

ANALYSIS AND EVALUATION OF THE POPULATION AGING PHENOMENON IN THE MOUNTAIN AND MARGINAL CONTACT AREA OF MUREȘ COUNTY BETWEEN 1992–2024. TRENDS AND IMPLICATIONS FOR PUBLIC POLICY DESIGN

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ABSTRACT. – **Analysis and Evaluation of the Population Aging Phenomenon in the Mountain and Marginal Contact Area of Mureș County between 1992–2024. Trends and Implications for Public Policy Design.** Our study started from the premise that demographic indicators represent essential instruments for substantiating public policies and for evaluating socio-economic dynamics at national, regional, and local levels. The population, together with its age structure and the evolution of demographic dependency indicators, constitutes key reference elements in the process of developing strategies regarding the pension system, social protection, education, and the allocation of financial resources from public budgets. At the same time, the analysis of demographic changes makes it possible to identify trends related to population aging, declining birth rates, and the intensification of migration phenomena, aspects that directly impact economic and social sustainability. In this context, the aim of this study is to analyze the evolution of relevant indicators for the demographic potential of the mountain and marginal contact area of Mureș County, identifying the evolution of the population by age groups, the demographic dependency ratio, and the old-age and youth dependency rates, as well as assessing these indicators for the substantiation of public policies. The analysis was carried out based on data provided by the National Institute of Statistics, using statistical methods of graphical and tabular representation for a clearer and more coherent interpretation of the results. The conclusions highlight the intensification of the

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demographic aging process and its implications for regional and local socio-economic development, thus enabling public authorities to establish local demographic development strategies and adopt measures aimed at mitigating the negative effects of demographic aging.

Keywords: *population, age pyramid, demographic structure, demographic dependency ratio, population aging.*

1. INTRODUCTION

The phenomenon of demographic aging represents one of the most profound structural transformations of contemporary society, with significant implications for economic, social, and territorial development (Harper, 2016; Țăruș et al., 2021a; Rusu et al, 2024; Rusu et al, 2025). It is a long-term population process generated by structural shifts in favor of older age groups ("third age") to the detriment of younger age groups. This process is durable and cumulative, and difficult to reverse in the absence of coherent demographic policies.

Romania, like other European states, is facing a continuous decline in birth rates, an increase in life expectancy, and an intensification of external migration, factors that contribute to altering the balance between the active and inactive population (Țăruș et al., 2022; Rusu et al, 2025). This process does not manifest uniformly across the territory, being much more pronounced in certain vulnerable areas, such as mountain regions, characterized by reduced accessibility, limited infrastructure, and restricted economic opportunities.

The longitudinal analysis of population structure is essential for understanding the mechanisms of persistence of aging and for identifying territorial differences that persist over time. The specialized literature emphasizes the existence of "demographic inertia," whereby age structures tend to reproduce themselves over several population cycles (Preston et al., 2001; Lutz & Samir, 2013a).

Mureș County presents significant demographic heterogeneity, especially in the mountain and marginal contact area, where depopulation and aging have intensified over recent decades. Here, the decline in the resident population, the increase in the share of elderly persons, and the reduction of the labor force affect both the local development potential and the sustainability of public services. Moreover, demographic changes influence the way rural communities can maintain their traditional economic structures, putting pressure on health systems, social assistance, and infrastructure.

Analyzing the aging phenomenon in this territorial context is essential for understanding demographic dynamics and for substantiating intervention policies adapted to local realities (Țăruș and Dezsi, 2021b; Rusu et al, 2024;

Rusu et al, 2025). An aging population leads to a decrease in the labor force and consequently to increased healthcare costs, placing pressure on pension and health systems. Conversely, a young and economically active population generates economic growth. Additionally, the age structure influences the type of goods and services consumed; for example, an aging population increases demand for medical services.

This study aims to investigate the evolution of the main indicators influencing population aging in the mountain and marginal areas of Mureș County, using official statistical data and analytical tools that allow a clear evaluation of trends. Through this approach, we seek to highlight the challenges and opportunities generated by demographic changes and to contribute to a better understanding of their implications for regional development.

2. LITERATURE REVIEW

Population aging has become a central topic in demographic and economic literature, both nationally and internationally, being analyzed from multiple perspectives that highlight its consequences for the labor market, social protection systems, and economic development.

At the international level, Andersen, Markussen, and Røed (2021) analyzed pension system reforms in Norway, emphasizing how these influence income distribution at older ages and revealing the need to adjust policies in response to demographic changes. In the same direction, Hernæs, Markussen, Piggott, and Røed (2024) showed that improving incentives for labor market participation increases employment rates among individuals approaching retirement age, thereby reducing pressure on public pension systems.

Bloom et al. (2010) argue that aging undermines innovation and growth trajectories driven by human capital. It has been demonstrated that workforce aging significantly reduces labor productivity growth, mainly through its negative effects on total factor productivity (Aiyar & Ebeke, 2017). Mason et al. (2022) further emphasize that sustainable development in Asia is threatened by demographic change, calling for a dual strategy that combines the transition from a “demographic dividend” to a “talent dividend” with a green transformation.

Feder (1985) and Munnich et al. (2003) find that population aging increases healthcare and pension expenditures, reduces agricultural capital investments, and slows the adoption of advanced agricultural technologies, thereby constraining productivity growth. Taken together, this evidence suggests that population aging has both common global impacts and context-specific transmission mechanisms, particularly in rural economies. Research by Cooley and Henriksen (2018) highlights that the slowdown in economic growth

can partly be explained by changes in demographic structure, especially population aging and increased life expectancy. Cruz and Ahmed (2018) analyzed the relationship between the share of the working-age population, per capita economic growth, and poverty rates, concluding that demographic dynamics directly affect economic performance and well-being levels.

Regarding environmental changes, Liddle (2014) demonstrated that demographic developments such as age structure, urbanization, and household size significantly influence energy consumption and carbon emissions, while Samways (2022) highlighted the interdependence between population growth and ecosystem transformations. Hummel et al. (2013) noted the fragmented nature of research on the links between demography and sustainability, emphasizing the need for an interdisciplinary approach. More recently, Ishika (2025) argued that demographic structure shapes labor markets, consumer behavior, and investment strategies, suggesting that policymakers must harness the potential of various demographic segments in the context of new social realities.

Addressing active aging, Schmidhuber, Fechter, Schröder, and Hess (2021) analyzed policies aimed at extending working life and postponing retirement, while Waddell et al. (2025) compared different support models for older persons, highlighting their limitations in relation to population diversity and the need to redefine the concept of “aging well.”

