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Drivers of winegrowers' decision on land use abandonment based on exploratory spatial data analysis and multilevel models

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ABSTRACT

The frequency of producers opting to abandon agricultural land has become increasingly, highlighting the significance of this phenomenon due to its environmental, landscape, and socio-economic impacts. The decisions of producers to abandon or maintain/improve their farms depend on individual and contextual factors. The aims of this research are twofold. Firstly, to evaluate the influence of the neighbours on the winegrowers' decisions, using spatial analysis. Secondly, to clarify the specific importance of each of the individual and contextual drivers in farmers' decisions to improve their farms, to keep them unchanged or to abandon them, using multilevel models. The results obtained for the case study of vineyards in Spain, reveal a strong agglomeration phenomenon in farmers' decisions indicating that producers make land use decisions influenced by what their neighbours do. A multilevel analysis identifies that individual factors are determinant and that the influence of contextual factors is conditioned by the innovation process at farm level. Individual drivers, such as size, innovation, Protected Designations of Origin and irrigation influence vineyard area, with irrigation having the greatest overall influence, and is expected to be decisive in climate change projections. The Protected Designations of Origin are driving forces that dynamize the territory and achieve productive concentrations, encouraging winegrowers to replant, but they are not enough to halt abandonment. The elements that slow down the abandonment of plots are irrigation and the combination of innovation and context variables, mainly the combination of modernised plots in the municipalities with trading options.

1. Introduction

In recent decades, the decision of producers to abandon agricultural land has become increasingly frequent, as shown by the growing scientific literature on the causes of agricultural abandonment, given the importance of this phenomenon due to its environmental, landscape and socio-economic impacts (Fayet et al., 2022; Lasanta et al., 2017; Movahedi et al., 2021). But some producers make decisions that are opposed to abandonment and instead improve or extend the cultivation area, through replanting or new plantations, i.e., carrying out modernisation processes, through innovation in processes and products to achieve better quality and competitiveness of their products (Lopez-Castro et al., 2020) and improving environmental sustainability (Dessart et al., 2019). An example of this dynamic of agricultural producers and sectoral complexity is the wine sector. The political economy of the wine sector has expanded over time and across political systems (Meloni and Swinnen, 2021), decisively influencing producers' decisions.

Economic models of crop area changes assume that land use decisions are made by farmers who maximise their profits and compare the returns to alternative land uses (Hendricks and Er, 2018). These decisions may be based on individual factors that benefit the producer in economic terms (Neuenfeldt et al., 2019), contextual factors, such as agricultural policy instruments (subsidies, tariffs, trade quotas, etc.) (Neuenfeldt et al., 2019), and market, geographical, social, cultural, and environmental constraints (Castillo-Valero et al., 2017). Other studies highlight the socio-demographic characteristics, such as educational level, age, gender (Tzanopoulos et al., 2012) and the membership of producer organisations (Nainggolan et al., 2013).

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This literature review reveals that the decisions of producers, and as an example winegrower, are influenced by many different factors, but few studies predict the behaviour of producers due to different factors together.

These decisions affect the vineyards area in the world, which it seems to be stable in global terms, but there are decreasing trends in some countries, especially in Europe, while other countries show a clear increase, especially in China (Ayuda et al., 2020; International Organisation of Vine and Wine, 2022). Five countries account for half of the world's vineyard area, with Spain contributing 13% of the world's vineyard area, followed by China (12%), France (11%), Italy (9%) and Turkey (6%). Spain is one of the countries that is losing the most area (Ministerio de Agricultura, 2020), with a decrease of 19.3% in 2000/2001 (26,728 ha). In many areas, this decrease in vineyard areas has not led to increase in alternative crops (mainly rainfed crops such as almonds or olives), resulting an increase the cropland abandonment areas (Fayet et al., 2022), with a consequent loss of the heritage and composition of the landscapes (Fayet et al., 2022), especially in areas at risk of depopulation (Lieskovský et al., 2013). On the opposite site, continuous advances in sectoral innovation have allowed for better yields and lower environmental impacts (Lopez-Castro et al., 2020), favouring the maintenance of vineyards, or the implementation of replanting or new plantings.

This study aims to predict the winegrower's behaviour, in terms of changing (abandoning or improving cultivation) or maintaining the cultivation areas, differentiating whether the producer is influenced by individual factors (specific to each production plot) and/or by contextual factors and what is the degree of importance of each factor (greater probability of causing changes), by using multilevel methodology, that differentiates between individual and contextual variables, and cross interaction, paying particular attention to innovation. The wine sector is analysed, as a dynamic agricultural sector, in a European Mediterranean region, such as the Valencian Community (VC) in Spain, with high land use conflicts (Recatalá et al., 2000) and with small and stratified agricultural areas. In this area all plots have similar climatic conditions (Castillo-Valero et al., 2017) and the suitability of wine cultivation and quality wine production is encompassed in two Protected Designations of Origin (PDO[1]) that define the terroir with similar viticultural and oenological characteristics, and where the behaviour of international markets affects them in the same way (Castillo-Valero et al., 2017).

