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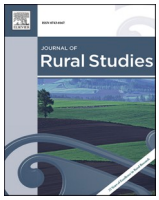

Demographic challenges and agricultural abandonment: Solutions for semi-arid winegrowing regions

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1. Introduction

Land abandonment is a major problem associated with land cover and land use change because of its environmental, landscape and socioeconomic consequences (Lasanta et al., 2015, 2017; MacDonald et al., 2000; Perpiña Castillo et al., 2021; Quintas-Soriano et al., 2022). Global land use has drastically altered rural landscapes in developed countries in Europe and North America (Li and Li, 2017). In Europe, approximately 120 Mha of land has been abandoned since the 1990s (Levers et al., 2018). The area of abandoned land is expected to reach 183 Mha by 2030 (Lopes Barbosa et al., 2015). Spain and Poland are likely to suffer the most from agricultural land abandonment. In Spain, Mediterranean regions face the biggest challenges in terms of land abandonment (Perpiña Castillo et al., 2021), due to a set of interconnected factors such as the strong pressure for agricultural land use, especially in coastal areas, the small size of farms (farms lacking the necessary scale to compete in an increasingly competitive market) and the lack of potential successors (Calafat-Marzal et al., 2023a).

Lasanta et al. (2017) extensively reviewed the causes of agricultural abandonment in Europe, categorising them into global and local causes. According to the scientific literature, global or external causes trigger the abandonment process, whereas local or internal causes affect the abandoned area and the areas where abandonment occurs (García-Ruiz et al., 2020; Jiménez-Olivencia et al., 2021; Lasanta et al., 2017; Quintas-Soriano et al., 2022). The leading external cause is agricultural policy measures. In Europe, such measures are summarised by the common agricultural policy (CAP). These measures can reduce or increase land abandonment (Lasanta et al., 2017). Internal factors include agroecological or biophysical factors. They also include the internal socioeconomic factors of each region, as well as the characteristics of the farms themselves. These characteristics influence the productivity of the land and the profitability and competitiveness of products. They ultimately help explain the spatiotemporal diversity of the abandonment process(Castillo et al., 2020; Perpiña Castillo et al., 2021).

Many studies have examined land abandonment in marginal or mountainous areas where biophysical characteristics are unfavourable and crop yields are low (Lasanta et al., 2017; MacDonald et al., 2000; Wyler et al., 2023). Fewer studies have focused on the drivers of abandonment in less marginal areas with higher-yielding crops (Debolini et al., 2018). One example is semi-arid areas of Europe such as wine-growing areas (Rodrigo-Comino, 2018). The abandonment of vineyards has adverse economic, environmental, and sociocultural effects on both the affected area and society as a whole (Tieskens et al., 2017; Vinatier and Arnaiz, 2018). The reason is that vineyards reflect a strong cultural legacy and support a crucial socioeconomic sector in European countries (Vinatier and Arnaiz, 2018). Winegrowing is also associated with complementary activities such as the supply of inputs and tourism (de Uña-Álvarez and Villarino-Pérez, 2019; Esteban Rodríguez and Fernández Portela, 2021).

Although the area covered by vineyards seems stable globally, it is decreasing in Europe. Meanwhile, in other countries, particularly China, the amount of land dedicated to winegrowing seems to be increasing (Yu and Rodrigo-Comino, 2021). In 2021, five countries accounted for half of the world's vineyard area. Spain had 13% of the world's vineyard area, followed by China (11%), France (11%), Italy (10%) and Turkey (6%). However, just 10 years earlier, China accounted for only 4%, and the other countries in this list had larger areas used for vineyards (International Organisation of Vine and Wine, 2022). This downward trend in European vineyard area has been greater in some countries than in others. Spain is one of the countries that has lost the most winegrowing area (MAPA, 2020), with a 17.3% decrease (202,449 ha) since the 2000/2001 campaign (International Organization of Vine and Wine, 2019). This decrease is at odds with the increase in the area dedicated to alternative crops, primarily rainfed crops such as almonds and olives. This trend has led to the abandonment of agricultural land and has aggravated erosion rates (Rodrigo-Comino et al., 2017) because of the

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layout of plots on sloping land. Crucially, vineyards are also a common crop in sparsely populated areas, where there is a higher risk of plot abandonment due to a lack of generational replacement (Lieskovský et al., 2013).

The main aim of this research is to assess how internal and external drivers influence the abandonment or resilience of vineyard land. The analysis focuses on the wine sector of the Region of Valencia (*Comunidad Valenciana, Spain*), a semi-arid area with varying dynamics. Despite urban pressures in agriculturally intensive areas along the coast, inland areas face depopulation problems. The presence of multiple demographic and sector-related issues in winegrowing means that different recipes can be used to tackle situations of high or low abandonment of vineyards. The diverse combinations of factors provide opportunities to define tailored strategies to address the specific challenges in each type of area. In this study, a configurational approach is used to examine causal complexity, instead of applying latent or net effects models. Scholars have highlighted the benefits of configurational methods such as fuzzy-set qualitative comparative analysis, or fsQCA. In this sense, configurational approaches analyze the casual complexity as group interconnected ingredients (conditions) that are specify by three characteristics: (i) conjunction, (ii) equifinality and (iii) asymmetry. By contrast, correlation-based methods are designed to deal with "general linear reality or net effects thinking" (Misangyi et al., 2017:256 see also Gabriel et al., 2018; Marx et al., 2014).

Taking in to account the properties and benefits of fsQCA, this approach was used to identify causal configurations of conditions that lead to the abandonment of vineyard plots, as well as pathways that mitigate this abandonment. Futhermore, fsQCA has been used in different regional contexts (Garcia-Alvarez-Coque et al., 2021b; Mas Verdú et al., 2020).

FsQCA evaluate causality through identifying necessary or sufficient conditions can help provide an understanding of the determinants of vineyard abandonment. By identifying such conditions, efforts can be focused on developing effective strategies to address vineyard abandonment. This approach can also help reveal which factors may affect the evolution of vineyards and which may be most relevant in preventing abandonment in European winegrowing areas.

2. Internal and external drivers of agricultural abandonment

The reasons for farmland abandonment in Mediterranean regions are multiple (Fig. 1). The abandonment of agricultural land does not depend on a single driver, but on co-occurrence and interactions of internal and external drivers (Terres et al., 2015). The analysis of internal and external factors can identify the determinants of highly intensive (high abandonment) or non-highly intensive (low abandonment) vineyard abandonment. Drivers are generally grouped into the following categories: market value (internal), socioeconomic (internal), farming system (internal) and institutional (external), and (Lasanta et al., 2017). The table in Appendix 1 summarises studies based on their use of external and internal drivers. It also outlines the methodology employed in these studies and presents the main results.

Researchers recognise that economic, social, and political factors have been causing agricultural abandonment since the mid-20th century. They tend to adopt two distinct perspectives (Dolton-Thornton, 2021). Some authors argue that land abandonment is detrimental to the environment because of the associated loss of biodiversity, soil erosion and other negative impacts (Estel et al., 2015; García-Ruiz et al., 2020; Levers et al., 2018; Quintas-Soriano et al., 2022; Tieskens et al., 2017). Other authors identify land abandonment with environmental benefits in the form of increased biodiversity, ecosystem restoration, carbon sequestration and increased water quantity and quality (Bruno et al., 2021). Authors who adopt the first view focus on semi-arid areas with intensive cultivation. Those who adopt the second perspective tend to focus on marginal mountain areas, where human action has encroached on natural forests. The approach in the present study is more closely associated with the first perspective than the second. The aim of this study is to analyze semi-arid Mediterranean areas, not marginal mountain areas. In those regions, depopulated areas coexist with highly urbanised areas. This choice of setting enables the identification of combinations of drivers that can affect high or low abandonment of vineyards. These diverse combinations of factors provide opportunities to define tailored strategies to address the specific challenges faced in each type of area.