In Romanian context, demographic aging is defined as the increase in the share of the elderly population (65 years and over) in total population (Rotariu, 2009; Netedu, 2016; Jemna, 2017). Other studies (Anghel, 2025) present population aging as a factor hindering economic growth by reducing the effective labor supply, decreasing household consumption, and accelerating the deterioration of demographic components, especially in rural areas. Anghel (2021) analyzed the situation of the elderly population in Romania during the pandemic, highlighting its impact on living standards and on the gap compared to European standards regarding pensioners' incomes.

The negative evolution of birth rates, the slight increase in mortality, and the migration of young people to urban areas or abroad intensify demographic decline, a phenomenon particularly accentuated after 1990, when the natural balance in rural areas became predominantly negative, while urban areas maintained positive values for a longer period. Analyses of the population structure by domicile (Anghel, Radu, & Bîrsan, 2020) provided a complex perspective on recent demographic changes, while other studies (Anghelache, Anghel, & Ciobanu, 2022) drew attention to the worrying decline in Romania's resident population, considering it a major risk for future development. Similarly, Anghelache et al. (2021) emphasized the role of population as a fundamental resource for a country's economic potential, underlining the importance of a detailed analysis of its structure and dynamics.

Regarding the natural recovery of the resident population, this can only occur over a long period and only if the number of deaths decreases and the number of births increases sufficiently to generate a positive natural balance. However, this objective is difficult to achieve in the short term, given that halting the decline in the annual number of births is challenging. As Ghețău (2007) stated: *“After 35 years of demographic decline, a return to positive natural growth could only result from a substantial recovery of fertility and a reduction in mortality, a development that is not foreseeable.”*

By combining these contributions, the literature reveals that demographic aging is a complex process located at the intersection of economic, social, and territorial trends. In the case of mountain and marginal contact areas, demographic vulnerability is amplified by geographical conditions, accessibility constraints, and limited economic opportunities, making a contextualized approach to the phenomenon necessary.

3. DATA AND RESEARCH METHODOLOGY

The informational basis of the study was constructed by integrating official national and international sources, as well as derived datasets processed within the research framework. Specifically, we used official statistical data provided by the National Institute of Statistics (INS), from which we extracted raw time series data covering the period 1992–2024 regarding the resident population and the population by age groups; Eurostat reports; and other academic studies on the evolution of population aging. Additional secondary sources included bibliographic materials.

Based on the processing of raw data, derived datasets were obtained as constructed time series. The constructed dataset covers a balanced panel of 19 administrative-territorial units in the mountain and marginal contact area of Mureș County, from 1992 to 2024, including two urban units and 17 rural units (Fig. 1).

Since the study aimed to explore the evolution of the population by age groups in correlation with the resident population, the adopted methodology is quantitative-analytical, integrating comparative temporal and spatial elements, structured into the following stages:

- Data collection and validation – validation of time series for consistency and accuracy, identification of gaps, and correction of errors through cross-checking between sources;
- Statistical processing – transformation of raw data into standardized indicators to ensure comparability between years, residential environments, and administrative-territorial units;

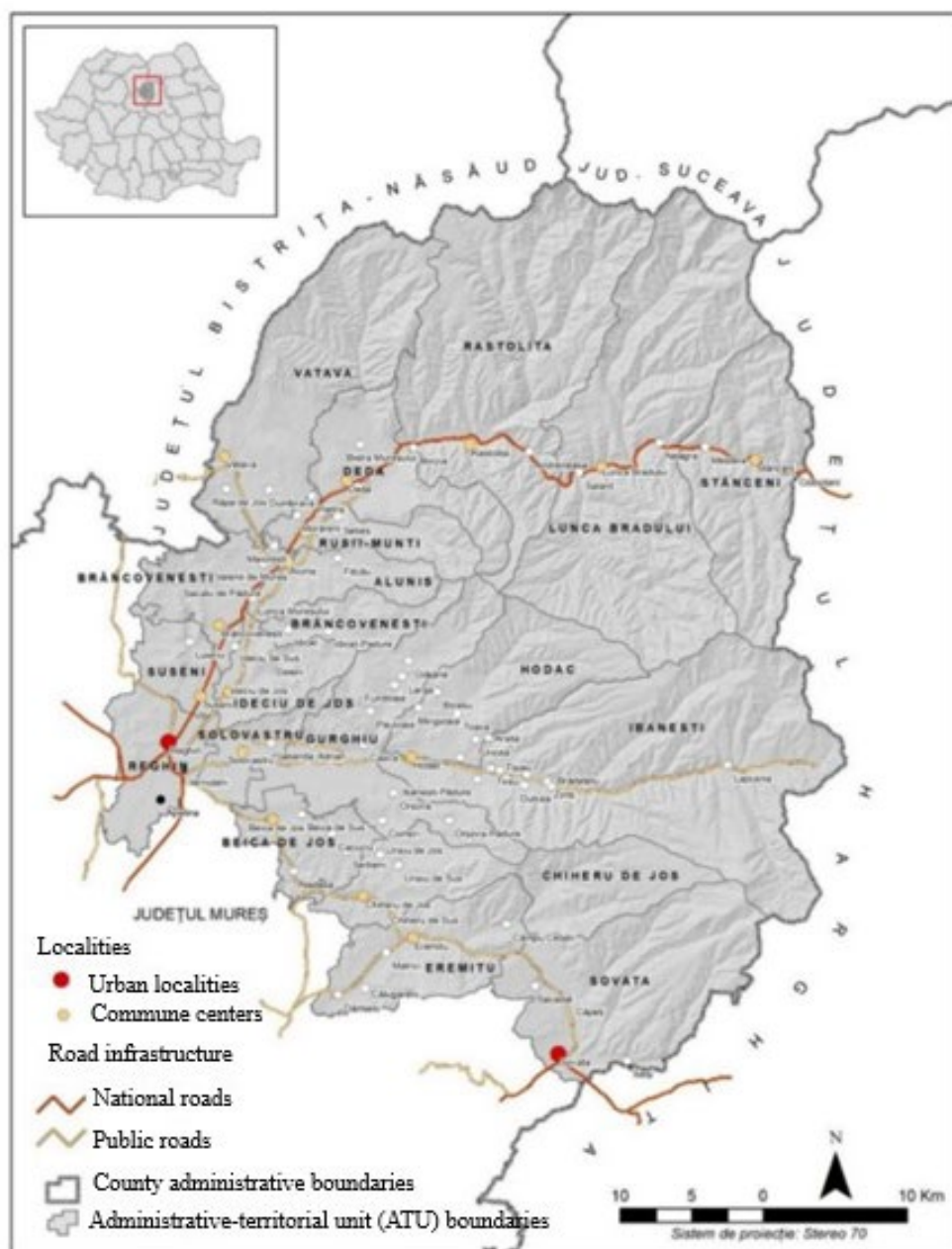


Fig. 1. Territorial Delimitation of the Study Area at Regional and National Level.
Source: the authors

- Trend analysis – identification of tendencies through time-series analysis and determination of structural changes;
- Correlation of indicators – use of correlation and regression techniques to investigate causal relationships between indicators;
- Demographic projections – modeling future scenarios through linear extrapolation and cohort-component methods (Cohort Component Method of Population Projection – CCMPP).

