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Mapping intersectional aging vulnerabilities in Aragón: A new GIS methodology from a gender perspective

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ABSTRACT

The research aims to develop an evidence-based feminist methodology to address aging vulnerability in the region of Aragón in Spain. The study is motivated by Spain's demographic aging and care crisis, caused by an increased aging population, life expectancy, and prevalence of age-related illnesses. The investigation targets the gender-specific challenges of caregiving, highlighting women's predominant roles in care practices. The main novelty of the study lies in integrating feminist epistemology and situated knowledge theories to quantify and map aging vulnerability, an approach previously unexplored in the context of regional planning and aging studies. Seventeen intersectional indicators, based on open-source municipal data across six dimensions (demographic aging, dependency, gender, aged care, healthcare, and territorial structure), are mapped using GIS tools and data-driven decision-making methods. The indicators are classified according to risk levels to visualize areas with higher aging vulnerability. The findings show Aragón's territorial disparities and challenges in demographic aging, gender gaps among older adults, and regional variations in aged care and healthcare access. The study offers policymakers a holistic roadmap for efficient resource allocation, promoting sustainable strategies to enhance the well-being of older adults in Aragón and other regions facing similar challenges.

Introduction

Demographic aging and care crisis in Spain

Like many European countries, Spain is undergoing rapid demographic aging. As of 2022 (Eurostat, 2024), Spain had the highest life expectancy in the European Union–83.2 years, 85.9 years for women and 80.4 for men–followed by Sweden (83.1), Luxembourg (83), and Italy (83). By 2030, around 11.5 million people, 22.8 % of the Spanish population, will be older adults. Based on National Institute of Statistics (*Instituto Nacional de Estadística*, INE) data, in 2050, Spain will reach its peak proportion of older adults (30.4 %), largely due to the aging of cohorts born during the Spanish baby boom (1957–1977), who are already entering retirement age. If Eurostat projections are taken into account (Eurostat, 2023a; Eurostat, 2023b), Spain is predicted to be the fourth most aged (32.7 %) country in Europe by 2050, only behind Greece (35.5 %), Portugal (33.9 %), and Italy (33.7 %).

Increased longevity has led to a higher prevalence of age-related diseases and cognitive impairments, such as hypertension, osteoarthritis, diabetes, and dementia (Jaul & Barron, 2017). These illnesses affect older people's autonomy, reducing their ability to perform activities of daily living. According to the Spanish healthcare system (*Sistema para la Autonomía y Atención a la Dependencia*, SAAD), around 1.9 million people aged 65 years and over receive financial support and care services, both in home-based settings and long-term care facilities (IMSERSO, 2023c). Simultaneously, the COVID-19 pandemic has contributed to an increase in struggles with loneliness and depression among older individuals (Armitage & Nellums, 2020). The investigation by González Ortega et al. (2023) found higher rates of social loneliness among older adults in Spain after the three-month COVID-19 lockdown, which was also associated with living alone, poor mental health, and a propensity towards unhealthy habits.

This research focuses on measuring the situational vulnerability of older adults by mapping and analyzing territorial aging vulnerability in the region of Aragón, Spain. Grounded in feminist theory, the aim of this paper is to develop an evidence-based, intersectional, and quantitative methodology from a gender perspective to inform policies and strategies that promote healthy, positive, and active aging.

Gender plays a significant role in understanding the issues of demographic aging. An examination of aging and caregiving data through

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a gender-centric approach reveals that women constitute a substantial proportion of the elders. Specifically, they represent 62.7 % of Spanish individuals aged 80 and over and 70.8 % of older adults living alone (INE, 2021). Furthermore, women comprise 80.1 % of widowed older adults in Spain and receive lower retirement income than men, leading to an increased susceptibility to poverty, lower levels of educational attainment, and a diminished health status (Eurostat, 2022a; Eurostat, 2022b; INE, 2021; INE, 2021b). Older women also face elevated instances of underdiagnosed mental and neurodegenerative diseases, such as depression, where 74.8 % of all diagnosed older adults are women (INE, 2021b), and dementia. According to an Alzheimer Europe report (Alzheimer Europe, 2019), dementia exhibits a higher prevalence among women, with a noticeable increase in occurrence corresponding to age. This incidence increases by 2.4 points between the ages of 80 and 84, by 8.6 points within the 85 to 89 age bracket, and surges significantly by 15.1 points for those aged 90 and beyond.

Regarding caregiving, women play a predominant role. According to SAAD data, a substantial 88.3 % of non-professional carers for dependent older people are women (IMSERSO, 2023b). Examining familial dynamics (INE, 2020), wives and female partners (46.7 %) predominantly assume caregiving duties for dependent individuals aged 65 to 79, while daughters (41.1 %) emerge as the primary carers of those aged 80 and over. In the realm of professional care, 49.2 % of home-based carers and 62.2 % of domestic employees are migrant women (Comas d'Argemir, 2023).

Moreover, the upcoming generation of pensioners, born in the Spanish baby boom between 1957 and 1977, signals a clear departure from the gender roles of the post-war generation, shaped by austerity and National Catholicism.[1] On the contrary, women from the baby boom generation entered the labour market from the late 1970s onward, disrupting the long-prevailing stereotype of wife and mother (Majón Valpuesta & Pérez Salanova, 2020). An ongoing decline in birth rates compounds this paradigm shift: 23.5 % of women over 40 have no children (INE, 2018). As these cohorts age, a growing proportion will reach old age without descendants who can assume caregiving roles, increasing pressure on formal care services.

Confronted with an increasingly over-aged, dependent, and feminized population, the care system is grappling with a profound structural crisis (Bettio et al., 2006; Costa-Font et al., 2016). Although there is observable progress in Spain's transition towards inclusive care practices, breaking away from exclusive reliance on female caregivers, the care sector remains deeply rooted in familial traditions, characterized by "strong gender inequalities based on class and racial distinctions" (Comas d'Argemir, 2023, p. 25). The population raised during the democratic transition, marked by values of individualism, consumerism, and personal fulfillment, rejects the idea of burdening their families during the last aging stages (Fishman, 2016; Majón-Valpuesta et al., 2016; Phillipson et al., 2008). Instead, they advocate for their right to plan for old age, aspiring to choose living arrangements, companionship, and lifestyle.

In this context, demographic aging and caregiving shifts pose a major challenge to long-term economic and social sustainability, impacting the future of retirement plans, healthcare systems, social services, elderly care infrastructure, and community-based care.

If the proportion of older adults increases, especially among those aged 85 and over (oldest-old), healthcare resources will be under pressure, potentially resulting in longer waiting times, reduced doctor-patient interaction, and higher costs, which challenge the provision of adequate medical care for all older individuals (Divo et al., 2014). Additionally, demographic aging will shift the dependency ratio, the ratio of working-age people to retirees. In a scenario where older adults represent a third of the population, more people will depend on pensions and social services. At the same time, fewer individuals will contribute to the social security system, reducing public welfare resources and leading to financial insecurity and economic vulnerability among older adults. This situation can lead to adjustments in retirement ages and contribution rates (Alonso-García & Rosado-Cebrian, 2021).