1.1. Literature review and hypotheses

The analysis of the agricultural decisions-making of producers using a geostatistical analysis indicates whether decisions on land use are influenced by other nearby producers or whether they are random behaviours according to the objectives of each producer. Paroissien et al. (2021) study the neighbours' influence in farmers in France, and identify that neighbour generate positive agglomerations economies, such as better access to suppliers and workforce, and faster technological transfer, but these positive spillovers may be positively related to the density of farmers, but also to their overall size and performance. Pastonchi et al. (2020), by a geostatistical analysis of vineyard surfaces, obtained to zoning of the terroir with homogeneous areas or differentiated management. To analyse whether winegrowers make decisions conditioned by other nearby producers, thereby generating trends and/or clusters, the first research hypothesis is put forward:

H1. . Producers make land use decisions influenced by what their immediate neighbours do.

The agricultural producer's behaviour in Europe has been strongly conditioned by agricultural policies (Pomarici and Sardone, 2020; Tieskens et al., 2017). EU agricultural policies and their funding have set out important prescriptions, both in terms of spending and regulatory measures for the 2014–2020 programming period. Underlining three main objectives as guidelines for European action in agriculture: viable food production, sustainable management of natural resources and climate action and, finally, balanced territorial development (European Commission, 2019, 2018; European Commission for Agriculture and Rural Development, 2020; European Parliament, 2015, 2012). The study by Pomarici and Sardone (2020), highlights that the policies related to this third objective are the system of authorisations for vineyard planting, Direct Payments (Regulation 1307/2013) and Rural Development Measures (Regulation 1305/2013). Structural measures (promotion, restructuring and conversion of vineyards, investment, innovation in the wine sector, by-product distillation), except for innovation, are the most funded by member states. The beneficiaries of these support measures are not only winegrowers; only three measures are exclusively targeted at farmers, and the others target a wider range of actors involved in wine production or marketing. The inclusion among the beneficiaries of expenditure measures of non-strictly agricultural actors is due to the structure of the European wine industry and the nature of wine grapes. Wine grapes assume value only as an input to the wine production process, but their perishable nature gives them a limited exploitation in space and time; therefore, to guarantee value for the grapes, it is necessary to ensure the existence of a viable processing sector (vinification and bottling). These production phases do not always take place on the farm, emphasising the important role of non-agricultural actors; this is particularly true if they are located in or near grape-growing areas, especially with regard to the production of wines identified with their geographical origin (European Parliament, 2017; Pomarici and Sardone, 2020), or in agriculture farm in general based on the production specialisation (Neuenfeldt et al., 2019). Thus, the following hypotheses are put forward:

H2. . Agricultural plots located in areas with high productive specialisation are more likely to remain in production and less likely to be abandoned.

H3. . Agricultural plots located in areas with companies that sell their production are less likely to be abandoned.

H4. . Agricultural plots located in areas receiving more support from the Common Agricultural Policy (CAP) support are less likely to be abandoned.

Some studies show PDOs as a positive factor to avoid land abandonment and contribute to dealing with the demographic challenge (del Río et al., 2021). The establishment of a PDO must be accompanied by other factors that favour the development of the activity in the region and the consequent settling down of the population (Bollati et al., 2015). This leads us to propose the following hypothesis:

H5. . Agricultural plots belonging to PDO are more likely to remain in production and less likely to be abandoned.

The size of the farms may condition the development of the sector (Neuenfeldt et al., 2019; Vinatier and Arnaiz, 2018) and the innovation-oriented practices that facilitate greater adaptation and more dynamic management (Giannoccaro and Berbel, 2011). Smallholdings with small plot sizes, low production, high fixed costs, and consequently low profitability, favour the abandonment (Lasanta et al., 2017). In Spain, Heider et al. (2021) mention 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. Consequently, we posit that:

H6. . Larger plots are more likely to remain in production and less likely to be abandoned.

Innovation in vineyards is recommended technologies for greater efficiency in wine production and adaptation to the region (Pastonchi

[1] Appendix 3 includes the abbreviations used in the manuscript.

