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Municipal patterns of systemic depopulation and SNAI investment: a "dose-response" analysis of three Italian regions

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Abstract

Concerns about the negative impact of population decline, and especially the systemic depopulation of remote and marginalised areas, have become a central issue in contemporary policy debates. The National Strategy for Inner Areas (SNAI), established in 2014, represents the main Italian policy framework explicitly aimed at supporting territories affected by long-term demographic fragility. This study applies the Systemic Depopulation Areas Index (SyDAs) to municipalities in three Italian regions—Abruzzo, Basilicata, and Emilia-Romagna—over the period 1994–2023 to identify and characterise systemic depopulation processes. Municipal trajectories are examined both in terms of exit from systemic depopulation (SyDAs Exit) and reduction in its intensity (SyDAs Reduction), measured through differences in population trend slopes before and after the introduction of SNAI. These outcomes are then examined in relation to the degree of economic implementation of SNAI projects at the municipal level. The results indicate a general expansion or stabilization of systemic depopulation across the analysed regions, while only a small minority of municipalities display either an exit from the SyDAs condition or a measurable reduction in its intensity. Moreover, no statistically significant association emerges between higher levels of SNAI economic implementation and either SyDAs Exit or SyDAs Reduction. Taken together, these findings suggest that observed demographic trajectories do not display systematic differentiation across levels of policy exposure. This evidence highlights the analytical importance of moving beyond financial implementation alone and points to the need for refined territorial targeting, outcome-oriented monitoring, and sustained, context-sensitive support for local governance in place-based development strategies.

Introduction and background

The accelerating depopulation of vast areas of southern and eastern Europe is a well-documented phenomenon (e.g. Newsham & Rowe, 2023, 2025; Majdzinska, 2024; Loras Gimeno et al., 2025; Zambon et al., 2019). Between 2014 and 2022, the Southern

European countries[1] lost approximately 1.3 million people and the share of people aged 65 and over increased from 20 to 22%. Baseline projections indicate a continued decline, with the population expected to decrease by about 7.1 million by 2065.[2]

From a national descriptive point of view (i.e. macro perspective), the demographic drivers of depopulation are evident. Some of these have their roots in the last century, such as the decline in fertility rates (e.g. Sauvy, 1949, 1957; Glass, 1940; Van de Kaa, 1987; Demeny, 1997). Others are more recent, such as the resurgence of international emigration (e.g. Potančoková, 2021; Christiaans, 2017; Ubarevičienė & Van Ham, 2017).

Nevertheless, recent studies have focused on two aspects of depopulation that go beyond the national descriptive approach: geographic heterogeneity and the systemic characteristics of the population decline process. National level hides a mosaic of local trends. Indeed, population decline can co-occur with population growth: depopulation can take place within a larger context of growth and vice-versa (Benassi et al., 2021; Franklin, 2019, 2020; Sonnino et al., 1990). Although national trends summarise local ones, the mechanism of depopulation lies in the interactions between local communities beyond the national level (see for example: Buonomo et al., 2024; Cuadrado-Roura 2023; Burillo et al. 2020). To understand depopulation processes and their drivers, the focus must be moved to a subnational level (Reynaud & Miccoli, 2018, 2023; Reynaud et al., 2020; Salvati et al., 2020). Moreover, Benassi et al., (2023a, 2024, 2023b) analyse local spatial patterns of depopulation processes and drivers and invite further research to consider spatial dimensions when using both global regression models and local regression models to go beyond classic ordinary least squares models, relaxing the unreliable assumption of spatial homogeneity in measuring associations and population trends.

Geographic heterogeneity overlaps with the characteristic inertia of depopulation processes. For example, when considering demographic trends and structures, especially at a local level, low fertility rates have become an important factor in depopulation by progressively decreasing the number of younger women, cohort after cohort (Goldstein et al., 2004). Moreover, emigration involving mainly the youngest has amplified the effects of low fertility, creating a vicious cycle whereby depopulation leads to reduced economic growth and a contraction in public services, thereby triggering further emigration and lower natality (Martins & Davino, 2023; Alamá-Sabater et al., 2021; Reynaud et al., 2020; Franklin, 2020; Christiaans, 2017; Ubarevičienė, van Ham 2017).

Indeed, depopulation is both an outcome and a process; a path-dependent process (González-Leonardo et al. 2023; Newshame & Rowe 2023; Franklin, 2020) with a high degree of inertia, typical of all demographic processes (Sauvy, 1957). While the decline in fertility rates may have initially triggered the process, it has now become self-sustaining, particularly at the local level and within small communities (Reynaud et al., 2020; Elshof 2014). The formation of such a self-reinforcing population decline is referred to a "systemic depopulation" process (Lallo et al., 2025; Elshof 2014; Benassi et al., 2023a).

Concerns about the negative impact of systemic depopulation on Europe's future economic and social development are becoming more prevalent in official documents (e.g. UNFPA, 2023; EU Parliament, 2021; EESC, 2020) and research papers (e.g. Lallo & Tomassini, 2023; Lutz & Gailey, 2020; Coleman & Rowthorn, 2011; Golini, 1997;

[1] Portugal, Spain, Italy, Greece and Malta. Data from Eurostat: https://ec.europa.eu/eurostat/databrowser/view/DEMO_PJAN/default/table?lang=en. (Last access on 28.07.2022).

[2] https://ec.europa.eu/eurostat/web/population-demography/population-projections

2000) which call for policies to be implemented to stop, reverse, or at least manage the phenomenon.

In Italy depopulation is already a key political issue, particularly in relation to urban–rural and regional imbalances (Italian Presidency of the Council of Ministers, 2023). Established in 2014, the National Strategy for Inner Areas (Strategia Nazionale per le Aree Interne—SNAI) is currently the most ambitious Italian public investment programme specifically designed to revitalise marginalised areas and counteract population decline (see PCM-DPC 2025; ISTAT, 2022, 2024a, 2024b, 2024c). The SNAI prioritises the promotion and preservation of municipalities marginalised in terms of access to essential public services (see the Data & Methodology section for more details), financing a wide range of interventions, promoting natural and cultural resources and establishing new employment opportunities. The SNAI's declared objective is to counteract substantial demographic decline through socio-economic structural transformation (Barca, 2015; Barca & Carrosio, 2020; Barca et al., 2014).

Nevertheless, designing and implementing policies to manage the process of depopulation encounters two orders of problems. The SNAI programme is no exception.

Firstly, many local communities lost the opportunity to prevent the cycle of systemic depopulation from taking hold many years ago. This means that the effects of policies implemented today to counteract depopulation processes are unlikely to be significant in the short term but may have an impact in the medium term if they are consistent enough (Sobotka et al., 2019). However, ensuring the stability and continuity of such policies could be very difficult in a political context of rapid change and short evaluation periods. Second, the geography of depopulation, administrative boundaries and policy objectives do not necessarily overlap. Ideally, "place-based" policies would be implemented (Benassi et al., 2023b; Muti 2023; Neumark & Simpson, 2015), but local administrative units typically only benefit from and implement policies designed at regional, national, or supranational levels. Indeed, a bottom-up decision-making process would require administrative and scientific resources that may not be available in local communities affected by depopulation. However, if a policy is formulated at a higher level without considering local peculiarities, it may result in the inefficient allocation of resources.

Statistical measures should inform every rational public policy, helping to manage the aforementioned problems. The average growth rate is the easiest index to access, especially at municipal level (see for example Reynaud et al., 2020). Unfortunately, traditional growth indices are not useful tools for policymakers when it comes to addressing demographic inertia and geographical heterogeneity related to systemic depopulation processes. Firstly, they are essentially averages that depend heavily on the years at which the observation period begins and ends. This hides changes in population trends that occurred within the period under consideration. This is, however, of the utmost importance when measuring a systemic depopulation process. Secondly, classifying "depopulation severity" based on growth rates requires conventional thresholds to define categorical indices. However, this can mask changes within a category, and can be a limit for comparative studies (see for example Newshame & Rowe 2023).

Lallo et al. (2025) proposed a new index, the Systemic Depopulation Areas Index (SyDAs), to overcome the limitations of monitoring systemic depopulation analysing growth rates at a municipal level. Based on time series analysis and a "symptomatic approach", this binary index is designed to detect reversals in systemic depopulation processes while ignoring some of the volatility in population changes that can occur when analysing very small populations (see the Data & Methodology section below for more information). The index is designed to be simple in terms of its assumptions and calculations, and to require minimal data. This makes it applicable at a local level and easily replicable by national and local policymakers. Finally, the index can be easily incorporated into local regression models to investigate the drivers of systemic depopulation, while taking spatial heterogeneity into account (see for example Benassi et al. 2024, 2023b).

