MEASURING THE AGEING OF ITALIAN POPULATION WITH COMPOSITE INDICATORS USING MUNICIPAL DATA FROM THE DECENNIAL POPULATION CENSUSES[1]

Gennaro Di Fraia, Valeria Quondamstefano, Mariangela Verrascina

Abstract. The aim of this study is to summarise the measures of Italian population ageing obtained from the results of the 2001, 2011 and 2021 decennial censuses by composite indicators. The goal is to analyse similarities and differences in the ageing behaviour of Italian municipalities in an attempt to identify trends over 20 years through the 'pictures' taken in Italy with the Censuses. The 2001 Census was the last one carried out in the traditional way, door-to-door with enumerators handing out paper questionnaires to all households. In 2011, some innovations were introduced: the mailing of questionnaires, the possibility of web-filling and the intervention of the enumerators only in the final phase of non-response recovery. Since 2018, the Census, carried out annually on a sample of municipalities and households, has become continuous, i.e. Permanent. Although the survey is a sample survey, the results are referred on the entire population, thanks to the integration of the data collected in the field with those in the available archives. Some indicators concerning the structure of the population are considered. The territory considered is the municipal territory as of 2021. In order to perform a temporal and spatial analysis highlighting differences and similarities between the municipalities, the composite Adjusted Mazziotta Pareto Index (AMPI) is used. A classification of the municipalities is then performed using the CHAID (Chisquared Automatic Interaction Detector) classification tree, incorporating geographic-territorial-demographic elements into the analysis. Finally, a focus on territories that can be considered case studies: the metropolitan city of Naples and the municipality of Naples.

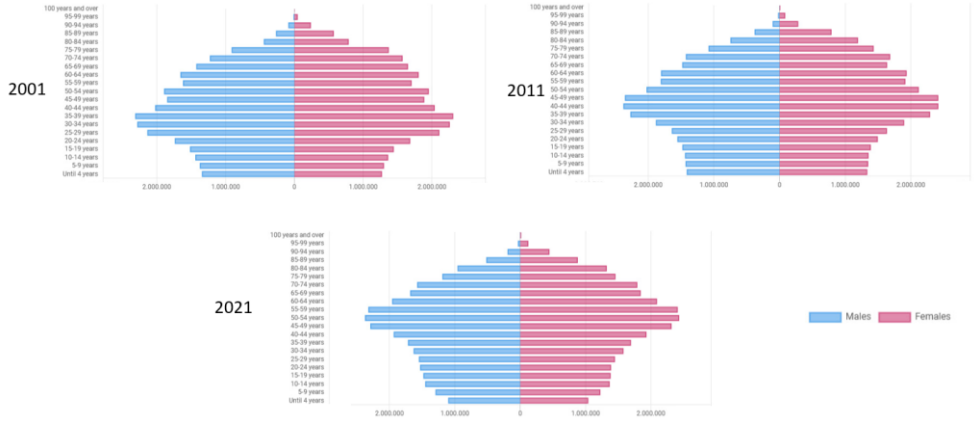
[1] The article exclusively expresses the opinions of the authors. Gennaro Di Fraia wrote paragraph 2.2, Valeria Quondamstefano paragraphs 1, 3, 4 and 5 and Mariangela Verrascina paragraph 2.1. Paragraph 6 was written jointly by the authors and is not divisible.

1. Introduction

Population ageing is now an inevitable process in many developed countries, and Italy is, as is well known, among the countries in the world and Europe that have aged the most in recent decades. "In European countries, many territories have experienced and are still experiencing a depopulation, caused by a deficit of births relative to deaths, a negative net migration, or both" (Reynaud and Miccoli, 2018).

This work focuses on the structure of the Italian population over the last 20 years. The aging of the Italian population is due to the effect of a unique age structure: the cohorts formed during the period of high birth rates (the famous years of the baby boom) are reaching the top of the age pyramid, effectively exiting the reproductive cycle, while the cohorts of newborns are indeed becoming smaller (in 2021, the total number of births was 400,249, the record low birth rate). (Figure 1).