The conditions for vineyard cultivation are biophysical factors. For example, the type of landscape may be coastal, intermediate, or inland. This feature determines the intensity of land use. Processes of intensification and urbanisation in coastal and intermediate areas contrast with processes of extensification and depopulation in inland areas with low land use intensity (Recatalá et al., 2000). Studies of vineyard abandonment show that the wine sector encourages settlement in rural areas and prevents depopulation (Bollati et al., 2015; Costantini et al., 2016; del Río et al.,2021; Lieskovský et al., 2013). One key concept in the European wine sector is that of protected designations of origin (PDOs) and protected geographical indicators (IGP). PDOs and IGP certify that a product originates from a specific place.[1] The idea is that product quality and characteristics are fundamentally due to a specific geographical environment with inherent natural and human factors. All stages of production must take place within the defined geographical area (Spanish Conference of Wine Regulatory Council, CECRV).[2] PDOs play a crucial role in both economic competition and changes in market demand in the wine industry. In terms of economic competition, PDOs allow producers to differentiate themselves and add value to their products by making them part of a region that is recognised for its quality and unique characteristics. They provide legal protection against unfair competition. They also help with market promotion and consumer loyalty, giving PDO-certified producers a competitive advantage. PDOs are useful to adapt to changing market demand. They provide the guarantee of authenticity and quality that consumers seek in a context of evolving preferences. They enable producers to meet new demands, communicate and encourage changes through promotional activities. They also allow producers to adjust production to meet changing consumer preferences. Hence, PDOs are market value drivers. In Spain, this system is used to certify quality. They refer to natural (soil and climate) and human (know-how) factors linked to the origin of a product to certify product quality (del Río et al.,2021). In addition to the internal and external drivers of land abandonment, PDO membership may be critical to avoid vineyard abandonment (Bollati et al., 2015; Costantini et al., 2016; del Río et al.,2021; Esteban Rodríguez and Fernández Portela, 2021).

2.1. External drivers of agricultural abandonment

In Europe, the common agricultural policy (CAP) strongly conditions the development of wine areas. Coherence between the 2008 EU wine policy reform and the 2013 general CAP reform meant that the wine policy model developed in 2008 could be included in the Single Common Market Organisation under Regulation (EU) 1308/2013. It resulted in the strictest regulations worldwide (Meloni et al., 2019). The main economic policy measures in the sector limiting supply were based on severe limitations on vineyard planting and a grubbing-up programme to reduce overproduction and balance supply and demand in the market (Carbone, 2021). These programmes incentivised winegrowers to grub up existing vineyards and reduce the area under cultivation to limit wine production and avoid surpluses that could affect prices and the profitability. Deconinck and Swinnen (2015) and Meloni et al. (2019) have reported that restrictions on winegrowing potential create efficiency losses through the misallocation of production. Planting restrictions also

[1] In this study, PDOs and IGPs are grouped together under the name PDO.
[2] https://vinosdo.wine/.

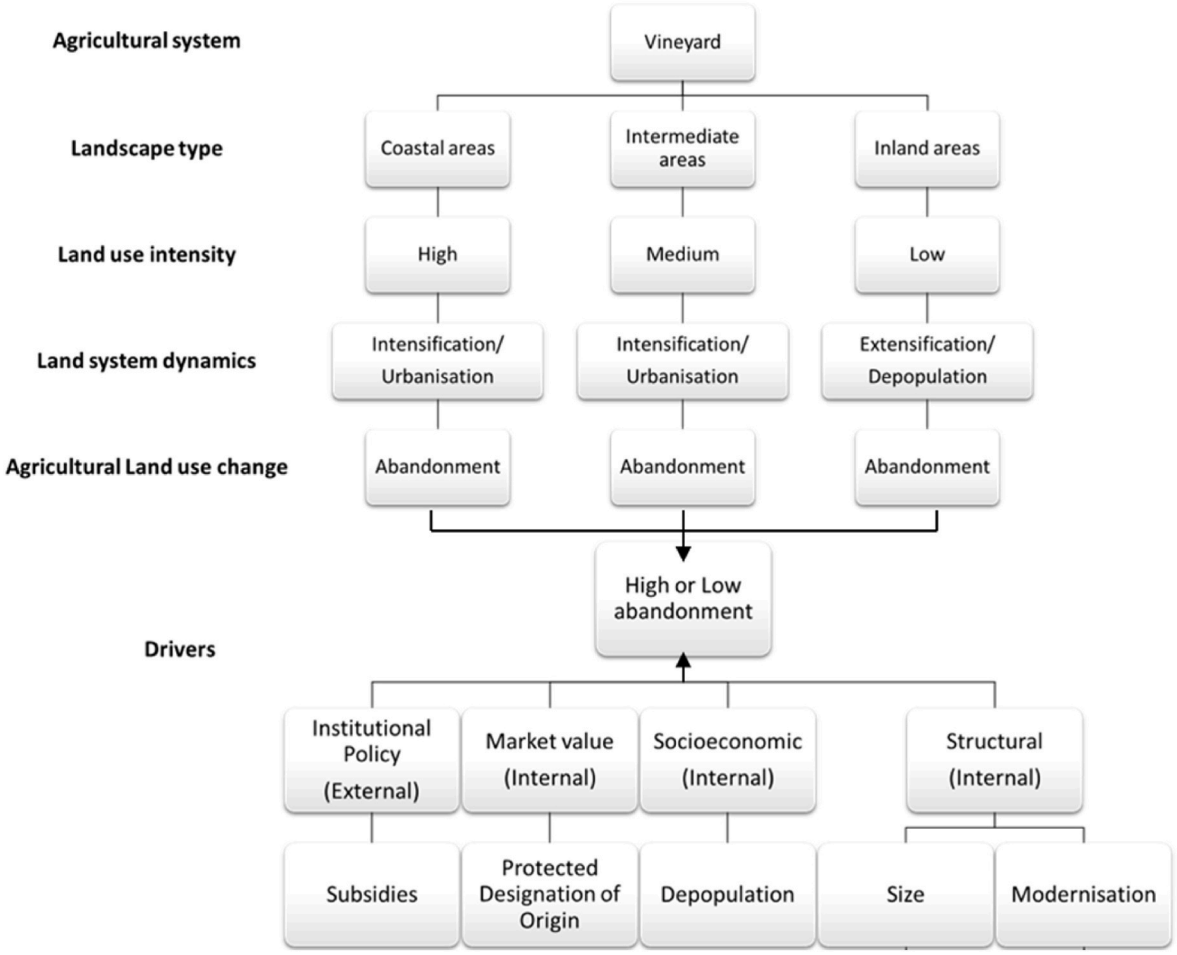

Fig. 1. Conceptual framework.

seem likely to limit innovation and adaptation in European wine markets.

These measures resulted in a major change in the composition and distribution of vineyard plantings (Carbone, 2021). Successive CAP reforms in this sector have led to measures to continue to promote the economic, social, and environmental sustainability of the sector. These reforms have three main objectives: viable food production, sustainable management of natural resources and climate action, and balanced regional development (European Commission, 2010; European Commission for Agriculture and Rural Development, 2020; European Parliament, 2015). In Spain, the wine sector receives CAP support mainly through the Wine Sector Support Programme. This programme aims to improve the competitiveness of the sector and encourage the restructuring and conversion of vineyards. It provides financial aid for measures such as the restructuring and replanting of vineyards, investments in wineries and equipment, promotion of wines in international markets, and information and promotion actions. The National Support Programme (NSP) for the wine sector complements European measures and provides additional aid to support investment, modernisation, and promotion of the wine sector in Spain.