For each stage, a comprehensive approach was applied to ensure both the validity and the relevance of the obtained results.

The research employed integrative modeling, facilitating the construction of prospective demographic scenarios. This allowed the anticipation of developments and impacts relevant for public policies and strategic planning. Demographic projection models enabled the estimation of population evolution based on current trends in natural and migratory dynamics, as well as the development of multiple scenario analyses, offering a flexible perspective on the future, including optimistic, pessimistic, and neutral variations regarding the evolution of the population aging phenomenon.

To determine the degree of population aging, we analyzed the evolution of internal factors as the basis of the demographic structure by age groups, fundamental to population aging (Miladinov, 2020; Rusu et al, 2025), by examining natural changes within the population using demographic indicators such as birth rate, mortality rate, and natural balance rate, which reflect the natural changes of the population (Kim et al.; Lai et al., 2023; Rusu et al, 2024).

Consequently, the study aims to contribute to the development of forecasts regarding the phenomenon of population aging in the mountain and marginal contact area of Mureș County and to demonstrate the importance of local and regional demographic strategies in formulating more efficient structural social development policies. These policies should address the various disadvantages faced by aging communities, especially in rural areas, reduce social shocks, and increase investments in sustainable aging.

4. RESULTS AND DISCUSSIONS

The structural changes in Romania after 1989, in a context where economic, social, and demographic transitions occurred simultaneously and influenced one another, led to significant modifications in birth and mortality rates, thus contributing to a negative natural balance over the past three decades.

The analysis of data series in the study area, by residential environment, regarding the evolution of the natural balance rate and its general trend shows a decline of the indicator across all three series (study area, urban environment, and rural environment), but with significant differences:

- urban environment values are generally higher and closer to zero, with several positive years (e.g., 1992, 1994, 1999–2009), indicating a relatively better situation compared to rural areas, maintaining positive values in certain periods;
- rural environment values are consistently negative throughout the entire study period, with pronounced declines in 1996, 2004, and especially after 2010, suggesting persistent demographic deterioration;
- the values for the study area represent the average of the values recorded in the two residential environments, following an intermediate pattern between the urban and rural trends (Fig. 2).

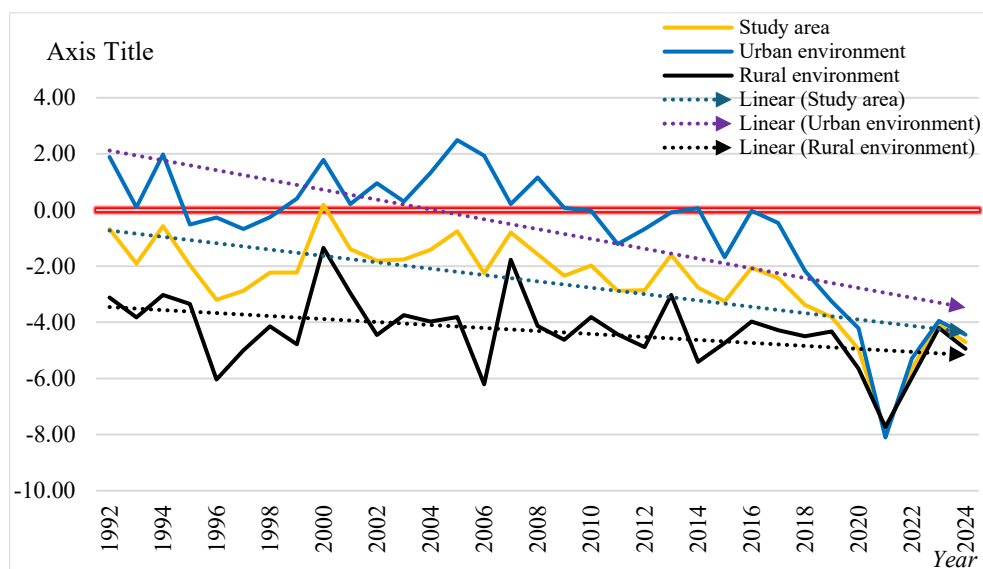


Fig. 2. Evolution of the Natural Balance Rate and Its Trends (1992–2024).

Source: the authors, based on INS data

This evolution shows that the phenomenon of natural depopulation is not specific only to the study area, but is part of a broader demographic trend at county and national levels. This situation has important implications for public policies, suggesting the need for coordinated measures at local, regional, and central levels to stimulate birth rates, reduce migration, and improve quality of life, especially in vulnerable areas.

The analysis of the natural balance rate (1992–2024) highlights that, during this period, at the level of the study area, differentiated by residential environments (urban and rural), there is a generalized downward trend, with a progressive intensification of negative values, particularly after 2016.

The study area, as a whole, recorded an average annual decrease of approximately -0.13% per year, shifting from relatively balanced values in the 1990s to a historic low in 2021 (-7.91%), followed by a slight improvement, yet remaining within negative values. This evolution reflects a structural deterioration of the demographic balance. The year 2021 marks a negative inflection point for all three series, associated with the effects of the COVID-19 pandemic and its interaction with pre-existing structural factors (population aging, external migration, declining fertility).

The observed trends indicate that, in the absence of consistent demographic and socio-economic interventions, the natural demographic imbalance will continue to deepen, particularly affecting rural communities. Projections for the next five years, based on linear regression, suggest the maintenance of negative natural balance values, with possible stabilization around current levels, without returning above the positive threshold (Fig. 9).

Against the background of this natural population evolution, the age structure of the population has also been influenced—an important indicator in assessing the qualitative aspects of the population—through which we evaluated demographic aging trends. When analyzed in combination with other demographic indicators, this measure supports the evaluation of population quality levels and the development of demographic forecasts necessary for the demographic and socio-economic stability of a state, region, or community.

In this context, the demographic pyramids by age groups and gender clearly reflect the structural developments in the study area in the two years selected for analysis and comparison (1990 and 2024).

During this period, the 0–14 age group recorded a significant decline both in absolute and relative terms, indicating a growing imbalance in the generational replacement mechanism and a weakening of the age pyramid structure, through the narrowing of its base and the gradual inversion of the age pyramid. This phenomenon is associated with the “fertility gap,” namely the difference between the desired and the actual number of children per family, exacerbated by economic uncertainty and the migration of the fertile population (Fig. 3).

The structural analysis shows that in the last five years the number of live births reached the historic minimum of the past three decades, with an average decrease of approximately 0.4% births per year, confirming the downward trend in the share of the young population (0–14 years) and the risk of an intensifying demographic gap in the coming period (Fig. 4).