The increased need for social services will also affect the sustainability of institutional caregiving, assisted living facilities (long-term care), and community-based support for older people who desire to 'age in place' (Costa-Font et al., 2009; Fernández-Carro, 2016). However, aged care resources are insufficient, lacking both qualified carers and up-to-date facilities with a person-centered care model (Martínez Rodríguez, 2013; Regato Pajares et al., 2023; Rodríguez Rodríguez, 2021). Disregarding these challenges could result in care gaps and higher risks of low quality of life, particularly among dependent and financially vulnerable older adults (Ferreira et al., 2022).

Aging vulnerability and feminist methodologies

Aging vulnerability is an indicator that can be implemented to address the multifaceted challenges posed by demographic aging and the care crisis in Spain.

In their 2022 systematic review, Sanchini et al. (2022) analyzed the concept of vulnerability in aged care and found that vulnerability could be distinguished into basic human and situational vulnerabilities. The authors identified six dimensions of older adults' vulnerability (physical; psychological; relational/interpersonal; moral; sociocultural, political, and economic; and existential/spiritual) and three ways to tackle aging vulnerability: understanding older adults' vulnerability (from an existentialist and virtue ethics approach), taking care of vulnerable older adults (principlist approach), and intervening through socio-political-economic measures (capability approach, feminist ethics, and public health ethics). Mixed strategies were proposed by care ethics and personalistic ethics approaches. On the other hand, the literature review of Barbosa et al. (2019) structured the concept of vulnerability of the elders as a compound of individual, programmatic, and social antecedents, individual and social attributes, and specific consequences. The researchers describe vulnerability as "a multidimensional construct where behavioral, sociocultural, economic, and political conditions interact with biological processes throughout life" (Barbosa et al., 2019, p. 342).

Building on the frameworks of aging vulnerability, situated knowledge, and intersectionality, this paper proposes the concept of territorial aging vulnerability as a situational condition arising from the interaction between an individual's intersectional characteristics (such as gender, age, health, race, etc.) and their specific territory. Within the ambit of contemporary feminism, the concept of situated knowledge emphasizes the idea that epistemology is not universal. Instead, feminist theorists such as Donna Haraway defend that knowledge is shaped by individuals' context, experiences, and perspectives within specific social, cultural, political, economic, and historical contexts, shaped by various factors like gender, race, class, and other intersecting identities (Crenshaw, 1991; Haraway, 1991; Harding, 1986).

In this research, we have conducted a study of the situational vulnerability of older adults in the region of Aragón in Spain. Our choice of Aragón as a case study stems from its status as a paradigmatic example, highlighting the significance of context-specific knowledge for understanding care dynamics and demographic aging. Aragón contends with a pronounced territorial imbalance: while the metropolitan area of Zaragoza, along with several medium-sized urban hubs like Huesca and Teruel, thrive with a growing population and economic activities, the remaining expanse of the region faces either sparse habitation or is at risk of rural depopulation. In fact, various areas in Aragón register one of the lowest population densities across Europe (Ayuda Bosque et al., 2000).

[1] *Nacionalcatolicismo* (National Catholicism) was a political ideology during Francisco Franco's regime (1939–1975) that intertwined the Catholic Church's values with authoritarian nationalism, shaping the Spanish identity and the state structure.

The territorial heterogeneity of Aragón presents challenges for traditional demographic analysis. Conventional methodologies, which rely on segmented statistical indicators at provincial or regional levels, are ineffective because they assume territorial uniformity. These standardized research methods fail to identify those territories and demographic groups influenced by intersectional inequality factors, such as gender, ethnicity, sexual orientation, geographic location, or economic status (Cubillos Almendra, 2015). Over the past decade, intersectional feminist methodologies have been increasingly applied in regional planning and geographical studies to address these vulnerabilities.

In Spain, integrating gender methodologies and indicators into the urban environment is a prominent area of research in architecture and urban planning. Notably, the contributions from feminist authors and collectives such as Inés Sánchez de Madariaga and Inés Novella (2021), Col·lectiu Punt 6 (2019), Zaida Muxí (2020), Pérez Moreno (2018), Izaskun Chinchilla (2020), María Novas (2021), Atxu Amann (2005), Eva Álvarez Isidro and Gómez Alfonso (2017), among numerous other researchers, have significantly shaped architectural practices and scientific discourse in this domain.

Feminist methodologies have delved into a wide range of subjects and geographical contexts. Most studies focus on developing guidelines and new methodologies to integrate gender perspectives into public policies and municipal management (Novas Ferradás, 2018; Rodríguez-García & Donati, 2021; Silvina Daldi, 2018). Other investigations revolve around building indicators to measure inequalities and vulnerabilities in urban planning and political interventions (Col·lectiu Punt 6, 2014; Sánchez de Madariaga, 2006; Sánchez del Sánchez Moreno, 2022). Furthermore, urban regeneration projects also implement transversal indicators from a sustainability approach (Levett, 1998; Paisaje Transversal, 2022).

On the other hand, several studies are centered on auditing case studies through participatory research methods and feminist strategies. Particularly notable is the investigation of women's experiences in the urban environment, evaluating the quality of life (Fadda & Jirón, 1999; Gutiérrez Valdivia, 2021), urban participation (Ortiz Escalante & Gutiérrez Valdivia, 2015), time policies and time planning (Boccia, 2016), urban safety (Michaud, 2002), and violence against women (Delgado, 2018; Sweet & Ortiz Escalante, 2015).

However, feminist research and methodologies have not addressed the difficulties encountered by older adults on a territorial level. Inversely, various studies focus on understanding older adults' experience in the urban-rural environment–investigating indicators of sustainable or healthy aging (Hsu et al., 2009; Landorf et al., 2008), self-reported health (Gardener & Lemes De Oliveira, 2020; Nummela et al., 2007; Sibai et al., 2017), social participation and mental health (Sun & Lyu, 2020; Wang et al., 2021), and overall quality of life (Baernholdt et al., 2012; Ferreira et al., 2022; Rantakokko et al., 2010; Usha & Lalitha, 2016)–but few of these investigations (Lewandowska-Gwarda & Antczak, 2020) provide gender-specific or intersectional analyses. Therefore, this study opens a new research area, transversal to aging, gender, and regional planning studies, proposing an intersectional quantitative methodology to comprehensively improve the well-being and quality of life among the most vulnerable collectives of older adults in Aragón.

