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How Service Exclusion Affects Rural Depopulation. An Approach Based on Structural Equation Modelling

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ABSTRACT

This paper explores the relationship between service exclusion and the depopulation phenomenon. To achieve this, we apply structural equation modelling (SEM) to evaluate the lack of development of primary services (healthcare, education, social services, commerce, restaurants and bars, as well as Internet access) at the municipal level, considering their relationship with population loss and ageing—two of the most defining aspects of depopulation. Additionally, using cluster analysis techniques, we classify municipalities based on their degree of service exclusion, identifying distinct typologies and highlighting the most critical service deficits within each group. The study focuses on the Spanish region of Aragon, a striking example of severe rural population loss and pronounced ageing within the European context. Our findings reveal significant heterogeneity in both depopulation patterns and service exclusion. This heterogeneity highlights the need to propose specific rural policy measures adapted to the peculiarities of each territory to contribute to more resilient rural communities.

1 | Introduction

It is not easy to demonstrate that the presence of services alone retains rural inhabitants; however, evidence suggests that their absence encourages the abandonment of the affected areas (Christiaanse 2020; Ruiz and Martínez 2022). In this context, the availability or lack of essential services emerges as a key factor in understanding demographic dynamics and the process of depopulation. Depopulation is characterised by a continuous loss of population and the progressive ageing of those who remain, with young people and women being the most likely to migrate (Alonso et al. 2024).

A robust network of basic public services is essential for maintaining the autonomy of older adults and reducing the need to move to urban areas in search of care (Repetti et al. 2018; Mseke et al. 2024). It is also important for families to ensure their children's education and access to activities and services

that promote their holistic development and guarantee their well-being (Escribano-Pizarro 2012).

Additionally, the availability of private services is vital for ensuring quality of life. Local shops, bars and restaurants not only meet daily needs but also create spaces for social interaction and community cohesion (Smith and Sparks 2000). Similarly, Internet access is indispensable for work, education and social life. It enables older adults to stay connected with their relatives and allows younger people to access educational and job opportunities (Dubois and Sielker 2022; Merino et al. 2024).

In this context, ensuring the availability of essential services is key to fostering territorial cohesion, preventing social exclusion and improving quality of life (European Commission 2020). These services boost sustainable development by creating jobs related to their provision and increase the likelihood that residents will stay and newcomers will settle, helping counteract depopulation and promoting sustainable growth in rural areas (Ruiz and Martínez 2022).

Given the importance of both public and private services in maintaining and rejuvenating rural populations, it is essential for governments to understand the level of exclusion faced by municipalities under their management with regard to the availability of these services (Reynaud and Miccoli 2018; Li et al. 2019). In this context, accurately identifying service gaps and mismatches in affected areas allows a more efficient allocation of resources to address the population's most pressing needs (Merino and Prats 2020; Ruiz and Martínez 2022).

The main objective of this study is, therefore, to analyse the level of service exclusion at the municipal scale and its influence on depopulation. The focus is Aragon, a Spanish region facing significant population loss and pronounced ageing in many municipalities (Alonso et al. 2023, 2024). The aim of the study is to identify deficiencies in essential services affecting specific municipalities in Aragon, establish profiles based on their level of service exclusion and analyse how these profiles relate to patterns of population loss and ageing. Additionally, the analysis seeks to determine which services are most deficient within each profile, providing insight into priority needs in specific contexts. Although Aragon alone cannot explain the generalised situation in rural Spain or Europe as a whole, it does present an interesting case study to help us understand the dynamics of service exclusion and its relationships with depopulation in these rural areas. The region illustrates the complex and varied processes of demographic decline, ageing and a lack of services, highlighting a potential heterogeneity in these trends (Alonso et al. 2023, 2024).

To achieve these objectives, structural equation models (SEMs) are used to analyse how service exclusion influences depopulation, understood as the loss of inhabitants and the ageing of those who remain. These complex and latent phenomena result from the interaction of multiple factors, making it impossible to measure them directly or through isolated variables (Hair et al. 2021).

In the case of service exclusion, SEMs allow a synthetic index to be constructed that combines different dimensions of essential service deficiencies, assigning specific weights based on their relationship with population loss and ageing. Similarly, to measure population loss and ageing in a municipality, the model integrates multiple observable indicators, providing a multidimensional view that captures the complexity of these processes and offers a more robust approach to territorial dynamics. Finally, cluster analysis is used to identify and classify municipality types based on their level of service exclusion, enabling us to associate these profiles with different patterns of population loss and ageing. The integrated use of SEM and cluster analysis provides a precise and contextual representation of the situation in Aragon, addressing the limitations of other statistical methods that fail to account for the multidimensional nature of these processes.

Building on this, the main contributions of this study can be summarised in four key aspects. First, it develops a process to measure service exclusion at the municipal level. Second, it shows how service deficiencies contribute to population decline and ageing. Third, it reveals the heterogeneity among municipalities in Aragon in terms of service exclusion levels, closely linked to patterns of depopulation. Fourth, it stresses the need for targeted interventions to address specific sources of exclusion within each municipality group; this could offer useful guidance for policymakers hoping to address the challenges more efficiently and effectively.

The rest of the paper is organised as follows: Section 2 provides the theoretical framework; Section 3 outlines the materials and methods, introducing Aragon as a case study, justifying the statistical methods used and detailing the variables considered; Section 4 presents and discusses the results; and finally, Section 5 concludes the paper with a summary and suggestions for future research. Additionally, an appendix includes the mathematical expressions for the selected variables, while the Supporting Information provides technical details of the statistical results. This latter can be made available upon request.

2 | Essential Services in the Fight Against Depopulation

Depopulation of rural areas is not a new issue, although it has recently gained social relevance and prominence at all institutional levels (OECD 2020; ESPON 2018; Ministerio de Política Territorial y Función Pública 2018). After decades of emigration, especially of young people and women, the ageing of the population that remains in many rural areas makes it difficult to sustain the reproductive capacity of their inhabitants (Coleman and Rowthorn 2011; Papadopoulos and Baltas 2024). This phenomenon, known as depopulation, represents the visible effect of territorial population emptying (Plaza Gutiérrez 2020) and leads to a severe demographic decline and loss of vitality (Rhubart et al. 2024).

The sustainability of services in depopulated areas is an increasing challenge for many European regions (European Parliament 2018). The population decline and progressive ageing of their inhabitants create a changing demand for basic services, the lack of which exacerbates depopulation and social exclusion problems (Haartsen and Gieling 2021; Vendemmia et al. 2021), turning some of these areas into true 'demographic deserts' (Pinilla et al. 2008).

The scarcity of services not only affects the coverage of essential needs but also limits access to economic opportunities (Green 2014; Rhubart et al. 2024), creating territorial inequalities that particularly affect those who remain in these communities (Cui et al. 2025).

The shortage of services and the consequences of this in rural areas affect several European regions. In the north, isolated areas of Finland (Muilu and Rusanen 2003; Albrecht et al. 2022; Jokela et al. 2024) and Sweden (Niedomysl and Amcoff 2011; Larsson 2014; Syssner and Siebert 2020; Sundqvist 2023; Henning et al. 2023) are facing a constant population decline, where the lack of opportunities and basic services, compared to cities has been a key factor driving rural exodus. In the south, Spain (Bruno et al. 2021; Esparcia 2019; Pinilla and Sáez 2021; Palacios et al. 2022; Santos and Fernández-Fernández 2023; Martínez-Carrasco and Colino 2024; San-Martín González and Soler-Vaya 2024) and Portugal (Almeida 2018; Fernandes 2019; Lorente et al. 2020; Ferreira et al. 2023) are experiencing similar patterns, especially in mountainous areas and inland regions where the lack of services and employment has driven migration to more dynamic urban areas. In Italy (Reynaud and Miccoli 2018; Fantechi et al. 2020), Greece (Papadopoulos and Baltas 2024; Panagiotopoulos and Kaliampakos 2024) and the Balkans (Mickovic et al. 2020; Nikitović et al. 2024; Miladinov 2024; Petrović and Ateljević 2024), the lack of sufficient services and the ageing of the population are resulting in a steady loss of young and qualified inhabitants, weakening the social and economic fabric of these areas. This issue also affects rural areas in central Europe, such as in Germany (Barakat 2015; Ivanov 2021; Schorn 2023), France (Doignon et al. 2016; Laménie 2016) and the Alpine region (Steinicke and Löffler 2019), where similar trends of depopulation and inequality of opportunities can be observed. Overall, this situation reflects a structural challenge in rural European areas, where it is difficult to retain or attract the population, especially young people, who seek better living conditions in more urban or dynamic areas.