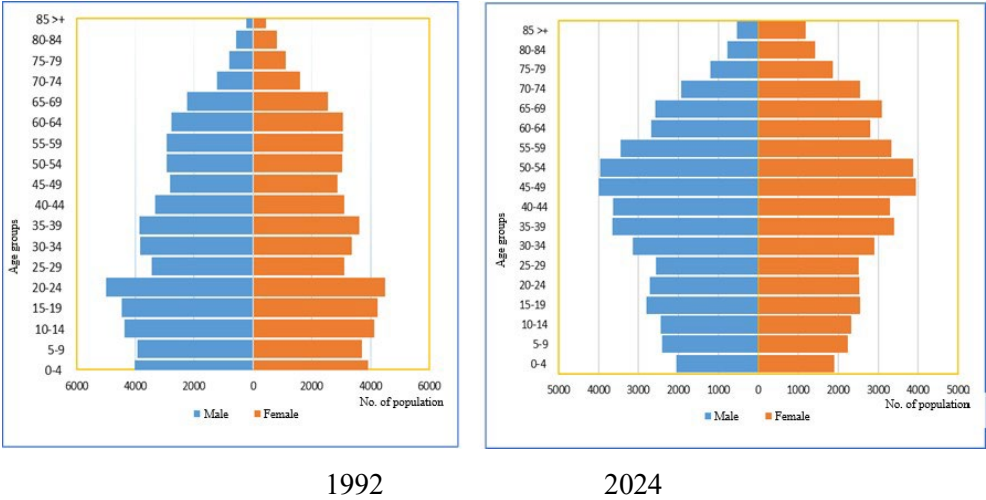


Fig. 3. Age and Gender Population Pyramids of the Study Area, in 1990 and 2024
Source: the authors, based on INS data

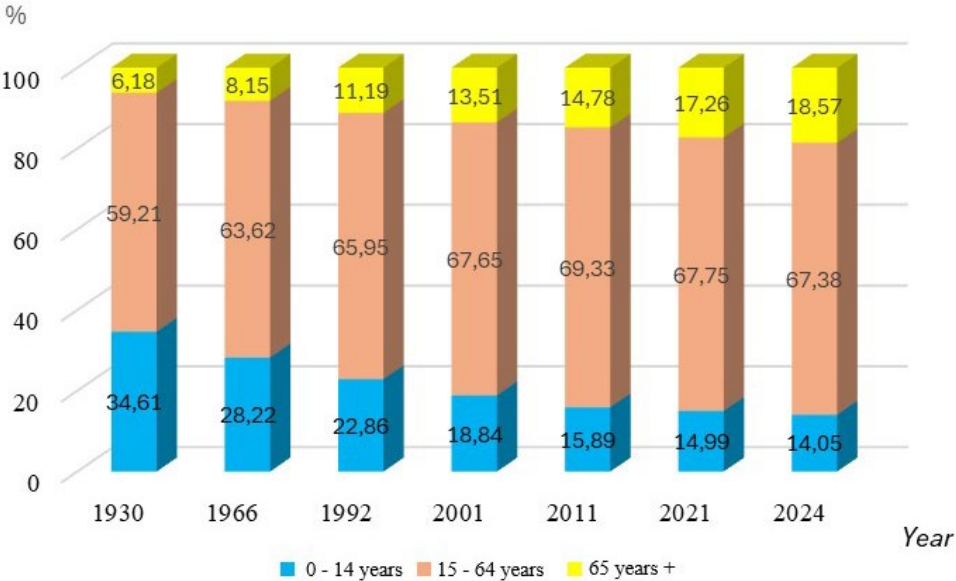


Fig. 4. Evolution of the Population Share by Age Groups in the Study Area, 1930–2024.
Source: the authors, based on INS data

In parallel, the proportion of elderly population (65 years and over) follows an upward trend, with an average annual increase of approximately 200 persons in urban areas and slightly less than 100 persons in rural areas. The demographic aging of the studied area is the result of the combination of declining fertility, increasing longevity, selective external migration and rural exodus - four processes whose interaction has generated an irreversibly modified demographic structure, in which the share of the elderly population is evolving upward, with differentiated intensity by residence area (fig. 4).

The resulting demographic polarization — characterized by the shrinking young population base and the expansion of older age groups — places the population of the study area in an advanced stage of the demographic transition. This trend also signals significant socio-economic sustainability risks in the absence of effective policies aimed at stimulating fertility, repatriating migrants, and adapting social systems to the aging population.

Data from Table 1 indicate that the share of the young population (0–14 years) in 2024 is 8.81% lower than in 1992. The working-age population (15–64 years) has also experienced a slight decline in recent years. Conversely, the proportion of the elderly population (65 years and over) in 2024 is 7.38% higher than in 1992. These data confirm the continuous decrease in the proportion of young people, alongside the growth of the elderly population share, highlighting the intensification of the demographic aging process.

Table 1. Evolution of the population share by broad age groups
in the study area, 1930–2024

Year	0–14 years (%)	15–64 years (%)	65+ years (%)	Total population (thousands)
1930	34,61	59,21	6,18	72004
1966	28,22	63,62	8,15	91818
1992	22,86	65,95	11,19	107608
2001	18,84	67,65	13,51	105070
2011	15,89	69,33	14,78	102501
2021	14,99	67,75	17,26	98359
2025	14,05	67,38	18,57	95512

Source: adapted by the author based on INS data

Analyzing the demographic trajectory at the study area level requires comparing the dynamics of the young population share (0 – 14 years) with that of the elderly population (65+ years) to identify the point at which the “third age” is reached and demographic aging becomes evident.

According to the criteria proposed by Laslett and Paillat (1999), the 10% threshold of the population aged 65 and over defines the beginning of the “third age,” while according to Eggericks and Tabutin (2001), demographic aging starts at 5% and becomes advanced when the threshold of 20% is exceeded (Table 2).

Table 2. Evolution of the elderly population share in the study area, 1930–2024

Year	Share 65+ (%)	Share 60+ (%)	Stage of the process
1930	6,18	8,33	Beginning of aging
1966	8,15	12,28	"Consolidation" of aging
1992	11,19	16,78	Entry into the "third age"
2001	13,51	18,61	Entry into the "third age" with trend of advanced aging
2011	14,78	20,03	Trend of advanced aging
2021	17,26	23,49	Advanced aging with tendency of complete structuring
2024	18,57	24,28	Advanced aging with tendency of complete structuring

Source: adapted by the author based on INS data

Thus, while at the beginning of the 1990s the phenomenon of population aging was only marginally present, it has gradually become critical by 2024, when the share of the population aged 65 and over rose from 11.19% (11,606 persons) in 1992 to 18.57% (17,123 persons) in 2024. At the same time, the population aged up to 15 years decreases from 22.86% (24,071 persons) in 1992 to only 14.05% (13,380 persons) in 2024.

