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Ageing in regions and cities: high resolution projections for Europe in 2030

Jacobs-Crisioni, C., Kucas, A., Lavalle, C.,
Lembcke, A., Ahrend, R.

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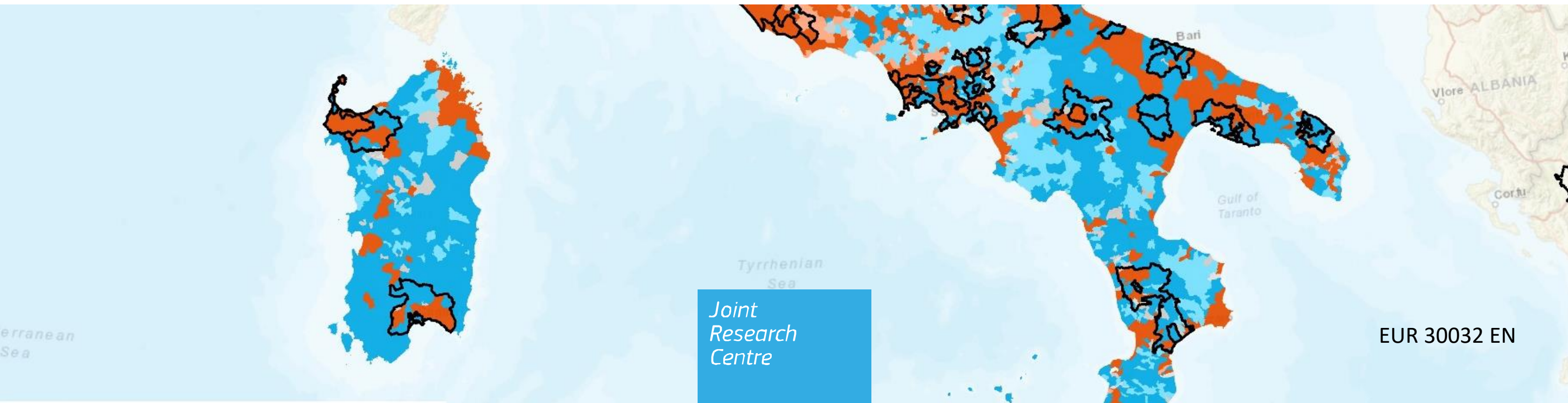

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Contact information
Name: Carlo Lavalle
Address: Via E. Fermi 2749
Email: carlo.lavalle@ec.europa.eu
Tel.:

EU Science Hub
https://ec.europa.eu/jrc

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Abstract

This report presents an experimental exercise in which the LUISA population distribution method has been extended to break down its local population distribution outcomes by broad age class. To do so, elaborate methods have been set up to disaggregate observed age class distribution data to fine spatial resolution raster data; to account for age-class specific demographic expectations; and to model changes in population composition while constrained by LUISA's local population results and expected age class sizes at the regional level. This report describes the developed methodology and summarizes the obtained results.

1 Introduction

It is very likely that many countries in the EU will face ageing and declining populations in the near future. The macro-economic impacts of that change, with regard to for example pension system sustainability and the workforce, are well known. Ageing and population decline come with locally relevant effects as well; for example, the deterioration of support for public services, and decreases in housing prices, which in many EU countries are an important part of total pension savings. Unfortunately, although highly relevant for public spending and quality of life, the local effects of ageing receive little attention in public and political debate.

It may be expected that through spatial sorting mechanisms, ageing and population decline will be a spatially heterogeneous process. Thus the effects of these processes will be felt more in some places than in others. This calls for projections on local changes in total population by age structure. Since 2013, the JRC's LUISA model projects total local population counts. However, changes in the age structure of the projected population were so far not accounted for.

In 2018 the LUISA team has produced 100m grids of population by broad age group, and an experimental extension of the LUISA model. In the model extension, the population allocation routines were complemented with local models for population change per broad age group. The outcomes of this exercise have been discussed in OECD, 2019. This report discusses above all the methods that were developed in the LUISA framework in order to obtain projections broken down by age class. In the next section, this report describes the methods by which the necessary reference data were obtained. This is followed by a description of the implemented extension of the LUISA model. Subsequent sections briefly discuss the modelling results and then reflect on the implemented methods and potential avenues of improvement.