Methodology

Case study

Aragón was selected as the case study for implementing the methodology. Located in northeastern Spain, Aragón is a region divided into three provinces–Huesca, Teruel, and Zaragoza–, 33 counties, and 731 municipalities (Fig. 1). According to the Aragonese Institute of Statistics (*Instituto Aragonés de Estadística*, IAEST), as of 1st January 2023, the resident population in Aragón reached 1,341,289 inhabitants, with

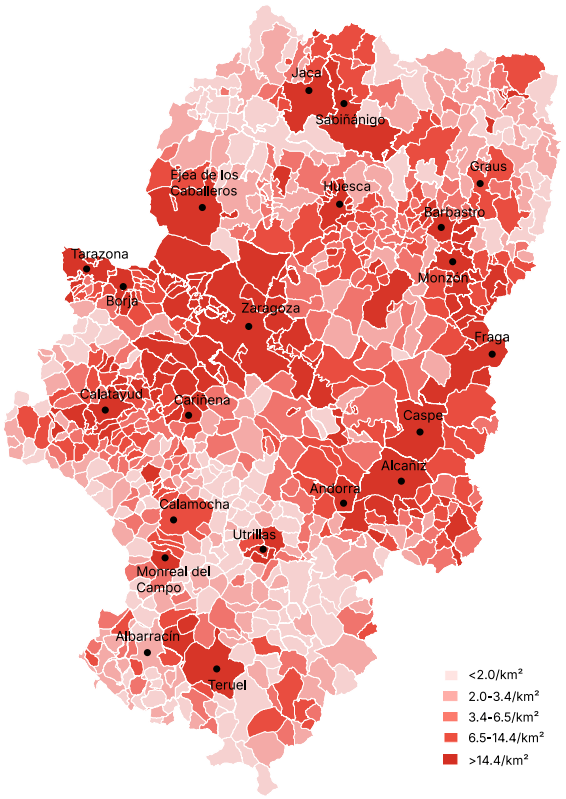


Fig. 1. Population Density in Aragón.

226,878 in Huesca province, 135,046 in Teruel province, and 979,365 in Zaragoza province (IAEST, 2023).

In terms of age distribution, Aragón's population is categorized into various groups: individuals under 16 years old constitute 14.4 % of the total population, those aged 16 to 25 years account for 10.1 %, the 26 to 45 age group represents 24.7 %, the 46 to 64 age range comprises 28.7 %, individuals aged 65 to 84 make up 17.9 %, and those 85 years and older constitute 4.2 % of the total inhabitants. Regarding nationality, migrants represent 13.5 % of the population.

Aragón exhibits stark disparities between its rural and urban areas. Approximately 11.2 % of the Aragonese population resides in municipalities with fewer than a thousand inhabitants, while a substantial 71.2 % live in municipalities with over ten thousand inhabitants. Notably, the municipality of Zaragoza alone accommodates 51 % of Aragon's total population.

Intersectional indicators

A quantitative research method from a data-driven decision-making approach (DDDM) was implemented in this study. Using statistical data from open sources facilitates the promotion of evidence-based policies, enhancing the effectiveness of interventions and resource allocation. Moreover, the DDDM approach allows the iterative use of feedback and new data to refine decisions and strategies over time, leading to continuous improvement and optimization. Multifactor analysis (MFA) was discarded due to heterogeneity in data scales and missingness at the municipal level.

The study utilizes a comprehensive set of 17 intersectional indicators to evaluate territorial aging vulnerability in Aragón. These specific indicators were chosen because they are consistently available in open-access public datasets, can be disaggregated at the municipality level, and offer high interpretability for policymakers.

Furthermore, the decision to work with this particular set is grounded in the feminist concept of situated knowledge. These intersectional

indicators are organized into six key domains or dimensions–demographic aging, dependency, gender, aged care, healthcare, and territorial structure–that capture the concrete, situated conditions of territorial aging vulnerability in Aragón: rural aging and depopulation, gender inequalities, uneven long-term care and healthcare access, and demographic imbalance.

Demographic aging indicators focus on the age composition of Aragón's population, assessing the relationship between older people and other age groups.

- Older population. Older adults are defined as people aged 65 and over. The indicator is expressed as a share of the total population.
- Aging index. This indicator measures the ratio between the older population (65 years and over) and the young population (19 years and under).
- Over-aging index. Older people can be classified into three groups (Lee et al., 2018): youngest-old (65 to 74 years), middle-old (75 to 84 years), and oldest-old (aged 85 and over). The over-aging index is defined as the proportion of the oldest-old people among the older population.

Dependency indicators evaluate the prevalence of individuals with cognitive and physical impairments among the Aragonese older population. This set also measures external factors that increase dependency rates, such as the proportion of older people living alone.

- Old-age dependency ratio. This demographic indicator represents the proportion of older people (65 years and over) to the working-age population (between 15 and 64 years).
- Dementia ratio. Dementia is an age-related disease that is one of the dominant causes of dependency among older adults globally, impacting memory, thinking, and the ability to perform daily activities. Women are disproportionately affected by dementia (World Health Organization, 2023). The rate is estimated as the percentage of people living with dementia per 1000 population.
- Older people living alone. This indicator expresses the rate of elders aged 65 or older who reside alone. Factors such as living alone can increase the risk of loneliness and social isolation, which have severe impacts on older adults' mental and physical health (Singh & Misra, 2009).

Gender indicators examine gender disparities among older adults, focusing on imbalances between men and women across specific age groups. This set of indicators highlights variations in the gender distribution among elders, which affect several societal and caregiving dynamics in Aragón. According to the literature review, older women experience higher rates of widowhood, receive lower pensions, and face a greater risk of dependency. Therefore, a larger proportion of this demographic can influence the demand for care and health services.

- Gender imbalance in older adults. Gender imbalance is an indicator of the gender gap within an age group, measuring the ratio of women to men among people aged 65 years and over.
- Gender imbalance in oldest-old adults. Similar to the previous indicator, but rating the gender gap among the oldest-old individuals (aged 85 years and over).

Aged care indicators assess the availability of care services (long-term care and daycare centers), focusing on the ratio of available places for Aragonese older adults.

- Long-term care beds-to-resident ratio. This indicator considers the relationship between the total number of places offered in public and private nursing homes per 100 older inhabitants aged 65 and over.
- Daycare places-to-user ratio. This index expresses the same relation as the nursing home beds-to-resident ratio, taking into account daycare places offered in both residential and community-based care centers.

Healthcare indicators revolve around the healthcare resources and support available to the overall population in Aragón. The COVID-19 mortality ratio is included due to its demographic and psychosocial impacts on older adults and the healthcare system, especially in counties with high care home mortality rates.

- Doctor-to-patient ratio. The indicator measures the number of practicing family doctors in primary healthcare centers per 10,000 people.
- Nurse-to-patient ratio. Similar to doctor-to-patient ratio but considering practicing nurses in primary healthcare facilities per 10,000 inhabitants.
- Primary healthcare equipment-to-patient ratio. Although healthcare infrastructures in Spain comprise public and private hospitals, primary healthcare centers, and pharmacies, this indicator only estimates the number of medical centers per 10,000 population. The purpose is to assess the accessibility of primary healthcare services for older adults, frequently used by this age group.
- COVID-19-related deaths ratio. The pandemic severely impacted the older population in Spain, particularly long-term care residents (Benet et al., 2022). This index expresses the deaths due to the COVID-19 pandemic per 1000 population.