This evolution confirms the acceleration of the demographic aging process, correlated with the continuous decline in birth rates and negative net migration. In the present study, the analysis of demographic aging focused on identifying inflection points in the population structure by correlating the reduction in the share of young people (0–14 years) with the increase in the proportion of elderly population (65 years and over), who are economically inactive.

Changes in the population structure by small age groups reflect profound demographic shifts with a direct impact on the functioning of social and economic systems. A comparative analysis of the data from 1992 and 2024 highlights a significant decrease in the share of children and youth, alongside a marked increase in the elderly population segment (Table 3).

Table 3. Share (%) of the population by small age groups in 1992 and 2024

Age group	1992	2024	2024 vs 1992 (%)
0-4 years	7,53	4,12	-45,29
5-9 years	7,24	4,97	-31,35
10-14 years	8,10	4,96	-38,77
15-19 years	8,31	5,64	-32,13
20-24 years	9,01	5,63	-37,51
25-29 years	6,17	5,30	-14,10
30-34 years	6,82	5,93	-13,05
35-39 years	7,07	7,69	8,77
40-44 years	6,12	7,15	16,83
45-49 years	5,41	8,29	53,23
50-54 years	5,70	8,27	45,09
55-59 years	5,76	7,79	35,24
60-64 years	5,59	5,71	2,15
65-69 years	4,63	5,95	28,51
70-74 years	2,72	4,86	78,68
75-79 years	1,85	3,44	85,95
80-84 years	1,34	2,41	79,85
85 years +	0,65	1,91	193,85

Source: the authors, based on INS data

Based on the data from Table 3, we analyzed the territorial persistence of the demographic aging process over the past three decades. The analysis was conducted using the population distribution by small age groups (standardized 5-year intervals), which allows a detailed assessment of structural changes in the population between 1992 and 2024. Using small age groups reduces the risk of excessive aggregation and ensures a statistically robust interpretation of the aging index.

To highlight the territorial persistence of aging, we constructed a simple linear regression model where the dependent variable is the Aging Index in 2024, and the predictor is the Aging Index in 1992. The dataset includes values for all 18 small-age intervals in the study area. The analysis was performed in Microsoft Excel, using the least squares method for parameter estimation (Fig. 5).

The results show a positive and statistically consistent, although moderate, association between the level of population aging in 1992 and that observed in 2024. The regression coefficient of 0.5229 indicates that a one-unit increase in the index in 1992 is associated, on average, with a 0.52-unit increase in 2024. This result confirms the persistence of stable demographic structures over the long term.

The positive intercept (0.2647) suggests a general trend of increasing aging, independent of initial values. This reflects the demographic pressure characteristic of the post-transition period, marked by declining fertility, increasing life expectancy, and intense migration (Bloom et al., 2010).

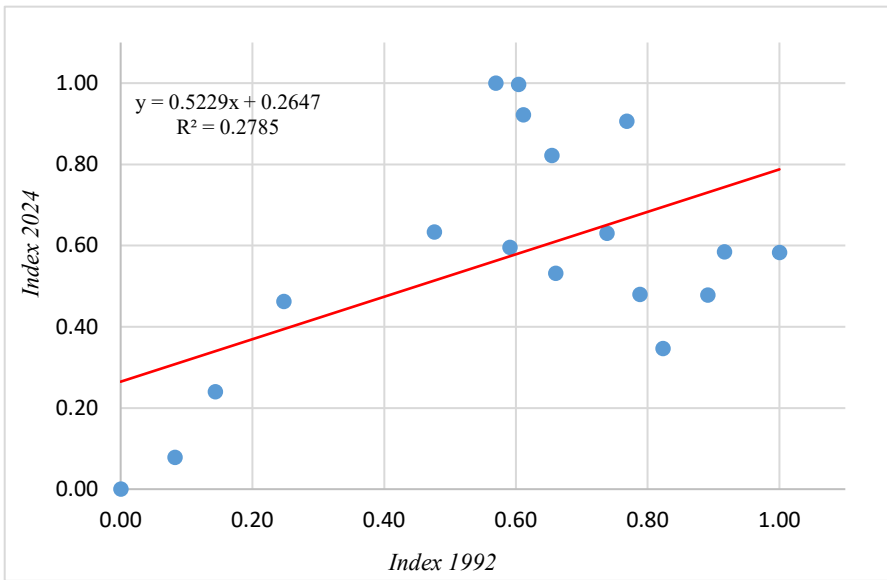


Fig. 5. Trend in population aging based on simple linear regression, comparing 2024 with 1992.

Source: the authors, based on INS data

The estimated regression line has the form:

$$\text{Index}_{2024} = 0.5229 \cdot \text{Index}_{1992} + 0.2647$$

The coefficient of determination $R^2 = 0.2785$ indicates that approximately 27.9% of the variation in the aging index in 2024 can be explained by its level in 1992, suggesting a moderate correlation. Although the relationship is not strong, the R^2 value confirms the existence of a stable structural trend: administrative units that exhibited high levels of aging in the early 1990s tend to maintain relatively high values today. The persistence identified by the model ($R^2 = 0.2785$) suggests that the population age structure is transferred predictably over time, a phenomenon documented in the demographic literature as “structural demographic inertia” (Goldstone, 1991).

The distribution of points around the regression line indicates significant variability between territorial units, reflecting the additional influence of contextual factors: external and internal migration, post-1990 economic restructuring, degree of urbanization, level of social infrastructure, access to services, and availability of elderly care services.

Nevertheless, the positive slope highlights the persistence of a “longitudinal demographic pattern,” where historical trends continue to influence the current population configuration (Lutz & Samir, 2013b).

In conclusion, the moderate R^2 value shows that roughly 72% of the recent variation in aging depends on subsequent external factors, such as massive external migration during 2000–2020, regional differences in economic development, and urban–rural dynamics including suburbanization; as well as internal factors, such as changes in reproductive behavior.

According to the National Institute of Statistics (INS), the level of population aging is calculated as the ratio between the number of elderly people (65 years and older) and the number of young people (under 15 years) in a population, expressed as the number of elderly per 100 young individuals. This is represented by the Population Aging Index (PAI).

Consequently, due to the demographic aging phenomenon, PAI values are expected to increase, and the population’s demographic quality is affected by numerous socio-economic consequences, placing pressure on social and healthcare systems.

To assess the evolution of the Population Aging Index (PAI) in the study area, the data for Mureș County were also plotted for comparison. Analyzing the PAI values in the study area, it is remarked that in 1992 there were 48.22 elderly persons per 100 young people, a phenomenon that over the next 32 years led to a continuous increase in the aging index, reaching 132.15 elderly persons per 100 young people in 2025. The trend in the study area is similar to that recorded for Mureș County, although the increase has been more pronounced in the last decade to the disadvantage of the study area (Fig. 6).