2 Creating reference population grid maps per age group

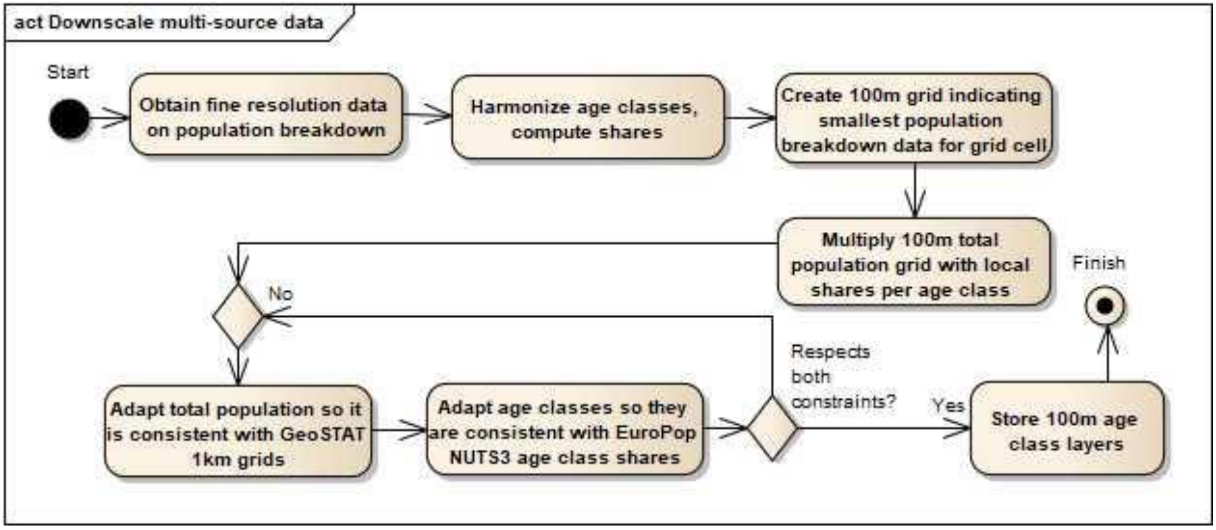
In the modelling extension at hand, total population is modelled alongside five population classes. Those classes are given in Table 1. These age classes were chosen because the majority of input data used for disaggregation accounted for at least these age classes. It must be noted that for future applications the age breakdown may need to be expanded, for example to further separate the group of pensioners. The introduced modelling method can easily be changed to allow for another classification of age groups.

Table 1. Modelled age classes and internal definitions. The variable y indicates age of people in integer years here.

Class number	Age class	Definition	Internal code
1	**Under 15**	$y < 15$	**Under15**
2	**15 to 29**	$15 \leq y \leq 29$	**Y15t29**
3	**30 to 49**	$30 \leq y \leq 49$	**Y30t49**
4	**50 to 64**	$50 \leq y \leq 64$	**Y50t64**
5	**Over 65**	$64 < y$	**Over65**

Like all LUISA sub models, the approach implemented here requires accurate high resolution reference data covering the entire EU territory at a 100m resolution. Following years of research and development, excellent data are now available covering land uses (the LUISA base map, see Jacobs-Crisioni et al., 2017; Rosina et al., 2018) and general population distribution (the ENACT nighttime population grids, see Batista e Silva et al., 2018). Unfortunately, suitable data covering population per age group is not readily available. Although plans do exist for the next EU Census to extend the GeoSTAT 1km population grids to include information on population age structure, such data will not be available soon. Therefore age-group specific population grid maps have had to be generated for the scope of this project, using the finest resolution data available.

Figure 1. Workflow to downscale multi-source data on age classes to 100m population totals, consistent with 1km GeoSTAT grids and NUTS3 age class shares.



The executed generation process was based on the objective of distributing age groups over grid maps in keeping with the greatest possible similarity to observed shares of that age group. Shares were observed in whichever spatial unit contains the finest representation of age classes. Given that objective, two constraints needed to be respected: 1) the shares of an age class in a NUTS3, as a percentage of the total population in that region, needed to be consistent with observed 2011 NUTS3 population shares; 2) the sum of people in all age groups in a grid cell needed to be consistent with the total population in that grid cell according to the ENACT nighttime population map. To do so, an iterative procedure has been adopted to downscale multi-scale information to grid maps. The workflow is outlined in Figure 1 and can roughly be separated into acquiring and pre-processing of data, conversion to initial grids, and an iterative fitting procedure necessary to make the outputs meet process constraints.