CAP aid for young people and small farms is provided to promote generational renewal, encouraging the entry of new farmers while supporting those with fewer resources or less capacity to compete in the market. This aid aims to maintain diversity and quality in wine production while ensuring the long-term sustainability of the sector (European Commission, 2018). The latest CAP reforms include agri-environmental and climate measures (Regulation (EU) 2021/2115). These measures provide support to wine producers who adopt environmentally friendly and sustainable agricultural practices such as soil management, reduced chemical use and protection of biodiversity (Pomarici and Sardone, 2020). These practices help preserve natural resources and mitigate climate change. Climate change is shifting the area suitable for wine production further north, even though regulatory restrictions discourage the migration of wine production (Ashenfelter and Storchmann, 2016). This high level of regulation indicates that CAP support is necessary for the economic, social and environmental sustainability of the sector. Hence, the first proposition can be formulated.

Proposition 1. *CAP support is necessary to halt the abandonment of winegrowing land.*

2.2. Internal drivers of agricultural abandonment

2.2.1. Protected designations of origin

The recognition of quality and regional differentiation through a PDO could provide sustainable competitive advantages to producers (Garcia-Galan et al., 2014). It could also allow them to charge more for their products (Delord et al., 2015). PDOs bring value and can especially favour small producers. For small producers, PDOs offer competitive advantages by generating a brand that increases visibility. They also favour economic development in regions with low income potential (Garcia-Galan et al., 2014). However, for consumers to appreciate this differentiation, it must be well communicated (Espejel and Fandos, 2009).

Studies have cited PDOs as a positive factor in avoiding land abandonment and contributing to overcoming this demographic challenge

(Bollati et al., 2015; Costantini et al., 2016;del Río et al.,2021).[3] Positive factors include the revaluation of local markets and internationalization, enabling both the development of local entrepreneurs and the arrival of niche innovators (de Uña-Álvarez and Villarino-Pérez, 2019; Fernández-Aldecua et al., 2017). However, del Río et al.,2021 found a marked reduction in the density of inhabitants per square kilometre in already depopulated areas. Therefore, PDOs must be accompanied by other conditions that encourage winemaking and the rootedness of the local population (Bollati et al., 2015).

PDOs could help reduce depopulation by creating a suitable sociocultural environment and greater economic dynamism (Fernández-Aldecua et al., 2017). Most studies of wine PDOs address agroecological and bioclimatic aspects (Bollati et al., 2015; Costantini et al., 2016; del Río et al.,2021) or tourism and regional identity (de Uña-Álvarez and Villarino-Pérez, 2019). They have highlighted a positive relationship between PDOs and population rootedness. These studies approach the problem from a social point of view. Therefore, the second proposition can be stated:

Proposition 2. *PDOs help make regions more dynamic and are necessary to reduce the abandonment of winegrowing land.*

2.2.2. Depopulation

The rural exodus of the second half of the 20th century led young people to emigrate to cities and become disengaged with farmland. This process has resulted in the depopulation and abandonment of land in rural areas. In areas at risk of depopulation, the decrease in local population has a direct impact on the demand and profitability of vineyards. The reduction of inhabitants translates into lower demand for wine products, leading to lower prices and lower profits for winegrowers (Carbone et al., 2019). This lack of profitability can lead to a decrease in interest in maintaining and cultivating vineyards, thus driving abandonment. Another economic factor in depopulated areas is the shortage of labour (Alamá-Sabater et al., 2019). Viticulture is labour intensive, especially during critical stages such as pruning and harvesting. However, the lack of workers hinders the management and maintenance of vineyards. This situation negatively affects crop productivity and efficiency and can lead to the abandonment of vineyards.

In contrast, larger coastal areas with no risk of depopulation face different problems. Urban pressure is high because the development of residential, tourist or commercial infrastructures can affect the economic viability of vineyards (Lammoglia et al., 2019). Competition for limited resources, such as water, is also a factor. Urban and tourist demand can reduce the availability of water for vineyards. However, employment opportunities in other economic sectors and the externalization of tasks allow farms to be maintained with part-time farmers (González-Puente, 2022).

This relationship between depopulation and agricultural abandonment intensifies each other's effects (Bruno et al., 2021; Lasanta et al., 2017). Some authors even consider abandonment to be a facet of rural depopulation because of a combination of economic, social, and political factors (Dolton-Thornton, 2021). Depopulation is an internal socioeconomic driver of abandonment, along with other factors such as poor soil quality (Lasanta et al., 2017) and structural elements such as physical and digital connectivity and loss of cultural diversity (Murin et al., 2022). Hence, the third proposition can be stated:

Proposition 3. *Along with other associated factors, depopulation drives the high abandonment of winegrowing land.*

[3] According to Regulation (EU) No. 1308/2013, a PDO is the name of a region associated with the quality and characteristics of a specific product. These characteristics are due to a particular geographical environment, with its inherent natural and human factors.

2.2.3. Size

The structural characteristics of plots and their degree of modernisation are internal factors that condition agricultural abandonment (Appendix 1). Low production, high fixed costs and low profitability of small farms are factors that aggravate the abandonment of productive land (Lasanta et al., 2017). They also make farming unattractive, leading to a lack of generational replacement, which exacerbates the problem (Bollati et al., 2015; Cossart et al., 2020; Lasanta et al., 2017; van Vliet et al., 2015).

Between 1990 and 2007, the average size of wine farms in France, Germany, Italy, and Spain almost doubled (Delord et al., 2015). Larger cultivation areas help with efficiency in the use of labour and increase gross value added per hectare when the size of the plot is larger than 1 ha (Cossart et al., 2020). The greater viability of these plots offers an incentive to reduce vineyard abandonment. Smallholdings with small plot sizes, low production, high fixed costs, and consequently low profitability, favour the abandonment (Lasanta et al., 2017; Wyler et al., 2023). In Spain, Heider et al. (2021) demonstrate that in recent years there has been an increase in the size of production in vineyards in PDO regions, and in an analysis of Spanish wine PDOs found a positive relationship between farm size and technology incorporation. Wyler et al. (2023) reported that the ongoing dropping of vineyard cultivation in agricultural land is clearly related to management difficulty (barriers to mechanization) and labour. Consequently, the fourth proposition can be stated in the following words:

Proposition 4. *The prevalence of smallholdings in a region is conducive to the abandonment of winegrowing land.*

2.2.4. Modernisation

Plot modernisation can be linked to the search for higher quality products, greater production, and higher incomes. It can even offer a strategy to reduce the risks of climate change (Burton and Otte, 2022; Leimer et al., 2022). In viticulture, there is a trade-off between modernisation and tradition (Beccaria and Pretto, 2021). In a study of technology adoption by Italian winegrowers, Garini et al., (2017) found that the main drivers of adoption were mainly due to the existence of site-specific pedoclimatic conditions and market requirements. Drip irrigation, varieties that are better adapted to local conditions and trellis training systems are recommended for more efficient wine production. Such modernisations could help vineyards adapt while maintaining their viability and sustainability (Graveline and Grémont, 2021). Calafat-Marzal et al. (2023b) identify that, in Mediterranean regions, the modernisation of winegrowing farms reduces the probability of abandonment. They show that modernisation must be combined with other factors to reduce the abandonment of plots. In this study they show the combination of modernisation with structural drivers, such as plot size or irrigation availability, and contextual drivers, such as municipal productive specialization, municipal trading firms and higher subsidies. In conclusion, the fifth proposition can be formulated as follows:

Proposition 5. *Modernisation of winegrowing plots increases efficiency by reducing the abandonment of winegrowing land.*

3. Empirical study: vineyards in the Region of Valencia (*Comunidad Valenciana*)

The study was performed in the Region of Valencia in the east of Spain. It is part of the Western Mediterranean area of Europe. It has a surface area of 23,255 km^2 (Fig. 2) and is home to around five million inhabitants. Its agri-food sector accounts for around 12% of GDP (Generalitat Valenciana, 2020). Approximately 44% of the area is used for agriculture, and 56% is forested. The topography creates varied regional environments. There are three orographic areas: inland, intermediate, and coastal. Dry fruit orchards, vineyards, intensive and extensive livestock farming, pastures, forests, and scrubland characterise the inland area.