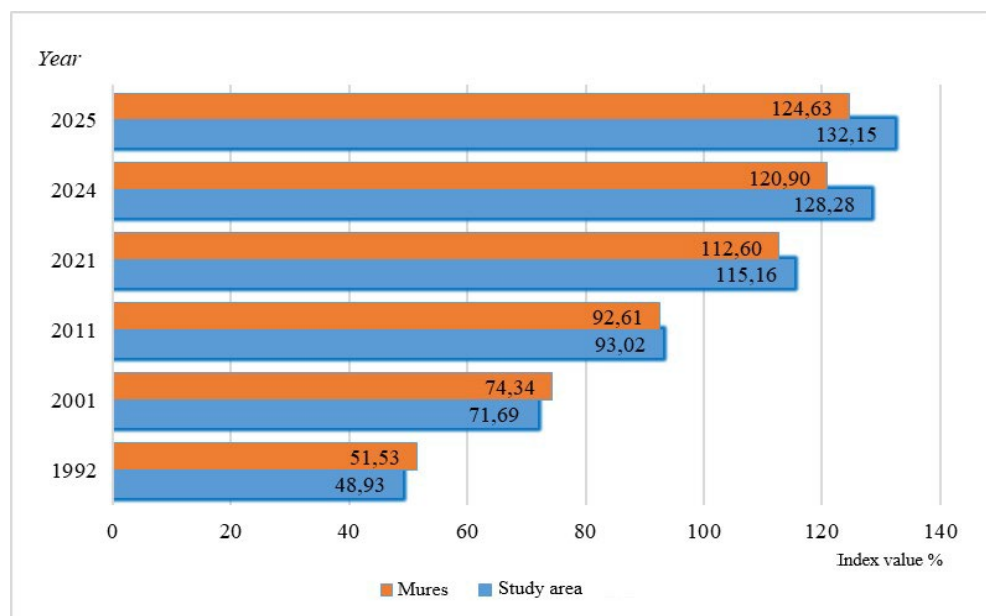


Fig. 6. Evolution of the Population Aging Index in the study area and Mureș County, 1992–2025

Source: the authors, based on INS data

Based on calculations of PAI for all administrative-territorial units (UATs) in the study area, a dynamic classification of the population aging phenomenon was performed. To better highlight the trend, the statistical series used begins in 1966 (Table 4).

Table 4. Dynamic types based on the evolution of the Population Aging Index for UATs in the study area (1966–2025)

UATs	1966	1992	2001	2011	2024	2025	Dynamic type
Aluniș	46,34	111,93	117,25	138,76	138,65	140,87	A – Early rapid aging
Chiheru de Jos	25,34	126,46	161,77	156,54	159,62	162,02	A – Early rapid aging
Vătava	45,40	81,17	113,89	143,79	143,01	137,50	A – Early rapid aging
Reghin	23,67	26,92	51,77	80,25	140,18	147,65	B – Late rapid aging
Sovata	22,95	39,60	59,89	91,99	164,10	166,53	B – Late rapid aging
Gurghiu	32,07	54,81	68,60	89,65	108,59	111,96	B – Late rapid aging

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Ibănești	24,68	58,41	78,03	109,66	127,99	128,00	B – Late rapid aging
Lunca Bradului	19,01	41,34	62,28	85,56	116,31	125,28	B – Late rapid aging
Răstolița	27,97	42,63	63,21	82,64	133,8	128,32	B – Late rapid aging
Suseni	29,78	79,72	97,44	101,83	120,00	125,62	B – Late rapid aging
Deda	52,79	72,34	98,21	89,01	103,68	107,55	C – Moderate aging
Ideciu de Jos	38,49	80,68	86,39	100,00	102,56	106,65	C – Moderate aging
Beica de Jos	30,31	88,18	113,47	106,42	87,53	86,03	D – Stabilization at aged level
Eremitu	27,97	70,32	71,30	73,30	75,34	74,97	D – Stabilization at aged level
Hodac	18,94	48,99	61,48	75,72	89,91	91,62	D – Stabilization at aged level
Solovăstru	28,43	75,79	87,13	96,00	95,66	96,28	D – Stabilization at aged level
Brâncovenești	40,91	92,66	130,42	150,09	179,77	181,22	E – Extreme aging
Rușii-Munți	34,86	87,87	92,56	101,89	169,88	183,77	E – Extreme aging
Stânceni	24,82	57,39	86,51	122,52	186,13	195,45	E – Extreme aging
PAI in the study area	28,83	48,22	70,75	91,94	127,97	132,15	B – Late rapid aging

Source: the authors, based on INS data

For the dynamic classification of population types based on PAI over the period 1966–2025, we used a typology adapted from UN models and Romanian demographers, taking into account the initial level, the growth rate, and the moment when the critical threshold (PAI = 100) is exceeded.

Thus, the main dynamic types resulting from the evolution of the Population Aging Index (Fig. 7) are:

Type A – Early rapid aging: Initial PAI is moderate (<50), but exceeds the threshold of 100 before the year 2000. The growth rate is accelerated, and the population becomes very aged at an early stage.

Type B – Late rapid aging: Initial PAI is low (<40), but surpasses 100 after 2000, with a rapid increase in the last decades.

Type C – Moderate aging: PAI increases steadily but remains below 100 for a long time, exceeding this threshold only recently (after 2011).

Type D – Stabilization at aged level: PAI has had high values already in the 1960s–1970s, with smaller increases thereafter.

Type E – Extreme aging: PAI currently shows very high values (>150), with a constant growth rate.

In conclusion, the demographic aging phenomenon in the study area has intensified, and at present it falls under *Type B – Late rapid aging*.

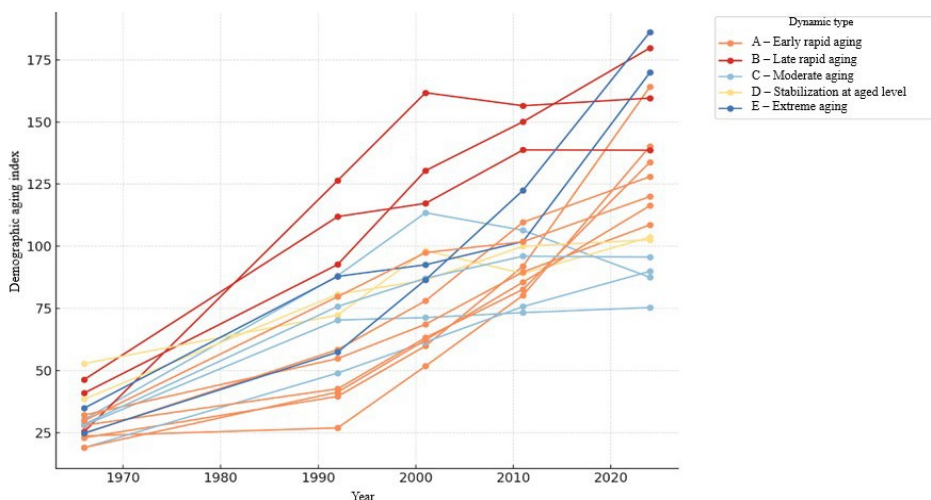


Fig. 7. Evolution of the Population Aging Index by dynamic types, 1966–2025

Source: the authors, based on INS data

The effects of demographic aging threaten the sustainability of social and healthcare systems through increased costs for social, psychological, and medical services. To counteract these effects, the main solutions should focus on: adjusting pensions, increasing employees' contributions to the pension fund, raising the retirement age, equalizing the retirement age for men and women, increasing the employment rate among the working-age population—especially women, who have higher life expectancy than men—and accepting an inflow of working-age immigrants.