2.1 Acquiring and pre-processing administrative data on population by age

Data has been searched within the LUISA team and with all accessible national statistics agencies to obtain the finest spatial resolution data available on population per age group. Municipal data on population per age group is readily available from EuroStat, covering LAU2 spatial units in most EU countries, except for Denmark, which is covered by LAU1 units. A limited number of member states are unfortunately not covered by these data; these countries are France, Greece and the United Kingdom. For a number of countries, LUISA team members have found data on population per age group at an even finer spatial resolution than the municipal level, often roughly neighbourhood levels. Those countries are Belgium, England, France, Italy, Malta, Netherlands, Northern Ireland, Portugal, Scotland, Slovakia, Spain. For three member states (The Netherlands, Slovakia and Slovenia) raster data were obtained at 100m to 1km resolutions. In the end, only for Greece and Wales the approach has had to revert to NUTS3 population per age class as the basis for the creation of the desired maps.

To create a consistent set based on the group classification used in the exercise at hand, some regrouping and data harmonization has been necessary. Most of these data cover at least the age classes that are modelled, although some exceptions are worth noting. Where data had more thematic detail than needed, fields have been summed to form the necessary age groups. In some cases age classes did not overlap well with the target classes, or did not have enough detail. In such cases, population in an age class was assumed to be distributed over ages uniformly and population from the source age class thus distributed proportionally over the target age classes. We acknowledge that a more refined approach could have been adopted here, for example using country-specific age pyramids. However, in keeping with the experimental nature of this work, it was felt that the additional data requirements and processing would have been excessive for the purpose. All used data sources, and aspects of the age group classification in that data that are relevant for the task at hand, are described in Table 2.

Table 2. Administrative units of population per age class used instead of or in addition to LAU2-level data obtained from EuroStat.

Country	N	Issues with age classes
Regional		
Greece	52	-
Wales	12	-
LAU1		
Denmark	99	-
Sub-municipal		
England	181,408	-
Scotland	6,976	-
Northern Ireland	905	-
Malta	1,161	-
Belgium	19,782	-
Netherlands	11,778	Not overlapping with age classes 2, 3, 4
Spain	35,960	Age classes 2, 3, 4 not discerned
Portugal	255,844	Age classes 2, 3, 4 not discerned
Slovakia	7,231	-
Italy	402,121	-
France	50,176	Not overlapping with age classes 3, 4, 5
Grid based (partial coverage)		
Netherlands	597,247	-
Slovakia	49,971	Age classes 2, 3, 4 not discerned
Slovenia	159,041	-

2.2 Conversion to initial population grids per age class

The pre-processing of administrative data finally yielded multiple large tables of population by age group, with rows indicating spatial units and a fixed range of columns indicating the designated age classes. These tables had to be reduced to one table here, with the additional issue that in many cases, spatial units overlapped each other, in particular where data was available on the sub-municipal, municipal and Nuts3 level.

To overcome this, tables of roughly equal spatial resolutions were first appended into resolution-specific tables. Subsequently, for each of these tables, 100m grids were produced containing a reference to the row of the spatial unit in which the grid cell is located. Grid cells not covered by a spatial unit in the particular table received a null value. With the raster grids per spatial resolution table, a simple prioritizing of resolutions could be done. For each grid cell, only one reference value was maintained, namely the reference to the spatial unit from the finest available resolution table that covers the grid cell. Thus all grid cells covered by a spatial unit in any of the input administrative data could be identified. In addition all the necessary administrative units could thus be identified. Those units and accompanying data on population per age class have been appended into one large matrix.

Based on the large matrix and maintained grid map of references, it was relatively straightforward to obtain a first estimate of shares of population by age class for each grid cell. A simple multiplication of relative shares of an age group with the total amount of residents in a grid cell then yields estimated total number of residents in a specific age group. In this exercise this has been done using the beforementioned ENACT nighttime grid data (Batista e Silva et al., 2018). The final result was a very first indication of population per age class at the 100m level.

2.3 Iterative proportional fitting on two constraints

The resulting estimate $PG^{(0)}_{i,c,t=2011}$ did not necessarily respect the constraints imposed upon the data, namely consistency with on the one hand EuroPop shares of people per age class in 2011 ($\%P_{c,j}$), and on the other hand with GeoSTAT population grids (P_g). It is important to note here that in principle the result here does respect the GeoSTAT population grids, as the ENACT nighttime grids are explicitly set up to be consistent with the GeoSTAT grids. However, due to the variety of input administrative data sources, it is highly unlikely that the result was already completely consistent with EuroPop population shares.