As a result, this multifaceted challenge requires solutions from various disciplines and is at the heart of a major political and social debate (ESPON 2020; Revuelta de la España Vaciada 2019). However, it is important to note that not all rural areas are equally affected by population decline (Bayona-i-Carrasco and Gil-Alonso 2013; Dolton-Thornton 2021; Álvarez-Montoya and Ruiz-Ballesteros 2024), and the magnitude of the phenomenon varies significantly between countries and regions, meaning that the risk of depopulation is not uniform (Dax and Fischer 2018).

For all these reasons, depopulation should be analysed within a broader context beyond the simply demographic aspect, as its causes and solutions also encompass socioeconomic and environmental factors. While these causes and solutions are not uniform, a common factor ties them together: the gradual deterioration of essential services (Guerrero-Bernal et al. 2018). The lack of these vital services significantly affects the quality of life and the sustainability of rural communities, further exacerbating the problem of demographic decline (Camarero and Oliva 2019).

This scenario creates a vicious circle in which the lack of opportunities (San-Martín González and Soler-Vaya 2024) and the absence of services drive the migration of young people (Bock 2016; Camarero and Oliva 2019), women (Johansson, 2016) and highly qualified individuals (Gil-Alonso et al. 2023). This exodus further weakens the social and economic fabric of the affected areas. In turn, the decline in demand in these areas leads to the disappearance of essential services, exacerbating the depopulation problem and undermining the viability of these services, perpetuating the situation.

In the scientific literature, some authors argue that the lack of basic services is a direct consequence of population decline, claiming that the exodus to urban areas reduces demand in less populated regions and, therefore, the sustainability of essential services (Westlund and Pichler 2013; Noguera-Tur and Ferrandis-Martínez 2014). In contrast, other studies suggest that insufficient infrastructure acts as a determining factor that drives residents, particularly young people, to migrate to urban areas where services are more accessible (Zurro Sánchez-Colomer 2020; Haartsen and Gieling 2021; Vendemmia et al. 2021; Rodríguez-Rodríguez and Larrubia-Vargas 2022; Alcaide Muñoz et al. 2024).

Thus, a bidirectional relationship is observed between a lack of services and depopulation, where each phenomenon feeds back into the other, reinforcing a cycle of decline. In this regard, Pinilla and Sáez (2021) suggest that a scarcity of services is not only a consequence of depopulation but also contributes to it, hindering the retention of inhabitants and the attraction of new residents, influencing the economic and social sustainability of rural areas.

Although it is difficult to prove that the mere presence of services can retain the population in a specific area (Christiaanse 2020; Ruiz and Martínez 2022), it is true that without these services, staying in these environments becomes challenging. Furthermore, the loss of services particularly affects the elderly, who predominate in rural areas and, due to their age, face mobility issues when seeking services in other municipalities (Paddison and Calderwood 2007; Mseke et al. 2024). Without services, it is difficult to reverse the loss of economic dynamism, especially with an ageing population that simultaneously depends on these, leading to the exclusion of those affected who are unable to access many basic services essential for their well-being (Reynaud and Miccoli 2018; Li et al. 2019).

Ultimately, while the availability of basic services alone is insufficient to reverse rural depopulation, it does play a key role in our understanding of the demographic dynamics of the affected territories. By examining service exclusion, we can identify the most vulnerable areas and understand how these deficiencies contribute to population loss and ageing. Thus, although it may not be the sole solution, improving access to these services could be a strategy to help address the phenomenon of depopulation.

3 | Materials and Methods

3.1 | Study Area

The demographic challenge facing Europe, particularly Spain, highlights the significant inequalities in rural areas. 'Empty Spain' is a prominent example, where young people face numerous professional, social and personal challenges, pushing them to migrate (Llorent-Bedmar et al. 2021) to urban hubs such as

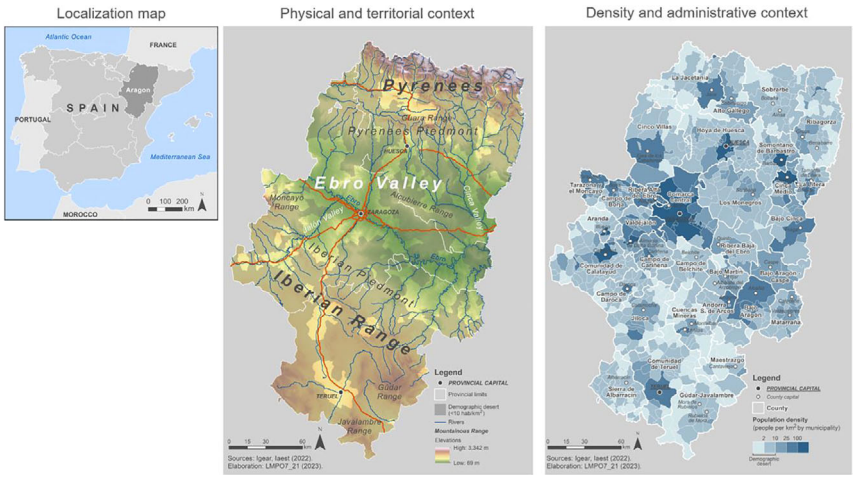

FIGURE 1 | Physical and demographic characteristics of Aragon.

Madrid and Barcelona (Gil-Alonso et al. 2023). While Spain's total population grew from 40.8 to 47.4 million between 2001 and 2021, 21.9% of Spanish municipalities—including small- and medium-sized towns—experienced a population decline, according to data from the Spanish National Institute of Statistics (INE).

The risk of population decline is not evenly distributed across the country. Coastal and insular areas, such as Catalonia, Valencia and the Canary Islands, have thriving communities that surpass the national average population density of 94.1 inhabitants/km^2. In contrast, many inland regions, including Aragon, Extremadura, Castile and Leon and Castile-La Mancha, have population densities less than one-third of the national average, reflecting stark regional contrasts.

Among these, Aragon—our case study—stands out as one of the Spanish Autonomous Communities that starkly highlights the demographic imbalance. Aragon is administratively divided into three provinces (Zaragoza, Huesca and Teruel), which are further subdivided into 33 counties or *comarcas*. According to data from the Aragonese Institute of Statistics, this region in the northwest of Spain occupies 47,720 km^2 and in 2021 had 1,326,261 inhabitants, giving a population density of 27.8 inhabitants per km^2. Its capital, Zaragoza, concentrates more than half its inhabitants (54%), and many of its municipalities have a low population and significant territorial organisation problems. However, these figures obscure significant differences. Of the 731 municipalities in the region, 522 (71.4%) have less than 10 inhabitants per km^2, a threshold below that is considered a 'demographic desert', and of these, 371 have less than five inhabitants per km^2. This phenomenon reflects a persistent, intense and ongoing depopulation trend that has left many areas with critically low population densities and raises concerns about their long-term viability (Ayuda et al. 2024).

These demographic vacuums are distributed throughout the region, although the mountainous areas of the Pyrenees and the Iberian Range that cross the region to the north and southwest are the most heavily affected. Nevertheless, we also find many places with sparsely populated municipalities in other parts of the region (Figure 1). The map of demographic and administrative characteristics in Figure 1 also includes the delimitation by counties, which may assist in the reading and interpretation of the results presented in Sections 4.2 and 4.3.

The ageing rates in numerous municipalities bring into question their future demographic sustainability, exacerbating concerns over services and economic viability (Pinilla et al. 2008; Alonso and López-Escolano 2021). This serious demographic situation coexists with the critical problems affecting the economic and social development of the most depopulated municipalities, such as the lack of essential services. Although the casuistry behind each municipality is different, the lack of services generates significant inequalities, compared to other more dynamic and densely populated municipalities that can access these essential services more efficiently. Quantifying the degree of service exclusion suffered by the different Aragonese municipalities makes it possible to highlight the various degrees of inequality depending on their geographical situation, allowing more precise action to be taken to alleviate the problem.

To summarise, the analysis of Aragon reflects a scenario that could be replicated in other regions of Spain and Europe with similar demographic trends, offering valuable insights when it comes to designing services tailored to the characteristics of other territories and helping mitigate the effects of depopulation.

3.2 | Method

In this section, we outline the method employed to achieve the objectives of the paper, which combines two statistical techniques. First, we use SEM (see, e.g., Hair et al. 2021) to examine how *Service Exclusion* influences depopulation dynamics, focusing on two key aspects: *Population Loss* and *Ageing*. This technique also allows us to estimate service exclusion values for each municipality. Second, we apply cluster analysis to identify typologies of Aragonese municipalities based on these values.

