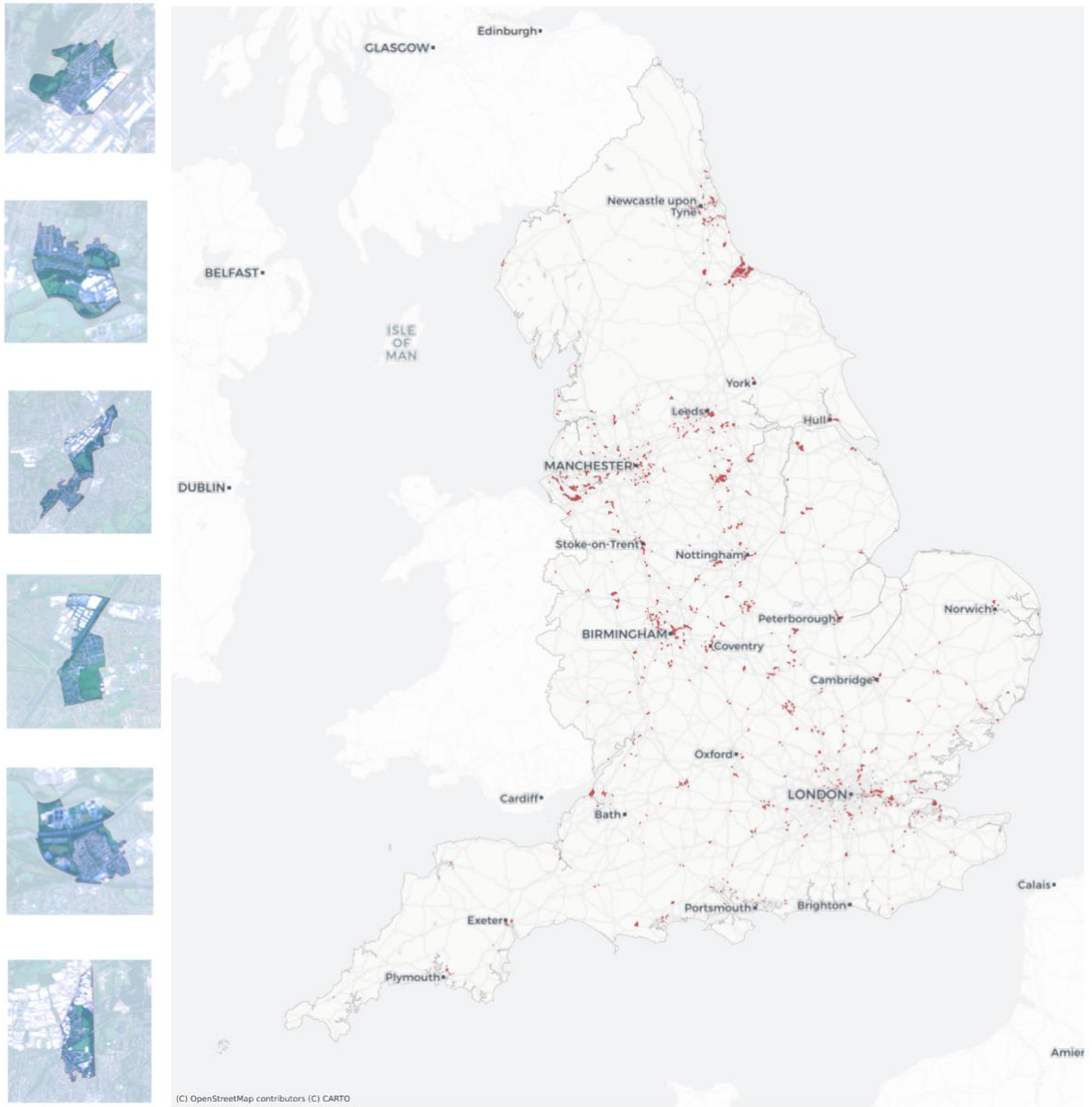
# Cluster VIII - Rural neighbourhoods (4.8% of all LSOAs)