To provide a perspective on the balance between economic and demographic conditions in the study area, another aspect of population quality was evaluated, namely the Dependency Ratio (DR), which measures the proportion of dependent individuals in a population relative to the working-age population. “Dependent” individuals generally include children (under 15 years) and the elderly (over 64 years), while the working-age population comprises those aged 15–64 years. The ratio is usually expressed numerically, indicating how many individuals from the dependent age groups exist per 100 individuals of working age (15–64 years).

A high dependency ratio indicates significant pressure on the working population, which must support dependent individuals both financially and socially. Conversely, a low dependency ratio suggests a larger proportion of working-age individuals compared to dependents, potentially facilitating economic growth and reducing pressure on social systems.

This phenomenon is caused by the continuous decline in fertility and birth rates starting during the communist period in the 1980s, which intensified after 1990, combined with increased migration flows and a positive trend in life expectancy.

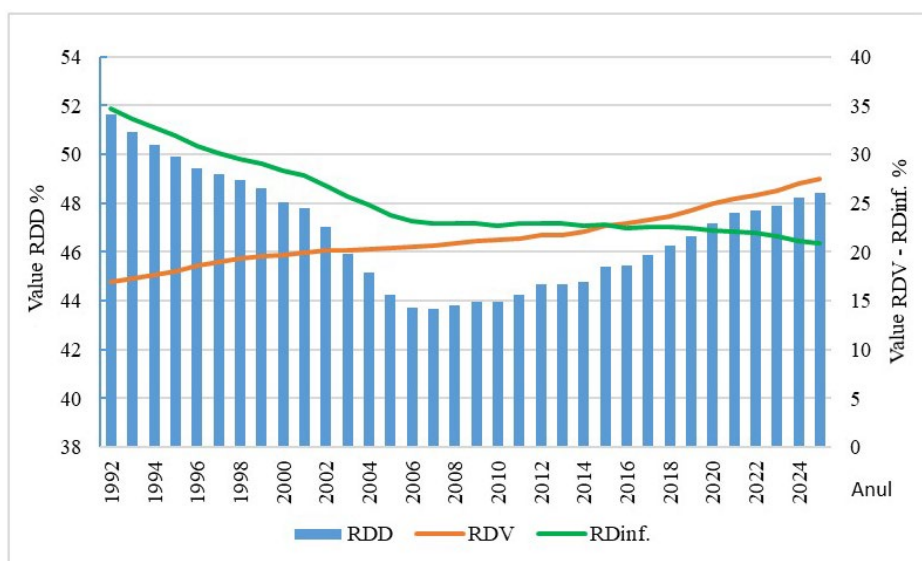


Fig. 8. Evolution of demographic dependency ratios in the study area, 1992–2025
Source: the authors, based on INS data

The analysis of the graph regarding the evolution of the RDD in the study area for the last 34 years (1992 – 2025) shows a decrease in the value, from 51.63% in 1992 to 43.69% in 2007. The decrease in the dependency ratio between 1992 and 2007 is the delayed effect of the pronatalist policy of the communist period, which generated numerous cohorts that reached full working age precisely during this interval, corroborated with the reduction in fertility after 1990, which narrowed the base of the pyramid. This combination - numerous entries into the active segment, reduced exits to the 65+ age group and fewer entries into the 0–14 age group - generated a "demographic window of opportunity" of approximately 15 years, after which the dependency ratio starts to increase again under the pressure of structural aging (48.40% in 2025). The phenomenon is consistent with general European trends, but with a specific temporal lag, dictated by the particularities of Romanian demographic history in the second half of the 20th century (fig. 8).

The demographic dependency ratio (DR) decreased for 15 years (1992–2007) by 7.94%, indicating a reduction in pressure on social systems. In the last 18 years (2008–2025), however, demographic pressure on the economically active population has increased due to the rising number of dependent individuals.

A clear conclusion is that the dependency ratio (DR) is continuously increasing, leading to challenges in demographic, social, and economic conditions. Due to these changes, the state is forced to adapt to new circumstances, particularly economic ones, through carefully planned and analyzed legislative measures designed to maximize positive societal impact (Suvac, 2020).

Another demographic indicator that demonstrates the “regressiveness or progressiveness of the population age structure” (Ridevsky, 2015) is the old-age dependency ratio (OADR). This ratio indicates the potential for generational replacement and the number of economically active individuals in the coming period.

The study shows that the OADR has increased from 16.96 elderly persons per 100 working-age adults in 1992 to 27.55 in 2025, demonstrating demographic aging that exerts pressure on social protection and healthcare systems, since elderly individuals may require more resources and care.

These effects are further reinforced by the evolution of the child dependency ratio (CDR), which has steadily decreased throughout the study period, from 35 young persons in 1992 to 21 young persons in 2025 per 100 working-age adults, reducing the pressure that the young population exerts on economic, educational, and social resources (fig. 11). Consequently, from 2016 onward, the number of elderly (OADR) surpasses the number of young dependents (CDR) per 100 working-age adults, indicating an imbalance in generational replacement (fig. 8). This trend is clear, and the ratio of elderly to young persons is likely to increase further if current economic and demographic conditions persist, unless functional demographic and economic policies are implemented.

In conclusion, the study area transitions from a relatively young population in 1992 to a population with a high dependency level in 2025. This dynamic suggests an accelerated process of structural aging, combined with chronic depopulation.

The main determinants of this trend are selective external migration (the outmigration of young, economically active population), fertility below replacement level (1.3–1.4 children per woman in recent decades), and increased life expectancy, all of which amplify the proportion of elderly individuals. Policy measures should therefore focus on integrated strategies to stimulate fertility (family policies, housing, childcare services), attract and reintegrate migrants, and recalibrate pension and healthcare systems to address dependency ratios above 120% in the coming decades.