3.2.1 | The SEM

To examine the relationship between service exclusion and depopulation—defined in terms of population loss and ageing—

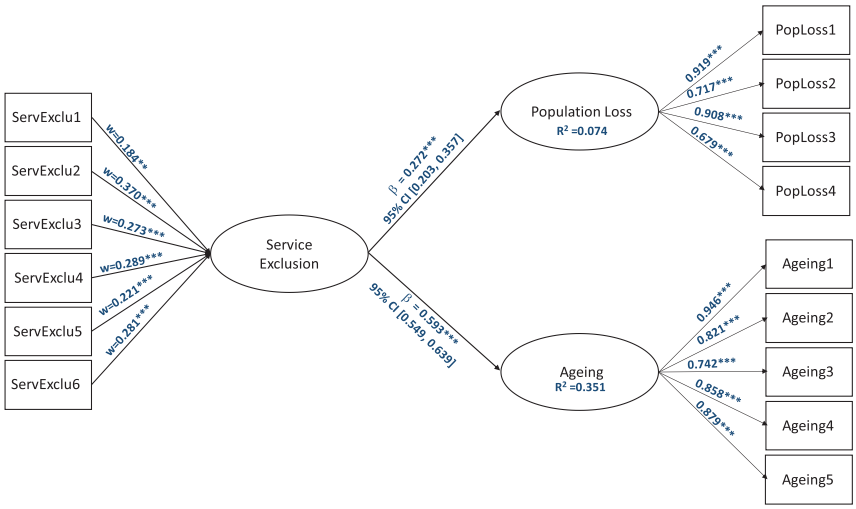

FIGURE 2 | Estimated path model.
** (***) significant at 5 (1%). 95% confidence intervals of each β regression coefficient below each point estimation.

across municipalities in Aragon, we apply SEM, a technique also used by Reynaud et al. (2020) to analyse depopulation in Italy, in a different context. SEM allows us to investigate latent constructs that cannot be measured directly but which are inferred from observable indicators. In this framework, *Service Exclusion* is treated as an exogenous variable, while *Population Loss* and *Ageing* are endogenous variables. Although we acknowledge the bidirectional nature of these relationships, we adopt a unidirectional approach to focus on estimating service exclusion levels, as it seems more feasible to intervene in tangible aspects, such as services, which are directly modifiable, rather than attempting to influence population dynamics directly.

Specifically, SEM constructs a *Service Exclusion* index that captures deficiencies both in essential public services (healthcare, education, social services) and private services (commerce, restaurants, Internet coverage) through a formative construct, with weights assigned based on their influence on depopulation. This index quantifies both the magnitude of exclusion and its impact on the demographic context of each municipality. To measure depopulation, two reflective constructs are used: *Population Loss* and *Ageing*. The model integrates multiple observable indicators for each construct, providing a comprehensive and robust view of the demographic changes in each municipality. This approach also identifies the most critical services for preventing depopulation, which could help policymakers prioritise targeted investments in key services in municipalities with high levels of exclusion.

Figure 2 illustrates the path model used in the study, with the latent constructs of *Service Exclusion*, *Population Loss* and *Ageing* represented by ovals, and their corresponding measurable indicators depicted as rectangles.[1]

3.2.2 | Description of Variables

Next, we define and justify the indicators used to compose each construct, which enable us to examine the socio-demographic realities of each municipality and the availability of services.

3.2.2.1 | Population Loss. In this case, we use a reflective construct that considers two key aspects: the *Population Growth Rate*, which reflects the natural change in population, and the *Residential Variation Rate*, which measures population changes due to migration. Both indicators are evaluated over time to capture dynamics in both the short and medium term, related to migration movements and natural population growth (Reynaud et al. 2020). This distinction is particularly important in areas facing service exclusion, where a lack of services may discourage new arrivals. We have calculated these rates for both the medium and short term: the *Population growth rate between 2021 and 2005* (PopLoss1) and the *Population growth rate between 2021 and 2015* (PopLoss2), respectively. Additionally, to capture migration dynamics, we have incorporated the *Residential variation rate between 2021 and 2005* (PopLoss3) and the *Residential variation rate between 2021 and 2015* (PopLoss4).

The four variables enter the model multiplied by (−1) so that the construct measures population loss and not population gain. In other words, the higher the value of these indicators after multiplying by (−1), the higher the value of the *Population Loss* construct. This means that as the indicators increase in magnitude, the construct will also increase, reflecting a greater population loss in the studied area. The detailed definitions of each indicator can be found in the Appendix.

3.2.2.2 | Ageing. In this case, we use a reflective construct based on several demographic structure indicators (Alonso et al. 2023, 2024). Thus, we have selected the *Average age of the population* (Ageing1), which indirectly reflects the possibilities of dynamism in a municipality. The *Youth Index* highlights the low proportion of young people in many rural areas, which, combined with a high average age, indicates insufficient generational renewal to ensure sustainability. However, we have calculated the difference as 100 minus the *Youth Index* and named it the *Maturity Index* (Ageing2) so that it aligns with the average age

of the municipality. Another variable closely related to the ageing of the population is the *Age dependency ratio* (Ageing3), which is also an important indicator of population balance since it relates the inactive or economically dependent population to the potentially active population. The *Percentage of women of childbearing age over the total* is used to assess the growth capacity of a population. We have therefore considered the difference 100 minus that percentage, that is, the *Percentage of women not of childbearing age over the total* (Ageing4).[2] To corroborate whether a high age dependency rate corresponds to an older population rather than a young population that is not yet of working age, we have selected the *Percentage of the population older than 64* (Ageing5). In addition, 65 is the most frequent retirement age, so this percentage also includes people without job opportunities. The detailed expressions for each indicator are provided in the Appendix, and the values of the indicators have been obtained from the corresponding data for the year 2021 provided by the Aragon Institute of Statistics.

3.2.2.3 | Service Exclusion Variables. The concept of *Service Exclusion* tries to capture the inequalities suffered by the inhabitants of depopulated municipalities, compared to the inhabitants of more prosperous localities, due to problems of access to essential public or private services. To that end, we use a formative construct derived from different basic services that contribute to increasing the well-being and quality of life of the inhabitants of a municipality. Next, we present the variables we have used to compose this construct.

3.2.2.3.1 | Healthcare Exclusion. Spanish healthcare is universal, and one of its basic principles is equity, which must also be understood from a geographical perspective. There are two types of primary healthcare services: health centres and doctor's offices, dependent on the former. However, doctors' offices do not have a stable staff and typically offer discontinuous and primary healthcare. Health centres tend to be concentrated in municipalities of a particular size. However, even though a high percentage of the Spanish population has access to a health centre in their municipality or within approximately 10 min of their home (Goerlich and Reig 2021), there are municipalities with high rates of ageing, which makes them more dependent on healthcare, that have a health centre more than 30 min away.

Bearing all this in mind, we have considered the average time (in minutes) of access to the nearest health centre as a variable measuring *Healthcare Exclusion* (ServExclu1). This variable allows us to focus particularly on populations in municipalities that do not have their own health centre. The population must therefore travel to another municipality to access healthcare.

3.2.2.3.2 | Educational Exclusion. In Spain, education is a fundamental right of citizens that the public authorities must guarantee. Primary and secondary education, from 6 to 16 years of age, is also compulsory, and many communities even finance or subsidise earlier stages. The public authorities must therefore guarantee access to education for an essential part of the population under equal conditions. All this is required, not only by the regulations that establish compulsory schooling but also by the principle of equal opportunities. Geographical accessibility to educational centres is only one step in this direction.

Within this context, we have defined the variable *Educational Exclusion* (ServExclu2) by using a weighted indicator, similar to the SITA[3] synthetic territorial development index. This indicator combines the different educational stages: primary education, which covers ages 3 to 12; compulsory secondary education (ESO), from 12 to 16; non-ESO, from 16 to 17; and university education, from 18 to 24 years of age. Thus, the indicator covers compulsory schooling and two post-compulsory stages (see the Appendix for details).

3.2.2.3.3 | Social Services Exclusion. Social services are essential for the sustainability of rural territories, and there has been a significant investment in these by regional governments as they contribute to fixing the population. These social services support older people or dependents who wish to stay at home by providing services either at home or in other facilities. Services such as laundry and catering, rehabilitation, home help and caregiver support favour the permanence of the elderly or dependent people in their municipality in the best quality-of-life conditions. However, social services are not equally present in all municipalities. For this reason, a lack of social services in a municipality is another dimension to consider in the composition of the *Service Exclusion* indicator. *Social Services Exclusion* (ServExclu3) is calculated using a weighted indicator like the SITA synthetic territorial development index (see the Appendix).