This class is made up of "discontinuous urban fabric" (45%) and "non-irrigated arable land" (43%). These areas are located outside cities in the countryside. They represent rural agricultural development. This class is more often found in eastern England, where the majority of English arable land lies.
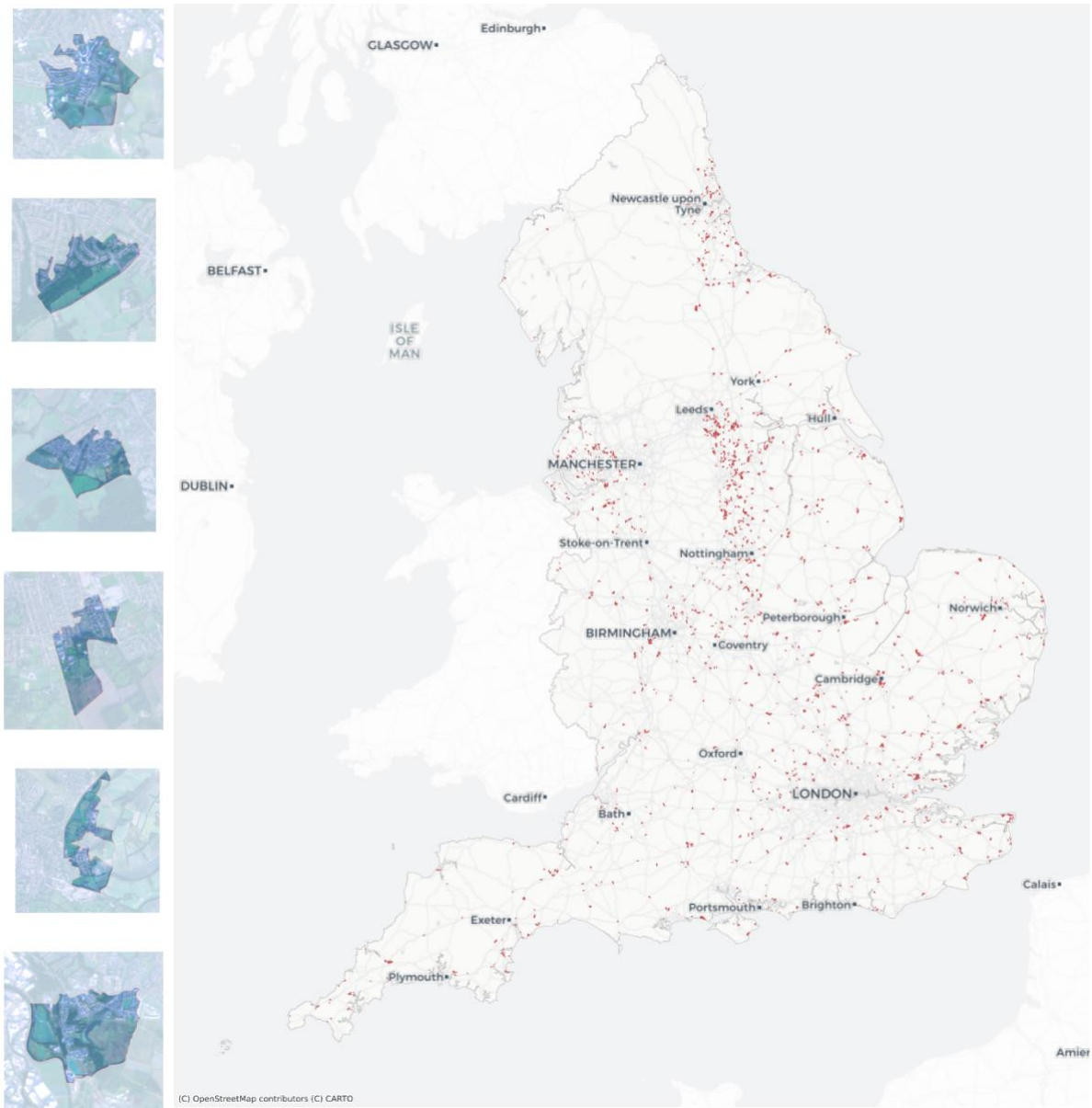
## Cluster IX - Noncentral mixed neighbourhoods (13% of all LSOAs)

This class is made up of "discontinuous urban fabric" (73%) with small proportions of other land cover classes: "continuous urban fabric" (4%), "industrial and commercial units" (4%), "green urban areas" (3%), "pastures" (4%) and "arable land" (3%). These areas represent predominantly residential neighbourhoods outside of city centres with a mixture of other uses. The geographical distribution closely matches the distribution of urbanized areas across England.
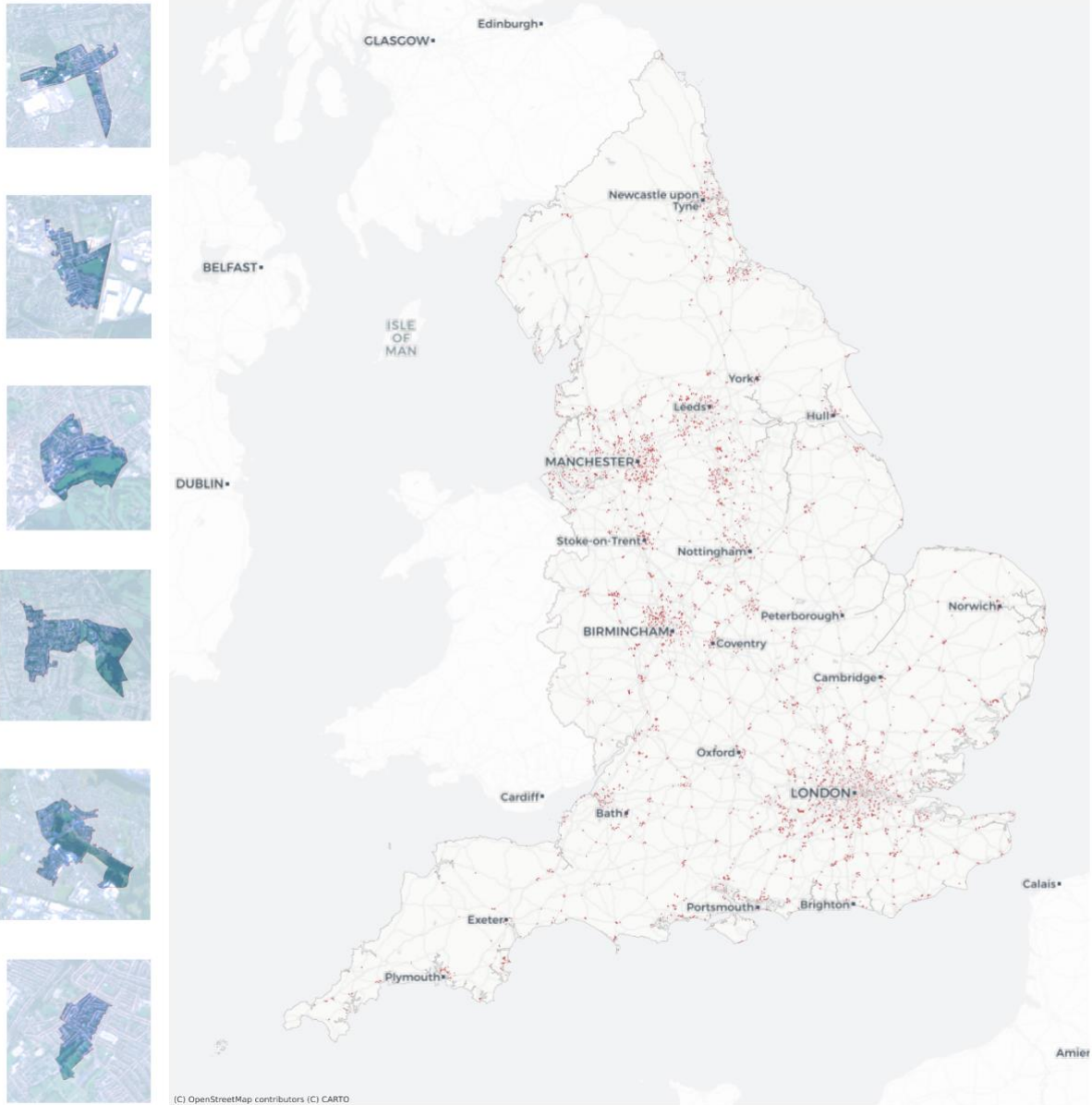
## Cluster X – Pastures (5.5% of all LSOAs)