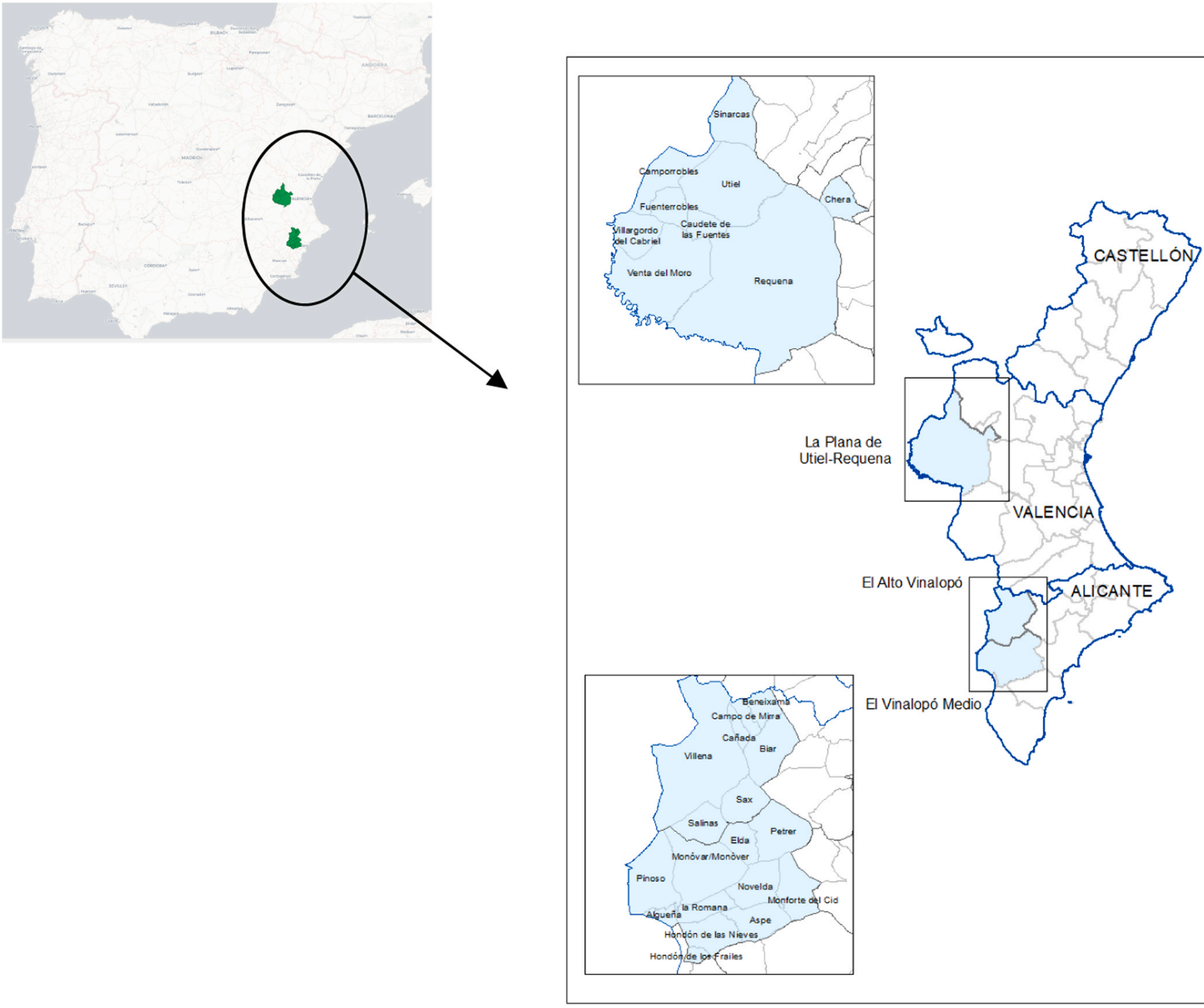


Fig. 1. Study Area.

et al., 2020) such as trellis training systems (process innovation), in addition to the availability of drip irrigation systems (Ortuani et al., 2019) and international varieties (product innovation). In this regard, the following two hypotheses:

H7. . Plots with a higher degree of innovation are more likely to remain in production, and less modernised plots are more likely to be abandoned.

2. Methodology

2.1. Study area

The study area (Fig. 1) is VC, a region located in the east of Spain, which is part of the western Mediterranean area of Europe, with a surface area of 23,255 km2. It is home to around 5 million inhabitants and the agri-food sector accounts for around 12% of its GDP (Generalitat Valenciana, 2020). The potential for wine production in the VC in 2020 is 61,002 ha. 94.5% of the wine production potential corresponds to the area planted with vines. The total area decreases of 23.3% (MAPA, 2020). This decrease in vineyard area has led to a concentration of vineyards mainly in the inland area of CV, specifically in two regions (Fig. 2): Utiel Requena (Valencia), Vinalopó (Alicante).