In order to obtain population maps that respect both constraints, an iterative proportional fitting procedure has been applied. This is a common approach used when solutions have multiple constaints, such as in doubly constrained spatial interaction models (Wilson, 1967) and land-use allocation methods such as LUISA's (Hilferink & Rietveld, 1999). It works by iteratively adjusting estimated population, so that first for each 100m gridcell *i* in NUTS3 region *j*,

$$PE^{(x)}_{i,c,t=2011} = PG^{(x-1)}_{i,c,t=2011} * \left(\% \, P^{EUROSTAT}_{j,c,t=2011} \Big/ \frac{PG^{(x-1)}_{i,c,t=2011}}{\sum_{c=1}^{n} PG^{(x-1)}_{i,c,t=2011}} \right), \tag{1}$$

so that age class sizes in a grid cell are corrected to reflect regional relative age class sizes. Subsequently, for each 100m gridcell *i* in GeoSTAT grid g,

$$PG^{(x)}_{i,c,t=2011} = PE^{(x-1)}_{i,c,t=2011} * \left(\frac{P^{GEOSTAT}_{g,t=2011}}{\sum_{i \in G}^{n} \sum_{c=1}^{n} PE^{(x-1)}_{i,c,t=2011}} \right). \tag{2}$$

This process is repeated recursively with $x = 1, x = 2, \ldots\ x = 10$, at which point the relative differences with GEOSTAT and EUROSTAT values are negligible. This way the process iteratively adjusts local population shares per age class, and total population counts, until the population maps per age class are consistent with 1km population grids and regional age class shares.

3 Extending LUISA population distribution maps with results per age class

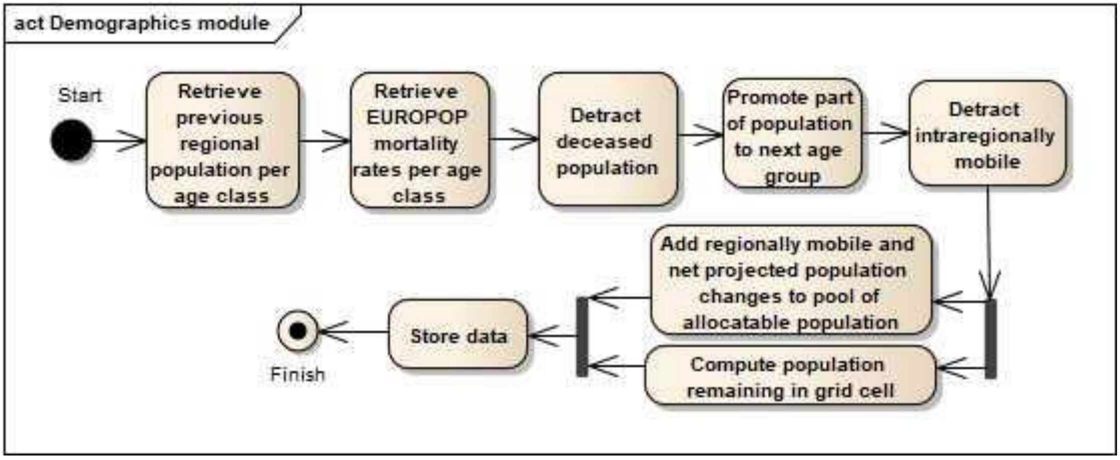
Reference population grid maps per age class have been produced with the method described in the previous section. Those have been added to the LUISA framework. The previously used 100m population grid map has been replaced by local sums of all accounted age classes. Including age classes in the LUISA population distribution mechanism has affected the overall procedure in other aspects as well. Most of the population distribution mechanic has stayed intact; for a detailed description of the previously implemented method, please refer to Jacobs-Crisioni et al. (2017).

At the core of the implemented method are population distribution functions, which have been estimated by regressions on a long time series of local population change. Due to data limitations those functions cannot yet be expanded to obtain age-class specific valuations. The reported work therefore is still based on said population distribution functions, in order to first estimate general population change. Age-class specific information has been used to produce informed estimates of how local age breakdown affects general population changes, and how, constrained by projected general local population change, local age breakdowns may change through the modelled years. Total population is distributed in discrete numbers, while shares of age classes are modelled as continuous values. In a newly setup demographics module, the model now accounts for age-group specific projections, mortality rates and intraregional mobility rates. In the actual population allocation procedures, the model now tracks housing supply per age group, in keeping with the expectation that different age groups have different preferences, so that housing supply for one age group is not a perfect substitute for housing for another group.