This class is made up of "pastures" (67%) and contains a low proportion of "discontinuous urban fabric" (11%). The areas represent rural neighbourhoods on the west and south of England surrounded by pastures and similar types of green areas.
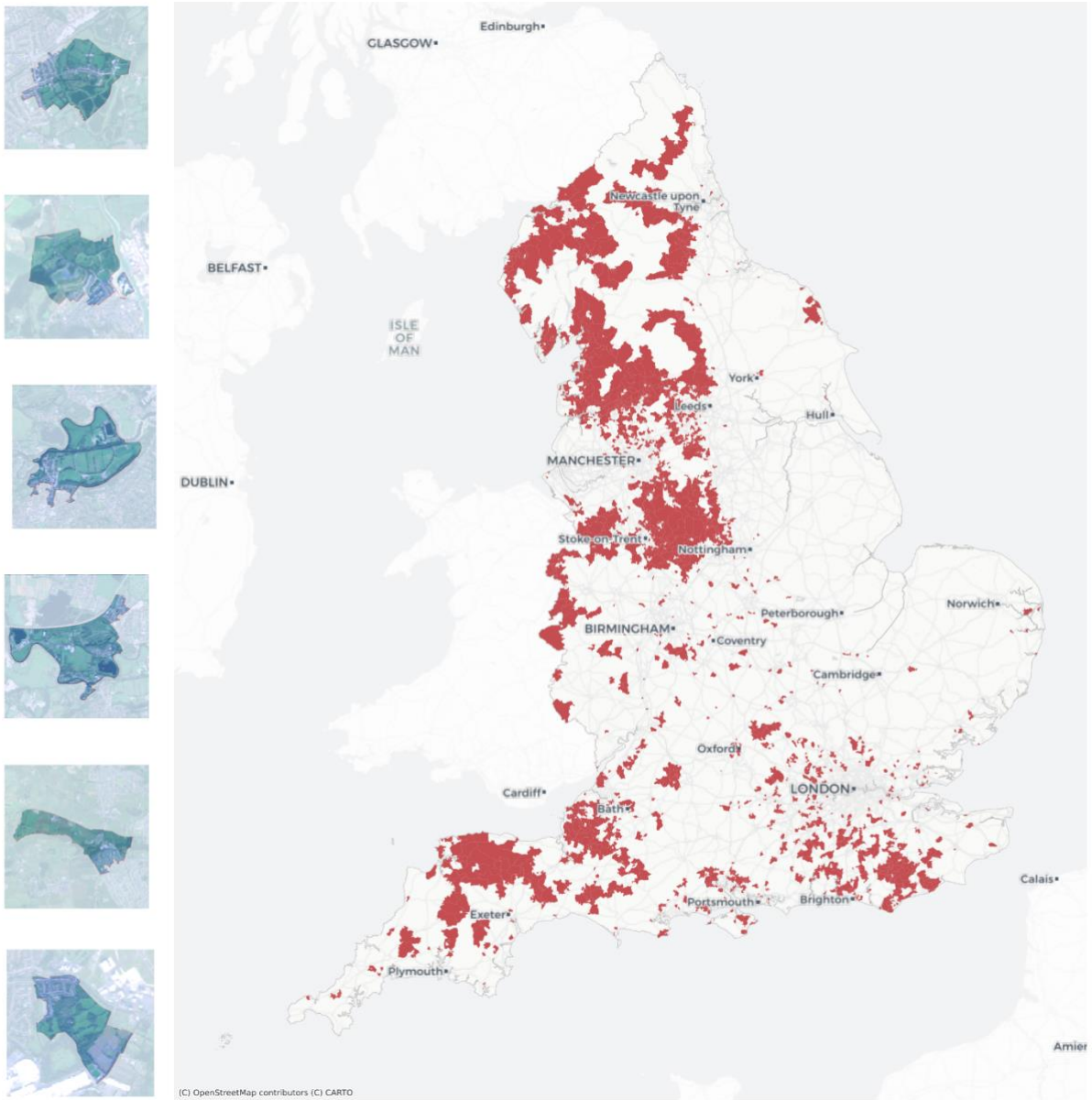
## Cluster XI – Farmlands (6.1% of all LSOAs)