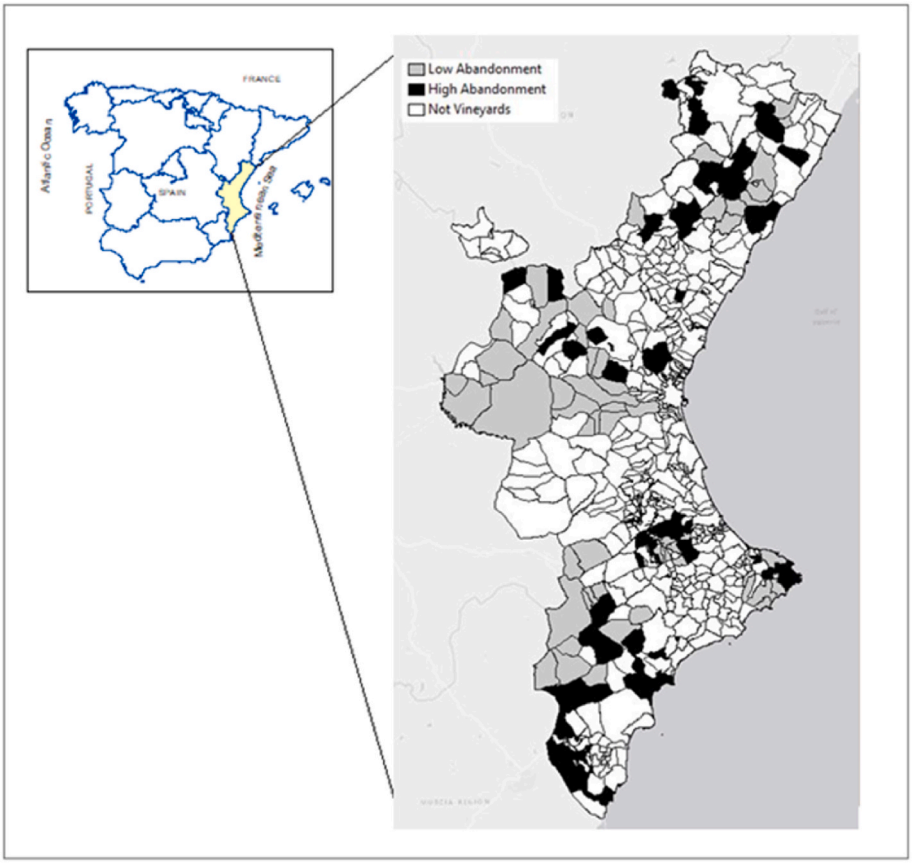

Fig. 2. Location of the Region of Valencia and municipalities with abandoned vineyard areas.

The region has two contrasting population profiles. The average population density is 214 inhabitants per km.[2] However, an area amounting to 27% of the region's total surface area is inhabited by only 0.8% of the region's population. This feature results in a sparsely populated segment of the region. Hence, depopulation is an important condition for analysis of the factors of vineyard abandonment (Alamá-Sabater et al., 2019).

Around 6.6% of the national vineyard surface area lies in this region (62,796 ha, on average, from 2016 to 2020). The wine sector contributes around 1.7% to the region's GDP, generating a total gross value added of more than 1885 million euros per year. It also contributes to around 32,160 direct, indirect, and induced (full-time equivalent) jobs (MAPA, 2020). Vineyards are planted throughout the territory. They are present in more than half of the municipalities across the region (279 of 542), including coastal, intermediate, and inland municipalities. However, vineyards cover the largest surface area in the provinces of Valencia and Alicante. The vineyard surface area in the Region of Valencia has decreased by 23.3% since the year 2000 (MAPA, 2020). This decrease is in addition to the reduction in production surface area between 1983 and 2019 of 105,485 ha of vineyards. This reduction was due in part to grubbing-up policies that left the vineyard surface area predominantly in the inland area. According to the 2021 wine census, the vineyard surface area is 81,376 ha across 115,823 plots. The Region of Valencia has three PDOs: Utiel-Requena (Valencia), Alicante and Castellón. These PDOs account for 11.24% of the surface area (9149.94 ha across 11,337 plots), distributed in coastal, intermediate, and inland municipalities.

The area of abandoned vineyards is 1088 ha across 1880 plots in 112 municipalities. Of these abandoned vineyards, 82.53% are dry-farmed, and 94% have no conduction system. Hence, they are mainly plots with no modernisation practices. The average plot size is 0.47 ha. Accordingly, this region seems to have separate fragmented agrarian structures due to traditional local land inheritance and transmission (Heider et al., 2018). Fig. 2 shows the municipalities with large abandoned areas (high abandonment) and small abandoned areas (low abandonment). It is important to note that the area of abandoned vineyards and the PDOs are distributed throughout the study area, and no significant relationship has been established between the size and modernisation of the plots and the territorial duality.

4. Sample and data collection

This study explored the conditions that drive vineyard abandonment in the municipalities of the Region of Valencia. The outcome used in the study was abandoned surface area as a percentage of total surface area of vineyards in the municipality. This percentage was calculated from the database of the Region of Valencia Wine Register (2020), provided by the Generalitat Valenciana.[4] The conditions used in the study are described in Table 1. The data were gathered for each municipality in the Region of Valencia with abandoned vineyard plots.

To characterise depopulation in the municipalities of the Region of Valencia, a depopulation index was calculated based on the indicators proposed in Decree 182/2018 of the Valencian Government. The data are from the period 1999 to 2020. Table 2 shows the indicators, a description of these indicators and the proposed thresholds.

The value of the demographic indicators classifies the municipalities according to their depopulation risk. Those at very high risk meet the criteria for all indicators. Those at high risk meet the criteria for five indicators. Those at moderate risk meet the criteria for four indicators or have a population of less than or equal to 120 inhabitants or have a population density of less than 12.5 inhabitants/km.[2] Table 3 shows the

[4] Generalitat Valenciana: Autonomous Government of the Comunitat Valenciana, Spain.

Table 1
Description of conditions.

Driver	Description	Source
Subsidies	Type: External. Institutional/ Policy ∑ Subsidies (2019) /Useable Agricultural Area The following subsidies are used: II.1 Basic payment programme II.4 Payment for agricultural practices that benefit the climate and the environment. II.6 Payment for young farmers II.9 Small farmers' programme III.5 Support programmes in the wine sector	Spanish Agricultural Guarantee Fund; Ministry of Agriculture, Fisheries and Food
PDO	Type: Internal. Market value Percentage of area in PDO/ vineyard area	Community of Valencia Wine Register (2020) (Generalitat Valenciana)
Modernisation	Type: Internal. Structural Modernisation Index: - Improvement of production method: trellised vineyards as a percentage of total municipal vineyard area. - Varietal improvement: Percentage of PDO-recognised varieties in the municipality.	
Size	Type: Internal. Structural Average area of abandoned vineyard plots (ha)	
Depopulation	Type: Internal. Socioeconomic Depopulation index calculated from indicators proposed in Decree 182/2018 of the Generalitat Valenciana (Calafat-Marzal et al., 2021). Data from 1999 to 2020. The range of values for depopulation risk is: 6 (very high); 5 (high); 4 (moderate); values below 4 (no risk).	Statistics portal Generalitat Valenciana

Table 2
Municipal depopulation indicators and thresholds.

Index	Description	Thresholds
Population density	Number of inhabitants per km^2 in 2019	≤ **20**
Demographic growth	Growth rate between 1999 and 2019 (%)	≤ **0%**
Vegetative growth	Percentage representing the natural balance (difference between the number of births and deaths) in a given population (1999–2019)	≤**-10%**
Ageing rate	Ratio of the number of people aged 65 years and over to the number of people aged 0–14 years (1999–2019)	≥ **250%**
Dependence index	Percentage of population aged under 15 years and over 65 years	≥ **60%**
Migratory rate	**Migratory balance in 2009–2019 divided by total population in the last year (%)**	≤ **0**

Source: Authors based on indicators proposed in Decree 182/2018.

correlation matrix for the causal conditions and outcome.