Figure 1 – *Age pyramid of Italian population (years 2001, 2011, 2021).*



Source: Processing of ISTAT data

Since the beginning of the new millennium, there has been increased attention on the impact of demographic transformations, especially on healthcare and pension expenditure. The definition of 'elderly' or 'old person' is a debated topic in the scientific community. Traditionally, the age of 65 has been used as a threshold to define the onset of old age, partly linked to the conventional definition of retirement age. However, with demographic changes and increasing life expectancy, the question has arisen whether this threshold is still appropriate. It has been suggested considering factors such as health status, physical and cognitive function, and overall quality of life (Walker and Maltby, 2012). Our analysis embraces tradition, considering 65 years of age as the threshold (still currently

prevailing on average) for retirement. Looking at the lower end of the age pyramids, there have been changes in recent years in the female population of childbearing age, conventionally defined as between 15 and 49. Within this age group, there are fewer and fewer Italian women. On the one hand, women born between the second half of the 1960s and the first half of the 1970s have almost completely exited the reproductive phase. On the other, the younger generations are becoming smaller. The latter generations are experiencing the effect of the so-called 'baby bust', which refers to a significant drop in fertility between 1976 and 1995, when the number of children per woman was at an all-time low of 1.19.

This study examines the latest three decennial Censuses (2001, 2011, and 2021) of the population to better understand the trend of population aging in Italy, considering both the increase in life expectancy and the decrease in birth rate over time. Given the multidimensionality of the concept of aging, this study utilizes the potential of composite indicators theory (Adjusted Mazziotta Pareto Index, AMPI) and classification trees (Chisquared Automatic Interaction Detector, CHAID) assess the exponential advancement of the phenomenon, both at the national level and in specific geographic areas. In particular, cartography is used to visualize the results in a clear and intuitive manner. The composite indicators theory allows for the combination of different demographic and social variables into a single indicator, providing an overall assessment of population aging. On the other hand, classification trees help identify the main factors contributing to aging and to understand how the phenomenon has developed over time.

2. Data source

2.1. Decennial censuses

The aim of this study is to highlight the trends over 20 years through the ‘pictures’ taken in Italy with the Population Censuses. Traditionally, the census was based on the fundamental characteristics of individual enumeration, simultaneity, universality and defined periodicity. Therefore, analysis at fine territorial detail (municipal and sub-municipal) was only possible every 10 years, during census rounds.

Since the Unification of Italy, population censuses in Italy were conducted in years ending with ‘1’ (with a jump in 1891 due to an economic crisis and 1941 due to the war and with the exception of the 1936 ‘small Census’). The 2001 Census was the last one conducted in the traditional way, door-to-door with enumerators handing out paper questionnaires to all households. The 2011 Census already introduced some innovations, with the questionnaires being sent by mail, the

possibility of web filling, and with the intervention of the enumerators only in the final phase of non-response recovery.

The effort and large economic investment involved in a huge 'one-shot' operation every 10 years meant that the data was processed and disseminated with little timeliness. By the time the data were published, they were already 'dated', although they were the only ones in Italy that allowed for municipal and sub-municipal analyses. For economic reasons and the need to provide more timely data, the new strategy was introduced in 2018, and the Census became Permanent.

Unlike the censuses of the past, Permanent Censuses involve only representative samples of the population from time to time. However, the return to the country of the data obtained is census-like. This is made possible by the integration of administrative sources with sample surveys, so as to ensure exhaustiveness, increase the quantity and quality of information supply, contain the statistical burden on citizens and reduce overall costs.

The objective is to show how analysing the data available every 10 years reveals large variations and overlooks the variations recorded in the short term (those variations that emerge with the results of the Permanent Census). Annual dissemination makes it possible to identify and monitor from year to year subgroups of the population or territories in distress, situations of criticality and greater vulnerability in order to launch promptly intervention on certain phenomena. In particular, in our case, the phenomenon of ageing is investigated.

2.2. Individual indicators

From the results of the latest three decennial Censuses (Istat, 2003; Istat, 2013; Istat, 2022) of the population, some demo-social indicators are calculated. The individual indicators are derived from information regarding the age structure of the population:

(A) Percentage of population aged 0-17 years. Ratio of the population aged 0-17 years to total population (percentage). The indicator measures the share of population under 18 in the total population. The Italian value of this indicator fell by 1.6 point between 2001 (17.2%) and 2021 (15.6%);