In this study, the SyDAs index is applied to the municipalities of three Italian regions—Emilia-Romagna, Abruzzo, and Basilicata—to examine long-term patterns of systemic depopulation over the period 1994–2023 and to explore how these patterns relate to the implementation of the National Strategy for Inner Areas (SNAI) at the municipal level. The three regions were selected because they display markedly different historical trajectories, demographic structures, and institutional configurations, allowing for a comparative analysis of systemic depopulation dynamics and policy exposure across heterogeneous territorial contexts. This pilot study deliberately includes one region from each of Italy's main macro-geographical areas ensuring that the analytical framework spans the full range of territorial conditions under which the SNAI operates, from institutional strength to structural fragility, without aspiring to national representativeness. Rather than providing a causal evaluation of policy effects, the study adopts an exploratory and diagnostic perspective, focusing on whether different degrees of exposure to SNAI are associated with observable demographic responses, in terms of both exit from and reduction in the intensity of systemic depopulation. The next section, Aims of the study, outlines the research questions guiding the analysis. The Data and Methods section introduces the geographic and institutional context of the study and details the construction of the SyDAs index, as well as the ordinal indicator used to capture the economic implementation status of SNAI at the municipal level. The results and discussion are then presented in the respective sections, where findings are interpreted in light of their methodological and empirical limitations, and avenues for further research are identified. The concluding section summarises the main contributions of the study to the understanding of systemic depopulation and place-based policy analysis.

Aims of the study

This study addresses three interrelated research questions, which together form a sequential analytical framework aimed at assessing the relationship between systemic depopulation and the National Strategy for Inner Areas (SNAI) at the municipal level:

- *Descriptive aim*: Is systemic depopulation expanding, regressing, or stabilising among Italian municipalities in Emilia-Romagna, Abruzzo, and Basilicata over the period 1994–2023?
- *Targeting aim*: To what extent does the SNAI investment programme involve municipalities characterised by systemic depopulation, as identified through the SyDAs index?
- *Evaluative aim (early demographic signals)*: Is there evidence that different degrees of economic implementation under SNAI are associated with exits from, or reductions in, systemic depopulation between 2014 and 2023?

As outlined in the background section, the SNAI programme was explicitly designed to counteract demographic decline in marginalised municipalities. Rather than providing a causal impact evaluation, this study adopts an exploratory and comparative perspective, aiming to detect whether systematic demographic responses emerge following policy implementation in contexts characterised by strong demographic inertia.

The study is designed as a pilot analysis, and as such it does not aim to generalise its findings to the entire national territory. The three regions were selected to represent three structurally distinct territorial contexts within the Italian landscape — a high-capacity northern region, a transitional central-southern region, and a structurally marginalised southern region — deliberately spanning the main macro-geographical and socioeconomic divides that characterise Italy's territorial development patterns. This selection ensures that the analytical framework captures a broad range of conditions under which the SNAI operates, providing a comparative and exploratory assessment of systemic depopulation dynamics and policy exposure across heterogeneous territorial contexts. The findings of this pilot study are intended to serve as a foundation for future research with broader national coverage.

The geographic context of the study, the rationale and methodology underlying the SyDAs index, and the main institutional and financial features of the SNAI programme are presented in the following section.

Data and methods

Geographical context

The selection of Emilia–Romagna, Abruzzo, and Basilicata for case study comparison is grounded in their distinct geographical, institutional, and historical-demographic profiles, making them particularly suitable for evaluating the performance of SNAI in contextually different settings. In the Italian policy framework, inner areas (aree interne) are defined as municipalities (comuni or Local Administrative Units, LAU, in the nomenclature of territorial units for statistics[3]) that are significantly distant—at least 28 min—from essential public services, specifically: a complete educational cycle, a hospital equipped with a 24-h emergency unit and intensive care, and a railway station of at least "silver" classification, i.e. offering frequent national and regional connections (Table 1).

This classification, developed under the SNAI, is used to identify territories characterized by structural disadvantages such as geographical isolation, demographic decline, and limited service accessibility (Barca et al., 2014). SNAI aims to counteract the decline in population in marginalised municipalities, and consequently in Italy. Figure 1 shows the inner areas and the main demographic characteristics of the three regions in 2025, the most recent year of data available.

The selection of Emilia-Romagna, Abruzzo, and Basilicata was not intended to provide a statistically representative sample of Italian regions. Rather, these regions were

Table 1 Definition of inner area according to SNAI

Central areas			Inner areas		
Poles	**Intermunicipal Poles**	**Belts**	**Intermediates**	**Peripheral**	**Ultraperipheral**
		$t < 27{,}7$ min	$27{,}7$ min $< t < 40{,}9$ min	$40{,}9$ min $< t < 69{,}9$ min	$t > 69{,}9$ min

Source: ISTAT, 2022. Poles and intermunicipal poles include all three essential services. Belts, intermediate, peripheral and ultra-peripheral areas are classified according to the travel time (in minutes) from poles and intermunicipal poles

[3] https://ec.europa.eu/eurostat/web/nuts/local-administrative-units

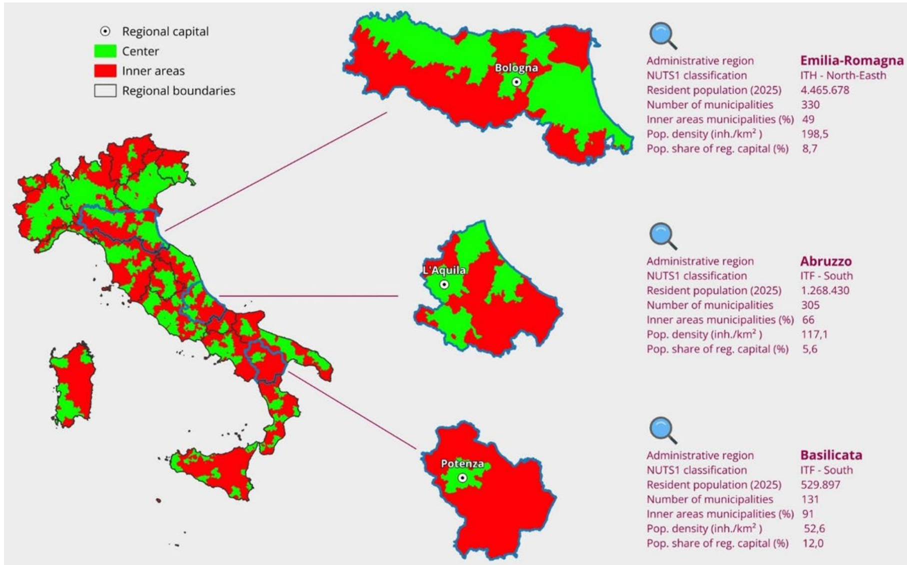

Fig. 1 Geographic summary of Emilia-Romagna, Abruzzo and Basilicata

Table 2 Population size and average annual growth of Italy and selected regions between 1994 and 2023

Year	1994	2014	2023	Avg. Annual growth rate (‰)		
				1994–2014	2014–2023	1994–2023
Emilia-Romagna	3,899,055	4,432,241	4,437,578	6.41	0.13	4.46
Abruzzo	1,252,329	1,329,918	1,272,627	3.01	−4.89	0.55
Basilicata	610,021	575,814	537,577	−2.89	−7.63	−4.36
Italy	56,842,392	60,345,917	58,997,201	2.99	−2.51	1.28

Source: own estimations on ISTAT data

purposively selected to capture three analytically distinct territorial contexts within the national landscape: a high-capacity northern region where demographic challenges coexist with strong institutional and economic resources; an intermediate central-southern region characterised by a mixed development trajectory and significant exposure to external shocks; and a structurally fragile southern region affected by long-standing demographic decline and territorial marginality. This comparative design allows the assessment of SNAI outcomes across heterogeneous territorial conditions, thereby providing an exploratory evaluation of the policy's effectiveness in contexts characterised by different combinations of institutional capacity, socio-economic development, and demographic vulnerability.