5. Method

Qualitative comparative analysis (QCA) entails systematic comparison of examples to identify configurations of factors that lead to a phenomenon of interest (Ragin, 2009). Fiss (2011) explained that regression analysis is a questionable approach for observing equifinality because it focuses on the added effects of variables rather than configurations of conditions that lead to an outcome (or the absence of an outcome). Whereas regression analysis focuses on one variable at a time, QCA investigates how different configurations of conditions affect a specific outcome. Woodside (2016) argued that dealing with asymmetric theory and data analysis requires asymmetric analytical methods such as fsQCA.

A step-by-step explanation of how to perform fsQCA is provided in this section. A more detailed description is given by Ragin (2009). The first step consists of a literature review to gain insight into the conditions that may lead to the outcome. The second step is calibration. Conditions must be calibrated to map values to the range 0–1 for each condition. In other words, the conditions must be presented in terms of presence or absence (Fiss et al., 2013; Schneider and Wagemann, 2012). This feature of fsQCA gives more realism and flexibility to conditions, given that most conditions in the social sciences are not categorical. To calibrate conditions, researchers can use the direct method recommended by Ragin (2009). Alternatively, they can use indirect calibration, according to which authors use their knowledge of cases to set thresholds that indicate membership or non-membership to a set.

The next step is to produce the truth table. This table shows all possible configurations of the selected conditions. The number of rows is equal to 2^k, where k is the number of conditions. Two key concepts must be considered at this point: coverage and consistency. Coverage indicates the degree to which a configuration is applicable and valid to explain cases. Higher coverage of a configuration means that the configuration can explain more cases. A high coverage value is useful but not essential. Even if a configuration has a low coverage value, it may still be helpful in explaining certain cases. It should therefore be analysed carefully when interpreting results. The second concept is consistency, which measures the level to which a condition belongs to a configuration. For example, if a condition has a low consistency, that condition may appear in a configuration that leads to the presence of the outcome. In another, it may explain the absence of the outcome (Schneider and Wagemann, 2012). For cases where the resulting configurations include conditions that are consistent with the outcome and its absence, the proportional reduction of inconsistency (PRI) measure (Cooper and Glaesser, 2011) is used. This technique reduces the influence of these cases in the consistency estimate. FsQCA reveals sufficient and necessary conditions. A condition is sufficient when its presence causes the outcome. In contrast, a necessary condition is present every time the outcome is present. A condition is sufficient but not necessary if a configuration of conditions not including the sufficient condition also causes the outcome.

The analyses were conducted using the R packages developed by Duşa (2018) and Oana and Schneider (2018). Specifically, the libraries QCA and SetMethods. Duşa (2018) and Oana and Schneider (2018)

Table 3
Correlation matrix.

Condition	1	2	3	4	5	6
1. Abandoned vineyard	–					
2. PDO	−0.203*	–				
3. Modernisation	0.071	0.077	–			
4. Subsidies	−0.064	0.062	0.325***	–		
5. Depopulation	0.173	−0.228*	−0.273**	−0.179	–	
6. Size of plot	0.040	−0.015	0.121	0.030	−0.324***	–

Note: Level of significance: *p < .05, **p < .01, ***p < .0001.

Table 4 shows the descriptive statistics for the sample and the calibration points. Specifically, the direct method proposed by Ragin (2009) was used to calibrate the outcome (high presence of abandoned vineyards) and the conditions for PDO, modernisation, subsidies and size were calibrated using the 80th, 50th and 20th percentiles for full membership, the point of maximum ambiguity and non-membership to the set, respectively (Garcia-Alvarez-Coque et al., 2021a). This practice is useful when there is no theoretical knowledge to define calibration thresholds (Greckhamer et al., 2018). In contrast, the depopulation index condition was calibrated by using the indirect method assigning fuzzy scores to each depopulation risk level: 6 (very high risk) = 1; 5 (high risk) = 0.8; 4(moderate risk) = 0.6; all other values (no risk) = 0.

6. Results

The fsQCA reveal the causal patterns that lead to the high or low abandonment of vineyard land. First, necessity analysis was carried out. This analysis established which conditions are necessary for high or low abandonment of plots in municipalities in the Region of Valencia. Second, sufficiency analysis was used to determine the combinations of conditions leading to high or low land abandonment.

The results of the necessity analysis for both high and low abandonment are detailed in Table 5. The table shows no necessary condition for abandonment, with consistency less than 0.9 (Schneider et al., 2010). In other words, land abandonment is a consequence of a combination of drivers. PDO membership has higher values than the other drivers. The absence of PDOs (0.761) suggests high levels of abandonment, whereas the presence of PDOs (0.654) suggests low levels of abandonment. These results may indicate the role of PDOs in regional dynamics, supporting Proposition 2. Another prominent driver is depopulation. Specifically, in the case of low levels of abandonment, the absence of depopulation (municipalities without risk of depopulation) has a higher value of necessity (0.742) than the other drivers. This finding supports Proposition 3.

Table 6 shows the sufficiency analysis for both high and low levels of vineyard land abandonment. In both cases, with a consistency score of more than 0.75, the models are valid (Ragin, 2009). No single causal configuration leads to land abandonment, reflecting the equifinality property of fsQCA. Three configurations lead to high vineyard land abandonment (1a, 2a and 3a) and four configurations leading to low levels of abandonment (1b, 2b, 3b and 4b). Following the approach described by Lou et al. (2022) that consist in increase the frequency threshold from 1 to 2, the robustness of the results was tested. Appendix 2 shows the Robustness test and Supplementary materials includes the Truth tables (high abandonment and low abandonment).

7. Discussion

This study advances knowledge of the necessary and sufficient conditions that affect the abandonment of vineyard areas. The study focuses on the Spanish Mediterranean area of the Region of Valencia. This semi-arid region is home to several different types of areas. Its coastal area faces major land use conflicts, whereas parts of its inland area are at risk of depopulation. This dichotomy is found within many European regions. Considering this feature of the region, depopulation was included in the analysis of the factors of vineyard abandonment, as an internal driver. The internal and external factors that have been most widely studied in the literature were also included in the study. These drivers were the effect of CAP agricultural subsidies (external), PDO membership (internal), modernisation (internal) and plot size (internal).

The results indicate no necessary conditions for abandonment. However, there are two drivers with high values: absent of PDO membership and depopulation. PDOs are not necessary. However, when combined with other drivers, they may mitigate the effect of agricultural abandonment. This result supports the conclusions of Bollati et al. (2015), Costantini et al. (2016) and del Río et al.,2021, who identified this internal driver as sufficient but not necessary. This finding also suggests that national support programmes should target farmers and actors involved in wine production and marketing such as PDOs. The absence of depopulation is a relevant condition in the case of low abandonment. This result is consistent with studies of the determinants of abandonment that identify depopulation as an internal driver (Bruno et al., 2021; Dolton-Thornton, 2021; Murin et al., 2022). Dolton-Thornton (2021) argued that abandonment should be considered part of the rural depopulation challenge and that a holistic set of targeted rural development initiatives should be proposed.

The analysis of sufficient configurations identified three configurations leading to high levels of land abandonment (Fig. 3). The absence of PDO is a common condition. This finding supports the results of the necessity analysis by showing that not belonging to a PDO is important in relation to the abandonment of winegrowing areas (Costantini et al., 2016; del Río et al.,2021; Esteban Rodríguez and Fernández Portela, 2021).

The first configuration (1a) describing the presence of high abandonment (absence of PDO AND depopulation AND absence of subsidies) can be labelled “demographic distress” or “lack of support”. It suggests

Table 5
Analysis of necessary conditions.