Lastly, territorial structure indicators explore the aspects of the Aragonese region that can impact the aging population and the support systems, involving socio-economic and geographical indexes.

- Population density. This indicator measures the population per unit land area, sorted by total inhabitants per square kilometer.
- Household net income per capita. Household net income describes the total gross income (salaries, wages, investments, and other forms of income) of all people sharing a household, subtracting direct taxes, social contributions, and other mandatory payments. It represents the money available to a household for spending on goods or services. The household net income per capita is expressed as a share of the total population.
- Migrants. This index considers the relationship between the population of a region born outside its country and the total population. The indicator highlights future dynamics in the care system, as migrants constitute a significant share of both the current and future care workforce in Aragón.

Data collection

The primary dataset utilized in this study is derived from the Municipal Register, which is available through the Local Statistic app offered by IAEST. Intersectional indicators about aged care (beds and places ratios) were obtained from the Registry of Entities, Centres, and Social Services, accessible at the Aragonese Institute of Social Services (*Instituto Aragonés de Servicios Sociales*, IASS). The COVID-19-related deaths ratio is available through the *datacovid.aragon* app provided by the Government of Aragón.

However, various indicators are not accessible at the municipality level. For instance, the dementia ratio is absent from the municipal dataset. The indicator can only be obtained from health districts documented in the Health Atlas (*Atlas de Salud*) provided by the Aragonese Geographic Institute (*Instituto Geográfico de Aragón*, IGEAR). Similarly, the data regarding the proportion of individuals aged 65 years and over living alone is available in the Health Atlas by IGEAR on a health district level. The indicator is also procured by INE, but it is only available for municipalities with populations exceeding 500 inhabitants. For this reason, both data sources are utilized and combined to evaluate the rate of older adults living alone. Additionally, information regarding

household income per capita is solely available for communities with populations surpassing 1000 inhabitants.

Moreover, the data collection years for the indicators vary, as specified in Table 1. While some indicators, such as the long-term care beds-to-resident ratio, the daycare places-to-user ratio, and the COVID-19 deaths ratio, were revised and reflect the most recent figures as of mid-2023, others rely on data from different years. Specifically, indicators sourced from the Municipal Register predominantly display statistics from 2022. Healthcare indicators are based on data from 2021. The household income per capita is sourced from 2020 data. The rate of older people living alone corresponds to figures from 2021. When the data is obtained from INE, and 2011, if the information is collected from IGEAR.

Table 1
Data Source and Year by Intersectional Indicator.

Dimension	Indicator	Source	Scope	Year
Demographic aging	Older population	Municipal Register (IAEST)	Municipal	2022
	Aging index	Municipal Register (IAEST)	Municipal	2022
	Over-aging index	Municipal Register (IAEST)	Municipal	2022
Dependency	Old-age dependency ratio	Municipal Register (IAEST)	Municipal	2022
	Dementia ratio	Health Atlas (IGEAR)	Health districts	2022
	Older people living alone	Population and Housing Census (INE) and Health Atlas (IGEAR)	Municipalities with more than 500 inhabitants (INE) and health districts (IGEAR)	2021 (INE) and 2011 (IGEAR)
Gender	Gender imbalance in older adults	Municipal Register (IAEST)	Municipal	2022
	Gender imbalance in oldest-old adults	Municipal Register (IAEST)	Municipal	2022
Aged care	Long-term care beds-to-resident ratio	Registry of Entities, Centres and Social Services (IASS)	Municipal	2023
	Daycare places-to-user ratio	Registry of Entities, Centres and Social Services (IASS)	Municipal	2023
Healthcare	Doctor-to-patient ratio	IAEST	Municipal	2021
	Nurse-to-patient ratio	IAEST	Municipal	2021
	Primary healthcare equipment-to-patient ratio	IAEST	Municipal	2021
	COVID-19-related deaths ratio	datacovid.aragon	Municipal	2023
Territorial structure	Population density	Municipal Register (IAEST)	Municipal	2022
	Household net income per capita	IAEST	Municipalities with more than 1000 inhabitants	2020
	Migrants	Municipal Register (IAEST)	Municipal	2022

GIS mapping

Once the data was collected, the intersectional indicators were mapped using Geographic Information System (GIS) software (ArcGIS Pro 3.1.2). GIS tools provide the capability to visualize and interpret data linked to specific areas. In this case, the software facilitated the spatial visualization of these indicators within the study area of Aragón, allowing for an in-depth exploration of aging patterns and vulnerabilities across the Aragonese municipalities. The effectiveness of GIS tools and open data sources in implementing a gender-sensitive agenda in urban planning and geographic research has been evidenced by Carpio-Pinedo et al. (2019) and Mei-Po Kwan (2002). The shapefile containing the Administrative Boundaries of Aragón (municipalities and counties) was obtained from Aragón Open Data. The website, created by the Government of Aragón, offers databases from several institutions under a Creative Commons Attribution 4.0 license.

Next, a quantile data classification method was applied to evaluate the intersectional risk of aging vulnerability. Five distinct groups or quintiles –very low, low, medium, high, and very high risk to aging vulnerability– were employed for each intersectional indicator, as shown in Table 2. This classification process ensured an equal distribution of data values across the five classes, enabling a nuanced representation of the Aragonese region's varying degrees of intersectional indicators. All indicators were weighted equally to maintain methodological simplicity, transparency, and replicability at the municipal scale.

Considering the previous risk levels, the risk of aging vulnerability is calculated as the sum of intersectional indicators with a high or very high score.

Three representations were developed in order to map Aragón's aging vulnerability: (1) a set of 17 visualizations comprising a cartography of intersectional indicators, where each representation displays one of the indicators, delineating the risk levels across municipalities in Aragón; (2) a risk map of aging vulnerability, showing the number of intersectional indicators categorized with high or very high scores per municipality in Aragón; (3) and an intersectional aging vulnerability table of Aragonese counties (*comarcas*), representing the rate of aging vulnerability based on the intersectional domains –demographic aging, dependency, gender, aged care, healthcare, and territorial structure–.

Results

Cartography of intersectional indicators

The average risk to aging vulnerability for Aragón as a whole was calculated at 9.0, meaning that 9 out of 17 intersectional indicators presented high or very high risk levels. If the score is broken down by intersectional dimensions, the most significant aging vulnerability comes from the aged care dimension, with an average score of 1.8 out of 2. In other words, 91 % of Aragón is vulnerable in terms of long-term care and daycare provision. Healthcare and territorial structure domains show a moderate risk of aging vulnerability: 2.5/4 points (63 %) and 1.7/3 (57 %), respectively. The other intersectional dimensions –demographic aging, dependency, and gender– present a low risk, ranging from 34 to 39 %.

However, these overall findings do not reflect the territorial diversity of Aragón. The cartography of intersectional indicators unveils a wide range of aging vulnerabilities across Aragonese counties and municipalities. Results have been visualized in 17 representations of the administrative boundaries of Aragón, grouped in tables according to the intersectional dimension. The lighter colors represent the lowest risk of aging vulnerability, while the darkest colors symbolize the highest risk. Municipalities without available data are shown in grey. Data gaps are caused by the absence of healthcare and aged care infrastructures,

Table 2
Aging Vulnerability Risk Levels by Intersectional Indicator.