Regarding natural population balance, calculations for the period 1992–2024 show that the highest value was recorded in 2000, the only positive value (0.19‰), while the remaining years show negative values, with a sharp decline after 2019. The historical minimum in 2021 (−7.87‰) is explained by a combination of high mortality (pandemic, structural factors) and low fertility. This trend reflects not only declining fertility but also the cumulative effects of young population outmigration.

Over the past four years, the natural balance index has highlighted instability in the country's demographic processes, exacerbated by the global COVID-19 pandemic (Fig. 9).

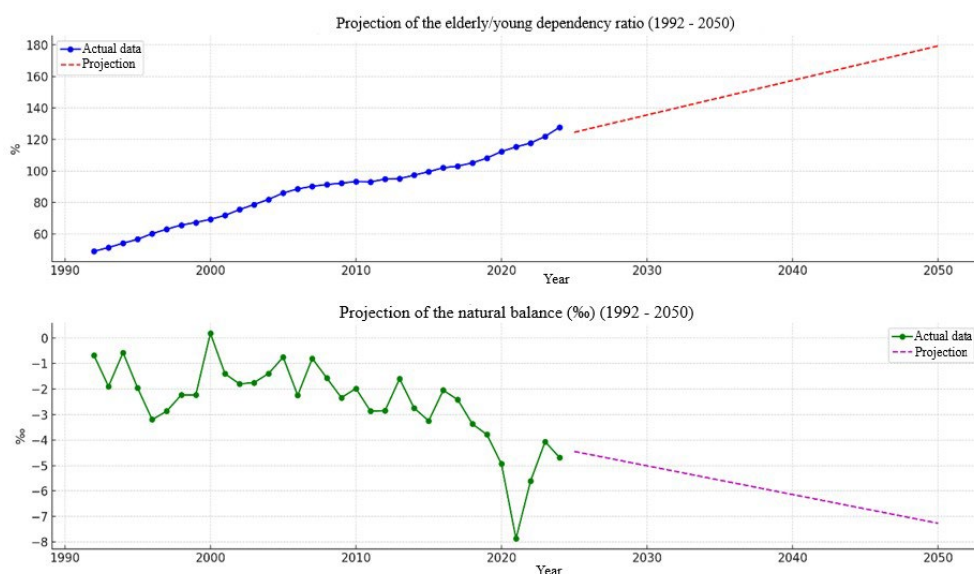


Fig. 9. Projection of natural balance and elderly/young ratio, 1992–2050

Source: the authors, based on INS data

Projections of the natural balance and the elderly-to-young ratio up to 2050 suggest a tense demographic scenario, in which the elderly-to-young ratio could reach approximately 180% by 2050, if recent trends persist—meaning nearly two elderly persons for each young individual (fig. 9). This would greatly increase pressure on the working-age population, requiring either a substantial rise in labor productivity or a massive positive net migration to sustain social systems. The natural balance is expected to continue a slow decline, reaching approximately −7.5‰ in 2050, indicating an annual net loss of a large number

of people due solely to the difference between births and deaths. Without compensation through migration, the population could decrease by over 10,000 individuals by 2050. This trajectory combines accelerated aging and structural depopulation—two phenomena that together could profoundly reshape the economy, labor market, and social structure of the study area, as well as at the regional level.

5. CONCLUSIONS

The study demonstrates that demographic aging is a process with high territorial persistence, with areas affected at the beginning of the post-communist transition tending to maintain high levels today.

Analysis of demographic dynamics in the mountainous and marginal-contact areas of Mureș County confirms the presence of an advanced and persistent population aging process, consistent with the broader trends of demographic decline specific to Romania and Southeast Europe (Eurostat, 2023; INS, 2024). Age-group structure reveals a pronounced generational imbalance, driven by a continuous decline in the young population and an increasing share of older age groups, especially in settlements with low accessibility and limited economic potential.

Population aging results from the combined action of several demographic and socio-economic factors. Declining birth rates are a primary driver of demographic imbalance, influenced by changes in reproductive behavior, economic insecurity, and reduced fertility potential among young people. Internal and external migration is another major factor, leading to the loss of active and reproductive-age cohorts (Sandu, 2010). Young people predominantly migrate to urban centers or international labor markets, leaving behind predominantly elderly rural communities. This phenomenon is exacerbated by the lack of local economic opportunities and the low attractiveness of mountainous and marginal-contact areas for productive investments. In addition, increased life expectancy contributes to the expansion of the upper base of the age pyramid without being offset by generational renewal.

Results indicate that demographic aging is significantly correlated with demographic and socio-economic factors, leading to a decline in the population's regenerative capacity in the study area. This mechanism generates a vicious cycle between economic decline, depopulation, and aging. The core mountainous areas and settlements in marginal contact zones emerge as territories with high demographic vulnerability (Surd, 2005).

The territorial distribution of aging by dynamic types highlights the existence of highly vulnerable demographic cores in the mountainous areas and marginal-contact zones, where low accessibility, poor infrastructure, and fragile economic bases amplify the effects of aging. These areas are characterized by low population densities, high economic dependence, and progressive loss of socio-territorial functions (Ianoș, 2000)

Consequently, demographic aging generates multiple impacts on the local socio-economic system. The reduction of the active labor force directly affects community productivity, leading to contraction of agricultural and forestry activities, land abandonment, reduced local economic competitiveness, and diminished collective incomes. Simultaneously, the rising dependency ratio exerts additional pressure on social protection and healthcare systems, under conditions of a shrinking tax base. From a social perspective, risks associated with poverty, isolation, and marginalization of the elderly are accentuated (Zamfir et al., 215).

Thus, demographic aging directly affects the territorial sustainability of mountainous and marginal-contact areas, compromising the continuity of traditional activities, transmission of local cultural capital, and community cohesion (Surd, 2005). In the long term, persistence of these trends could lead to settlement disappearance, degradation of cultural landscapes, and increased territorial polarization.

The results support the need for integrated public policies, specifically adapted to mountainous and marginal-contact areas, aiming simultaneously at demographic revitalization and strengthening of the local economic base through investment in local economy and non-agricultural activities (Zamfir et al., 22). Interventions should focus on stimulating employment, improving accessibility and public services, supporting youth through housing and employment policies, expanding medical-social services for the elderly, and leveraging local resources through sustainable rural and mountain tourism.

Only a coherent, multisectoral territorial approach can mitigate the negative impacts of population aging and strengthen the foundations for sustainable development. Otherwise, rural areas may progressively transform into territories dominated by an elderly population, with limited economic roles and territorial functions.

In conclusion, population aging in the mountainous and marginal-contact areas of Mureș County represents a deep structural phenomenon, impacting demographic balance, socio-economic functionality, social cohesion, and territorial resilience. Addressing it requires a strategy that goes beyond purely demographic measures, integrating aging into regional development and territorial cohesion strategies as a key indicator of territorial sustainability in Mureș County.

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