	High abandonment			Low abandonment		
	Cons. Nec	Cov. Nec	RoN	Cons. Nec	Cov. Nec	RoN
PDO	0.349	0.383	0.665	0.654	0.737	0.823
Modernisation	0.480	0.491	0.679	0.597	0.628	0.743
Subsidies	0.493	0.503	0.682	0.607	0.636	0.746
Depopulation	0.433	0.620	0.834	0.312	0.459	0.779
Size	0.543	0.561	0.714	0.551	0.585	0.725
~PDO	0.761	0.682	0.720	0.452	0.417	0.583
~Modernisation	0.636	0.606	0.702	0.516	0.505	0.652
~Subsidies	0.643	0.614	0.708	0.526	0.516	0.659
~ Depopulation	0.622	0.468	0.497	0.742	0.574	0.552
~Size	0.598	0.564	0.677	0.586	0.569	0.680

NOTE: The symbol “~” means that a condition is absent; the indicator of consistency for necessity is Cons. > 0.9 (Schneider et al., 2010); Cons = consistency; Cov = coverage; Nec = necessity; RoN = relevance of necessity.

Table 4
Calibration and descriptive statistics.

	Descriptive statistics						Calibration anchors		
	Max		*Min*		*Mean (SD)*		*Fully in*	*Crossover point*	*Fully out*
Abandoned vineyard	143.37		0.02		7.83 (18.26)		6.55	2.35	0.71
PDO	43.55		0.00		4.18 (6.94)		7.75	0.99	0.00
Modernisation	92.90		0.00		9.30 (16.27)		12.52	2.61	0.00
Subsidies	95580.19		0.00		15799.51 (15572.99)		22985.25	11827.07	4880.26
Size of plot	2.74	0.06	0.47 (0.39)	0.65	0.37	0.22			
Depopulation	6.00		0.00		2.13 (2.61)		6 = 1; 5 = 0.8; 4 = 0.6; 0 = 0		

Note: The outcome and the conditions PDO, modernisation, subsidies and size plot were calibrated using the direct method (Ragin, 2009). The condition depopulation was calibrated using the indirect method.

Table 6
Analysis of sufficient configurations for the entire region.

	High abandonment			Low abandonment			
	1a	2a	3a	1b	2b	3b	4b
PDO	○	○	○	●	●		●
Modernisation			○		○		●
Depopulation	●		●		○	●	●
Subsidies	○	○		●		●	
Size		●	○			●	●
Consistency	0.840	0.798	0.854	0.815	0.820	0.795	0.929
PRI	0.779	0.699	0.796	0.748	0.718	0.601	0.892
Raw coverage	0.285	0.265	0.267	0.412	0.242	0.087	0.070
Unique coverage	0.041	0.165	0.056	0.247	0.980	0.033	0.024
Overall solution consistency	0.823			0.808			
PRI solution	0.756			0.739			
Overall solution coverage	0.507			0.570			

Note: Frequency cut-off for analysis of high abandonment = 1; Consistency cut-off for analysis of high abandonment = 0.78; Direct expectation for analysis of high abandonment (0, 0, 0, 1, 0). Frequency cut-off for analysis of low abandonment = 1; Consistency cut-off for analysis of low abandonment = 0.80; Direct expectation for analysis of low abandonment (1, 1, 1, 0, 1). As per the notation of Fiss (2011), black circles (●) indicate the presence of conditions, whereas white circles (○) indicate the absence of conditions. PRI = proportional reduction of inconsistency.

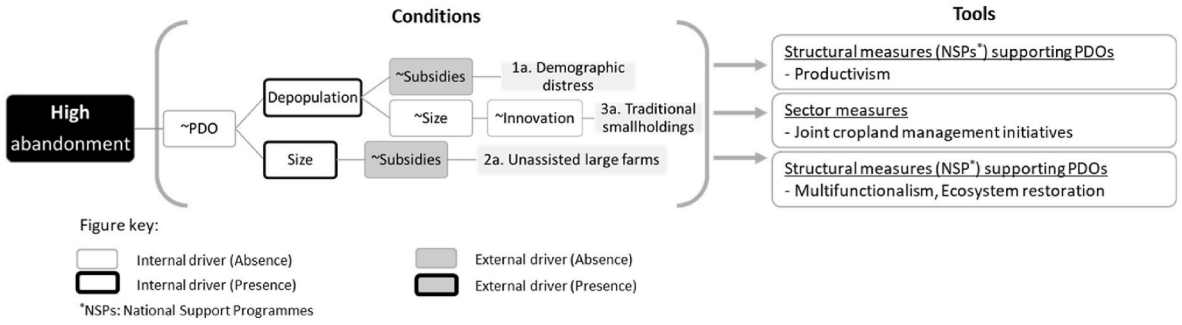

Fig. 3. Combinations of factors describing the presence of high abandonment of vineyards.

that municipalities at risk of depopulation with plots that are not part of PDOs and that have little CAP support tend to have high levels of abandonment, confirming Propositions 1, 2 and 3. The combination of two internal drivers (absence of PDO and depopulation) with an external driver (absence of subsidies) leads to abandonment. This configuration reflects vineyard restructuring and reconversion (subsidies). PDOs offer a strong driver for balanced regional development to compensate for the production difficulties of depopulated areas. Such measures would be defined by Dolton-Thornton (2021) as policy options that combine holistic rural development strategies with productivism.

Configuration 2a describe the presence of high abandonment (absence of PDO AND large plots AND absence of subsidies) can be labelled "unassisted large farms". It suggests that large non-PDO plots without CAP subsidies tend to be abandoned. This finding supports Propositions 1, 2 and 4. Thus, land accumulation alone is not sufficient to stop abandonment if not combined with other conditions. This configuration differs from the previous one in that it contains plot size rather than depopulation as a causal condition. This may be one of the mechanisms that may drive the abandonment in areas with high land use pressure due to urbanisation and industrialisation, which can lead to gentrification (Kan, 2021; Lorenzen, 2021; Phillips et al., 2021). Cossart et al. (2020) studied the abandonment of vineyards in France in non-marginal areas. They showed that winegrowers tend to abandon vineyard plots because of the difficulty of maintenance (remote and steep plots) and because of the opportunity to convert plots into building land. Larger plots are easier to sell to create new areas for construction or a new agricultural activity. Policies aimed at the restoration of ecosystems, the revalorisation of rurality, outdoor life and sustainable rural tourism can favour the permanence of wine production to the detriment of urban use of this land.

The third configuration (3a) describing the presence of high abandonment (absence of PDO AND depopulation AND absence of large plots AND absence of modernisation can be labelled "traditional smallholdings". This configuration shows that the combination of municipalities at risk of depopulation with small, non-modernised, non-PDO plots leads to crop abandonment. This configuration supports Propositions 2, 3, 4 and 5. This configuration combines all internal drivers but does not include the external driver (subsidies). These are family farms operating with limited resources. Lack of investment in modernisation not only makes it difficult to obtain optimal production, but can also reduce yields, compromise quality, and increase production costs (Calafat-Marzal et al., 2023b). In depopulated areas, labour force limitations further aggravate this situation (Alamá-Sabater et al., 2021). Hence, it suggests that the sector itself should promote measures to mitigate abandonment in depopulated areas by modernising and increasing the size of farms. One way of making plots larger is through land consolidation based on common land management (Calafat-Marzal et al., 2022; Piñeiro et al., 2021). These combined plots could be led by PDOs or production cooperatives to strengthen the impact of their social capital and provide economies of scale (Kumar et al., 2018; Ma and Zhu, 2020).

Fig. 4 shows four configurations leading to low levels of abandonment. In three configurations (1b, 2b and 4b), PDO membership is combined with other drivers to curb land abandonment, supporting Proposition 2. However, one combination (3b) does not depend on the PDO, failing to confirm Proposition 2. These results are consistent with the scientific literature in identifying PDOs as regional drivers that curb abandonment (de Uña-Álvarez and Villarino-Pérez, 2019; Garcia-Galan et al., 2014). However, they go further by indicating that there are routes in which PDOs may be necessary and others in which PDOs are not.