Dimension	Indicator	Aging vulnerability				
		Very low	Low	Medium	High	Very high
Demographic aging	Older population	<23.9 %	23.9–29.2 %	29.2–33.6 %	33.6–39.2 %	>39.2 %
	Aging index	<147.6 %	147.6–221.6 %	221.6–318.2 %	318.2–510 %	>510 %
	Over-aging index	<17.9 %	17.9–21.7 %	21.7–25.8 %	25.8–31.0 %	>31 %
Dependency	Old-age dependency ratio	<53.1 %	53.1–61.5 %	61.5–69.5 %	69.5–81.8 %	>81.8 %
	Dementia ratio	<12.6	12.6–15.2	12.6–15.2	18.9–24.4	>24.4
	Older people living alone	<10.7 %	10.7–13.2 %	13.2–14.5 %	14.5–17.5 %	>17.5 %
Gender	Gender imbalance in older adults	<80.0 %	80.0–98.5 %	98.5–111.3 %	111.3–123.1 %	>123.1 %
	Gender imbalance in oldest-old adults	<100 %	100–140 %	140–171.4 %	171.4–216 %	>216 %
Aged care	Long-term care beds-to-resident ratio	>34.2	34.2–19.7	19.7–14.2	14.2–8.4	<8.4
	Daycare places-to-user ratio	>8.8	8.8–4.1	4.1–2.2	2.2–1.3	<1.3
Healthcare	Doctor-to-patient ratio	>57.4	57.4–36.4	36.4–20.3	20.3–11.1	<11.1
	Nurse-to-patient ratio	>42.4	42.4–26	26–19.6	19.6–11.4	<11.4
	Primary healthcare equipment-to-patient ratio	>140.8	140.8–83.3	83.3–43.9	43.9–17.9	<17.9
	COVID-19-related deaths ratio	0	0–3.2	3.2–4.6	4.6–8.5	>8.5
Territorial structure	Population density	>14.4	14.4–6.5	6.5–3.4	3.4–2.0	<2.0
	Household net income per capita	>16,428.3€	16,428.3-14,771.4€	14,771.4-13,480€	13,480-11,725.9€	<11,725.9€
	Migrants	<3.5 %	3.5–6.1 %	6.1–9.2 %	9.2–13.9 %	>13.9 %

resources, and professionals in the municipality. In the case of the household net income per capita indicator, missing values are due to the data scope limitations previously addressed in the methodology section.

Table 3 displays the cartography of intersectional indicators related to demographic aging. The proportion of the older population shows a similar pattern as the aging index. Municipalities with the lowest risk levels in both indicators correspond to the Ebro river basin (crossing the central counties in the Aragonese region from west to east), some areas of the northern counties of La Jacetania, Alto Gállego, and Sobrarbe, and several municipalities from Gúdar-Javalambre and Comunidad de Teruel counties. In contrast, the aged population dominates the southwest, central-south, and central-north regions. Aranda County, situated in northwest Aragón, has an average aging index of 807.7 %, indicating an extreme concentration of older adults compared to the younger generation. Central County has a 19.2 % older population and a 116.4 aging index due to the influence of Zaragoza as the capital city of Aragón.

On the other hand, the over-aging index indicates that most municipalities have elevated proportions of the oldest age group. Particularly, around 40 % of Aragonese municipalities are formed by an over-aged population, of which one-quarter of the older adults are 85 and over. This value is reduced to 17.7 % in the city of Zaragoza.

Table 4 gathers the geographical representation of intersectional indicators concerning dependency. The old-age dependency index is more evenly distributed than the demographic aging indicators, ranging between 52.1 % in Central County and 80.6 % in Cuencas Mineras County, located in central-south Aragón. Higher old-age dependency ratios signify a bigger dependency of older adults on the working-age population for support.

Indicators addressing dementia prevalence and older people living alone are available on a health district level. Therefore, the cartography is not as precise as the other intersectional indicators regarding territorial disparities. Nevertheless, maps show similar aging patterns to those exposed by the demographic aging indicators, with lower risk levels of dependency in the northern, central, and Eastern municipalities. The greatest dementia ratios are dispersed across the Aragonese region, reaching a maximum of 62.7 cases per 1000 inhabitants in the Báguena health district (north of Teruel). Higher proportions of older people living alone are mostly based in southwest municipalities, corresponding to the health districts of Herrera de los Navarros (23.5) and Sabiñán (21.7).

The cartography of intersectional indicators respecting gender and aged care domains is collected in Table 5. Gender imbalance in older adults and the oldest-old group (85 years and over) show an analogous territorial distribution in the region, where central-west municipalities present higher gender gaps than southeast and northern counties. When both gender indicators are compared, results manifest that the gender gap substantially increases within the over-aged population, almost doubling in many municipalities in the Province of Huesca. In several

Table 3
Cartography of Demographic Aging Intersectional Indicators by Risk Level.

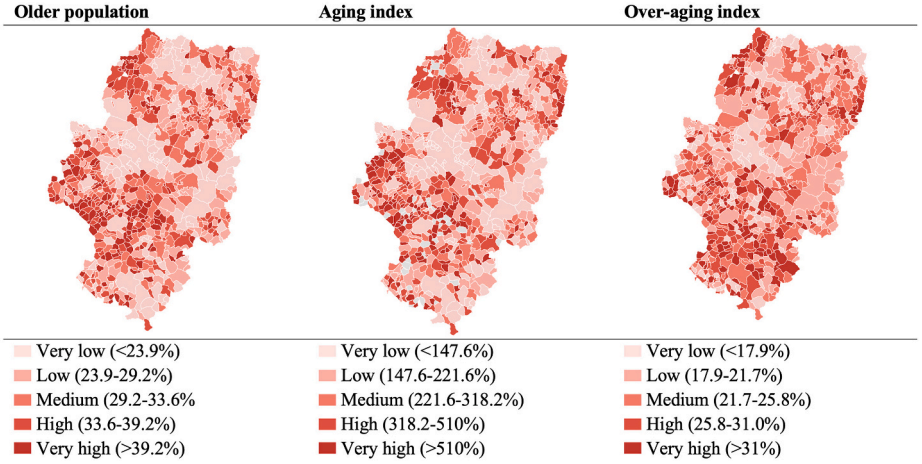


Table 4
Cartography of Dependency Intersectional Indicators by Risk Level.