Emilia-Romagna, located in north-eastern Italy, is widely recognised as one of the country's most economically advanced and institutionally capable regions. It has experienced continuous population growth (see Table 2) and boasts high-quality public services, efficient local governance and a diverse economy (Aiello et al., 2019; ISTAT, 2025). Nevertheless, such development coexists with significant territorial heterogeneity: approximately 49.4% of the region's territory is officially classified as inner area under the National Strategy for Inner Areas (SNAI) framework (Agenzia per la Coesione Territoriale, 2020), especially across its Apennine mountain belt (see Fig. 1). The 2012 seismic events—which struck the provinces of Modena, Ferrara, Reggio Emilia and Bologna—highlighted the vulnerability of inland and peri-urban zones to natural disasters.

According to regional estimates, the earthquakes caused over €11.5 billion in total damages, including extensive losses in productive infrastructure, housing, cultural heritage and local services (Regione Emilia-Romagna, 2013). Though the region mounted a rapid recovery, supported by institutional coordination and civil protection mechanisms, the event exposed structural fragilities in inland municipalities, especially regarding demographic ageing, depopulation and the resilience of small economic systems (Meroni et al., 2017). These dynamics underscore the importance of evaluating place-based policy outcomes not only in historically disadvantaged southern regions, but also in areas where advanced development coexists with internal peripherality. Emilia-Romagna thus represents a high-capacity but territorially uneven context, where the impact of SNAI initiatives can be assessed under conditions of relative institutional strength but persistent demographic stress.

Situated between Central and Southern Italy, Abruzzo benefited significantly from the industrialisation policies implemented through the "Cassa per il Mezzogiorno—CpM" public investment programme, particularly during the 1950s and 1960s. This state-led intervention fostered convergence during Italy's economic boom and enabled Abruzzo to emerge as one of the better-performing southern regions in that phase. Thanks to a virtuous use of CpM funds, particularly targeted at infrastructure development and industrial policy, the region achieved notable economic progress, surpassing other southern areas in terms of per capita income and industrial growth. These advances laid the foundation for reversing previously negative migratory trends observed between 1951 and 1961, with net in-migration becoming more common after the 1970s (Felice, 2013a, 2013b). However, the region's trajectory was severely disrupted by the 2009 L'Aquila earthquake, which caused long-lasting economic and demographic damage—particularly in its most marginal and mountainous municipalities—further complicating long-term stabilization efforts (Miccoli et al., 2023). While the population increased at an annual rate of + 3.01‰ between 1994 and 2014, Abruzzo experienced a population decline with an annual growth rate of – 4.89‰ between 2014 and 2023. Today, 66.2% of Abruzzo's territory is officially classified as inner area under the national SNAI framework, reflecting both its persistent geographic marginality and the strategic relevance of this region for place-based policy experimentation.

Basilicata, located in Southern Italy, represents one of the most structurally fragile territories in the country. Characterized by low population density, difficult topography, and limited infrastructure, the region has long struggled with demographic decline (see Table 2) and economic marginality. Historically included in the core intervention zone of CpM, Basilicata benefited from targeted public investments in the post-war period—especially in the areas of agriculture, road construction, and later industrial complexes such as the FIAT plant in Melfi. However, unlike Abruzzo, the long-term effects of these investments were less transformative, and the region continued to experience low per capita income and persistent emigration (Felice, 2013a, 2013b; Viesti, 2009). Demographically, Basilicata suffers from severe population ageing, a high rate of youth out-migration, and a shrinking labor force (Istat, 2022). Between 1994 and 2023, the region lost nearly 11.9% of its resident population, with decline essentially endemic, but characterized by stronger magnitude in inner areas. According to the official SNAI classification, over 90.8% of Basilicata's territory is categorized as inner area, making it the most "inner" region of the country (Agenzia per la Coesione Territoriale, 2020; see Fig. 1). This condition reflects both the geographic dispersion of settlements and the chronic difficulty in guaranteeing timely access to essential services such as healthcare, education, and mobility. Basilicata thus constitutes a paradigmatic case for the SNAI: a structurally disadvantaged southern region where place-based policy must operate in the absence of strong endogenous drivers, under conditions of institutional fragility and demographic stress. Its inclusion in the analysis allows for a critical comparison with better-endowed territories like Emilia-Romagna, and transitional cases like Abruzzo.

Table 2 shows the population size and average annual growth rate for Italy and its three regions in 1994, 2014, and 2023, i.e. the temporal limits of this study (the first and last years) and 2014, which is important for two reasons. Firstly, the SNAI investment programme was established, and secondly, the Italian population began to decline.

The three regions display differentiated demographic trajectories. Over the entire observation window (1994–2023), only Basilicata registers a net population decline. However, when disaggregating the period into two phases—pre-SNAI (1994–2014) and post-SNAI (2014–2023)—Emilia-Romagna emerges as the sole region exhibiting positive population growth in the latter interval. This illustrates one of the limitations of using annual growth rates to measure long-term population changes: estimates of rates depend heavily on the start and end years of the observation period.

In the next paragraph the SyDAs will be described as a measure of systemic depopulation at municipal level.

The systemic depopulation areas index

Systemic depopulation at municipal level will be detected in this study through the application of the SyDAs Index (Lallo et al., 2025).

Systemic depopulation is a self-reinforcing process involving demographic factors such as natality, fertility and migrations, as well as economic factors such as occupation and service availability. It impacts the demographic structure of a population by age, sex and education, leaving long-term effects that give the process high inertia. Collecting and analysing the determinants of a systemic depopulation process correctly is complex. It requires data, skills and resources in terms of time and expertise, which may not always be available in a timely manner at national or local levels.

Although it is difficult to take direct measurements of the determinants of systemic depopulation, analysing population changes over time can help us to understand this phenomenon symptomatically. Modelling and estimating municipal population trends while accounting for potential temporal autocorrelations emerges as a way to detect systemic depopulation. However, at the very local level and within small communities, there is the potential for erratic and exceptional temporary fluctuations without consequences for the mid-long run trend. Lallo et al. (2025) applied a "symptomatic approach" and time-series analysis to develop the SyDAs index, a binary index designed to help policymakers assess the effectiveness of policies intended to counteract systemic depopulation. This index is based on a linear regression model that incorporates an ARIMA process in the error structure and has been applied to municipalities that had experienced severe population decline (i.e. average annual population decline $< -0.8‰$, see Lallo et al., 2025, Reynaud, Miccoli. 2018, Reynaud et al., 2020, Benassi et al., 2023a, 2023b).

Consider data on the population of a given municipality, "Pop", which has been collected on 1 January each year from year "t" to year "$t + \mathrm{n}$", encompassing a total period of "n" years. In order to estimate a population trend managing an autoregressive structure of data (demographic inertia) and avoiding volatility (erratic changes at local level) it is necessary for the error component "ε" of a simple OLS linear regression (Eq. 1) to contain an ARIMA "η'" (Eq. 2 and 3) process. A regression containing an ARIMA process facilitates the modelling of a stochastic trend (see: Hyndman & Khandakar, 2008; Hyndman & Athanasopoulos 2008) that constitutes the foundation of the Systemic Depopulation Areas Index (SyDAs, Eq. 4).[4]

$$Pop_{m,t} = \beta_{m,0} + \beta_{m,1} * t + \varepsilon_{m,t} \tag{1}$$

$$Pop_{m,t} = \beta_0 + \beta_{m,1} * t + \eta_{m,t'} \tag{2}$$

With:

$$\eta_{m,t'} = \eta_{m,t-d'} + \delta_{k,m} * \eta_{m,t-k} + \gamma_{j,m} * \varepsilon_{m,t-j} + \varepsilon_{m,t}$$

The ARIMA process is determined by the order of differencing ("d") and autoregressive and moving average components, including the order of autoregressive ("k") and moving average ("j") processes. A stochastic ARIMA trend regression model comprises two error terms: the total regression model error (η') and the ARIMA process error (ε). The former is modelled using δ and γ parameters, which capture the autoregressive structure of the error (i.e. demographic inertia) and control the impact of other non-trend components, such as random changes, exceptional events, and short cycles, on the estimation of $\beta_{m,1}$ and the regression's goodness of fit.