3.1 Introducing a demographics module

Three novel data elements were introduced into LUISA in the demographics module. In later model versions, this module may be expanded further. The elements added here refer to available EUROPOP 2013 projections per age group; country-specific projected mortality rates per age group from EUROPOP 2013; census-based age-group specific intraregional migration estimates. In addition, a separate module keeps track of natural changes in the age class due to people ageing into subsequent age classes. Vis a vis the 2017 reference scenario, the main modelling elements affected here are the stock of people remaining in a grid cell (in the Reference 2017 scenario, $Q_{r,t-1} * (1 - 0.038T)$; here, $P_{i,c,t}^{remaining}$), and the pool of people to be distributed in a modelling step (in the Reference 2017 scenario, $K_{j,t}$; here, $K_{j,c,t}$). The workflow in the LUISA demographics module is shown in Figure 2. It is separated into a module computing natural changes, a module computing intraregional mobility, and a module computing net population change as a result of interactions with other regions.

Figure 2. Demographics module workflow.



3.1.1 Modelling natural changes in regional population stocks

In the natural changes module, averaged mortality rates are used to compute the population that have survived the years passed since the previous modelling time step. This is done by multiplying mortality rates for a specific country, age class and year with the number of years covered in the time step, so that:

$$P_{i,c,t}^{survived} = T * \left(1 - M_{c,t}\right) * P_{i,c,t-1}. \tag{3}$$

For this exercise, projected national mortality rates have been obtained from the EUROPOP 2013 exercise (EC, 2015). Subsequently, the amount of people in an age class that ages into the subsequent age class. This is done by computing number of modelled years T divided by the length L_c of an age class. Thus, as in the creation of the reference maps, the age distribution within an age class is assumed equal. So in case of the under 15 year age class (which contains the years 0 until 14, ie 15 years), and the model steps the regular 5 years, $5/15 = \frac{1}{3}$ of all survivors in the under 15 age class are expected to move to the next age class, ie the group of 15 to 29 year olds. This leads to new variables, namely the population entering an age class $P_{i,c,t}^{in}$ and population exiting an age class $P_{i,c,t}^{out}$:

$$P_{i,c,t}^{in} = P_{i,c-1,t}^{survived} * \left(\frac{T}{L_{c-1}}\right), \tag{4.1}$$

$$P_{i,c,t}^{out} = P_{i,c,t}^{survived} * \left(\frac{T}{L_c}\right). \tag{4.2}$$

Births are not taken into account in this section of the model. Births enter into a region through the pool of allocatable people, when the remaining people in the youngest age group is smaller than the amount of people there after the enacted natural changes. Naturally, population in the last age class cannot move to a next age class, so that this group only diminishes because of mortality. Given age class changes in the population, population stock in an age class after natural changes is computed as:

$$P_{i,c,t}^{natural} = P_{i,c-1,t}^{survived} + P_{i,c,t}^{in} - P_{i,c,t}^{out}. \tag{5}$$

3.1.2 Modelling intraregional migration

After accounting for natural changes in the population, the introduced approach accounts for intraregional mobility of the population. As in the Reference scenario 2017, intra-regionally mobile people are removed from the grid cell population stock and added to the pool $K_{j,c,t}$ of people to allocate. In previous modelling runs, one general parameter was used to compute intraregional mobility for the entire population. To model differences in mobility between age classes, this has been expanded into separate parameters ρ_c for every age class.

Table 3. Assumed annual intraregional mobility of the EU population per age class.

Age class	Intra-regional mobility
Under 15	3.8%
15 to 29	6.6%
30 to 49	3.9%
50 to 64	1.8%
Over 65	1.4%

The values of ρ_c have been obtained from the EU census 2011 and are given in Table 3. They reflect the EU-wide percentage of people of an age class who had moved in the year prior to the census, but had remained within their NUTS3 region. These percentages are imposed on all countries, and assumed fixed throughout the modelling period. From the table it is immediately clear that there are substantial differences in mobility between age classes. Adolescents in particular have much higher mobility than other age classes. Mobility is particularly low among the eldest. With the given parameters, the population not moving is logically computed as:

$$P_{i,c,t}^{remaining} = (1 - \rho_c)P_{i,c,t}^{natural}. \tag{6}$$

Both $K_{j,c,t}^{moving}$ and $P_{i,c,t}^{remaining}$ are relevant in later stages of the modelling procedure.

3.1.3 Accounting for net migration from interactions with other regions

Lastly, external projections are imputed to account for births and interactions with other regions. In the exercise at hand this is done through EUROPOP 2013 projected population changes. Those are converted into absolute population changes, given the reference population map, so that:

$$P^{proj}_{j,c,t} = \left(P^{EUROPOP}_{j,c,t} - P^{EUROPOP}_{j,c,t=0}\right) + \sum_{i \in j}^{n} P_{i,c,t=0}. \tag{7}$$

Subsequently, allocatable population is computed as:

$$K_{j,c,t} = P^{proj}_{j,c,t} - \sum\nolimits_{i \in j}^{n} P^{remaining}_{i,c,t}. \tag{8}$$

As noted before, the resulting age-class specific population pools replace the generic population pool used before.