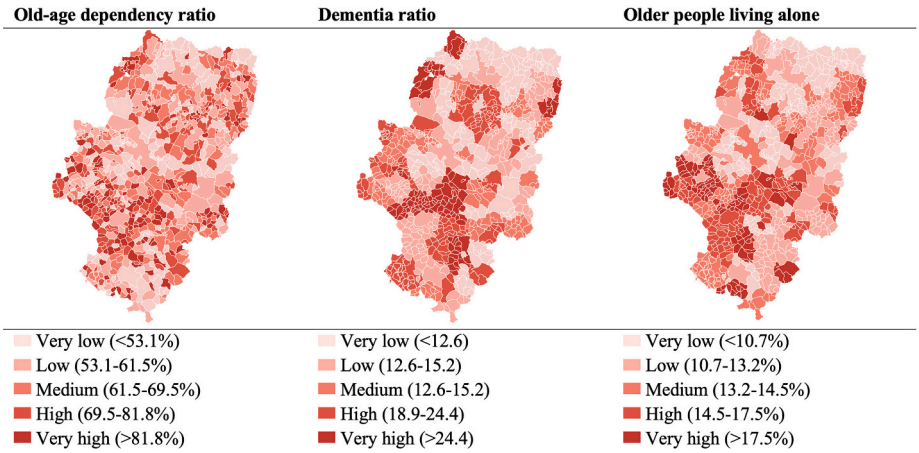
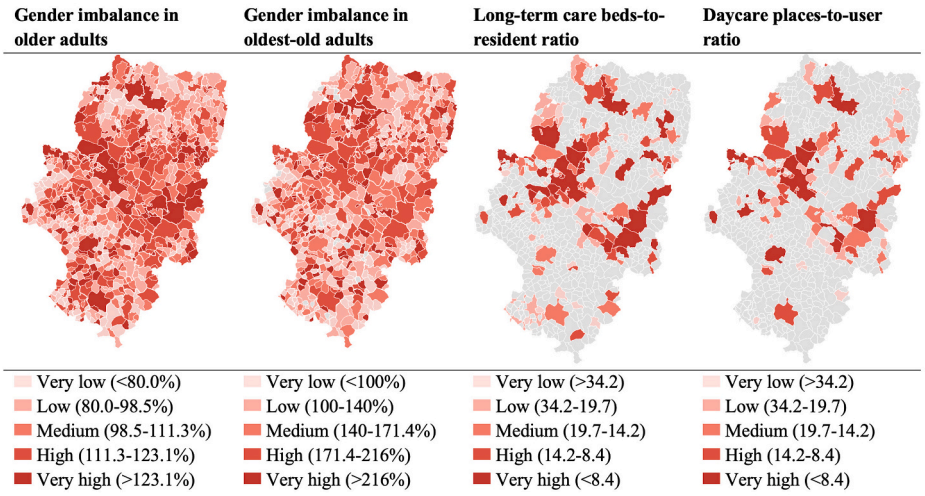


Table 5
Cartography of Gender and Aged Care Intersectional Indicators by Risk Level.



counties, such as Hoya de Huesca and Alto Gállego, there are more men than women aged 65 years and over. In contrast, the oldest-old group is predominantly female, switching from 98.2 to 191.6 % gender imbalance and 95.8 to 174.1 %, respectively.

Long-term care and daycare provision cartographies indicate substantial differences in access to aged care infrastructure across Aragonese municipalities. Only 136 out of 731 municipalities offer long-term places in nursing homes, 89 in the case of daycare services. The lowest mean bed-to-resident ratios are found in Cinca Medio (6.5) and Bajo Aragón-Caspe (8). Furthermore, three counties –Aranda, Gúdar-Javalambre, and Sobrarbe– have no community-based infrastructure, constituting a severe risk of aging vulnerability.

Table 6 displays the maps representing healthcare intersectional indicators. Compared to aged care indicators, doctor-to-patient, and nurse-to-patient ratios are more uniformly distributed across the autonomous community of Aragón. However, the availability of healthcare professionals per patient also varied considerably, ranging from a mean ratio of 6.4 doctors and nurses per 10,000 inhabitants in Alto Gállego County, located in northwest Huesca, to 200.2–205.7 practitioners per patient in La Ribargoza (northeast Huesca).

Regarding primary healthcare infrastructure, municipalities with the lowest rates of medical centers correspond to those with the lowest levels of the older population, aging index, and old-age dependency ratio, located in rural areas of Aragón. However, infrastructure ratios can also offer a false image of the healthcare situation in a municipality. That is the case of Zaragoza, where the equipment-to-patient ratio is 0.7 due to high population figures, but the city has 48 primary healthcare centers and 16 hospitals. Conversely, rural municipalities may have a higher number of healthcare centres per capita, but this ratio is skewed by very low population figures rather than a higher availability of services. In practice, these centres operate for limited hours and often lack specialists, which limits effective access to healthcare.

Respecting the indicator of COVID-19-related deaths, the highest ratios occur in the most densely populated areas of Aragón, which coincides with the municipalities that have long-term care homes for the elders. 2648 residents died in Aragonese nursing homes during the COVID-19 pandemic, 765 of them with compatible symptoms and 1884 confirmed with a positive test, which represents 36.5 % of the total COVID-19-related deaths in Aragón (IMSERSO, 2023a).

The last intersectional dimension mapped is the territorial structure (Table 7). These indicators address challenges on an urban level that can affect care resources for the older population, as is the case of the

Table 6
Cartography of Healthcare Intersectional Indicators by Risk Level.

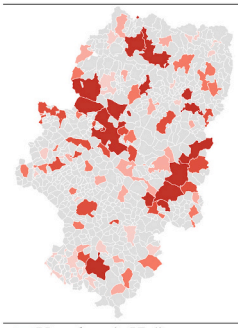
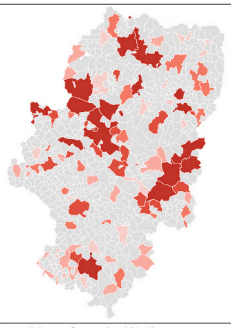
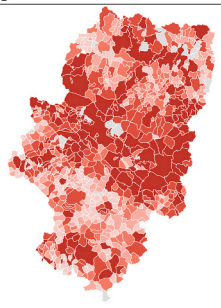
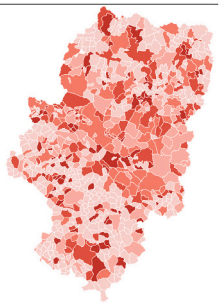
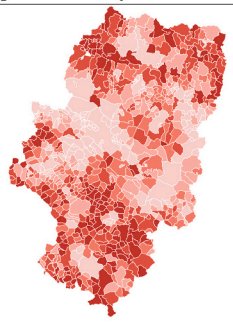
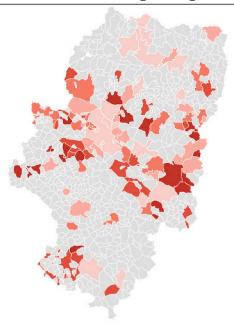
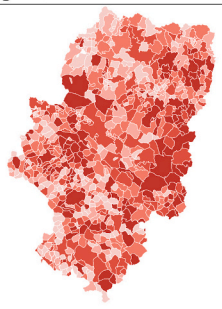
Doctor-to-patient ratio	Nurse-to-patient ratio	Healthcare equipment-to-patient ratio	COVID-19-related deaths ratio
			
Very low (>57.4)	Very low (>42.4)	Very low (>140.8)	Very low (0)
Low (57.4-36.4)	Low (42.4-26)	Low (140.8-83.3)	Low (0-3.2)
Medium (36.4-20.3)	Medium (26-19.6)	Medium (83.3-43.9)	Medium (3.2-4.6)
High (20.3-11.1)	High (19.6-11.4)	High (43.9-17.9)	High (4.6-8.5)
Very high (<11.1)	Very high (<11.4)	Very high (<17.9)	Very high (>8.5)

Table 7
Cartography of Territorial Structure Intersectional Indicators by Risk Level.