(B) Old age dependency ratio. Ratio of population aged 65 years and over to population aged 15-64 years (percentage). This ratio indicates how many people aged 65 and older there are for every 100 individuals of working age. It has economic and social relevance: in fact, it relates people who are not self-sufficient for demographic reasons (age) - in our case the elderly - to the people who are supposed to support them. In Italy, between 2001 and 2021, this ratio has increased by 9.6 point: from 27.8% to 36.5%;

(C) Childbearing per fertile woman. Ratio of population aged 0-4 years to woman female population aged 15-49 years (percentage). It is calculated

by relating the number of children aged 0-4 years and women in the 15-49 age group. The sociodemographic significance derives from the fact that this indicator estimates the 'load' of preschool children per woman of childbearing age, that is, at an age when, especially in more economically developed countries, there is a higher frequency of working women also engaged in childcare. Between 2001 and 2021, the value of this indicator dropped by 0.9 point (from 19.1% to 18.2%);

(D) *Percentage of women 15-49 years.* Ratio of female population aged 15-49 years to total female population (percentage). The indicator measures the share of women of reproductive age in the total female population. This share, from 2001 to 2021, decreases from 46.7% to 38.9%;

(E) *Aging index.* Ratio of population aged 65 years and over to population aged 0-14 years (percentage). Represents an indicator of the degree of aging of the population. It is obtained by relating the elderly population (over 65 years old) to the young population (up to 15 years old). When a population ages there is, at the same time, a decrease in the weight of the very young: this leads to an increase in the value of this index. In the 20 years analysed in this paper, this indicator grew by 56.2 points: 131.4% in 2001 and 187.6% in 2021;

(F) *Population turnover index.* Ratio of population aged 0-29 years to population aged 65 years and over (percentage). The indicator estimates the degree of generational turnover of a population, in which the population in the age group of zero to 29 years and the elderly population (65 and over) are related. Between 2001 and 2021, this indicator dropped by 60.1 point (from 176.0% to 115.9%).

3. Methodology

3.1. Composite Indicators

In order to synthesize the individual indicators in a unique measure, a composite indicator is used. The Adjusted Mazziotta-Pareto Index (AMPI) is a partially non-compensatory composite indicator based on a standardization of the individual indicators, at the reference time, that makes the indicators independent from the unit of measure (De Muro *et al.*, 2011). Therefore, all the individual indicators are assigned equal weights and absolute time comparisons are allowed (Mazziotta and Pareto, 2016). In fact, a re-scaling of the individual indicators in the range (70; 130) according to two 'goalposts' is proposed, i.e., a minimum and a maximum value which represent the possible range of each variable for all time periods and for all units. The 'price' to pay for comparable scores over time is that indicators

with different variability are aggregated. However, the normalised indicators in an identical range have a much more similar variability than the original ones (Mazziotta and Pareto 2013).

3.2. Classification trees

The method of sorting the municipalities by AMPI is interesting and can provide information on the evidence of the phenomenon. However, a more systematic approach is needed that can classify municipalities considering the ageing composite indicator as a function of some covariates. In this perspective, a good classification method is the Chisquared Automatic Interaction Detector (CHAID), a multiple tree statistics algorithm that allows the data to be visualised quickly and efficiently, creating segments and profiles according to the results. In particular, the AMPI is the dependent variable, while the independent variables are the administrative subdivisions (Geographical area, Region, Province/Metropolitan City) some geographic characteristics (Altitude zone, Population density) and some demographic characteristics (Degree of urbanisation, Demographic size of municipalities class). For the classification of Degree of urbanisation, the Eurostat definition was followed (Eurostat, 2019).

4. Main results

4.1. Descriptive data analysis

The first step of analysis concerned correlations. The correlation analysis shows how the AMPI is highly correlated (positively or negatively) with individual indicators (more than 0.75), except for Childbearing per fertile woman (Figure 2).

The second step was to identify which indicator was the most influential for the construction of the ranking of Italian municipalities according to ageing. For the first two years under consideration, the indicator that on average moves the most positions is 'Percentage of Population aged 0-17 years' (298 and 236 respectively), while for 2021 the indicator 'Childbearing per fertile woman' (290). The least influential indicator in the 3 census years is the 'old age dependency ratio' (10, 15, 20 positions shifted on average in the ranking of municipalities).