3.2.2.3.4 | Commercial Exclusion. Many Spanish and Aragonese municipalities have no stores. However, unlike other services, the closure of stores and businesses has not been treated with the same intensity. It is noteworthy that residents find it difficult to access fresh food. Those who suffer the most from the lack of stores are inhabitants without cars and the elderly.

Local businesses directly benefit the populations of the municipalities where they operate, as they help retain residents, generate wealth, reinvest their profits locally and bring vitality to these areas. However, depopulation accelerates much more rapidly in municipalities where small businesses close. As a result, more people are increasingly turning to alternatives such as seeking aid for multi-service centres, co-financing taxis to shop in nearby towns, ordering products on demand so street vendors can adjust their offerings and even relying on online shopping.

For this reason, commercial exclusion is another dimension to consider in the geographic exclusion indicator. The variable *Commercial Exclusion* (ServExclu4) has been calculated, a value of 1 being assigned if there are no retail or wholesale businesses and 0 otherwise.

3.2.2.3.5 | Restaurant and Bar Exclusion. Bars and restaurants are powerful underpinning elements in rural areas, where the offer is much smaller but guarantees a social and economic boost in these nuclei. Bars in small municipalities are not just businesses; they play a crucial social role since they are considered meeting places, activity rooms and neighbourhood hubs where the inhabitants of the municipalities, especially if they are older, can see each other, talk and entertain themselves. Considering all this, it is not strange to see initiatives from time to time by municipalities in 'Empty Spain' searching for people to run their bars, which have mostly been left unoccupied due

to retirement. They offer housing and other facilities to attract people to take over the business. Small municipalities stay alive if their bars and restaurants remain open.

Restaurant and bar Exclusion (ServExclu5) is, therefore, a dimension to consider in the *Service Exclusion* indicator. This variable has been calculated by assigning a value of 1 if there are no bars or restaurants in the municipality and zero otherwise.

3.2.2.3.6 | Internet Exclusion. The social reality that Spain is experiencing has become unsustainable for the rural world. So-called 'Empty Spain' is suffering the consequences of the globalisation of society that increasingly demands Internet access to conduct any procedure or action, whether public or private, promoting the so-called digital divide between the rural and urban worlds (Czubala Ostapiuk et al. 2022).

Although Internet connections have improved remarkably over the last few years, there is still a long way to go to bring this virtual service closer to everyone without distinction. In 2022, 5G mobile coverage reached 82% of the population; in rural areas, it is still 50.4%, while ultra-fast broadband coverage (> 100 Mbps) is already 71.91% in rural areas, with populations of less than 500 inhabitants generally having less than 50% coverage penetration (Government of Spain 2022). In any case, Spain is moving towards the digital connectivity objectives set by the European Union, which seek to guarantee coverage of at least 100 Mbps for 100% of the population in every part of the country by 2025, and Gigabit and 5G connectivity for the entire population by 2030 (Government of Spain 2022).

The large proportion of the population with no quality Internet access in rural areas leads us to deduce that the geographical location and the age of the users comprise a determining and conditioning factor in Internet use. Rural areas often have a triple digital divide: broadband connections, skills development and utilisation. In addition to the lack of next-generation Internet access network offerings, many rural populations lack the necessary digital literacy, and the use of digital technologies is lower than in urban areas. A detailed expression for this indicator is provided in the Appendix.

Table 1 presents all the constructs and their corresponding indicator variables. It summarises the key dimensions related to *Service Exclusion*, *Population Loss* and *Ageing* in Aragon's municipalities, providing a clear framework for interpreting the subsequent results and the relationships between these factors.

3.2.3 | Classification of Municipalities

Once the structural model has been determined, the resulting service exclusion values estimated for each municipality are used to identify the typologies found in Aragon. This is achieved through cluster analysis, which groups municipalities based on similar levels of service exclusion, enabling us to identify patterns of deprivation and shared characteristics.[4] This helps isolate areas where deficiencies are more pronounced, providing a clear picture of how these vary across the region. Moreover, this analysis reveals how different combinations of service exclusion contribute to population loss and ageing, helping us to better understand the specific needs of each group.

The combination of SEM and cluster analysis provides a practical framework that could support policymakers when designing targeted, evidence-based measures. By categorising municipalities based on their exclusion profiles and analyzing how these relate to population trends, this approach could help identify tailored interventions. Moving away from one-size-fits-all policies, it enables solutions that address the specific needs and characteristics of each municipality. This approach could contribute to combating rural depopulation more effectively.

4 | Results

This section presents the results of the paper, organised to address the research questions. Section 4.1 demonstrates the significant impact of *Service Exclusion* on both *Population Loss* and *Ageing* in Aragonese municipalities. Section 4.2 identifies key deficiencies in essential services affecting certain areas. Section 4.3 categorises municipalities according to their *Service Exclusion* levels and investigates the connections to *Population Loss* and *Ageing*. Section 4.4 highlights the varied characteristics of municipal groups, identifying the most deficient services in each case. Finally, Section 4.5 explores how these findings could guide the development of effective, tailored policies to address specific municipal needs, aligning with long-term strategies outlined in both Aragonese and Spanish policy frameworks.

4.1 | How Does Service Exclusion Affect Population Loss and Ageing?

Figure 2 illustrates the results of the PLS-SEM model, where the numbers on the arrows represent the strength of the relationships between the variables. All the coefficients in the model are statistically significant at the 95% confidence level and align with our expectations. Specifically, the results confirm that a lack of essential services directly influences both *Population Loss* and *Ageing* in a municipality. However, the influence on *Ageing* is stronger (0.593) than on *Population Loss* (0.272), highlighting the fact that ageing is not only driven by the loss of young people but also by the rupture of the demographic structure caused by the lack of services and opportunities, which accelerates this process.

When looking at the individual components of service exclusion, educational exclusion plays the most significant role, while healthcare exclusion has the least impact. Even so, the differences between their contributions are not very pronounced. Regarding *Population Loss* and *Ageing*, the results show that all the selected indicators are reliable, meaning they give an accurate picture of what is happening. This makes our analysis a strong starting point for understanding how a lack of essential services is linked to both fewer people living in an area and an increase in the age of the population.[5]

TABLE 1 | Indicator variables for the three constructs.

Constructs	Indicators	Variables
Population Loss	PopLoss1	Population growth rate between 2021 and 2005
	PopLoss2	Population growth rate between 2021 and 2015
	PopLoss3	Residential variation rate between 2021 and 2005
	PopLoss4	Residential variation rate between 2021 and 2015
Ageing	Ageing1	Average age of the population
	Ageing2	Maturity index
	Ageing3	Age dependency ratio
	Ageing4	Percentage of women not of childbearing age over total
	Ageing5	Percentage of population older than 65
Service Exclusion	ServExclu1	Healthcare Exclusion
	ServExclu2	Educational Exclusion
	ServExclu3	Social Exclusion
	ServExclu4	Commercial Exclusion
	ServExclu5	Restaurant and bar Exclusion
	ServExclu6	Internet Exclusion

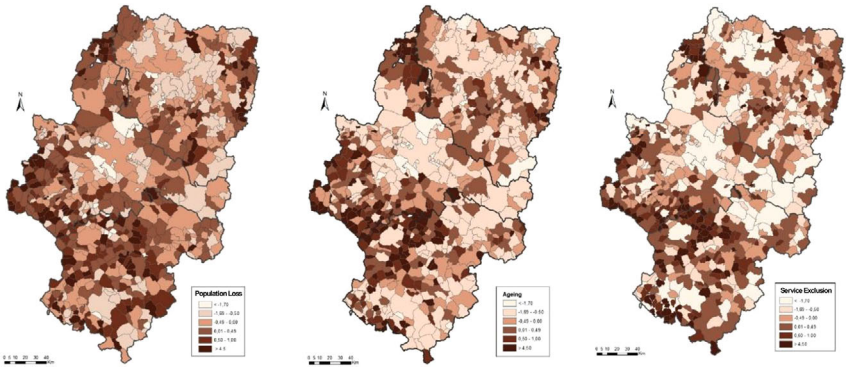

FIGURE 3 | Spatial distribution of the three construct scores.

4.2 | Where in Aragon are the Municipalities With the Highest and Lowest Levels of Service Exclusion, and How Do These levels relate to Population Loss and Ageing Trends?