3.2 Adapting general population allocation procedures

As noted, the method to distribute the allocatable population pool over a general population distribution, as described in section 3.1.2 in Jacobs-Crisioni et al. (2017), has remained largely intact. The only relevant differences here are that in equations 9 and 11, K_j is replaced by $\sum_{c=1}^{n} K_{j,c,t}$ and $Q_{r,t-1}$ is replaced by $P^{remaining}_{i,c,t}$. All other aspects of the procedure remain, so that the prime final outcome here still consists of one 100m grid map indicating ordinal population numbers $P^{general}_{i,t}$ for every time step that the model produces. The changes reported here thus only affect the general population distribution mechanism through the refined linkage between projections and age-class specific mortality and internal migration. This may be expected to have a limited effect on the general population changes as they were modelled in for example Jacobs-Crisioni et al. (2017).

3.3 Introducing a method to model changes in population breakdown

A new module has been introduced in the LUISA framework to dynamically model changes in the sizes of the modelled age classes. The purpose of this module is to obtain continuous population sizes within each age class, within the bounds of general population changes and projected regional population sizes of each modelled age class. Thus, the general population sizes $P^{general}_{i,t}$ modelled in the previously discussed population distribution function are explicitly used as a constraint in this module. The regionally projected number of people in a specific age class $P^{proj}_{j,c,t}$ are used as a second constraint. Because of the doubly constrained nature of the question at hand, an approach is taken based on iterative proportional fitting. This is similar to the approach presented in Section 2.3. As a first step, the amount of general residual space that needs to be allocated in a grid cell is defined. This is computed as:

$$R_{i,t} = P^{general}_{i,t} - \sum\nolimits_{c=1}^{n} P^{remaining}_{i,c,t}. \tag{9}$$

This is followed by a first age-class specific estimate of how many people in age class would need to be filled in a grid cell, computed as:

$$TF_{i,c,t} = R_{i,t}\left(\max 0 \mid \frac{K_{j,c,t}}{\sum_{c=1}^{n} K_{j,c,t}}\right) + \left(P_{i,c,t-1} - P^{remaining}_{i,c,t}\right). \tag{11}$$

Which is subsequently used to define attractiveness of a grid cell for an age class so that:

$$A_{i,c,t} = \begin{cases} TF_{i,c,t} \ if \ K_{j,c,t} > 0 \\ R_{i,c,t} \ if \ K_{j,c,t} \leq 0 \end{cases}. \tag{12}$$

Thus, in case people in an age class need to be allocated to grid cells, attractiveness is based partially on the amount of space left in a grid cell and the relative sizes of age classes that need to be allocated, and partially on the age class distribution of the people that left the grid cell due to natural changes or intraregional migration. Both factors are used here in combination to ensure, one the one hand, that all grid cells have some degree of attractiveness for all age classes for which people need to be allocated; while on the other hand accounting for the assumption that space left by people from a specific age class will be more attractive for the same age class. This is a rather ad-hoc specification of attractiveness, that in the future may need to be replaced by a function based on empirical findings. This indicator of attractiveness is used to downscale population over grid cells, so that:

$$QJ_{i,c,t}^{(0)} = P_{i,c,t}^{remaining} + \left(\frac{K_{j,c,t} A_{i,c,t}}{\sum_{i \in j}^{n} K_{j,c,t} A_{i,c,t}} \sum\nolimits_{i \in j}^{n} K_{j,c,t} \right). \qquad (13)$$

Subsequently, an iterative proportional fitting procedure is started in which distributed population is fitted onto projected general population counts, using factor differences between general population result and the sum of population over all age classes:

$$QI_{i,c,t}^{(x)} = QJ_{i,c,t}^{(x-1)} * \left(\frac{P_{i,t}^{general}}{\sum_{c=1}^{n} QJ_{i,c,t}^{(x-1)}} \right). \qquad (14)$$

The result of which is subsequently fitted by the factor difference of distributed versus projected regional population:

$$QJ_{i,c,t}^{(x)} = QI_{i,c,t}^{(x)} * \left(\frac{P_{j,c,t}^{proj}}{\sum_{i \in j}^{n} QI_{i,c,t}^{(x)}} \right). \qquad (15)$$

So that a recursive procedure x=1, x=2, …, x=10 fits population estimates in $QI_{i,c,t}$ and $QJ_{i,c,t}$ while respecting regional age class sizes and local distributed total population counts.. Tests yielded that after 10 iterations the factor differences between distributed population, general local population and regional age class size are negligible. The final result is then $P_{i,c,t} = QJ_{i,c,t}^{(10)}$, the total population distribution of that time step broken down by age class.