Figure 2 – *Correlations analysis among individual indicators and AMPI (years 2001, 2011, 2021).*

2001

Correlations	A	B	C	D	E	F	AMPI
A	1.000	-0.688	0.566	0.744	-0.692	0.824	-0.911
B	-0.688	1.000	-0.348	-0.918	0.782	-0.778	0.903
C	0.566	-0.348	1.000	0.287	-0.421	0.449	-0.564
D	0.744	-0.918	0.287	1.000	-0.724	0.829	-0.919
E	-0.692	0.782	-0.421	-0.724	1.000	-0.572	0.793
F	0.824	-0.778	0.449	0.829	-0.572	1.000	-0.906
AMPI	-0.911	0.903	-0.564	-0.919	0.793	-0.906	1.000

2011

Correlations	A	B	C	D	E	F	AMPI
A	1.000	-0.789	0.488	0.794	-0.774	0.858	-0.937
B	-0.789	1.000	-0.305	-0.901	0.846	-0.811	0.929
C	0.488	-0.305	1.000	0.276	-0.368	0.356	-0.492
D	0.794	-0.901	0.276	1.000	-0.731	0.854	-0.929
E	-0.774	0.846	-0.368	-0.731	1.000	-0.626	0.835
F	0.858	-0.811	0.356	0.854	-0.626	1.000	-0.908
AMPI	-0.937	0.929	-0.492	-0.929	0.835	-0.908	1.000

2021

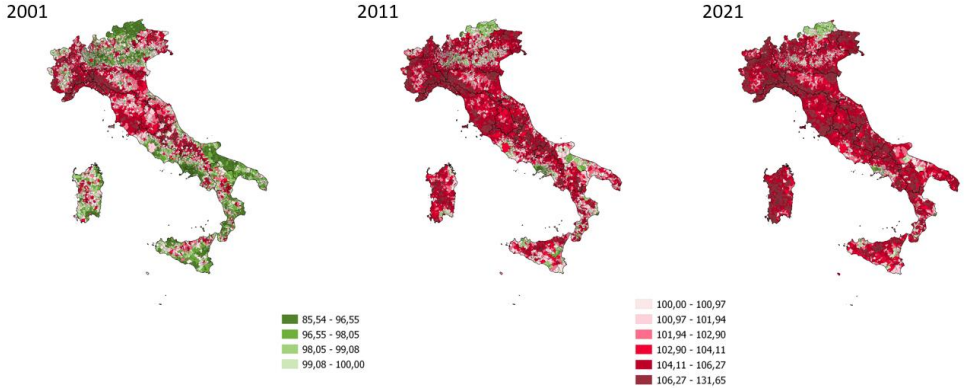
Correlations	A	B	C	D	E	F	AMPI
A	1.000	-0.79	0.556	0.803	-0.732	0.877	-0.944
B	-0.79	1.000	-0.362	-0.882	0.715	-0.862	0.913
C	0.556	-0.362	1.000	0.318	-0.413	0.46	-0.586
D	0.803	-0.882	0.318	1.000	-0.649	0.869	-0.91
E	-0.732	0.715	-0.413	-0.649	1.000	-0.599	0.786
F	0.877	-0.862	0.460	0.869	-0.599	1.000	-0.924
AMPI	-0.944	0.913	-0.586	-0.91	0.786	-0.924	1.000

Indicators	Meaning
A	Percentage of Population aged 0-17 years
B	Old age dependency ratio
C	Childbearing per fertile woman
D	Percentage of Women 15-49 years
E	Aging index
F	Population turnover index

4.2. AMPI ranking results

The aim of the work is to compare the levels of ageing in Italy in space and time. Ageing results calculated on a municipal basis, considering the Italian territory as of 31 December 2021 (7,903 municipalities), were compared over 20 years. The base year considered was 2001. Figure 3 shows the map of Italian municipalities according to the value of ageing, calculated by AMPI method.

Figure 3 – *AMPI ranking: Maps of Italian municipalities (years 2001, 2011, 2021).*



The map highlights municipalities with a low level of population aging using a dark green color. As the intensity of the green color becomes lighter, the aging phenomenon increases in intensity, eventually transitioning to shades of red. The darker the color, the higher the level of aging in those areas.