To visualise the territorial reality through the three constructs estimated with PLS-SEM, we map their factorial scores in Figure 3. In each map, municipalities coloured deep brown are those with the most ageing and greatest population decline, as well as the most exclusion. In contrast, municipalities in light brown are the least ageing and most densely populated and have no service exclusion.

The three maps reflect the fact that many municipalities have high values for *Population Loss*, *Ageing* and *Service Exclusion*, indicating that this region is facing significant problems.[6] The notable high values in the municipalities to the south of the province of Zaragoza and northwest of Teruel coincide with the location of the mountainous Iberian Range. Other high-value municipalities are found in the northeast of the region, corresponding to the Pyrenees Mountains and its foothills, and other minor mountain ranges, such as Alcubierre or Guara. These physical environments do not favour the presence of dense populations due to the attraction of nearby urban spaces.

Observing the geographical distribution of the values of each construct separately, and looking specifically at *Population Loss*, we can see the tremendous territorial imbalance caused by the existence of just a few locations that concentrate practically the entire population of Aragon, together with extensive rural areas with serious population loss problems. This issue is particularly acute in the province of Teruel, where there is a strong predominance of municipalities with remarkably high *Population Loss* values. In contrast, the lowest values are focused on the municipalities located around the Ebro axis, the provincial capitals of Huesca and Teruel, the county of Cinca Medio and some nuclei of the Pyrenees such as Jaca, Sabiñánigo, Benasque and Graus, which are associated with significant development, especially of a tourist nature (see Figure 1 for geographical references). This construct corroborates the low occupation of the Aragonese territory and

the survival problems of many municipalities because of a long history of depopulation explained by the migratory currents emptying rural spaces, especially mountain areas. This process is further accentuated today, in this case, due to the mortality rate related with the increased ageing of the population in these areas.

For this reason, another relevant factor for understanding the organisational problems of this region is the *Ageing* construct. The degree of ageing in Aragon is exceptionally high, being more pronounced in the municipalities that suffer from depopulation problems and increasing the detrimental loss of demographic dynamism in which many municipalities are immersed. However, this factor affects even more municipalities, which is undoubtedly important, as it is necessary to consider the service needs of an ageing population. Especially pronounced is the degree of *Ageing* in the province of Teruel and in the southwest area of the province of Zaragoza, where it coincides with the population loss processes, accentuating the emptying process of these spaces. In contrast, the map highlights some municipalities with lower ageing values, corresponding to localities adjacent to Zaragoza, where young people have settled in search of cheaper housing. Also noteworthy are the municipalities with an immigrant population attracted by job offers. This happens, for example, in municipalities dedicated to fruit growing or other agricultural work that requires cheap labour (e.g., Valdejalon, Bajo Cinca or Bajo Aragon-Caspe). In any case, the high degree of *Ageing* in Aragon, due to the migration of the young population over the years, accentuates a regressive demographic structure, putting at risk the survival capacity of many municipalities with low population numbers.

The spatial distribution of the *Service Exclusion* construct clearly contrasts municipalities with more favourable conditions (such as the banks of the Ebro River, provincial capitals, some county capitals and certain tourism centres in the Pyrenees and Gudar-Javalambre counties) with the rest of the region, where exclusion levels are significantly higher. These levels vary in intensity, with some municipalities experiencing very marked exclusion (Figure 3). Considering the results obtained and the importance of improving access to services as an effective measure for mitigating the depopulation issue affecting many of these regions, it is essential to classify municipalities based on their level of service exclusion. Given the significance of this classification, it is the focus of the following section.

4.3 | How Can Aragonese Municipalities be Classified According to Their Levels of Service Exclusion, and What Demographic Patterns Are Associated With These Profiles?

Figure 4 shows a two-panel graphic; the left panel displays a map illustrating the spatial distribution of the six groups identified using cluster analysis, with *Service Exclusion* as the classifying variable. The right panel features three boxplots and three graphs with error bars, which are generated by cross-referencing the three constructs with the municipality groups.

By analysing the results from the boxplots and error bars, the groups have been clearly ranked in ascending order according to *Service Exclusion* as this is the classifying variable. However, it can be seen that this increasing order is maintained in *Ageing* and, to a lesser extent, in *Population Loss*, reflecting the direct relationship between the three constructs, as highlighted in Section 4.1.

We notice that the first two groups (in dark and light green) tend to take the lower values in the three constructs. Municipalities for both groups correspond to the three province capitals, the Ebro corridor and other bigger localities, most of which are county capitals (see Figure 1 to identify the location of these areas on the map). In contrast, the municipalities in shades of pink and maroon suffer from higher levels of service exclusion. The most extreme cases correspond to the Group 6 municipalities (dark garnet), which are the most excluded, the most aged, and the ones that have lost the most population in relative terms.

Our findings highlight the diversity of Aragonese municipalities in terms of *Service Exclusion*, *Population Loss* and *Ageing*, which calls for a tailored approach to address their service shortages. While this may not be the only solution, as previously mentioned, improving access to these services could be an effective strategy for tackling the depopulation issue.

4.4 | Which Services Are Most Deficient Within Each Group of Municipalities?

The Service Exclusion construct is a weighted average of six indicators that capture some of its most important aspects. It is, therefore, a composite indicator, which quantifies the *Service Exclusion* intensity in a municipality but does not identify the underlying causes of this exclusion. Two municipalities might have a similar *Service Exclusion* value, but the services they lack might be different. Thus, to discern the differences in the exclusion process according to its different sources in the groups found, Figure 5 shows the error bars for the six indicator variables that comprise the formative construct of *Service Exclusion* by groups of municipalities. Furthermore, Table 2 offers a quick overview of the shortcomings, those aspects where each group shows significantly worse values being highlighted with crosses.

To further refine the group profiles, we also compare the groups with municipality population size, which should also help to establish or prioritise action measures. Thus, Figure 6 shows the boxplots for the population logarithm by groups (left panel) and back-to-back bar charts with the distribution of the groups of municipalities according to their number of inhabitants (right panel). We can see the apparent inverse behavior of the *Service Exclusion* construct value (an increasing trend in the boxes) with the population logarithm value (a decreasing trend in the boxes). In other words, the larger the population in the municipality, the less service exclusion, and vice versa. However, if we look at the graph of the attached bars, most of the municipalities in Groups 5 and 6, which tend to contain the most excluded municipalities, tend to be the least populated, with the majority having less than 500 inhabitants in Group 5 and 100 inhabitants in Group 6.

In addition, Table 3 is a cross table of municipality groups with the categorised size variable that contains the percentage of the population living in each type of municipality. The majority of the Aragonese population (86.78%) live in Groups 1 and 2 municipalities, which are those with almost no service exclusion

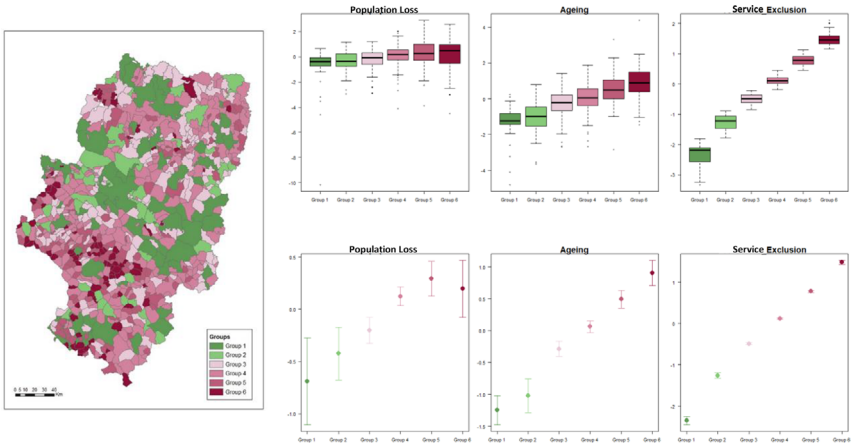

FIGURE 4 | Two-panel graphic with the results of the cluster analysis. Left panel—spatial distribution of the groups. Right panel—boxplots and error bars by groups for the three factors.