Equation 3 can be "differenced" (see: Hyndman & Athanasopoulos, 2021) on both sides:

$$Pop_{m,t} = Pop_{m,t-d} + \beta_{m,1} + \eta_{m,t} \tag{3}$$

With:

$$\eta_{m,t} = \delta_{k,m} * \eta_{m,t-k} + \gamma_{j,m} * \varepsilon_{m,t-j} + \varepsilon_{m,t}$$

Finally, the binary SyDAs index is determined by the stochastic trend estimate:

$$SyDAs_{m,t,t+n}^{Stochastic\ ARIMA} = \begin{cases} 0 \text{if} \beta_{m,1} \geq 0 \text{ or } p \text{ - value} \geq 0.001 \\ 1 \text{if} \beta_{m,1} < 0 \text{ and } p \text{ - value} < 0.001 \end{cases} \tag{4}$$

The municipality is experiencing a systemic depopulation process when the SyDAs index is equal to 1. The stochastic trend in Eq. 4 yields a non-stationary error structure in the linear model. This property is particularly appropriate in scenarios where the slope of the trend changes over time while retaining an average negative gradient. This property enhances the flexibility of model estimation of parameter $\beta_{m,1}$ and consequently improves estimation of the binary SyDAs index, which aims to capture symptoms of an active systemic depopulation process rather than the magnitude of the depopulation rate.

[4] Stochastic ARIMA regression is modelled using the Hyndman-Khandakar algorithm that use KPSS test to determine the order of differencing "d", AICc to determine the order of autoregressive ("k") and moving average ("j") component and MLE do estimate parameter β. AICc is the "corrected" Akaike Information Criteria for small sample sizes. AICc is a particularly useful tool when managing short time series, see: Hyndman, Athanasopoulos 2018, chapter 12.

In this study, we analyse population data from the municipalities of Emilia-Romagna (330 municipalities), Abruzzo (305 municipalities), and Basilicata (131 municipalities) over the period 1994–2023. The data, provided by ISTAT, were derived through the integration of census records, administrative sources, and statistical interpolation methods (see: ISTAT, 2021, 2024b, 2024c). To detect the evolution of systemic depopulation during this time frame, the SyDAs index was applied first to the years 1994–2014, prior to the launch of the National Strategy for Inner Areas (SNAI), and then extended to 2023 to capture subsequent changes.

To ensure geographic consistency over time, all municipal boundaries were harmonised with the January 2024 configuration and all populations were reconstructed according to the 2024 boundaries. This approach allows population changes to be measured on a stable statistical base, neutralising the effects of administrative mergers, boundary adjustments, or reclassifications that occurred during the period. In other words, the analysis observes population variations as if the spatial units had remained constant throughout, thereby enhancing the comparability and internal validity of longitudinal estimates.

Then, the SyDAs index was applied to the entire period (1994–2023). By comparing the results from these two periods, we can assess whether systemic depopulation is increasing, stabilising, or decreasing at the municipal level and recognise whether there has been an exit or reduction, entrance, or permanence in the systemic depopulation process following the implementation of the SNAI investment programme. When comparing the period before and after the SNAI programme, we analyse the full period (1994–2023) rather than just the period after the programme's establishment (2014–2023). This enables the ARIMA process to detect changes in population trends more effectively.

To complement the primary outcome based on SyDAs exit, we also analyse SyDAs reduction. This secondary measure captures partial improvements in systemic depopulation intensity among municipalities that remain within the SyDAs category. Reduction is measured through the percentage change in the slope coefficient β between the two observation periods, where β represents the angular coefficient of the linear trend of the resident population for each municipality. The percentage change is defined as:

$$\Delta\beta\%_{m,1} = \left[\frac{\left(\beta_{m,1}^{1994-2023} - \beta_{m,1}^{1994-2014}\right)}{\beta_{m,1}^{1994-2014}}\right] \times 100$$

Since municipalities classified as SyDAs between 1994 and 2014 are by definition characterised by a negative slope coefficient—reflecting a persistent downward trend in resident population — the sign of $\Delta\beta\%$ carries a precise directional interpretation: a negative value of $\Delta\beta\%$ indicates that the slope has become less negative between the two periods, meaning that the intensity of systemic depopulation has attenuated, representing a demographic improvement; conversely, a positive value of $\Delta\beta\%$ indicates that the slope has become more negative, meaning that the intensity of systemic depopulation has worsened.

To avoid reliance on a single arbitrarily chosen threshold and to assess the robustness of the findings across different specifications, five alternative threshold specifications were tested: $\Delta\beta\% \leq -5\%, \leq -10\%, \leq -20\%, \leq -30\%$, and $\leq -40\%$. Each threshold defines a progressively more stringent criterion for classifying a municipality as experiencing a meaningful reduction in systemic depopulation intensity, with lower thresholds capturing only the most pronounced attenuations. For each threshold specification, a binary outcome variable was constructed — taking value 0 if the municipality's Δβ% fell at or below the threshold, and 1 otherwise — and the Cochran–Armitage trend test was subsequently applied to assess whether municipalities with higher levels of SNAI economic implementation were systematically more likely to exhibit a reduction in depopulation intensity. The full results of this sensitivity analysis, including the distribution of Δβ% across the municipal samples of the three regions, are reported and discussed in the supplementary material.

The SNAI programme and the estimation of its impact on systemic depopulation

The results of the SyDAs analysis were then cross-referenced with publicly available project-level data from the OpenCoesione platform,[5] focusing on the economic implementation status of interventions funded under SNAI. Although SNAI targets inner areas, not all municipalities classified as "inner" are automatically involved in the direct implementation of interventions. SNAI defines "project areas" as aggregations of geographically proximate municipalities with similar vulnerabilities and development challenges, selected for the implementation of integrated local development strategies. The first programming cycle of SNAI started in 2014 and formally concluded in 2020, while the second cycle, beginning in 2021 and scheduled to run through 2027, involves dynamic reassessment of accessibility indicators, reclassification of inner areas, and redrawing of project area boundaries. Inclusion in a project area requires a minimum level of institutional activation and planning capacity; as a result, not all inner areas are part of a SNAI project area. This distinction is analytically relevant: inner area status identifies territorial need, while inclusion in a project area reflects institutional readiness and prioritization. SNAI funding and implementation are channeled exclusively through project areas.

This study analysed the first programming cycle of SNAI (2014–2020) and its impact on systemic depopulation. On 31 December 2023, each municipality was evaluated based on its inclusion in a designated SNAI project area and the level of economic resources received. A five-tier ordinal classification represents the municipality's advancement in SNAI implementation (Agresti, 2013; Pinzari et al., 2018):

0: Not included in any SNAI project area;

1: Included in a project area, but with no funds allocated;

2: Included in a project area with allocated funds, but no disbursement recorded;

3: Included in a project area with disbursement up to 50% of allocated funds;

4: Included in a project area with disbursement exceeding 50% of allocated funds.

The percentage of economic progress was calculated as the ratio between total funds received and total funds allocated at the municipal level, covering key SNAI domains: transport and mobility, social inclusion and health, education and training, culture and tourism, environment, energy, digital networks and services, business competitiveness, administrative capacity, research and innovation, and employment and labor. This structured classification provided the empirical basis for the Cochran–Armitage test for trend (Armitage, 1955; Cochran, 1954), a non-parametric test designed to detect a

[5] https://opencoesione.gov.it/it/AI/

linear trend between an ordinal independent variable and a binary dependent variable (Tekindal, 2022).

The test was applied to both outcomes: the primary SyDAs exit and the secondary SyDAs reduction. For exit, the binary outcome corresponds to whether a municipality left systemic depopulation between 2014 and 2023. For reduction, the binary outcome corresponds to whether $\Delta\beta_{m,1} \leq -X\%$ for municipalities initially classified as SyDAs. The explanatory variable is the ordinal measure of economic progress (0–4). The Cochran–Armitage test preserves the ordinal nature of the explanatory variable, is robust to small sample sizes in some categories, and provides a formal trend test rather than comparing unordered proportions. Methodologically, a positive and significant test statistic ($p < 0.05$; $|Z| > 1.96$) suggests that higher levels of SNAI implementation are associated with increased probability of exit or reduction, supporting the hypothesis of policy impact. Non-significant or negative results indicate no systematic association.