4 Results

In an initial run, the model has been used to compute results for 2030 for six EU member states for which sub-municipal or grid-based data were available. Those countries are France, Italy, Spain, Slovakia, Slovenia and The Netherlands. In this section, results will be shown for all countries, focusing on the spatial heterogeneity of the modelled processes. This is done by aggregating raster maps to the municipality level, and then visualizing results in two dimensions (see Table 4). Changes in population breakdown are expressed as modelled changes in the share of pensioners in a municipality, versus the national average change in share of pensioners. This is done because, by far, ageing is the dominant change in population breakdown in most of Europe.

Table 4. Dimensions in which modelled population change are visualized, and corresponding colours.

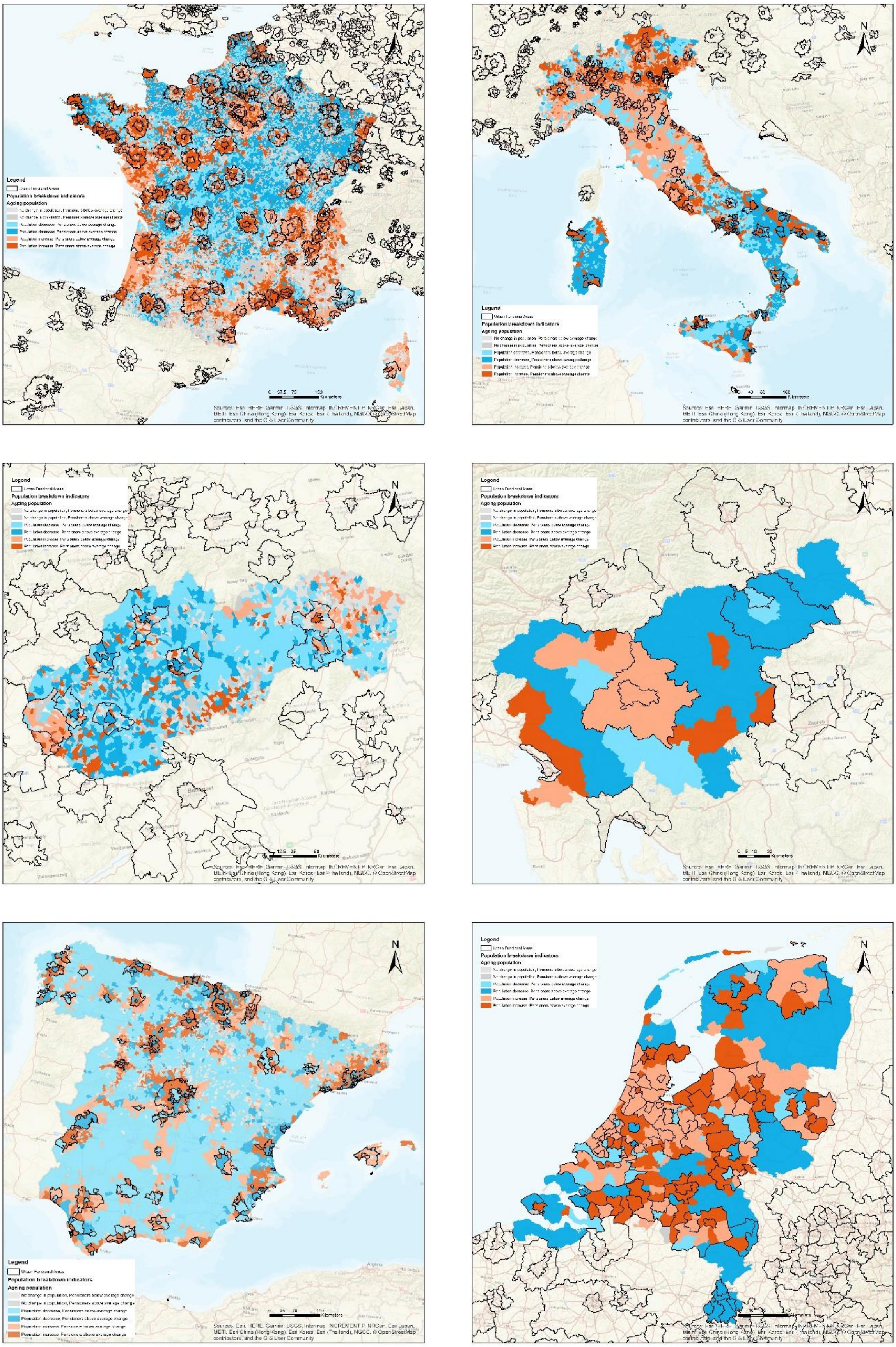
	Change in pensioners equal to or below national average	**Change in pensioners above national average**
Population increase	Light red	Dark red
No population change	Light gray	Dark grey
Population decrease	Light blue	Dark blue