This class is made up of "arable land" (44%) and "pastures" (34%), with a very small proportion of "discontinuous urban fabric" (8%). These areas represent the countryside outside of main cities with mixed agriculture. The geographical distribution tends to be dominant in south and west of England.
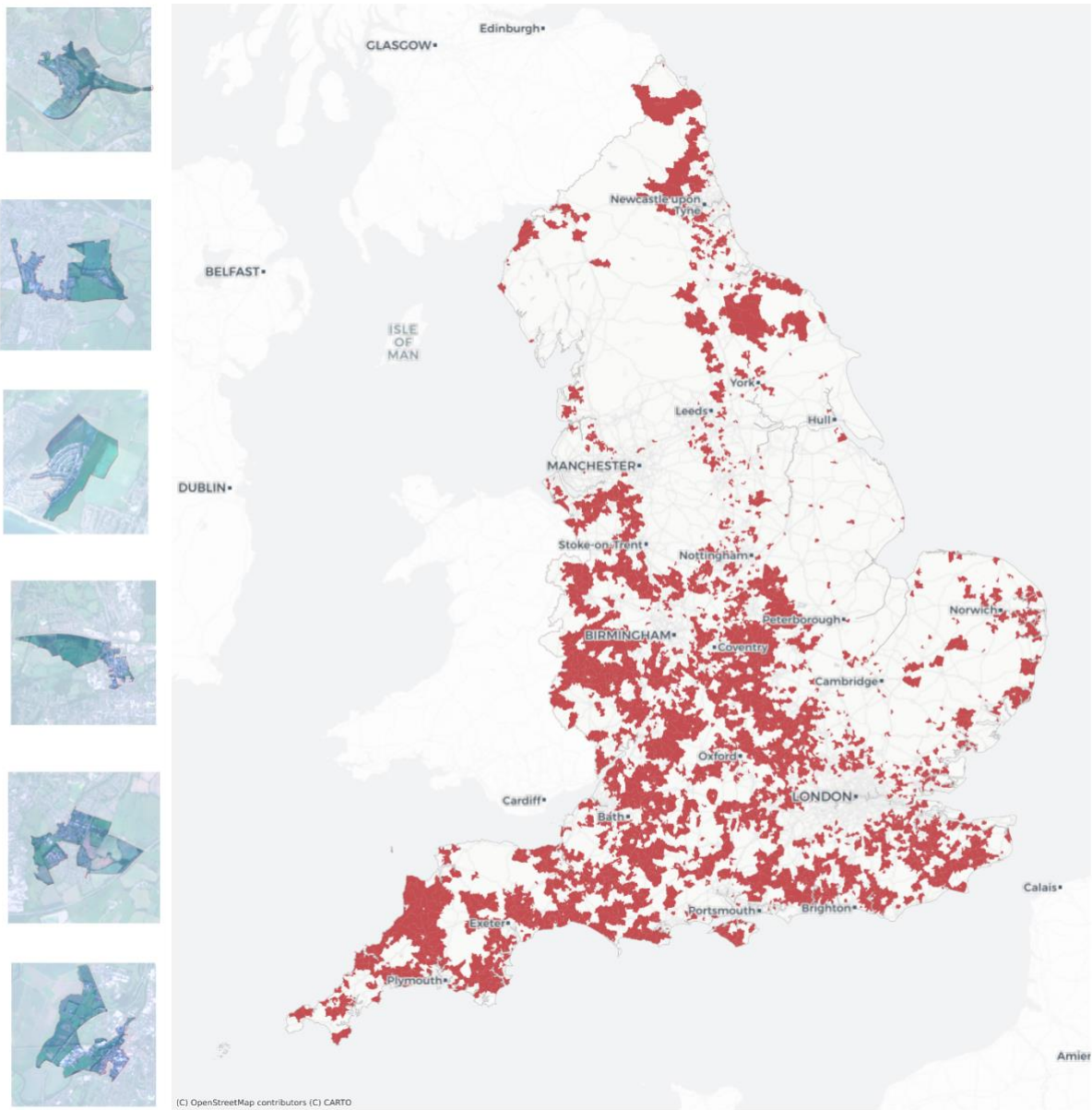
## Cluster XII - Neighbourhoods nearby golf & other leisure (2.4% of all LSOAs)

This class is made up of "discontinuous urban fabric" (41%) and "sport and leisure facilities" (44%). These areas represent (residential) urban development adjacent to golf courses or other types of sports facilities like playing fields, mostly in peripheral areas of cities. The overall geographical distribution closely matches the distribution of cities and towns across England.
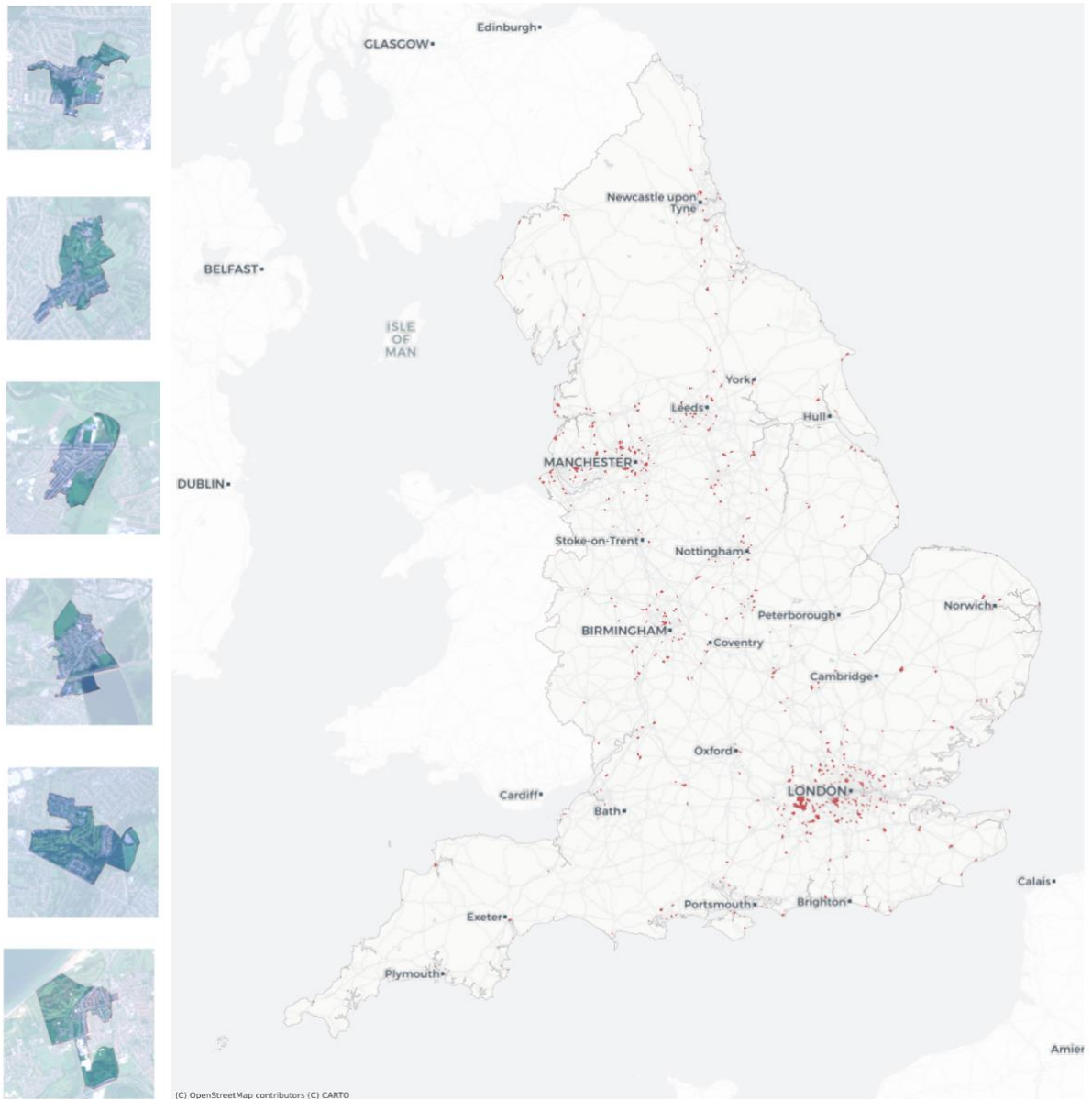
# Appendix B: Static Classification – Class proportions