The conceptual logic aligns with a dose–response framework (Gutiérrez Amaros et al., 2025): systemic depopulation is the pathological condition, SNAI is the intervention, and economic advancement categories represent dosage levels. Municipalities that transitioned out of SyDAs between 2014 and 2023 are interpreted as "recovered" (exit), while municipalities with $\Delta\beta_{m,1} \leq -X\%$ represent partial improvement (reduction). Statistical significance was evaluated using standard two-sided tests, separately for Emilia-Romagna, Abruzzo, and Basilicata, allowing for regional differentiation and comparative assessment.

Results

The results of the analysis provide valuable insights into the evolution of systemic depopulation and the impact of the SNAI initiative in three selected Italian regions since 2014. Comparing the two time periods (partial = 1994–2014, i.e. before the SNAI programme was established; and complete = 1994–2023) highlights a persistence and, in some cases, a worsening of systemic depopulation, particularly in municipalities not included in SNAI project areas (see Table 2).

In Abruzzo, the number of municipalities affected by systemic depopulation increased from 62 to 87 (+ 25 in abs. numbers and + 40% in percentage, see Table 2, Figs. 2 and 3). Of the 62 municipalities classified as SyDAs in 1994–2014, 43 were located within one of the five SNAI project areas (Alto Aterno–Gran Sasso Laga, Basso Sangro Trigno, Subequana, Valfino Vestina, and Valle Roveto), while 19 were outside the strategy's scope (Table 2). By 2023, the number of SyDAs municipalities not included in any project area had risen to 34, while 53 remained within project areas (60% of all SyDAs municipalities), displaying highly heterogeneous levels of economic advancement (Table 2). Despite the implementation of SNAI, only six municipalities exited the SyDAs condition by 2023—the highest number among the three regions (Table 3). Among these, two (Bisegna and Montebello sul Sangro) were included in project areas with meaningful economic progress (advancement categories 3 and 4). The remaining four (Barrea, Borrello, Guilmi, and Roio del Sangro) were either outside the strategy or in lower advancement categories.

In Basilicata, the situation was similarly critical. Considering the entire period 1994–2023 systemic depopulation municipalities accounts for the 57% of total municipalities and inner areas represent 90.8% of the regional territory, underscoring the strategic importance of the intervention. Between 1994 and 2014, the region had 61 municipalities

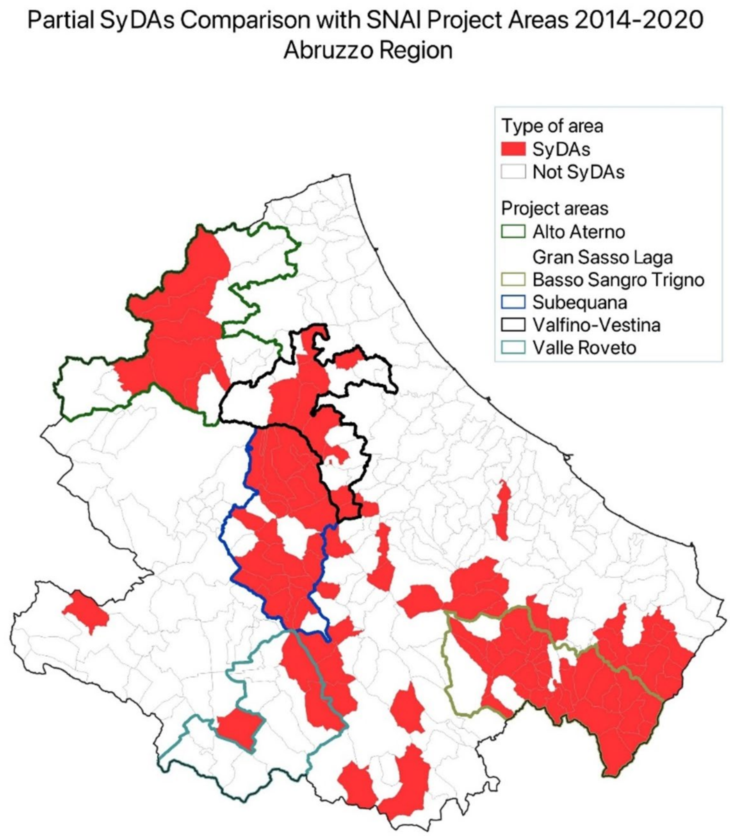

Fig. 2 Municipalities affected by systemic depopulation according to Sydas in the period 1994–2014, Abruzzo

affected by systemic depopulation, of which 32 (52.5%) were not included in any SNAI project area (Table 2 and Fig. 4). The remaining 29 were distributed across the four identified project areas: Alto Bradano, Marmo Platano, Mercure–Alto Sinni–Val Sarmento, and Montagna Materana (Table 2). By 2023, the number of SyDA municipalities rose to 75 (+ 14 in abs. numbers and + 23% in percentage), with 41 (54.7%) still excluded from the strategy and 34 within project areas (Table 2 and Fig. 5). Among the latter, the majority exhibited economic advancement levels in categories 3 and 4 (Table 2). However, only one municipality (Fardella, PZ) successfully exited SyDAs status—despite showing high economic advancement—suggesting that the funding progress did not translate into demographic resilience (Table 3).

The case of Emilia-Romagna shows a more stable but still complex scenario. In both 2014 and 2023, 29 municipalities were identified as SyDAs (Table 2, Figs. 6 and 7). In 2014, 25 of them were located within one of the four SNAI project areas (Alta Valmarecchia, Appennino Emiliano, Appennino Piacentino Parmense, and Basso Ferrarese), while four were not (Table 2). By 2023, while the total number of SyDAs remained unchanged, their distribution shifted: the number of SyDAs outside project areas increased, while some municipalities within project areas exited the condition of systemic depopulation (Tables 2 and 3). Notably, only two municipalities—Ferriere and Pellegrino Parmense—successfully exited SyDAs status, both in the Appennino Piacentino–Parmense area and both in advancement category 4 (Table 3). The advancement levels in project areas were polarized, with clusters in categories 1 and 4, and a smaller share in category 3 (Table 2). In this region, 9% of all municipalities are subject to systemic depopulation, and inner

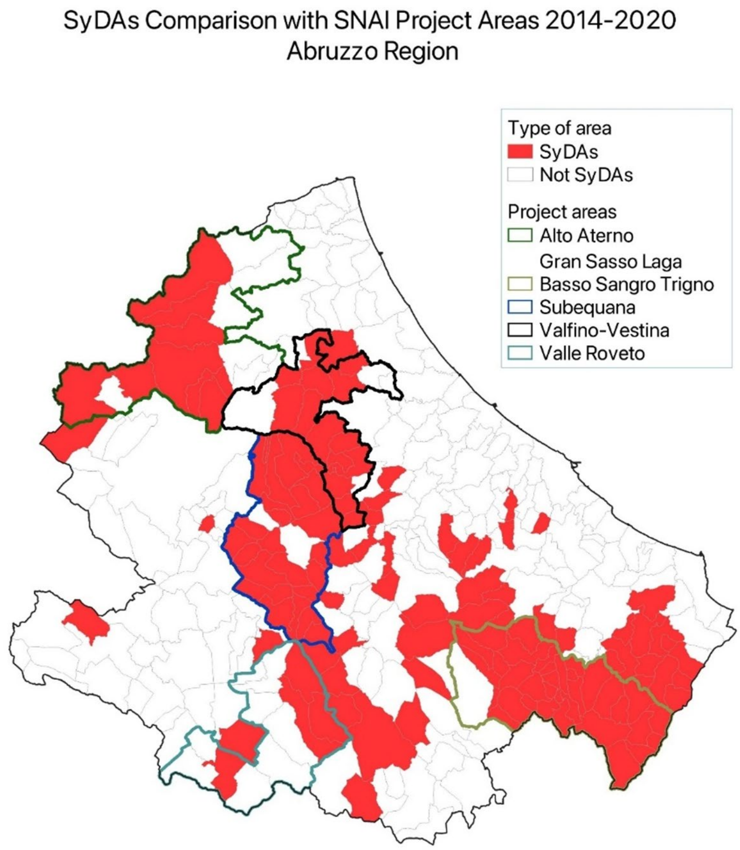

Fig. 3 Municipalities affected by systemic depopulation according to Sydas in the period 1994–2023, Abruzzo. *Source*: Own elaborations based on Istat and Open Coesione data

areas cover 49.4% of the total territory — a considerably lower share than in Basilicata and Abruzzo (Table 4).