It is evident that over the course of 20 years, the level of population aging in Italy has exponentially increased, even in areas that have traditionally been

considered less affected by this phenomenon. If in 2001, only certain areas of Italy had high levels of population aging (particularly in Liguria and neighboring areas), by the time we reach 2011 and 2021, the phenomenon has spread extensively. In 2001, the base year of the analysis, 40.0% of Italian municipalities had a value of AMPI equal to or below 100. In 2011, this percentage dropped to 11.7%, and in 2021 it further decreased to 4.6%. These percentages indicate a significant surge in population aging during the 2001-2011 decade. In 2021, only the autonomous province of Bolzano/Bozen had a percentage of municipalities below the value of 100 that exceeded 50% (66.4%).

4.3. Chisquared Automatic Interaction Detector (CHAID) results

As mentioned above, the CHAID, using the composite AMPI index as the dependent variable and some administrative-geographic-demographic indicators as the independent variables, makes possible to identify groups of municipalities with similar AMPI index values. Figure 4 shows the results of the best and worst nodes in every year of observation.

Figure 4 – *The best and worst nodes (years 2001, 2011, 2021).*

EDITION	2001	2011	2021
BEST NODE	NODE 32	NODE 23	NODE 15
	1-Degree of urbanisation: Urban Audit cities	1-Degree of urbanisation: Urban Audit cities	1-Demographic size of municipalities class: 2,001-5,000 and 100,001 and over
	2-Region: Campania	2-Region: Campania	2-Province/Metropolitan City: Bolzano/Bozen
	Number of municipalities: 77	Number of municipalities: 77	Number of municipalities: 51
WORST NODE	NODE 69	NODE 45	NODE 60
	1-Degree of urbanisation: Rural areas	1-Degree of urbanisation: Rural areas	1-Demographic size of municipalities class: up to 500
	2-Province/Metropolitan City: Alessandria, Genoa, La Spezia	2-Population density: up to 35 persons per km2	2-Population density: up to 20 persons per km2
	3-Population density: up to 35 persons per km2	3-Region: Liguria, Emilia-Romagna	3-Region: Liguria, Friuli-Venezia Giulia, Emilia-Romagna, Lazio, Campania, Abruzzo, Molise, Puglia, Basilicata, Calabria
	Number of municipalities: 68	Number of municipalities: 61	Number of municipalities: 169

77 municipalities, where at least 50 per cent of the population lives in one or more urban centres of the Campania were found to be the best node at the AMPI level of ageing. Basically, these municipalities, on average, had the best level of the composite indicator for 2001 and 2011. In 2021, the situation changes: 51 municipalities in the Autonomous Province of Bolzano/Bozen with a population between 2,001 and 5,000 inhabitants or more than 100,001 inhabitants will be the least 'old' municipalities.

The situation becomes more complex for municipalities with a high level of population aging. In 2001, 68 municipalities in rural areas of the provinces/metropolitan cities of Alessandria, Genoa, and La Spezia, with a population density of up to 35 inhabitants per kmq, had the highest average level of

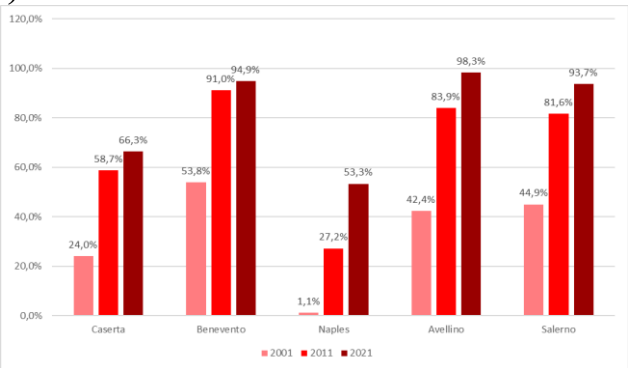
AMPI (an index measuring population aging). In 2011, 61 rural municipalities with less than 35 inhabitants per kmq in the regions of Liguria and Emilia-Romagna were at the forefront in terms of population aging. In 2021, an even higher number of 169 municipalities, with a demographic size class of up to 500 inhabitants and less than 20 inhabitants per kmq, in the regions of Liguria, Friuli-Venezia Giulia, Emilia-Romagna, Lazio, Campania, Abruzzo, Molise, Puglia, Basilicata, and Calabria, were on average the 'oldest'. These results demonstrate how the phenomenon of population aging has spread across the entire Italian territory over the past two decades.