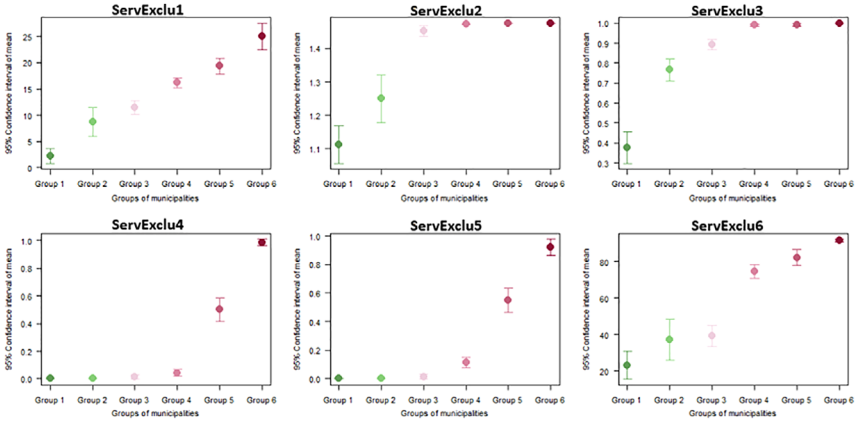

FIGURE 5 | Error bars for the six indicator variables that compose the formative construct of *Service Exclusion* by groups of municipalities.

TABLE 2 | Critical aspects for each group of municipalities.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Healthcare Exclusion				X	X	X
Educational Exclusion			X	X	X	X
Social Services Exclusion		X	X	X	X	X
Commercial Exclusion					X	X
Restaurant and bar Exclusion					X	X
Internet Exclusion				X	X	X
Population Loss				X	X	X
Ageing			X	X	X	X

problems. Table 4 shows the percentage of municipalities out of the total for each group, compared with municipality size. This table reveals the severe population concentration problems in Aragon since Groups 1 and 2 municipalities represent only 14.37% of all Aragonese municipalities.

Based on an analysis of the results shown in Figures 4–6 and Tables 2–4, the differences between the six groups of municipalities are discussed below, along with the need to adapt specific solutions to the characteristics of each group.

Group 1: This mainly contains three classes of municipalities: (i) provincial and county capitals; (ii) municipalities closest to the regional capital that are part of its urban environment; and (iii) other municipalities located in the areas of most remarkable economic and productive dynamism (Figures 1 and 4). Although

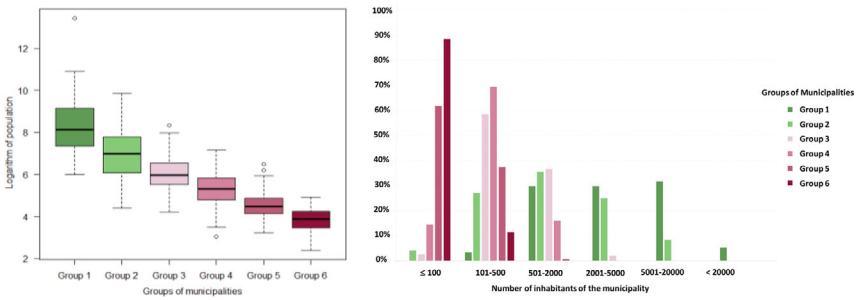

FIGURE 6 | Boxplots for the population logarithm by groups (left panel) and back-to-back bar charts with the distribution of the groups of municipalities according to their number of inhabitants (right panel).

TABLE 3 | Percentage of the population out of the total by groups and municipality size.

Size of municipalities								
		Less than 100	101–500	501–2000	2001–5000	5001–20,000	More than 20,000	Total
Groups of municipalities	Group 1	0.00%	0.06%	1.65%	4.21%	15.78%	57.66%	79.37%
	Group 2	0.01%	0.29%	1.37%	2.68%	3.07%	0.00%	7.41%
	Group 3	0.03%	1.88%	3.75%	0.74%	0.00%	0.00%	6.40%
	Group 4	0.20%	2.92%	2.23%	0.00%	0.00%	0.00%	5.36%
	Group 5	0.41%	0.65%	0.05%	0.00%	0.00%	0.00%	1.11%
	Group 6	0.27%	0.09%	0.00%	0.00%	0.00%	0.00%	0.35%
	Total	0.92%	5.88%	9.05%	7.63%	18.85%	57.66%	100.00%

TABLE 4 | Percentage of municipalities out of the total by groups and municipality size.

Size of municipalities								
		Less than 100	101–500	501–2000	2001–5000	5001–20,000	More than 20,000	Total
Groups of municipalities	Group 1	0.00%	0.27%	2.33%	2.33%	2.46%	0.41%	7.80%
	Group 2	0.27%	1.78%	2.33%	1.64%	0.55%	0.00%	6.57%
	Group 3	0.55%	11.76%	7.39%	0.41%	0.00%	0.00%	20.11%
	Group 4	5.06%	24.35%	5.61%	0.00%	0.00%	0.00%	35.02%
	Group 5	11.49%	6.98%	0.14%	0.00%	0.00%	0.00%	18.60%
	Group 6	10.53%	1.37%	0.00%	0.00%	0.00%	0.00%	11.90%
	Total	27.91%	46.51%	17.78%	4.38%	3.01%	0.41%	100.00%

some municipalities have a solid economic base in the most productive and exporting primary sector allowing them to attract foreigners, others stand out for an industrial base or excellent specialisation in tourism. They are all characterised by low levels of service exclusion. This group contains almost 80% of the Aragonese population (Table 3) but constitutes just 8% of the municipalities (Table 4 and Figure 6). More than one-third of the municipalities in this group have more than 5000 inhabitants (Table 4 and Figure 6).

Group 2: This contains municipalities that function as regional sub-centres, which have fewer services than the provincial capitals. They tend to be located close to Group 1 municipalities (Figures 1 and 4) around industrial or tourist areas, and some have specific shortages involving social services. This group encompasses around 7.4% of the regional population (Table 3) and 6.5% of all municipalities (Table 4). Around one-third of these municipalities have between 2000 and 20,000 inhabitants (Table 4 and Figure 6).

Group 3: This contains municipalities with a much lower population size than the previous groups and is where deficiencies are beginning to be detected in some essential services, such as secondary schools (Table 2 and Figure 5). They are in intermediate areas between Group 1 and 2 municipalities and those of Groups 4 and 5. Their geographical characteristics are diverse—from high-mountain municipalities with a tourism vocation to others in the foothills and the transition between the

Ebro Valley and the mid-mountain areas (Figures 1 and 4). Most of them have between 100 and 2000 inhabitants. They represent a little more than 6% of the Aragonese population but more than 20% of the municipalities (Tables 3 and 4, Figure 6).

Group 4: This contains municipalities with low demographic volumes since they account for more than 35% of the municipalities in the region (Table 4 and Figure 6) but barely more than 5% of the population (Table 3). This shows that the municipalities in this group are becoming part of the region's aged and at-risk depopulation areas (Table 2 and Figure 5); most of them have between 100 and 500 inhabitants. In addition, there are some shortcomings in terms of Internet access (Table 2 and Figure 5), and, in general, these municipalities are further away from health centres. Most of the municipalities in Group 4 are in mid-mountain areas, both in the Pyrenees and Pre-Pyrenees, as well as in the Iberian Range and its foothills (Figures 1 and 4). However, some are also in the Ebro Valley, related to municipalities with tenuous demographic viability in the face of migration and a lack of job opportunities.

Group 5: This includes tiny municipalities with less than 500 inhabitants that, in total, include little more than 1% of the distributed population (Table 3); however, they represent nearly 19% of the municipalities. Their geographical location is irregular, although there is a greater concentration in mid-mountain areas in the Iberian Range, in the provinces of both Zaragoza and Teruel (Figures 1 and 4). These municipalities are lacking a large part of the range of services analysed (Figure 5 and Table 2), so the quality of life and the facilities for the settlement of the population are highly compromised. In this case, we can classify the municipalities as doubly excluded since added to the demographic problems is this lack of essential services. Services such as shops and bars are crucial for guaranteeing social relations and maintaining the basic needs of its inhabitants.

Group 6: This last group of municipalities is characterised by having populations of less than 100 inhabitants that account for only 0.35% of the people in the region (Table 3) but almost 12% of its municipalities (Table 4 and Figure 6). They tend to be located in mountain or mid-mountain areas of the Pyrenees and the Iberian Range and far from the municipalities of Groups 1 and 2 (Figures 1 and 4). Their level of services is the worst of all the *Service Exclusion* indicators (Figure 5 and Table 2). For this reason, providing services is particularly challenging, and they present a high level of service exclusion.

4.5 | How Can Understanding This Heterogeneity Assist in Designing Effective and Tailored Policies to Address The Specific Needs of Each Type of Municipality?