Configurations 3b and 4b show configurations for low abandonment

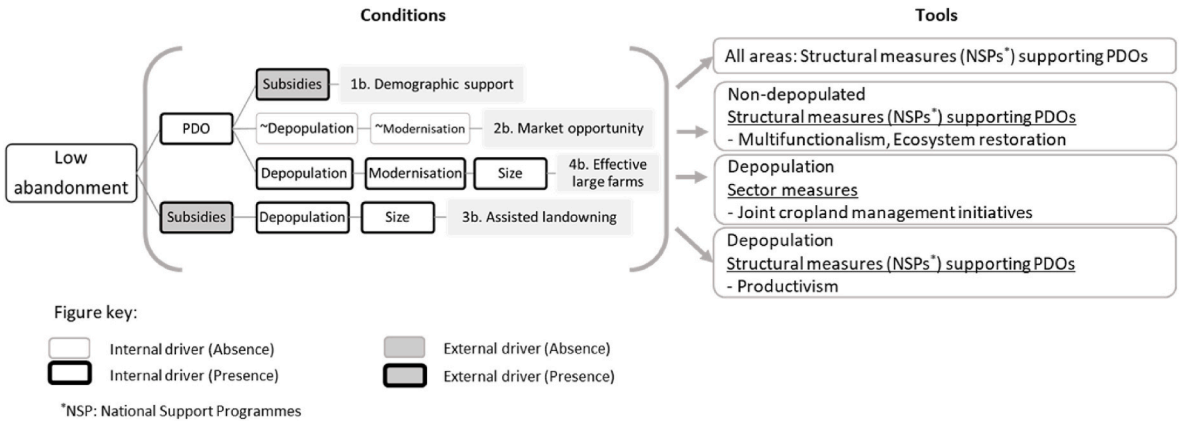

Fig. 4. Combinations of drivers leading to low land abandonment rates.

of areas with demographic constraints. Configuration 3b (subsidies AND depopulation AND size) can be labelled "assisted landowning". This configuration suggests that municipalities at risk of depopulation with large plots and external support can mitigate the effect of abandonment. In this case, policy measures are based on productivism for larger plots, corresponding to the measures defined for Configuration 1a. This configuration that combines the subsidies with larger plot sizes are in line with Pomarici and Sardone (2020), which indicates that CAP measures provide support for winegrowers to adopt farming practices that allow them to be more resilient.

In the combination 4b of drivers leading to low abandonment (PDO AND depopulation AND modernisation AND size), all internal drivers are present. It can be labelled "effective large farms". This configuration can be compared to Configuration 3a, which also comprises all internal drivers. In both configurations the size of the farms has a direct influence, coinciding with the results of Debolini et al. (2018) and Wyler et al. (2023) indicating that they are more suitable for the use of machinery. Configuration 4b applies to municipalities with large, modernised, PDO-associated plots that experience depopulation but have low abandonment. This configuration highlights the positive role of PDOs in preventing land abandonment in areas with demographic challenges (Bollati et al., 2015; Costantini et al., 2016; del Río et al., 2021). This beneficial impact is attributed to the revaluation of local markets and openness to internationalization, which, in turn, fosters the development of local entrepreneurs (de Uña-Álvarez and Villarino-Pérez, 2019; Fernández-Aldecua et al., 2017). This finding implies that land consolidation through the joint management of PDOs is an effective measure. The two configurations apply to areas at risk of depopulation. They show two ways to mitigate agricultural abandonment. The first is primarily based on measures taken by the sector itself (PDOs, increase in size and modernisation), whereas the second also relies on public policies (subsidies).

The combination of driver leading to low abandonment in Configuration 2b (PDO AND absence of depopulation AND absence of modernisation) can be labelled "market opportunity". It suggests that in municipalities without demographic problems and with non-modernised traditional plots, growers must belong to PDOs to reduce abandonment. This configuration may offer a response to Configuration 2a for coastal or intermediate areas, where there is greater conflict over land use due to urbanisation and industrialisation intensification. In these areas, vineyard abandonment is more related to the existence of alternative land uses (e.g. urbanization pressure) than to aspects such as difficulty of management and labour intensity (Wyler et al., 2023). Traditional winegrowing plots are not abandoned thanks to the promotion of service sector activities such as tourism, which provide alternatives to wine production (Fernández-Aldecua et al., 2017; Espejel and Fandos, 2009; Garcia-Galan et al., 2014). Such municipalities are helped by PDOs to offer more well-organised and professional services.

Finally, Configuration 1b, which leads to low abandonment, combines PDO membership and CAP support, without regional differentiation. It can be labelled "demographic support". This configuration mitigates abandonment, regardless of land use pressure. These drivers are not necessary on their own. However, the combination of the two is sufficient to mitigate abandonment. This configuration is in line with the literature addressing the importance of holistic policies to avoid abandonment (Dolton-Thornton, 2021; Lieskovský et al., 2013) and the opportunities of PDOs for sustainable competitive advantage (Garcia-Galan et al., 2014).

The results show that in the configurations for low land abandonment, the conditions of PDO membership and subsidies are present individually or jointly. These findings show the importance of policies and the recognition of regional quality in the wine sector for depopulated regions with large plots and regions characterised by smallholdings.

8. Limitations

This study addresses the challenge of vineyard abandonment, a process influenced by an amalgam of factors, some objective, and others subjective, which are difficult to quantify statistically. We have adopted a pragmatic approach, focusing on the physical and socioeconomic aspects that most influence vineyard abandonment. We have highlighted and compared the most objective and quantifiable causes, such as the structural characteristics of vineyard plots, CAP subsidies and the demographic environment.

Despite the inherent limitations of our study, such as the impossibility of addressing socioeconomic factors and individual conditions of winegrowers, as well as the lack of detailed information on the circumstances that may lead to vineyard abandonment (such as the age of winegrowers or the lack of generational succession), our methodological approach allows us to obtain understandable and easy-to-replicate causal configurations. This, in turn, provides us with a reference point for the formulation of measures and policies to support the wine sector.

9. Conclusions

The European wine sector is heavily regulated by the CAP. This situation affects decisions on land use. The sector aid programme within this regulatory framework is described in all studies as a necessary condition for development and thus for preventing the abandonment of crops. However, the results of the current study suggest that this condition is sufficient rather than necessary. The wine sector is a competitive sector, and CAP aid is not essential for its survival. However, this aid is a force for slowing abandonment, as reflected by various configurations found in the current analysis. Moreover, a lack of aid is a sufficient condition for abandonment in several configurations. In other words,

abandonment is greater in the absence of subsides, absence of PDO membership, presence of risk of depopulation or presence of smallholdings. Public measures should be adapted to the demographic conditions of each municipality. They should target productivism for municipalities with unfavourable conditions. In contrast, they should target multifunctional ecosystem restoration for municipalities with greater land use pressure. Such measures promote tourism-based service sector activities.

The most important internal conditions are PDO membership and location, and in second place, plot structure (size and degree of modernisation). The study reveals that these conditions are not necessary. However, they may be sufficient in several configurations. Despite being a non-necessary condition, belonging to a PDO drives regional development, contributing to maintaining landscape heritage and preventing crop degradation. This condition should be emphasised in national support programmes to mitigate abandonment. Depopulation should also be included in programmes to curb abandonment to correct imbalanced regional development in disadvantaged areas. Configurations targeting these areas result from both the promotion of public measures and PDO-led sector restructuring, such as joint land management initiatives.

This study opens the way for research applying similar methodological approaches in other countries or at different regional levels. It highlights the physical potential and constraints of winegrowing areas. It can help improve the regional planning of different production systems. Similar approaches could also be applied to other high-quality foods such as olive oil, coffee, and cheese. These products have both quality seals and PDOs. To enhance the understanding of specific domains, surveys can be conducted. These surveys should collect data on internal economic variables within vineyards, as well as external variables such as changes in demand or economic competition. This comprehensive approach enables profiling of both general and individual behaviours associated with vineyard abandonment.