Population density	Household net income per capita	Migrants
		
Very low (>14.4)	Very low (>16,428.3€)	Very low (<3.5%)
Low (14.4-6.5)	Low (16,428.3-14,771.4€)	Low (3.5-6.1%)
Medium (6.5-3.4)	Medium (14,771.4-13,480€)	Medium (6.1-9.2%)
High (3.4-2)	High (13,480-11,725.9€)	High (9.2-13.9%)
Very high (<2)	Very high (<11,725.9€)	Very high (>13.9%)

population density indicator. The lowest risks of aging vulnerability are concentrated in the municipalities in the Ebro and Gállego river basins. In contrast, the rest of the Aragonese region is significantly depopulated, impacting the accessibility to healthcare services for the older adults living in these areas. Sierra de Albarrín County, in south Teruel, has a population density of 3.4/km^2, whereas Central County's density is 225.5/km^2. Considering the 12.5/km^2 depopulation benchmark by the European Union (Ministerio de Política Territorial y Función Pública, 2019), 76.3 % of the municipalities in Aragón are at risk of rural depopulation.

Household net income per capita is a crucial intersectional indicator to assess aging vulnerability, particularly within the older population with physical and cognitive impairments. The economic situation of older adults can noticeably affect their healthy aging. However, this indicator is only available for municipalities with more than 1000 people, hiding the financial state of rural areas in Aragón. If the cartographies of population density and household income are compared, the statistical invisibility of the depopulated territory is even more evident.

Finally, the proportion of migrants may have a long-term impact on older adults, considering that most migrants are part of the working-age group. By 2050, the healthcare system will have to offer care services to a diverse older population in terms of race and religion. In Aragón, migrants primarily work in the agricultural sector. Thus, they are uniformly distributed across the territory, ranging from 10.9 % in Campo de Daroca to 6.8 in Central County.

Aging vulnerability in Aragón

In order to assess the aging vulnerability of Aragón, intersectional indicators with a high or very high score were added up for each municipality. The result can be seen in Fig. 2, which represents the risk map of aging vulnerability in the Aragonese region.

Municipalities with the highest aging vulnerability (more than ten indicators with a high or very high level) are situated in a central north-to-south axis in the province of Teruel – Comunidad de Teruel, Cuencas Mineras and Jiloca counties –, west and north of Zaragoza province – Campo de Daroca, Campo de Belchite, Comunidad de Calatayud and Cinco Villas counties – and the east and south of Huesca province – Los Monegros and La Ribagorza counties –.

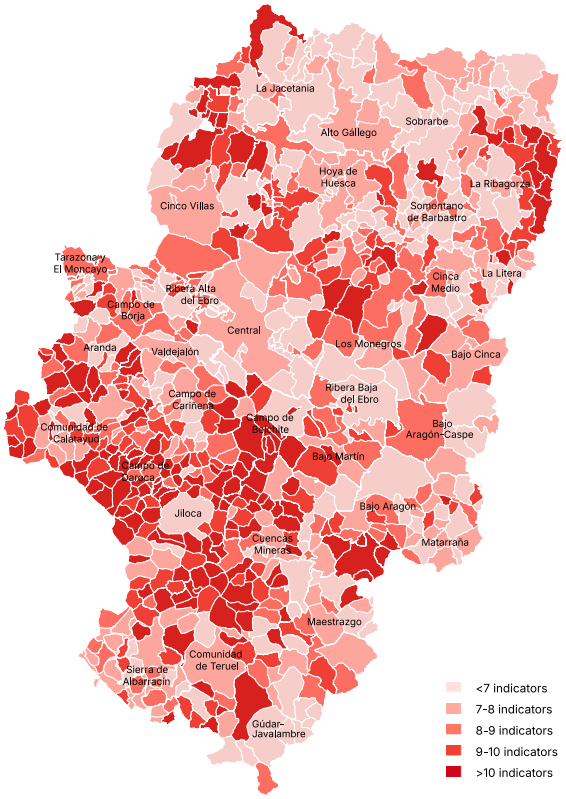


Fig. 2. Risk Map of Intersectional Aging Vulnerability.

By Aragonese county, Campo de Daroca (10.9), Campo de Belchite (10.8), and Jiloca (10.5) show the highest average risks of aging vulnerability. Conversely, Comarca Central (6.8), Alto Gállego (7.3), Sobrarbe, and Cinca Medio (7.4) manifest the lowest mean risks.

The disaggregated results by intersectional dimensions for each county in Aragón are gathered in Table 8. The radial graphs represent the proportion of indicators with high and very high risk levels of aging vulnerability in relation to the number of indicators under the intersectional domains. The solid line displays the average aging vulnerability in the county, whereas the dotted line shows the average score in Aragón. The color legend is described at the bottom of the table.

Campo de Belchite shows the highest intersectional vulnerability (64 %) and elevated demographic aging and dependency scores (60 % and 78 %). This county combines advanced rural depopulation (58 %) with limited healthcare (65 %) and aged care access (83 %), making it emblematic of peripheral rural Aragón, where aging and isolation interact. In contrast, Comarca Central displays the lowest intersectional vulnerability (40 %), supported by extremely low aging and dependency scores (5 % and 0 %). Although it exhibits higher gender vulnerability (62 %) than Campo de Belchite (33 %), its overall profile illustrates how denser populations with diversified economies and strong healthcare ecosystems mitigate aging-related risks.

Lastly, Somontano de Barbastro has a more moderate vulnerability (45 %), placing it closer to the lower-risk end of the spectrum, although it still faces challenges related to insufficient infrastructure. The vulnerabilities in aged care (95 %) and healthcare (59 %) indicate that services are not evenly accessible, a common issue in semi-rural areas. These findings suggest that strengthening the community-based care network could help prevent the development of high intersectional vulnerability.

Conclusions

In this paper, we conducted a study that innovatively addresses the unique territorial challenges faced by older adults in Aragón, diverging from conventional demographic analyses that often overlook intersectional factors. Traditional methodologies tend to assume territorial uniformity, neglecting crucial elements such as gender, ethnicity, and economic status. Additionally, unlike existing research that primarily explores sustainable aging indicators and overall quality of life in urban-rural environments, this study is also innovative in its transversal approach to exploring the intersection of aging, gender, and regional planning studies. On the other hand, while feminist methodologies have significantly influenced architecture and urban planning, they have yet to comprehensively address the specific territorial difficulties encountered by older adults. This research seeks to fill these gaps by proposing an intersectional quantitative methodology tailored to the Aragón context. The objective was to provide a nuanced understanding of the experiences of the most vulnerable older adults in the region, contributing fresh insights into their well-being and quality of life. By emphasizing the intersectional and gender-specific aspects of the study, it sought to advance the current understanding of aging vulnerability and promote more inclusive and effective strategies for this demographic in Aragón.