The coloured table (heatmap) below presents the proportions of original CORINE land-use/cover classes that each cluster displays. On the vertical axis (rows), each class from CORINE found in England is represented, while the horizontal axis (columns) contains the 12 clusters identified in the static classification. The values in the table represent the proportion of a given class in a given cluster. Such values are also encoded in a colour gradient with darker blues representing higher concentrations of a given class in a particular cluster.

*Table B.1 CORINE land use and cover classes, by neighbourhood class*

| | Neighbourhoods with parks | Neighbourhoods near countryside | Mixed countryside | Agricultural land | Dense central neighbourhoods | Non-central neighbourhoods | Industrial and commercial neighbourhoods | Rural neighbourhoods | Non-central mixed neighbourhoods | Pastures | Farmlands | Neighbourhoods nearby golf & other leisure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Continuous urban fabric | 0.01 | 0.00 | 0.00 | 0.00 | 0.77 | 0.00 | 0.02 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 |
| Discontinuous urban fabric | 0.51 | 0.49 | 0.18 | 0.07 | 0.19 | 0.98 | 0.32 | 0.45 | 0.73 | 0.11 | 0.08 | 0.41 |
| Industrial or commercial units | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.00 | 0.53 | 0.02 | 0.04 | 0.01 | 0.01 | 0.02 |
| Road and rail networks and associated land | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Port areas | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Airports | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mineral extraction sites | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Dump sites | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Construction sites | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Green urban areas | 0.42 | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.03 | 0.01 | 0.03 | 0.00 | 0.00 | 0.02 |
| Sport and leisure facilities | 0.01 | 0.01 | 0.03 | 0.01 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.44 |
| Non-irrigated arable land | 0.00 | 0.03 | 0.04 | 0.77 | 0.00 | 0.00 | 0.02 | 0.43 | 0.03 | 0.06 | 0.44 | 0.03 |
| Rice fields | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fruit trees and berry plantations | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pastures | 0.01 | 0.41 | 0.13 | 0.07 | 0.00 | 0.00 | 0.03 | 0.03 | 0.04 | 0.67 | 0.34 | 0.04 |
| Complex cultivation patterns | 0.00 | 0.00 | 0.08 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| Land principally occupied by agriculture, with significant areas of natural vegetation | 0.00 | 0.00 | 0.06 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| Broad-leaved forest | 0.01 | 0.01 | 0.12 | 0.02 | 0.00 | 0.00 | 0.01 | 0.01 | 0.02 | 0.03 | 0.04 | 0.01 |
| Coniferous forest | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| Mixed forest | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| Natural grasslands | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 |
| Moors and heathland | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 |
| Transitional woodland-shrub | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Beaches, dunes, sands | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Bare rocks | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sparsely vegetated areas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Inland marshes | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Peat bogs | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 |
| Salt marshes | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Intertidal flats | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water courses | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Water bodies | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Coastal lagoons | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Estuaries | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Sea and ocean | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Salines | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Burnt areas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Agro-forestry areas | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

# Appendix C: Static Classification – LSOA concentrations by geography and year

This appendix presents 4 variations of Table 2, splitting by year. As with the original, each column reflects how the LSOAs are distributed across the neighbourhood classes.

*Table C.1 Class proportions by geography, 2000*

| | LSOA (32844) | LBA (1468) | IMD (3283) | Coastal (14033) | Coastal LBA (705) |
|---|---|---|---|---|---|
| Agricultural land | 0.098 | 0.049 | 0.017 | 0.074 | 0.048 |
| Dense central neighbourhoods | 0.027 | 0.010 | 0.042 | 0.048 | 0.017 |
| Farmlands | 0.037 | 0.007 | 0.003 | 0.028 | 0.013 |
| Industrial and commercial neighbourhoods | 0.030 | 0.043 | 0.055 | 0.029 | 0.054 |
| Mixed countryside | 0.062 | 0.052 | 0.032 | 0.056 | 0.062 |
| Neighbourhoods near countryside | 0.047 | 0.046 | 0.036 | 0.033 | 0.027 |
| Neighbourhoods nearby golf & other leisure | 0.021 | 0.014 | 0.012 | 0.021 | 0.018 |
| Neighbourhoods with parks | 0.039 | 0.061 | 0.063 | 0.045 | 0.052 |
| Noncentral mixed neighbourhoods | 0.134 | 0.171 | 0.173 | 0.130 | 0.182 |
| Noncentral neighbourhoods | 0.400 | 0.475 | 0.535 | 0.447 | 0.462 |
| Pastures | 0.061 | 0.024 | 0.012 | 0.054 | 0.016 |
| Rural neighbourhoods | 0.044 | 0.048 | 0.019 | 0.035 | 0.048 |