5. Territorial insights

5.1. Campania

Given the results generated by the classification trees, a focus was placed on the Campania region to understand the evolution over time of population aging in what was once the most virtuous territory (i.e., the least 'old') in Italy. Figure 5 displays, in percentage, the number of municipalities in each province of Campania that, in the three examined censuses, had an AMPI value higher than 100 (the baseline value for Italy in 2001).

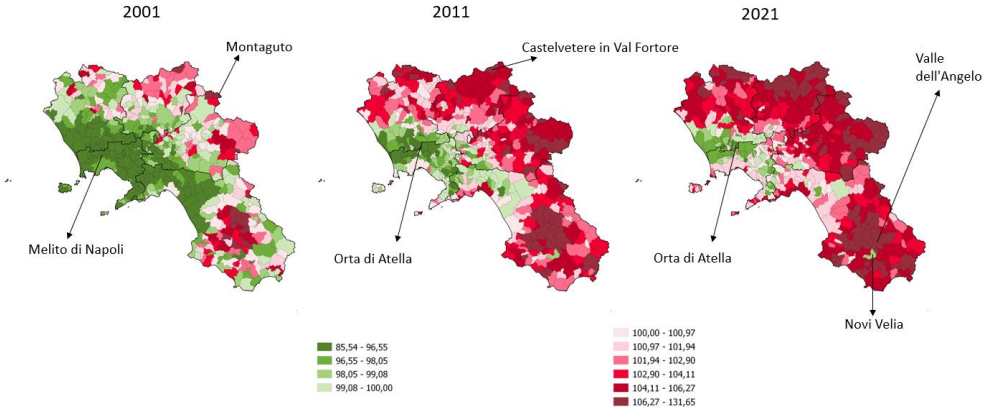
Figure 5 – *Percentage of municipalities with an AMPI value > 100 (years 2001, 2011, 2021).*



In 2001, only the province of Benevento had more than half of its municipalities (53.8%) with an AMPI level higher than 100. After 10 years 3 provinces (Salerno, Avellino and Benevento) have more than 80.0% of municipalities with an AMPI value > 100; the same provinces at the end of the 20-year period of analysis have more than 90.0% of municipalities with an AMPI value above 100.

Figure 6 shows the aging trend in the municipalities of Campania.

Figure 6 – *Map of the aging trend in the municipalities of Campania (years 2001, 2011, 2021).*



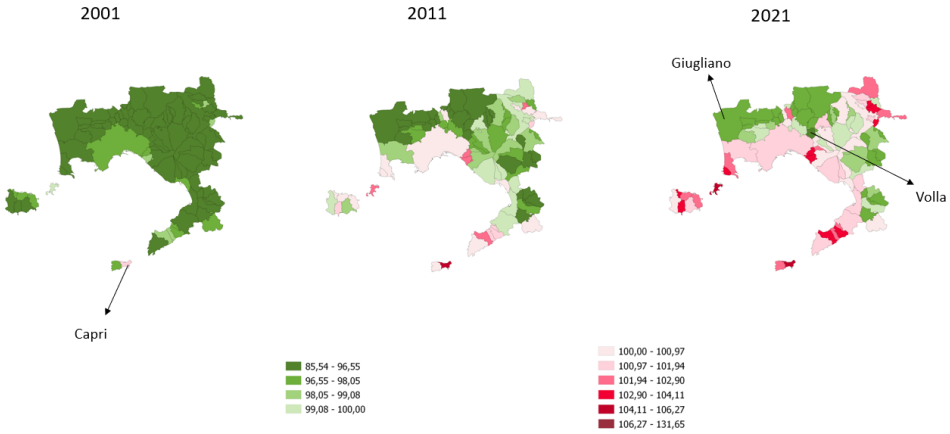
The worst Ampi value in 2001 (111.54) was in Montaguto (AV), in 2011 (113.24) in Castelvetere in Val Fortore (BN), in 2021 (115.98) in Valle dell'Angelo (SA). The best Ampi value in 2001 (85.54) was in Melito di Napoli (NA), in 2011 and 2021 (90.36, 92.89) in Orta di Atella (CE). The widest gap was recorded between 2001 and 2011 in the province of Salerno (+41.5%), between 2001 and 2021 in the province of Avellino (+55.9%).