In Table 4 the modelling results for 2030 are shown for all six member states. Those maps show clear spatial heterogeneity in processes of population growth and ageing, both within regions and between regions. In France, population growth is expected to concentrate on the west coast and around major urban centres. Patterns of ageing are very scattered, without clear geographical patterns; although the South of France seems to have slightly lower overall increases in the share of pensioners. In Italy, population growth is expected to be concentrated in the North of the country, around the major cities and around the major transport axes. The biggest increases in shares of pensioners are expected to occur in the Po plains, the very South of the countries and the major islands.

In Slovakia, population decrease appears to be the dominant expected trend. Only in parts rural areas in the Northeast and South, and the cities Bratislava, Košice and Prešov, some population growth is expected. As in France, ageing seems to be expected in scattered patterns, although in particular in the centre and the east of the country, ageing seems to be relatively limited. For Slovenia, population increases are expected in the west and around Ljubljana. And only mostly around Ljubljana the average share of pensioners is expected to change less than the national average.

In Spain, population increases are mostly expected in the municipalities surrounding the country's major cities, mostly paired with above average increases in the number of pensioners. In most of the country's territory, the population is expected to decrease. However, counterintuitively, this is paired with relatively low changes in the share of pensioners. Possibly the already high shares of pensioners in Spain's rural territory plays a role here. Lastly, in The Netherlands, population is only expected to decrease in the country's most peripheral provinces, such as Limburg, Zeeland, Groningen and Drenthe. Population decrease is almost always coupled with above average increases in the share of pensioners. The country's largest cities are expected to have relatively little growth in shares of pensioners.

Figure 3. Modelling results for 2030 for France (top left), Italy (top right), Slovakia (middle left), Slovenia (middle right), Spain (bottom left) and The Netherlands (bottom right).



5 Conclusions

This report introduces the methods and results of an exercise that aimed at enriching LUISA population projections by discerning population by age class. For this exercise, the JRC's ENACT night time population grids (Batista e Silva et al., 2018) have been used in conjunction with Eurostat regional population shares per age class and local administrative data on population composition in order to create maps of population distribution per age class. New modules have been added to the LUISA framework in order to compute age-class specific effects of demographic change and migration; and to compute changes in population distribution per age class. The adopted methods are constrained by LUISA's general population allocation method and NUTS3 population projections per age class, and mostly informed by expectations considering mortality and migration per age group. Age-class specific locational preferences, or age-class specific economic situations are not accounted for in the modelling; therefore, the resulting estimates can be considered fairly conservative.

Results were computed for six countries. They are derived from NUTS3 projections obtained from the EUROPOP2013 study and the LUISA methods introduced in Jacobs-Crisioni et al. (2017) and this report. In general, the results show that demographic developments in the EU may have substantial spatial heterogeneity at the local level. This implies that the undesirable consequences of depopulation and ageing, such as loss of real estate value and increased strain on public service delivery, may be exacerbated locally. At this point, the method has not been validated, and there are several aspects of the adopted approach that can clearly be improved upon.

First, the current reference map is the result of a doubly constrained disaggregation exercise that uses input data with considerable differences in terms of spatial resolution and age classification. In some member states age-class specific data was only available at the regional level, which is too coarse a resolution for the exercise at hand. Recreation and validation of this map, while including universally fine resolution administrative data on population per age class, would considerably improve the quality of the projections. In addition, the adopted attractiveness function, that partially governs population distribution per age class in the model, is specified in an admittedly ad-hoc way. Ideally this function is based on observed changes in population of an age class, such as is done in LUISA's general population change method. In case of unavailable data, it may be perhaps be substituted by functions that explain the current distribution of an age class, although such an approach is less attractive as it may introduce biases in the approach.

All in all, the methods introduced here may be very useful instruments to obtain EU-wide estimates of the local effects of ageing and depopulation. We are not aware of any other exercise to produce such population projections by age group at LUISA's fine spatial resolution. Paths of further improvement can be easily identified, but require substantial additional data.

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