*Table C.2 Class proportions by geography, 2006*

| | LSOA (32844) | LBA (1468) | IMD (3283) | Coastal (14033) | Coastal LBA (705) |
|---|---|---|---|---|---|
| Agricultural land | 0.081 | 0.042 | 0.017 | 0.068 | 0.041 |
| Dense central neighbourhoods | 0.031 | 0.012 | 0.055 | 0.050 | 0.021 |
| Farmlands | 0.069 | 0.020 | 0.005 | 0.057 | 0.027 |
| Industrial and commercial neighbourhoods | 0.047 | 0.064 | 0.097 | 0.046 | 0.075 |
| Mixed countryside | 0.025 | 0.025 | 0.017 | 0.022 | 0.031 |
| Neighbourhoods near countryside | 0.054 | 0.034 | 0.030 | 0.037 | 0.024 |
| Neighbourhoods nearby golf & other leisure | 0.026 | 0.022 | 0.017 | 0.028 | 0.024 |
| Neighbourhoods with parks | 0.039 | 0.062 | 0.061 | 0.042 | 0.058 |
| Noncentral mixed neighbourhoods | 0.129 | 0.161 | 0.164 | 0.123 | 0.159 |
| Noncentral neighbourhoods | 0.395 | 0.488 | 0.504 | 0.449 | 0.487 |
| Pastures | 0.053 | 0.014 | 0.008 | 0.038 | 0.007 |
| Rural neighbourhoods | 0.050 | 0.056 | 0.026 | 0.040 | 0.045 |

## Table C.3 Class proportions by geography, 2012

| | LSOA (32844) | LBA (1468) | IMD (3283) | Coastal (14033) | Coastal LBA (705) |
|---|---|---|---|---|---|
| Agricultural land | 0.079 | 0.041 | 0.017 | 0.067 | 0.041 |
| Dense central neighbourhoods | 0.031 | 0.012 | 0.055 | 0.050 | 0.021 |
| Farmlands | 0.068 | 0.020 | 0.004 | 0.056 | 0.027 |
| Industrial and commercial neighbourhoods | 0.047 | 0.064 | 0.097 | 0.046 | 0.075 |
| Mixed countryside | 0.025 | 0.024 | 0.017 | 0.022 | 0.031 |
| Neighbourhoods near countryside | 0.053 | 0.035 | 0.029 | 0.037 | 0.024 |
| Neighbourhoods nearby golf & other leisure | 0.026 | 0.022 | 0.018 | 0.028 | 0.024 |
| Neighbourhoods with parks | 0.038 | 0.059 | 0.059 | 0.041 | 0.057 |
| Noncentral mixed neighbourhoods | 0.130 | 0.162 | 0.163 | 0.123 | 0.159 |
| Noncentral neighbourhoods | 0.399 | 0.490 | 0.508 | 0.452 | 0.488 |
| Pastures | 0.053 | 0.014 | 0.008 | 0.038 | 0.007 |
| Rural neighbourhoods | 0.049 | 0.057 | 0.026 | 0.040 | 0.045 |

## Table C.4 Class proportions by geography, 2018

| | LSOA (32844) | LBA (1468) | IMD (3283) | Coastal (14033) | Coastal LBA (705) |
|---|---|---|---|---|---|
| Agricultural land | 0.082 | 0.043 | 0.016 | 0.069 | 0.041 |
| Dense central neighbourhoods | 0.030 | 0.009 | 0.051 | 0.048 | 0.016 |
| Farmlands | 0.070 | 0.020 | 0.006 | 0.057 | 0.027 |
| Industrial and commercial neighbourhoods | 0.044 | 0.057 | 0.087 | 0.042 | 0.068 |
| Mixed countryside | 0.026 | 0.024 | 0.014 | 0.022 | 0.030 |
| Neighbourhoods near countryside | 0.055 | 0.042 | 0.033 | 0.040 | 0.031 |
| Neighbourhoods nearby golf & other leisure | 0.025 | 0.020 | 0.016 | 0.027 | 0.020 |
| Neighbourhoods with parks | 0.040 | 0.063 | 0.065 | 0.043 | 0.048 |
| Noncentral mixed neighbourhoods | 0.127 | 0.155 | 0.159 | 0.121 | 0.160 |
| Noncentral neighbourhoods | 0.396 | 0.490 | 0.515 | 0.450 | 0.494 |
| Pastures | 0.055 | 0.016 | 0.008 | 0.042 | 0.011 |
| Rural neighbourhoods | 0.051 | 0.062 | 0.030 | 0.040 | 0.054 |

# Appendix D: Static Classification – LSOA Concentrations

This appendix presents two variations of Table 1: one generated by using *only* LSOA areas labelled as left-behind (D.1); and the other created with *only* LSOAs in the top 10% most deprived of the Index of Multiple Deprivation (D.2). As with the original figure, the values represent the proportion of areas in a year allocated to every cluster.

*Table D.1  Class proportions across years for 'left behind' LSOAs*

| | 2000 | 2006 | 2012 | 2018 |
|---|---|---|---|---|
| Agricultural land | 0.049 | 0.043 | 0.042 | 0.041 |
| Dense central neighbourhoods | 0.010 | 0.009 | 0.012 | 0.012 |
| Farmlands | 0.007 | 0.020 | 0.020 | 0.020 |
| Industrial and commercial neighbourhoods | 0.043 | 0.057 | 0.064 | 0.064 |
| Mixed countryside | 0.052 | 0.024 | 0.025 | 0.024 |
| Neighbourhoods near countryside | 0.046 | 0.042 | 0.034 | 0.035 |
| Neighbourhoods nearby golf & other leisure | 0.014 | 0.020 | 0.022 | 0.022 |
| Neighbourhoods with parks | 0.061 | 0.063 | 0.062 | 0.059 |
| Noncentral mixed neighbourhoods | 0.171 | 0.155 | 0.161 | 0.162 |
| Noncentral neighbourhoods | 0.475 | 0.490 | 0.488 | 0.490 |
| Pastures | 0.024 | 0.016 | 0.014 | 0.014 |
| Rural neighbourhoods | 0.048 | 0.062 | 0.056 | 0.057 |