Table 3 reinforces the picture of stagnation. The vast majority of municipalities classified as SyDAs in 2014 retained this status in 2023, with persistence rates exceeding 89% in all three regions—and reaching 98.3% in Basilicata. Cases of reversal are exceptionally rare and appear disconnected from the degree of economic advancement achieved through SNAI interventions. Notably, in Abruzzo, three of the six municipalities that exited the SyDAs condition belonged to category 0—indicating no exposure to SNAI investments—while the remaining three were spread across higher advancement levels. In Emilia-Romagna, two municipalities exited the SyDAs condition from category 4, but these instances remain isolated. In Basilicata, only one municipality (Fardella) exited, despite strong economic progress.

To validate the descriptive evidence and provide a formal statistical assessment of the study's hypotheses, the Cochran–Armitage test for trend was employed to examine whether municipalities with higher levels of economic implementation under the SNAI (ordinal categories from 0 to 4) were more likely to exit from or reduce the intensitysystemic depopulation (as defined by the SyDAs index) between 2014 and 2023.

From the perspective of reduction in systemic depopulation intensity—measured through the percentage variation of the slope coefficients estimated for the two periods (Δβ%)—the analysis depicts a slightly more encouraging overall picture compared to outright exits from SyDAs status. Nevertheless, across all three regions, SyDAs

Table 3 Number of municipalities in systemic depopulation according to SyDAs index in the first period (1994–2014) and in the second period (1994–2023), by Region, SNAI project area and SNAI advancement category

Region	SNAI project area	Period 1994–2014	Period 1994–2023						Δ Period 2 -Period 1
				SNAI adv. Cat. 1	SNAI adv. Cat. 2	SNAI adv. Cat. 3	SNAI adv. Cat. 4	TOT	
Abruzzo	Alto Aterno-Gran Sasso Laga	5		0	0	5	0	5	0
	Basso Sangro Trigno	20		8	4	5	7	24	4
	Subequana	9		0	0	11	0	11	2
	Valfino Vestina	7		0	10	0	0	10	3
	Valle Roveto	2		0	2	1	0	3	1
	Total included in a project area	43	Total	8	16	22	7	53	10
	No Project Area	19	% on total Sydas municipalities	9.2%	18.4%	25.3%	8.0%	60.9%	
	Total SyDAs abs. and (%)	62 (20%)						87 (29%)	25 (+40%)
Emilia-Romagna	Alta Valmarecchia	1		0	0	1	0	1	0
	Appennino Emiliano	5		4	0	0	1	5	0
	Appennino Piacentino Parmense	17		6	0	3	6	15	−2
	Basso Ferrarese	2		1	0	0	1	2	0
	Total included in a project area	25	Total	11	0	4	8	23	−2
	No project area	4	% on total Sydas municipalities	37.9%	0.0%	13.8%	27.6%	79.3%	
	Total SyDAs abs. and (%)	29 (9%)						29 (9%)	0
Basilicata	Alto Bradano	4		0	1	4	1	6	2
	Marmo Platano	2		0	0	3	1	4	2
	Mercure—Alto Sinni—Val Sarmento	15		0	0	5	11	16	1
	Montagna Materana	8		0	0	2	6	8	0
	Total included in a project area	29	Total	0	1	14	19	34	5
	No project area	32	% on total Sydas municipalities	0%	1.3%	18.7%	25.3%	45.3%	
	Total SyDAs abs. and (%)	61 (47%)						75 (57%)	14 (+23%)

Source: Own estimation on OpenCoesione and ISTAT data

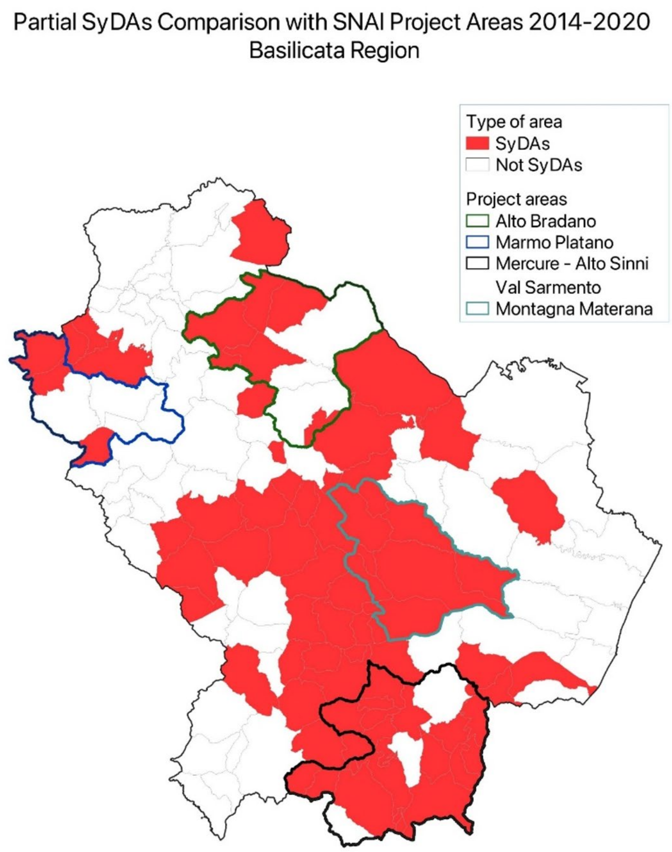

Fig. 4 Municipalities affected by systemic depopulation according to Sydas in the period 1994–2014, Basilicata. *Source*: Own elaborations based on Istat and Open Coesione data

reduction still concerns a minority of municipalities (even with less conservative thresholds), confirming the persistence and structural nature of the phenomenon. A detailed discussion of the results, together with the complete sensitivity analysis, is provided in the Discussion section and in the Appendix.

The test yielded non-significant results in all three regions, indicating the absence of a monotonic dose–response relationship between SNAI implementation intensity and SyDAs Exit. In Emilia-Romagna, the Z-statistic was -0.158 ($p = 0.874$), suggesting no detectable trend. Similarly, Abruzzo returned $Z = +0.429$ ($p = 0.668$), while Basilicata yielded $Z = -1.305$ ($p = 0.192$).

Regarding the results of the Cochran-Armitage test applied to the cases of SyDAs Reduction, even with the least conservative thresholds (see sensitivity analysis in the Appendix), no statistically significant results are observed for any of the three regions.

Overall, while some descriptive clustering of exits and reductions is observed in the highest categories of economic advancement, particularly in Basilicata, these patterns do not translate into statistically significant trends. Consequently, the results do not support conclusions regarding a monotonic association between SNAI implementation intensity and either exit from or reduction of systemic depopulation during the 2014–2023 period across the three regional contexts examined in this pilot study.

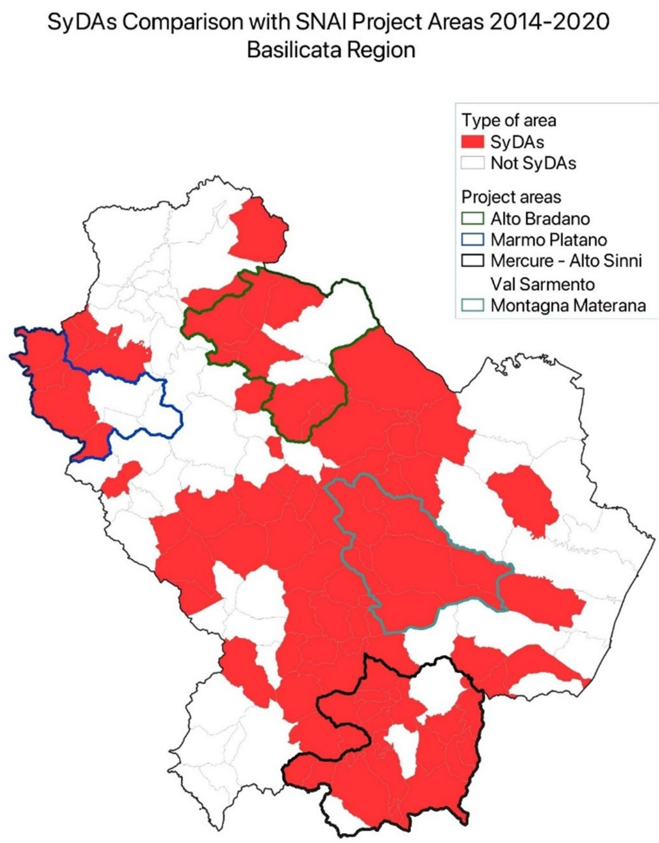

Fig. 5 Municipalities affected by systemic depopulation according to Sydas in the period 1994–2023, Basilicata. *Source*: Own elaborations based on Istat and Open Coesione data