The study ran a holistic assessment of aging vulnerability in Aragón, using case study and quantitative research methods based on feminist epistemology and situated knowledge theories. Seventeen intersectional indicators were investigated within six key dimensions: demographic aging, dependency, gender, aged care, healthcare, and territorial structure. The findings, obtained through GIS mapping and data-driven decision-making analysis, offer a contextualized and comprehensive understanding of the spatial distribution of aging vulnerabilities across the Aragonese territory. Although Aragón is not the most vulnerable autonomous community on a national or European level, the results demonstrate that aging vulnerabilities are not uniformly distributed. On a municipal level, certain regions face higher risks than others: the central-north-to-south axis in the province of Teruel, west and north of Zaragoza province, and the east and south of Huesca province emerged as the territories with higher aging vulnerability.

Demographic aging indicators highlighted regional variations in the older population. The southwest and northeast counties exhibit higher proportions of older adults. Similarly, the over-aging index in these areas also indicated a substantial percentage of the oldest-old people, accentuating the potential challenges in caregiving. The current support system in Aragón will need to provide specialized care from a person-centered approach, considering the diverse needs of an over-aged population that is more likely to suffer from age-related diseases and impairments. In particular, dependency indicators – old-age dependency ratio, dementia ratio, and older people living alone – portrayed the fragility of the intricate web of interrelations and dependencies in the Aragonese care system.

One of the key findings lies in the disparity between men and women within specific age brackets among older adults. The striking gender gap in the oldest-old group indicates a shift towards higher proportions of older women, impacting caregiving dynamics and support structures. Policy initiatives must address gender-specific disparities and include tailored interventions like gender-sensitive healthcare programs and support networks for family carers.

On the other hand, aged care and healthcare indicators underscored the local disparities in access to care services, resources, and infrastructures: the most pronounced vulnerability arises in the aged care dimension, with 91 % of the region vulnerable in terms of long-term care and daycare provision. The limited availability of these crucial care resources in some rural areas poses a challenge to improving the quality of life for future aging populations.

Territorial structure indicators, including population density and household net income per capita, highlight challenges associated with urbanization and economic disparities. Furthermore, the dependent, feminized, and over-aged population in Aragón is mainly located in rural municipalities, undergoing a continuous process of depopulation.

Table 8
Aging Vulnerability by Intersectional Dimension and Aragonese County.

Aging vulnerability	Dimensions	Aging vulnerability	Dimensions	Aging vulnerability	Dimensions
Alto Gállego 7.3/17 (43%)		**Central** 6.8/17 (40%)		**La Ribagorza** 8.8/17 (52%)	
Andorra-Sierra de Arcos 8.3/17 (49%)		**Cinca Medio** 7.4/17 (44%)		**Los Monegros** 8.9/17 (52%)	
Aranda 8.6/17 (51%)		**Cinco Villas** 9.6/17 (57%)		**Maestrazgo** 8.7/17 (51%)	
Bajo Aragón 8.8/17 (52%)		**Comunidad de Calatayud** 10.1/17 (59%)		**Matarraña** 8.3/17 (49%)	
Bajo Aragón-Caspe 8.2/17 (48%)		**Comunidad de Teruel** 10.2/17 (60%)		**Ribera Alta del Ebro** 7.7/17 (45%)	
Bajo Cinca 8.5/17 (50%)		**Cuencas Mineras** 9.8/17 (58%)		**Ribera Baja del Ebro** 8.3/17 (49%)	
Bajo Martín 9.2/17 (54%)		**Gúdar-Javalambre** 7.8/17 (46%)		**Sierra de Albarracín** 8.6/17 (51%)	
Campo de Belchite 10.8/17 (64%)		**Hoya de Huesca** 8.2/17 (48%)		**Sobrarbe** 7.4/17 (43%)	
Campo de Borja 8.5/17 (50%)		**Jiloca** 10.5/17 (62%)		**Somontano de Barbastro** 7.6/17 (45%)	
Campo de Cariñena 8.6/17 (51%)		**La Jacetania** 7.9/17 (46%)		**Tarazona y El Moncayo** 8.6/17 (51%)	
Campo de Daroca 10.9/17 (64%)		**La Litera** 8.4/17 (49%)		**Valdejalón** 8.5/17 (50%)	

Demographic aging Dependency Gender Elderly care Healthcare Territorial structure

The proportion of migrants, uniformly distributed across the territory, introduces considerations for the long-term demographic composition of the older population.

The findings of this study hold significant implications for policy formulation aimed at mitigating aging vulnerability in Aragón. The identification of specific dimensions contributing to vulnerability, such as demographic aging, dependency, aged care, healthcare, and territorial structure, provides a roadmap for targeted interventions. Policymakers can use these insights to allocate resources efficiently, prioritize areas with higher vulnerability, and tailor action plans to address the unique challenges of each dimension. The geographical disparities underlined in the study can inform the development of region-specific policies. For instance, regions with higher aging vulnerability may require additional investment in healthcare infrastructure, community-based programs, and care initiatives to improve social interaction among older adults. Recognizing the socio-economic and geographical factors influencing aging vulnerability is crucial for devising effective strategies.

While the study suggests valuable insights, it is essential to acknowledge its limitations. The use of data from different years introduces temporal disparities, and the absence of several indicators at the municipality level required data combinations from multiple sources. Future research could focus on obtaining more recent and comprehensive datasets to enhance the accuracy and relevance of these findings. Moreover, while the investigation provided a snapshot of the current scenario, longitudinal studies could offer insights into the evolving nature of aging vulnerabilities, facilitating the development of dynamic and adaptable policies.

Additionally, this study is only focused on quantitative indicators. Incorporating qualitative research methods and data could provide a better understanding of older adults' experiences and vulnerabilities in different regions. Simultaneously, further studies could explore similar methodologies in other territorial contexts, emphasizing intersectionality in understanding vulnerabilities among older adults.

In conclusion, this research significantly contributes to the understanding of aging vulnerability in Aragón. Feminist and situated methodologies, encompassing intersectional indicators and GIS mapping, provide a holistic perspective that can inform evidence-based policymaking. As Aragón and other regions continue to deal with the complexities of an over-aged, dependent, and feminized aging population, research endeavors of this nature are pivotal for creating sustainable and impactful strategies to enhance the well-being of older adults.

CRediT authorship contribution statement

Irene González-Fernández: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Belinda López-Mesa:** Writing – review & editing, Supervision. **Lucía C. Pérez-Moreno:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

None.

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Data availability

Data will be made available on request.

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