*Table D.2 Class proportions across years for top 10% most deprived LSOAs*

| | 2000 | 2006 | 2012 | 2018 |
|---|---|---|---|---|
| Agricultural land | 0.017 | 0.016 | 0.017 | 0.017 |
| Dense central neighbourhoods | 0.042 | 0.051 | 0.055 | 0.055 |
| Farmlands | 0.003 | 0.006 | 0.005 | 0.004 |
| Industrial and commercial neighbourhoods | 0.055 | 0.087 | 0.097 | 0.097 |
| Mixed countryside | 0.032 | 0.014 | 0.017 | 0.017 |
| Neighbourhoods near countryside | 0.036 | 0.033 | 0.030 | 0.029 |
| Neighbourhoods nearby golf & other leisure | 0.012 | 0.016 | 0.017 | 0.018 |
| Neighbourhoods with parks | 0.063 | 0.065 | 0.061 | 0.059 |
| Noncentral mixed neighbourhoods | 0.173 | 0.159 | 0.164 | 0.163 |
| Noncentral neighbourhoods | 0.535 | 0.515 | 0.504 | 0.508 |
| Pastures | 0.012 | 0.008 | 0.008 | 0.008 |
| Rural neighbourhoods | 0.019 | 0.030 | 0.026 | 0.026 |

# Appendix E: Sequence analysis

This supplementary material provides information on the sequence analysis and how its implementation in our study.

In Social Sciences, sequence analysis is used to analyse longitudinal categorical data and enables the identification of representative sequence of transitions between states over time. In the context of our study, we used sequence analysis to identify representative trajectories of change between the land use and cover classes reported in our static classification.

The TraMineR package in the R programming language was used to for the implementation of the following steps. First, the input dataset (i.e. our static land use and cover classification of LSOAs) was transformed so that each row identifies each LSOA and each column identifies each of the four years in the analysis (i.e. 2000, 2006, 2012 and 2018) and their corresponding year-specific land use and cover type. Second, transition rates were computed indicating probability of a LSOA to transition from one land use and cover class to another. These matrices are reported below. The diagonal indicates the share of LSOAs which remained in the same land use and cover class.
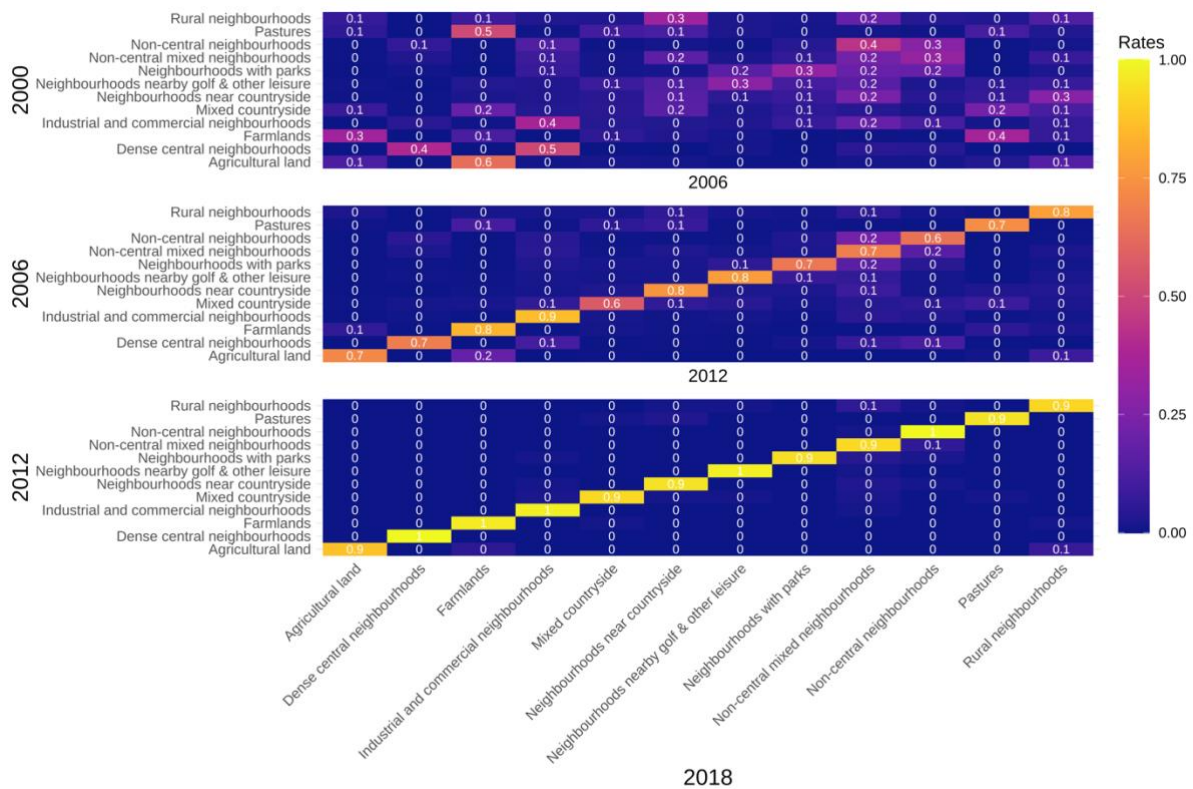