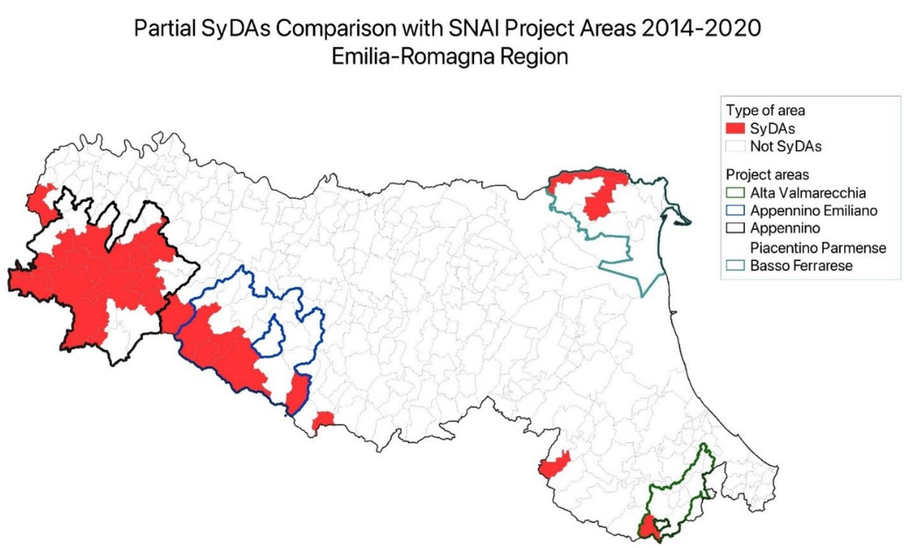

Fig. 6 Municipalities affected by systemic depopulation according to Sydas in the period 1994–2014, Emilia-Romagna. *Source*: Own elaborations based on Istat and Open Coesione data

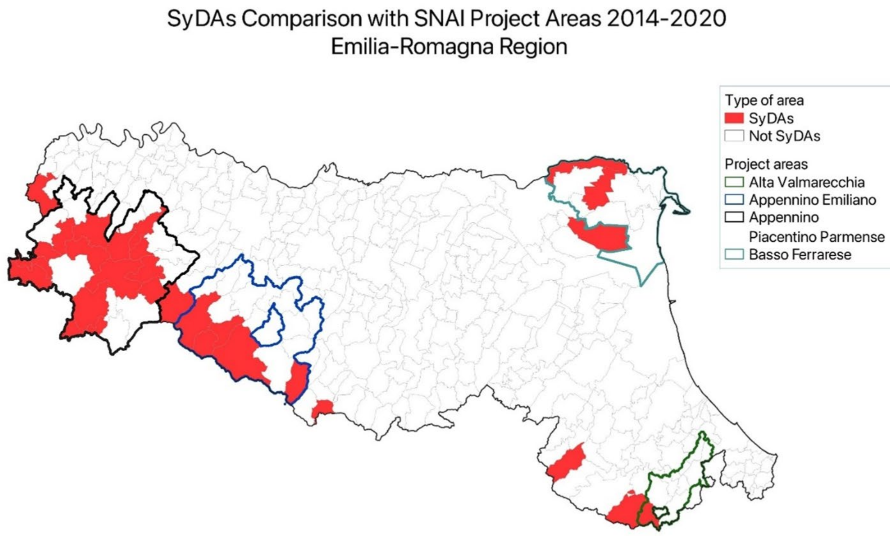

Fig. 7 Municipalities affected by systemic depopulation according to Sydas in the period 1994–2023, Emilia-Romagna. *Source*: Own elaborations based on Istat and Open Coesione data

Discussion

The results presented in this study indicate that, under a demographic perspective, the implementation of the Italian National Strategy for Inner Areas (SNAI) has not been associated with a statistically significant response in terms of systemic depopulation dynamics. This assessment is based on the analysis of both exit from and reduction in the intensity of the SyDAs condition across three regional contexts—Abruzzo, Basilicata, and Emilia-Romagna—over the period 2014–2023.

Despite marked differences in territorial structure, demographic profiles, and institutional capacity, a common pattern emerges across the three regional contexts examined in this pilot study: no systematic demographic response is statistically detectable in association with the implementation of the strategy, either in terms of full reversal or partial attenuation of systemic depopulation.

First, the quantitative expansion of SyDAs municipalities in both Abruzzo (+ 25 municipalities; + 40%) and Basilicata (+ 14; + 23%), alongside the stability observed in Emilia-Romagna, indicates that the structural drivers of long-term population decline remain largely unaltered (Table 2). These trends suggest that, even during the period of SNAI implementation, systemic depopulation continued to intensify or persist in substantial portions of the territory.

Second, when considering the entire period 1994–2023, the SNAI programme was able to involve only 60.9% of municipalities affected by systemic depopulation in Abruzzo and 45.3% in Basilicata (Table 2). This coverage further contracts when focusing exclusively on municipalities that reached meaningful levels of economic implementation (categories 3 and 4): 33% in Abruzzo and 44% in Basilicata. Emilia-Romagna performs comparatively better, with nearly 80% of SyDAs municipalities included in a project area, although only 41% attained advanced implementation stages. These figures reveal a persistent misalignment between demographic need and policy activation, highlighting a gap between the potential scope of SNAI—formally targeting inner areas—and its actual territorial deployment. Basilicata provides a paradigmatic case: despite encompassing the highest share of inner areas (90.8% of its territory) and the largest proportion

Table 4 Transitions of municipalities from first period (1994–2014) to the second period (1994–2023) by Region, Systemic depopulation state and level of SNAI advancement category

		Municipalities in systemic depopulation in the first period (1994–2014) according to SyDAs			Municipalities not in systemic depopulation in the first period (1994–2014) according to SyDAs		
Region	**SNAI advancement category**	**Remained in a state of systemic depopulation**	**Exited systemic de-population status**	**Total**	**Remained ouside the systemic depopulation process**	**Entered in a state of sytemic depopulation**	**Total**
Abruzzo	Cat. 0	17	2	19	166	17	183
	Cat. 1	5	2	7	4	3	7
	Cat. 2	12	0	12	14	4	18
	Cat. 3	19	1	20	26	3	29
	Cat. 4	3	1	4	2	4	6
	Total	56	6	62	212	31	243
	Percentage	90.3%	9.7%	100%	87.2%	12.8%	100%
Emilia-Romagna	Cat. 0	3	1	4	257	3	260
	Cat. 1	11	0	11	17	0	17
	Cat. 2	0	0	0	1	0	1
	Cat. 3	4	0	4	15	0	15
	Cat. 4	8	2	10	8	0	8
	Total	26	3	29	298	3	301
	Percentage	89.7%	10.3%	100%	99.0%	1.0%	100%
Basilicata	Cat. 0	32	0	32	48	9	57
	Cat. 1	0	0	0	0	0	0
	Cat. 2	1	0	1	0	0	0
	Cat. 3	12	0	12	3	2	5
	Cat. 4	15	1	16	4	4	8
	Total	60	1	61	55	15	70
	Percentage	98.4%	1.6%	100%	78.6%	21.4%	100%

Source: Own estimation on OpenCoesione and ISTAT data of municipalities experiencing systemic depopulation (57%), it also exhibits the lowest inclusion rate in SNAI project areas (45.3%).

Third, with respect to demographic response to policy implementation, Abruzzo is particularly illustrative. Although it records the highest number of exits from systemic depopulation (six municipalities), most of these occurred outside SNAI project areas or within low implementation categories, weakening the hypothesis that SNAI investment played a primary role (Table 3). This pattern underscores the difficulty of attributing demographic improvements to policy exposure alone.

The application of the Cochran–Armitage trend test further corroborates these descriptive findings. For SyDAs Exit, the absence of statistically significant monotonic trends across all three regions indicates that increasing levels of SNAI economic implementation (from category 0 to 4) did not translate into higher probabilities of demographic reversal. While Basilicata exhibits a weak clustering of exits in the highest advancement category, the associated statistic ($Z = -1.305$) remains below conventional significance thresholds, reinforcing the non-systematic nature of such outcomes.