Our work aligns with key policy briefs on combating depopulation. Aragon's spatial planning and development guidelines documents, '*Estrategia de Ordenación Territorial de Aragón*' (EOTA; Gobierno de Aragón 2014) and '*Directriz Especial de Política Demográfica y contra la Despoblación*' (Gobierno de Aragón n.d.), emphasise the need to understand the heterogeneity of municipalities to design tailored policies. The first document, the territorial planning strategy, aims to promote balanced development and address demographic challenges such as depopulation. It calls for a more targeted approach to population management that focuses on the relationship between populations and their territories, to ensure a more efficient allocation of resources. The second document, the special directive on demographic policy to combat depopulation, contains specific objectives, strategies, measures and standards to counteract rural depopulation. Particularly relevant to our topic, it focuses on reinforcing the network of medium-sized municipalities to enhance service provision across the wider territory. Beyond regional policy documents, the Spanish policy brief '*130 Medidas ante el Reto Demográfico*' (Ministerio para la Transición Ecológica y el Reto Demográfico n.d.) incorporates a cross-cutting programme of governmental action on the demographic challenge and the fight against depopulation and is the result of coordinated action by all ministries. Specifically, Axis 7 aims to strengthen public services and address decentralisation. However, the reality is that the public services that can be decentralised by the State are very limited for smaller municipalities as local services (health, education, social services) are provided by the individual regions.

To implement these measures, the Government of Aragon is currently using European funds (LEADER, ERDF, *Next Generation EU*[7]) to improve services in rural areas, especially the most depopulated. The *Rural Development Programme of Aragon*[8] is leading initiatives to promote economic revitalisation, improving basic services and population renewal in areas of socioeconomic influence within protected natural areas. Additionally, in order to create services while promoting the generation of employment opportunities, the *Local Development Strategy*[9] subsidies financed by LEADER select the types of municipalities where these investments are viable and financially sustainable.

Tackling depopulation by improving services is achieved by offering incentives that encourage health and education professionals to work in rural areas. For instance, mobile health units have been implemented, online educational resources are promoted and significant investments are being made to improve broadband and mobile network infrastructure in rural areas to bridge the digital divide and promote teleworking, entrepreneurship and digital literacy programmes.[10] However, there has been a lack of a regional policy to strategically address the specific problems of the territory and its inhabitants since public and private services must be provided efficiently, equitably and with stability in specific municipalities. Both are driven by profitability criteria and therefore localisation cannot be spontaneous.

In this context, our study introduces a municipal classification system based on the degree of service exclusion, population loss and ageing trends. This system enables a deeper understanding of the challenges each municipality faces, facilitating the design of specific, context-driven policies. Grouping municipalities allows targeted interventions to be implemented that address the unique needs, such as improving service access or enhancing connectivity. The measures proposed in the special directive could thus be organised into categories based on service availability and demographic structures, ensuring relevance and sustainability. This approach could enhance the effectiveness of policies aimed

at combating depopulation and promoting balanced territorial development in Aragon.

Similarly, our recommendations align with the EOTA territorial planning document by focusing on the need for targeted, sectoral actions aimed at improving service provision, particularly in municipalities classified as Groups 3 and 4. These municipalities are currently the most vulnerable to depopulation, and without timely intervention, they risk falling into the more at-risk categories, Groups 5 and 6, in the future. To avoid this trajectory, our recommendation is to prioritise population rejuvenation measures, attract new residents and encourage the establishment of businesses. The role of foreign-born populations, as highlighted in previous studies (Bayona-i-Carrasco and Gil-Alonso 2013; Collantes et al. 2014; Palacios et al. 2022), is particularly crucial for revitalising rural areas.

For Group 3, the priority must be improving access to essential services, especially education and social services (Table 2 and Figure 5). Measures could include enhancing secondary education by integrating the first cycle of ESO within existing primary schools. This initiative could benefit larger population centres, while simultaneously supporting neighbouring municipalities within the same group. Additionally, social services should be strengthened, particularly for vulnerable groups, through initiatives like community-based support programmes or by expanding access to healthcare and social assistance.

For Group 4, in addition to the improvements mentioned for Group 3, there is a pressing need to focus on improving the Internet infrastructure, as connectivity issues are particularly severe in these municipalities (Table 2 and Figure 5). High-speed Internet access could support essential services like telemedicine and e-learning, while also facilitating remote work opportunities, an increasingly vital element for sustaining rural populations. Moreover, expanding healthcare services, such as establishing or upgrading doctor's offices and health centres, would also make these municipalities more attractive for families and reduce the risk of social exclusion, especially among the elderly.

For municipalities in Groups 5 and 6, where depopulation has already reached a critical stage (Figure 4 and Table 2), the focus should urgently shift towards maintaining and reinforcing multi-service centres. These centres—comprising shops, bars and communal spaces—are vital not only for social cohesion but also for the basic functioning of daily life in these areas. However, to make these centres sustainable in the long term, the local infrastructure should also be enhanced. For example, urgent attention should be paid to improving healthcare services, even if only on a basic level, as the elderly population requires immediate care. Strengthening tourism, particularly through sustainable rural options, should be prioritised as a strategic economic recovery tool, providing new sources of income for residents. Additionally, implementing tailored social programmes—such as personalised elderly care assistance and grants to support young families and local entrepreneurs—could stimulate the local economy and create conditions that promote repopulation. Creating attractive living conditions for young families, by improving access to housing and providing incentives for agricultural innovation or remote working, should also be considered for tackling the demographic challenges head-on.

5 | Conclusion

This study has made several key contributions to our understanding of the challenges of depopulation and service exclusion in Aragon, offering valuable insights for the design of effective and context-sensitive policies. First, it has established a comprehensive process for measuring service exclusion at the municipal level, which could serve as an essential tool for local analysis and decision-making. Local governments could leverage this methodological approach by assessing service adequacy, identifying vulnerable areas and developing targeted interventions. The importance of this measure is supported by the literature, which highlights the role the absence of services plays (San-Martín González and Soler-Vaya 2024) as a key driver of migration, particularly among young people (Camarero and Oliva 2019; Gil-Alonso et al. 2023). Additionally, the provision of services is emphasised as a critical determinant of local well-being and population sustainability (Farrington and Farrington 2005; Ruiz and Martínez 2022).

Despite the bidirectional relationship discussed in the literature (Pinilla and Sáez 2021), this study provides empirical evidence on how deficiencies in essential services contribute to both population loss and ageing in municipalities, underscoring their relevance in demographic dynamics (Augère-Granier 2017; Alamá-Sabater et al. 2021). As previous research has pointed out, a lack of key services such as healthcare, education and digital connectivity plays a central role in shaping demographic trends (Escribano-Pizarro 2012). By analysing the relationship between service exclusion and demographic decline, this study has reinforced the conclusion that improving service availability could mitigate the negative effects of depopulation, in line with the recommendations of studies like those by Sánchez et al. (2024), who advocate for service-centred interventions in rural areas.

Third, the research has revealed significant heterogeneity among Aragonese municipalities in terms of their degree of service exclusion and highlighted how these variations correlate with patterns of population decline and ageing. This heterogeneity mirrors findings in the broader literature on rural depopulation, where municipalities face different challenges depending on local contexts, such as infrastructure availability, economic opportunities and demographic composition (Bayona-i-Carrasco and Gil-Alonso 2013; Álvarez-Montoya and Ruiz-Ballesteros 2024). By identifying and categorising these differences, this study has provided a nuanced understanding of how service exclusion interacts with demographic factors, enabling more precise interventions to be implemented in municipalities at different stages of demographic change.

Finally, the study has emphasised the importance of identifying the specific sources of exclusion within each group of municipalities. Even municipalities with similar levels of service exclusion may face different underlying challenges, which require tailored interventions rather than one-size-fits-all solutions. This finding aligns with the arguments made by Pinilla and Sáez (2021), who assert that interventions must be contextualised to address the diverse realities of rural areas. Our study advocates for differentiated approaches that target the unique needs of each group, whether by improving digital connectivity, expanding the

healthcare infrastructure or providing incentives for local economic development. By recognising and acting on these localised differences, policymakers could design more effective strategies to combat depopulation and promote sustainable development.

It is important to note that, while we believe the study provides important results, it also has limitations that we intend to address in future research. First, we plan to expand our approach beyond the Aragon region by applying similar methods to different contexts and regions. This will allow us to develop broader and more adaptable strategies for addressing depopulation and service exclusion.

This study also recognises the opportunity to improve the variables used by incorporating additional indicators in future research, such as childcare facilities, home support for elderly people, and measures related to service quality and coverage. We know that, even when two municipalities offer similar services, their quality and accessibility may vary significantly. Factors such as the operating hours of medical centres, stores or bank branches can influence their perceived quality and effectiveness in terms of meeting local needs. While these aspects are not incorporated into the current analysis, their inclusion will provide a deeper understanding of territorial inequalities and the dynamics between service exclusion, ageing and depopulation.