CRediT authorship contribution statement

Consuelo Calafat-Marzal: Conceptualization, Data curation, Formal analysis, Investigation, Resources, Supervision, Visualization, Writing – original draft. **Veronica Piñeiro:** Data curation, Formal analysis, Investigation, Methodology, Supervision, Visualization, Writing – original draft. **Norat Roig-Tierno:** Formal analysis, Investigation, Methodology, Project administration, Software, Visualization, Writing – review & editing. **Mercedes Sánchez-García:** Conceptualization, Formal analysis, Funding acquisition, Project administration, Validation, Visualization, Writing – review & editing.

Declaration of competing interest

We wish to confirm that there are no known conflicts of interest associated with this publication. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property. We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). He is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jrurstud.2023.103159.

Appendix 1

Literature review of drivers of land abandonment

Authors	Driver	Data	Econometric approach	Result
Alamá-Sabater et al. (2019)	Socioeconomic	Regional database	Mixed approach (QCA and ESDA)	Factors that lead to depopulation
Aldecua et al., 2017	Market value	Case study	Qualitative approach (Social Network Analysis)	Importance of creating and strengthening intra-regional links
Ashenfelter and Storchmann (2016)	Institutional/Policy	Literature review	Qualitative approach	How climate change is likely to affect wine economics. Possible adaptation strategies
Beccaria and Pretto (2021)	Structural	Interviews	Qualitative approach	Socio economic factors led to changes in the culture and consumption of alcohol
Bollati et al. (2015)	Market value, Socioeconomic; Structural	Case study	Quantitative approach (Bioclimatic indices and GIS)	Suitability map distinguishing sectors for wine production in a vine cropping area
Bruno et al. (2021)	Socioeconomic	Demographic data and ecosystem services	Quantitative approach (Additive and Linear Mixed Models)	Depopulation trends affected land use and the ecosystem services evaluated
Burton and Otte (2022)	Structural	Survey	Quantitative approach (Cluster analysis)	Link between farm family life-cycle and climate change mitigation
Carbone, 2021	Institutional/Policy Socioeconomic	Case study	Qualitative approach (literature review)	Sector increasingly polarised between large leading groups and small producers

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Authors	Driver	Data	Econometric approach	Result
Cossart et al. (2020)	Structural	Surveys, stats, cadastral plots	Quantitative approach (Case study)	Factors for land abandonment
Costantini et al. (2016)	Socioeconomic	Public stats	Quantitative approach (multivariate analysis)	The different WESs of a country are influenced by specific landscape characteristics
Debolini et al. (2018)	Socioeconomic Institutional/Policy	Literature review	Mixed approach (Case studies)	Social and demographic drivers relevant for abandonment; intensification processes
Deconinck and Swinnen (2015)	Market value Institutional/Policy	Planting rights	Mixed approach (conceptual model of planting rights system)	Differences between states on restrictions to trade in planting rights
del Río et al.,2021	Socioeconomic	Data from regional vineyards	Quantitative approach (statistical techniques)	Integrated methodology to optimise and delimit suitable areas for wine production
Delord et al. (2015)	Structural, Market value	FADN database	Quantitative approach (Multiple Correspondence Analysis)	Wine selling price is more relevant than farm size respect to farms performances
de Uña-Álvarez and Villarino-Pérez (2019)	Market value	Interviews	Qualitative approach	Cultural landscape and its intangible value are highly relevant in modern wine culture
Dolton-Thornton (2021)	Institutional/Policy Socioeconomic	Viewpoint	Quantitative approach (Policy analysis)	Responses to land abandonment need holistic development programmes
Espejel and Fandos (2009)	Market value	Personal questionnaire	Quantitative approach (SEM)	PDO influence on consumers
Esteban Rodríguez and Fernández Portela (2021)	Market value, Structural	Public stats	Quantitative approach (production worlds model)	Two types of guidance for PDO
García Garcia-Galan et al., 2014	Structural	Irrigation experiment	Quantitative approach (Cost-benefit analysis)	More efficient irrigation systems are no more economically viable in some circumstances
Garcia-Galan et al. (2014)	Market value	Semi-structured in-depth interview	Qualitative approach	PDO as opportunity for sustainable competitive advantage
García-Ruiz et al. (2020)	Socioeconomic	Literature review	Qualitative approach	Ecological restoration opportunity
Garcia-Galan et al., 2014	Structural	Farmers interviews	Qualitative approach (social cognitive map)	Farmers adopt agroecological practices mainly by choice
Graveline and Grémont (2021)	Structural	Internet-survey data and terroir data	Quantitative approach (econometric models)	Terroir and socio-economic factors significant in irrigation adoption
Jiménez-Olivencia et al. (2021)	Socioeconomic	Systematic review	Qualitative approach (case study)	Causes and consequences of the changes in land use in the mountain regions
Lammoglia et al. (2019)	Socioeconomic	Data from regional vineyards	Quantitative approach (Geosimulation)	Simulation to understand the spatial dynamics of wine at the municipal scale
Lasanta et al. (2017)	Structural, Socioeconomic Institutional/Policy	Literature review	Qualitative approach (Case studies)	Internal and external causes of abandon
Leimer et al. (2022)	Structural	Survey data	Quantitative approach	Land transactions depend on the location and infrastructure of the plots
Lieskovský et al. (2013)	Institutional/Policy Socioeconomic, Structural	Statistical and Corine Land Cover data	Quantitative approach	Importance of policies to protect small scale vineyards in Slovakia
MacDonald et al. (2000)	Institutional/Policy Socioeconomic	Literature review	Qualitative approach (case study)	Agri-environment policy in relation to land abandonment
Marx et al., 2014	Institutional/Policy	Global stats and National Support Programme	Quantitative approach (Macroeconomic analysis)	Distribution of wine policies
Meloni et al. (2019)	Institutional/Policy Market value	Public stats	Mixed approach (policy analysis)	Overview and analysis of global wine regulations
Murin et al. (2022)	Socioeconomic	Case study	Quantitative approach (anthropological analysis)	Depopulation can be reversed by turning to more sustainable communities
Pomarici and Sardone (2020)	Institutional/Policy Market value	Wine policies, synthetic indicators, etc	Mixed approach (Analytical evaluation)	Overview of EU wine policy, and a perspective on the evolution
van Vliet et al. (2015)	Structural, Socioeconomic Institutional/Policy	Systematic review	Mixed approach (Case studies)	Intensification/disidentification drivers
Vinatier and Arnaiz (2018)	Institutional/Policy	Database of aerial pictures	Quantitative approach (Land use changes analysis)	Change in land management through a severe transformation of vineyards areas

Note: External drivers: Institutional/Policy; Internal drivers: Market value, Socioeconomic; Structural drivers.

Appendix 2

Robustness test

Frequency cut-off for analysis of high abandonment = 2; Consistency cut-off for analysis of high abandonment = 0.78; Direct expectation for analysis of high abandonment (0, 0, 0, 1, 0).

	inclS	PRI	covS	covU
~PDO*~Subsides*Depopulation	0.840	0.779	0.285	0.041
~PDO*~Subsides*Size	0.798	0.699	0.265	0.165
~PDO*~Modernisation*Depopulation*~Size	0.854	0.796	0.267	0.056
Solution	0.823	0.756	0.507	

Note: (*) is logical operator AND; (~) means absence of condition.

Frequency cut-off for analysis of low abandonment = 2; Consistency cut-off for analysis of low abandonment = 0.80; Direct expectation for analysis

of low abandonment (1, 1, 1, 0, 1).

	inclS	PRI	covS	covU
PDO*Subsides	0.815	0.748	0.412	0.247
PDO*~Modernisation*~Depopulation	0.820	0.718	0.242	0.098
Subsides*Depopulation*Size	0.795	0.601	0.087	0.033
PDO*Modernisation*Depopulation*Size	0.929	0.892	0.070	0.024
Solution	0.808	0.739	0.570	

Note: (*) is logical operator AND; (~) means absence of condition.

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