*Figure E.1 Transition rates between land use and cover class, 2000-2006, 2006-2012, and 2012-2018*
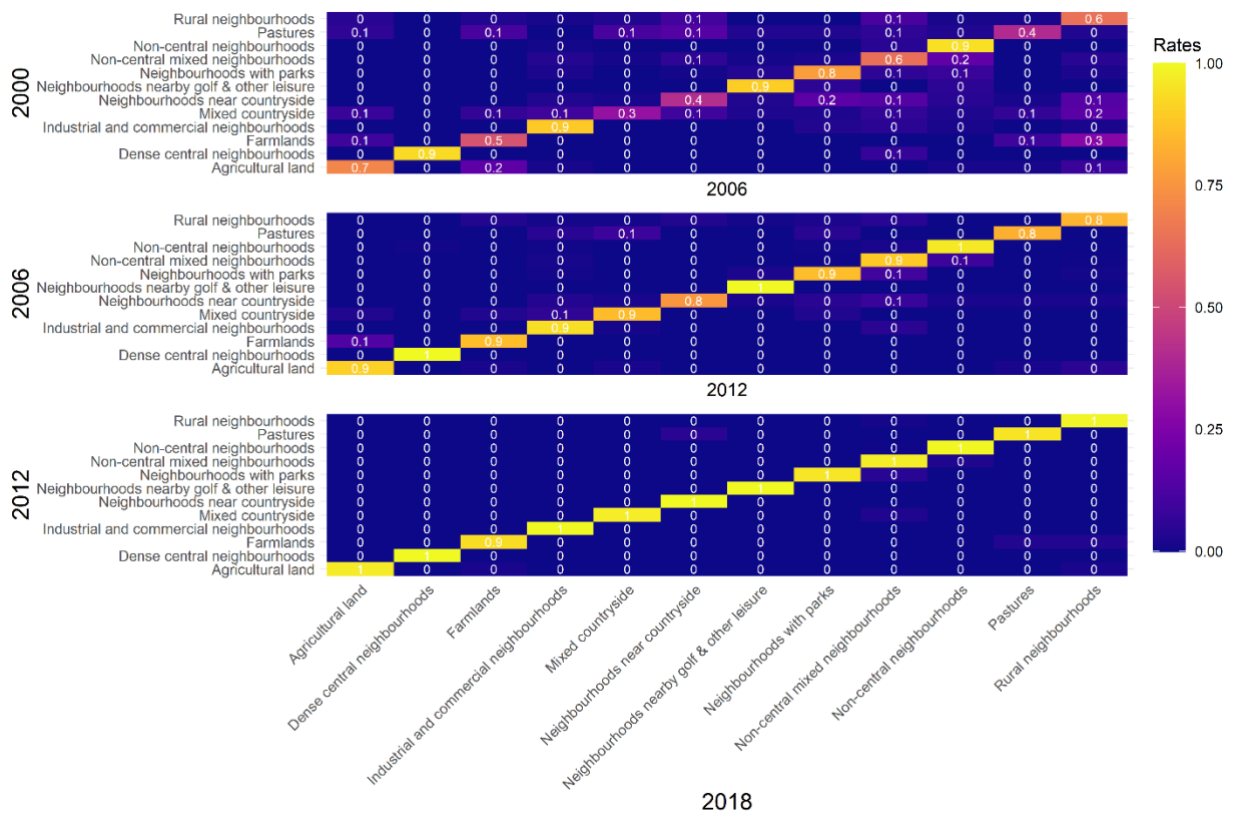
*Figure E.2 Transition rates between land use and cover class, 2000-2006, 2006-2012, and 2012-2018, left behind LSOAs (n = 1468)*
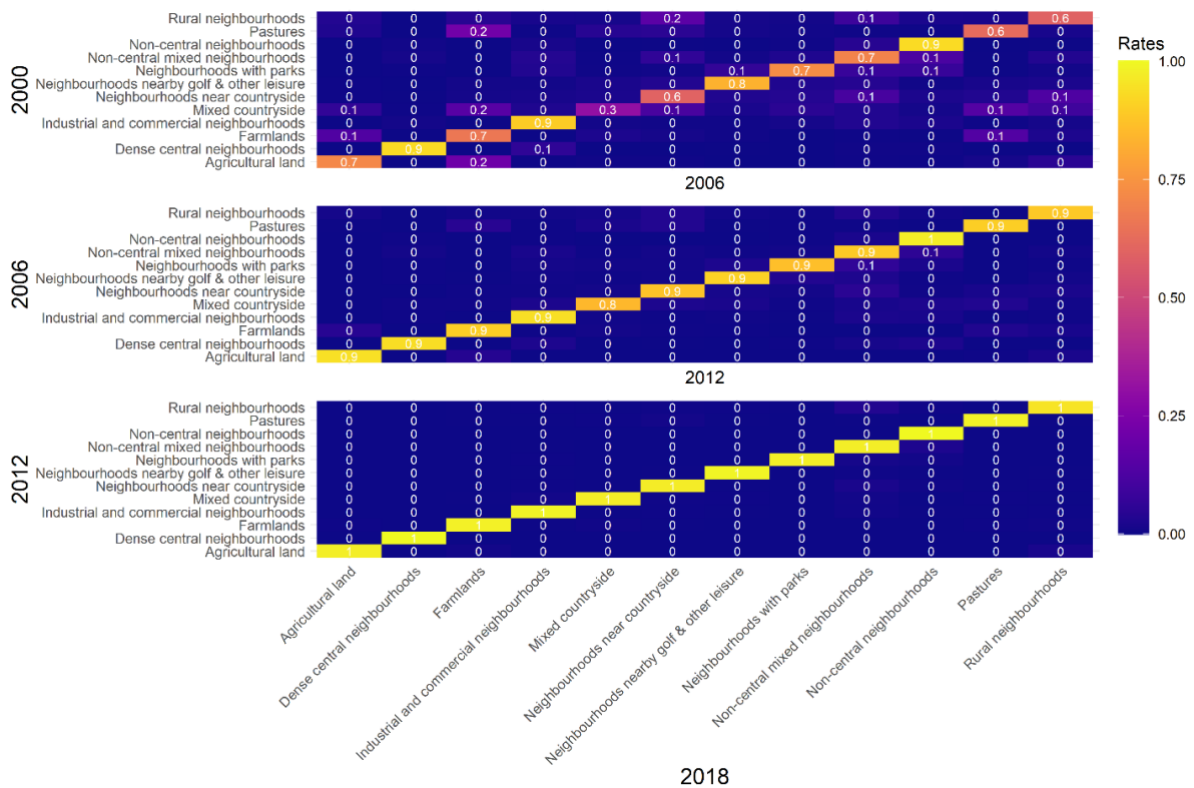


*Figure E.3 Transition rates between land use and cover class, 2000-2006, 2006-2012, and 2012-2018, not left behind LSOAs (n = 31376)*