Importantly, extending the analysis to SyDAs Reduction—capturing partial improvements in demographic trajectories rather than full exits—yields a slightly more nuanced but ultimately consistent picture. Although a non-negligible share of municipalities shows a reduction in the intensity of systemic depopulation, particularly in Emilia-Romagna and Basilicata, the Cochran–Armitage test again reveals no statistically significant dose–response relationship between the degree of SNAI implementation and the likelihood of demographic attenuation. Even where descriptive patterns suggest a concentration of reductions among municipalities with higher disbursement levels, these signals remain statistically fragile and confined to the three regional contexts examined in this pilot study.

Taken together, these results indicate that graduated levels of SNAI economic advancement—ranging from non-inclusion to advanced disbursement—did not correspond to measurable differences in either exiting or mitigating systemic depopulation during the 2014–2023 period across the three regions analysed. Even municipalities that had received more than 50% of their allocated SNAI funds did not display a consistent or statistically detectable demographic response, suggesting that financial activation, as measured by the degree of fund disbursement, is not in itself associated with observable demographic change. The persistence of demographic decline reflects the deeply structural nature of the phenomenon, characterized by inertia, path dependence, and long-term cumulative processes.

More broadly, these findings suggest that demographic trajectories may represent one of the most demanding dimensions through which to examine the relationship between place-based policies and territorial change. Population dynamics evolve slowly and are shaped by the cumulative interaction of multiple structural factors, including migration patterns, fertility behaviour, labour-market conditions, service accessibility, and broader socio-economic opportunities. In this context, the absence of a statistically detectable association between levels of SNAI implementation and changes in systemic depopulation should be interpreted with caution. Rather than indicating that local transformations have not occurred, it may reflect the fact that demographic trends are typically characterised by strong inertia and long temporal lags. Consequently, demographic indicators may respond more slowly than other territorial dimensions to processes of local development and institutional activation. From this perspective, systemic depopulation can be regarded as a particularly stringent outcome indicator, as it captures the cumulative demographic consequences of long-term economic, social, and territorial processes. Detecting substantial changes in such trajectories may therefore require observation periods extending well beyond those currently available for the analysis of SNAI implementation.

Three main limitations of the present study should be acknowledged.

First, the degree of SNAI implementation is proxied through an indicator of economic advancement based on fund disbursement, which does not necessarily coincide with the effective completion or local materialisation of investments. Municipalities classified in higher advancement categories may have progressed administratively and financially, while the concrete availability of services, infrastructure, or opportunities for local populations may still be partial or delayed. This potential gap between financial execution and experienced outcomes may attenuate any observable demographic response, particularly in the short to medium term.

Second, SNAI interventions are highly heterogeneous in terms of sectoral focus, scale, and objectives, and different types of investments may plausibly interact with demographic dynamics in distinct ways. However, the limited number of municipalities that have reached advanced stages of financial implementation constrains the possibility of conducting disaggregated or sector-specific analyses. As the programme matures and a larger number of municipalities enter higher advancement categories, future research may be able to explore these differentiated pathways more systematically.

Third, systemic depopulation is operationalised exclusively through the SyDAs index, which captures long-term and persistent demographic decline in a structurally coherent way. While this choice is consistent with the aims of the study, complementary analytical approaches—such as average population growth rates, alternative time windows, or sequence-based methods—could provide additional validation and nuance to the findings. Integrating such perspectives represents a promising direction for future research.

From a policy perspective, three key implications emerge. First, territorial prioritisation appears to warrant further refinement. The presence of a substantial number of SyDAs municipalities outside SNAI project areas—particularly in Basilicata—suggests a potential spatial misalignment between demographic vulnerability and policy activation. This pattern raises questions about selection criteria and strategic focus, without implying that inclusion alone would necessarily generate demographic change. Second, institutional activation appears necessary but insufficient. Even municipalities that successfully engaged in planning processes and funding absorption often remained demographically fragile, suggesting that endogenous constraints—such as service accessibility, labour demand, and youth retention—require more targeted and integrated interventions. Third, financial implementation should not be conflated with demographic outcomes. The presence of funding, even at advanced stages of disbursement, does not automatically correspond to observable changes in population trajectories. The demographic relevance of SNAI therefore appears to depend less on financial execution per se than on its capacity to interact with long-term structural dynamics and territorial resilience.

Conclusions and future steps

This study has examined the relationship between the National Strategy for Inner Areas (SNAI) and systemic depopulation dynamics across three Italian regions—Abruzzo, Basilicata, and Emilia-Romagna—by analysing municipal demographic trajectories over a nearly thirty-year period (1994–2023). By applying the SyDAs index and distinguishing between full exits from systemic depopulation and partial reductions in its intensity, the study provides an integrated assessment of demographic responses following the introduction of SNAI.

The results point to a continued expansion of systemic depopulation in Abruzzo and Basilicata and to a substantial stabilization in Emilia-Romagna, suggesting that long-term demographic trajectories have remained largely unaffected by the introduction of the strategy. While a limited number of municipalities experienced either an exit from or a reduction in systemic depopulation, these outcomes remain numerically marginal and territorially fragmented, and do not form a consistent pattern linked to policy intensity.

From an implementation perspective, the analysis highlights a partial and uneven territorial coverage of SNAI project areas with respect to both inner areas and municipalities affected by systemic depopulation. In particular, a substantial share of demographically fragile municipalities remained outside project areas, while many of those included failed to reach advanced stages of economic implementation. This misalignment underscores the gap between territorial need and policy activation.

The application of the Cochran–Armitage trend test—designed to detect dose–response relationships—provides further support for these conclusions. Across all three regions, no statistically significant monotonic association emerges between higher levels of SNAI economic implementation and either the probability of exiting systemic depopulation or the likelihood of reducing its intensity. Even where descriptive patterns suggest clustering of improvements among municipalities with higher disbursement levels, these signals do not reach conventional thresholds of statistical significance. As such, the findings do not support the presence of a systematic demographic response to increasing policy intensity during the 2014–2023 period.

Importantly, the study deliberately refrains from causal interpretation. Given the well-documented inertia and path dependence of demographic processes, the results should be read as early signals rather than as definitive evidence of policy ineffectiveness. In this sense, the absence of statistically significant associations does not imply that SNAI has failed in absolute terms, but rather that no measurable demographic response has yet emerged at the municipal level in relation to the degree of economic implementation observed.

Taken together, the findings suggest that a funding-centred approach, even when embedded in a place-based framework, is unlikely on its own to produce short- to medium-term demographic effects in structurally fragile territories. Financial execution and institutional activation, while necessary, do not automatically translate into demographic resilience. Future policy efforts may therefore benefit from a reorientation that combines investment with stronger attention to local absorptive capacity, service accessibility, labour-market dynamics, and long-term governance support.

From a policy-evaluation standpoint, the study also underscores the importance of moving beyond financial indicators as proxies for effectiveness. Refining territorial targeting, strengthening outcome-based monitoring, and ensuring sustained institutional support to local administrations may be critical steps toward enhancing the demographic responsiveness of national cohesion policies.

The primary objective for future research is to extend the analysis to the whole of Italy, covering all regions and a larger set of municipalities, in order to verify whether the patterns observed in the three pilot regions hold at the national scale. At the time of data collection for this pilot study, the platform that provided access to the relevant data underwent an update, resulting in temporary data unavailability. Only recently have the data become accessible again through alternative sources. This renewed availability now makes it possible to expand the geographical scope of the analysis and to conduct more robust statistical evaluations. Further research—leveraging longer post-implementation time horizons, richer outcome indicators, and complementary methodological approaches—will be essential to fully assess the long-term demographic implications of the SNAI.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41118-026-00296-1.

Supplementary Material 1

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Author contributions
The authors EC, CL, FB, and GdF contributed equally to the article. EC collected necessary data, conducted and performed statistical analysis and drafted a complete first version of the article. The initial concept of the study and its analytic strategy were designed by CL and FB, who also made a critical revision of the article. GdF was responsible for the geographical analysis and participated in both the drafting and revision of the manuscript. All authors read and approved the final manuscript.

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Data availability
The data supporting these findings is available from ISTAT and OpenCoesione, the Presidency of the Council of Ministers' data portal for the Department for Cohesion Policies and the South.

Declarations

Competing interest
The authors declare that they have no competing interest.

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