5.2. Metropolitan city of Naples

From the results obtained in the analysis of AMPI in Campania, it was immediately noticed the uniqueness of the municipalities in the metropolitan city of Naples, with values of the index exceeding 100 by 1.1% in 2001, 27.2% in 2011, and 53.3% in 2021. Figure 7 shows the aging trend in the municipalities of metropolitan city of Naples. In 2001, Capri was the only municipality with an AMPI value > 100 and for all years under analysis had the worst AMPI value (101.11, 104.38, 106.17). The best Ampi value in 2001 and in 2011 was in Melito di Napoli (85.54 and 93.27 respectively), in 2021 in Volla (96.22). The municipality of Naples has a similar AMPI value between 2011 and 2021 (100.81 vs 100.82). Volla is the only one municipality to have an AMPI value within the first decile in all years (87.34; 94.46; 96.22). No island municipality in 2021 has an AMPI value < 100. Giugliano in 2021 is the only one costal municipality to have an AMPI value > 100. No municipality has a higher AMPI value in 2001 than in 2011.

Looking at the population figures over the last 20 years, a very slight decrease can be seen: from 3,059,196 in 2001 to 2,988,376 in 2021. The population by age shows that individuals over 64 years of age have increased by 6.7%, from 12.5% to 19.2% of the total population. Furthermore, women of childbearing age decrease from 51.1% in 2001 to 43.1% in 2021. All this could suggest that ageing in the metropolitan city of Naples is actually due to the phenomenon of a decline of births compared to deaths. Migration phenomena and their impact on the population structure could be analysed although "The effect of migration on population aging is generally regarded as minor in most situations […] So, the demographic dynamics has caused and will continue to cause population aging, which is the increase in the population above the age of 65 in absolute terms, both as compared to the younger population and as a proportion of the total population." (Reynaud and Miccoli, 2018).

Figure 7 – *Map of the aging trend in the municipalities of metropolitan city of Naples (years 2001, 2011, 2021).*



6. Conclusions and Next Steps

The phenomenon of population ageing at municipal level, using data from the traditional Population Census, provided a snapshot of the Italian situation at a ten-year interval. If it had been possible to access annual data, as the new Permanent Population Census allows, understanding population ageing at municipal level would have been more efficient. Indeed, it could have facilitated the identification of demographic changes and supported the implementation of more timely and effective policies to address the challenges associated with an ageing population.

This study could be further developed by comparing the trend of Italians and foreigners in the territory, expanding the set of elementary indicators used (e.g. Labour Force and Education) and by analyse internal and international migration. Furthermore, one could study ageing as a function of other territorial classifications (e.g. Local Employment Systems, Ecoregions, Inner Areas).

References

DE MURO P., MAZZIOTTA M., PARETO A. 2011. Composite Indices of Development and Poverty: An Application to MDGs. *Social Indicators Research*, Vol. 104, pp. 1-18.

EUROSTAT. 2019 - *Methodological manual on territorial typologies, 2018 edition*. Luxembourg: Publications Office of the European Union.

ISTAT. 2022. *Censimento permanente della popolazione e delle abitazioni*, Nota tecnica diffusione edizione 2021.

ISTAT. 2013. *Censimento della popolazione e delle abitazioni*, Comunicato stampa, edizione 2011.

ISTAT. 2003. *Censimento della popolazione e delle abitazioni*, Comunicato stampa, edizione 2001.

MAZZIOTTA M., PARETO A. 2016. On a Generalized Non-compensatory Composite Index for Measuring Socio-economic Phenomena. *Social Indicators Research*, Vol. 127, No. 3, pp. 983-1003.

MAZZIOTTA M., PARETO A. 2013. Methods for Constructing Composite Indices: One for all or all for one. *Rivista Italiana di Economia Demografia e Statistica*, Vol. LXVII, No. 2, pp.67-80.

REYNAUD C., MICCOLI S. 2018. Depopulation and the Aging Population: The Relationship in Italian Municipalities. *Sustainability*, Vol. 10, No. 4.

WALKER A., MALTBY T. 2012. Active ageing: A strategic policy solution to demographic ageing in the European Union, *International Journal of Social Welfare*, Vol. 21, No. S1, pp. S117-S130.

Gennaro DI FRAIA, Istat, difraia@istat.it
Valeria QUONDAMSTEFANO, Istat, quondamstefano@istat.it
Mariangela VERRASCINA, Istat, verrasci@istat.it