Various factors influence the exclusion of a territory, beyond a lack of services, such as economic stagnation, a lack of businesses, limited job opportunities and lack of real estate dynamism, as well as limited employment prospects as well as other related aspects. These factors require deeper analysis, which we are already addressing in our current research agenda. Studying how these elements impact migration patterns and community cohesion should provide valuable insights to help develop effective policies aimed at combating depopulation and territorial exclusion, both locally and globally.

Finally, in our future research agenda, we plan to incorporate methods that allow us to explore the temporal dimension of the relationships between depopulation and service exclusion. Specifically, we will investigate the use of dynamicSEMs (DSEMs), which will enable us to model these interactions more accurately. Although DSEM is still under development, its implementation, along with emerging tools such as the recursion estimator (ER), should provide more efficient estimates and shed light on the dynamics of demographic changes and their impact on access to services, thus enriching our analysis and understanding of rural dynamics.

Author Contributions

M. Pilar Alonso: conceptualisation, resources, writing – original draft, visualisation, investigation, supervision. **Pilar Gargallo**: conceptualisation, methodology, software, formal analysis, writing – original draft, funding acquisition, project administration, supervision. **Luis Lample**: validation, resources, writing – review and editing. **Carlos López-Escolano**: validation, resources, writing – review and editing, visualisation, investigation. **Jesús A. Miguel**: software, formal analysis, data curation. **Manuel Salvador**: conceptualisation, methodology, software, project administration, supervision.

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Conflicts of Interest

The authors declare no conflicts of interest

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Endnotes

[1] Model parameters were estimated using the *PLS-SEM* algorithm via the *SEMinR* package (Hair et al. 2021). This non-parametric method accommodates reflective and formative models, as well as both metric and binary variables. To address potential endogeneity issues from the bidirectional nature of the model, we applied advanced statistical tools from Hult et al. (2018).

[2] Note that we have considered the difference 100 minus the youth rate (Ageing2); and the difference is 100 minus the percentage of women of childbearing age (Ageing4) so that these appear with positive loadings in the construct *Ageing*.

[3] The Aragon Territorial Indicators System (SITA) is the set of quantitative or qualitative territorial variables and indicators used to monitor and evaluate the territorial model established in the Aragon Territorial Planning Strategy (EOTA).

[4] We used a combination of hierarchical (Ward's method) and non-hierarchical (k-means) clustering techniques. Ward's method determined the number of groups and provided an initial classification, while k-means refined these results. The analysis was performed using the *hclust* and *kmeans* functions in the R4.1.3 package.

[5] The evaluation of both formative and reflective measurement models, including detailed estimations and the endogeneity analysis, is provided in the Supporting Information and can be made available upon request.

[6] To better understand the geographical context in Section 4.2, refer to Figure 1 for the location of the areas mentioned in the analysis.

[7] https://www.aragon.es/-/next-generation-eu.

[8] https://www.aragon.es/-/programacion-de-desarrollo-rural.

[9] https://www.aragon.es/tramitador/-/tramite/convocatoria-de-seleccion-de-los-grupos-de-accion-local-para-el-periodo-2023-2027.

[10] www.interregeurope.eu/sites/default/files/inline/Final_Report_Online_Peer_Review_Aragon.pdf.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Table S1.1: Path coefficient estimates, significance, and confidence intervals. **Table S1.2**: Reliability and validity of Population Loss and Ageing constructs. **Table S1.3**: Fornell-Larcker criterion table. **Table S1.4**: HTMT results table. **Table S1.5**: Bootstrapped HTMT table. **Table S1.6**: Bootstrapped weights and VIF values of the indicators comprising the *Service Exclusion* construct. **Table S2.1**: Normality test of the Service Exclusion construct. **Figure S2.1**: Graphical Exploratory Analysis of Service Exclusion. **Table S2.2**: Estimation of regression model corresponding to *Population Loss*. **Table S2.3**: Estimation of regression model corresponding to *Ageing*.

Appendix

This appendix contains the mathematical expressions for the indicator variables used to construct the latent variables for *Population Loss*, *Ageing* and *Service Exclusion*.

TABLE A1 | Indicators related to the *Population Loss* construct.

Population growth rate between 2021 and 2005	$\text{PopLoss1} = (1 - \frac{P_{2021} - P_{2005}}{P_{2005}}) \cdot 100$
Population growth rate between 2021 and 2015	$\text{PopLoss2} = (1 - \frac{P_{2021} - P_{2015}}{P_{2015}}) \cdot 100$
Residential variation rate between 2021 and 2005	$\text{PopLoss3} = (1 - \frac{\sum_{t=2005}^{2021} VR_t}{P_{2005}}) \cdot 100$
Residential variation rate between 2021 and 2015	$\text{PopLoss4} = (1 - \frac{\sum_{t=2015}^{2021} VR_t}{P_{2015}}) \cdot 100$

Note: P_t is the number of inhabitants, and VR_t is the residential variation, both for year *t*.

In greater detail, the definitions are as follows:

ServExclu1 is the average time needed access to the nearest health centre in minutes.

TABLE A2 | Indicators related to the *Ageing* construct.

Average age of the population	$\text{Ageing1} = \frac{\sum_{i=0}^{\max age} P_i x(i+0.5)}{P}$
Maturity index	$\text{Ageing2} = (1 - \frac{P_{<15}}{P_{>64}}) \cdot 100$
Age dependency ratio	$\text{Ageing3} = \frac{P_{>64}+P_{<15}}{P_{15-64}} \cdot 100$
Percentage of women not of childbearing age over total	$\text{Ageing4} = (1 - \frac{W_{\text{Childbearing Age}}}{P}) \cdot 100$
Percentage of population older than 64	$\text{Ageing5} = \frac{P_{>64}}{P} \cdot 100$

Note: P is the number of inhabitants, and W is the number of women.

TABLE A3 | Indicator related to the *Service Exclusion* construct.

Healthcare Exclusion	ServExclu1 = T_health (min)
Educational Exclusion	$\text{ServExclu2} = \frac{A}{300+200+100+50+25+15+10+5+1}$
Social Exclusion	$\text{ServExclu3} = \frac{B}{25+15+5}$
Commercial Exclusion	ServExclu4 = 1 − SB
Restaurant and bar Exclusion	ServExclu5 = 1 − RB
Internet Exclusion	ServExclu6 = 100 – (10 · COV10+90 · COV100)

ServExclu1 = T_health(min)

ServExclu2 is a weighted index that measures the absence of educational services in a municipality.

$\text{ServExclu2} = \frac{A}{300+200+100+50+25+15+10+5+1}$

where A = 300 · (1-UNIV1) + 200 · (1-UNIV2) + 100 · (1-UNIV3) + 50 · (1-HIGHSCH) + 25 · (1-SEC1) + 15 · (1-SEC2) + 10 · (1-PRIM1) + 5 · (1-MAN_GRC) + 1 – CLASS_GRC).

UNIV1: Availability of 30 or more general university degrees.

UNIV2: Availability of fewer than 30 university degrees.

UNIV3: Availability of a National University of Distance Education (UNED) centre.

HIGHSCH: Availability of a secondary school offering a high school diploma.

SEC1: Availability of a secondary school that does not offer a high school diploma.

SEC2: Availability of the first cycle of ESO.

PRIM1: Availability of early childhood and primary education centres.

MAN_GRC: Availability of a manager of rural grouped schools.

CLASS_GRC: Availability of a grouped rural school classroom.

The formula accounts for both the absence and relative importance of these services to provide an overall measure of educational exclusion in the municipality.

ServExclu3 is a weighted index that measures the absence of social services in a municipality.

$\text{ServExclu3} = \frac{B}{25+15+5}$

where B = 25 · (1-HSS) + 5 · (1-DSS) + 15 · (1-ELDERESID).

HSS: Availability of a county-based social service headquarters.

DSS: Availability of a regional-based social service delegation.

ELDERESID: Availability of residences for older people

ServExclu4 = 1–SB, where SB is a dummy variable that is assigned a value of 1 if retail or wholesale businesses exist in the municipality, and 0 if no such businesses are present.

ServExclu5 = 1–RB, where RB is a dummy variable that is assigned a value of 1 if there are bars or restaurants in the municipality and 0 otherwise.

ServExclu6 = 100 – (10 · COV10+90 · COV100), where COV10 represents the percentage of Internet coverage with a speed of 10 Mbps, and COV100 represents the percentage of Internet coverage with a speed of 100 Mbps.