The data used were provided by the vineyard registry of the VC in 2020. The vineyard register is the most complete on the characteristics of the plots, being very rigorous in the planting rights of the plots in production. The register of abandoned plots provides information on the characteristics of the plots, but the study of MAPA (2020), Perpiña-Castillo et al. (2020) and Perpiña Castillo et al. (2021) indicate that the number of abandoned plots is much higher than indicated by this register. Nevertheless, they have been used in the study because they are the most reliable data on the characteristics of abandoned plots. The total sample of the study is 67328 vineyard plots, of which 1015 are abandoned, 3022 are new plantings, 31272 are replanting and 32019 are in production and there have been no modifications of rights on the plot.

The studied areas are in PDO zones, namely PDO Utiel-Requena in Valencia and PDO Alicante in Alicante. The production obtained in these areas is not marketed in its entirety under the PDO label.

2.2. Sample and data collection

The land use decisions of winegrowers (dependent variable) are analysed in terms of individual and contextual factors (independent variables). Fig. 2 describes how the factors and the interactions between them have been classified.

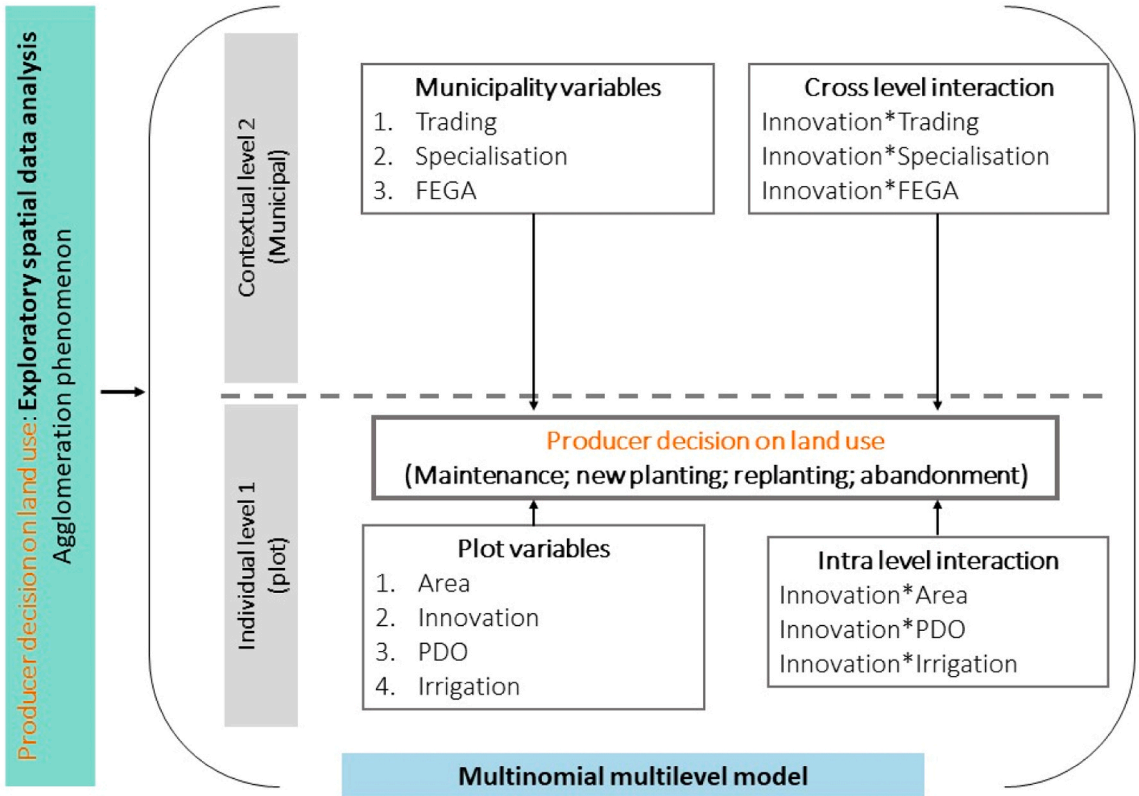


Fig. 2. Methodology workflow.

Table 1
Description of level 1 variables (plots).

Variable	Description
Area	Plots with a percentile equal to or greater than 75 (large plot); index 1. Plots with a percentile equal to or less than 25 (small plot); index 0. Plots between the 75th and 25th percentile; index equal to the percentile value.
Innovation	Varietal improvement: 1; Production mode improvement (a trellis for wine vineyard; trellis and/or tutor for table grape vineyard): 0.5; Modernisation (varietal improvement + production mode): 1.5
POD	If it belongs to PDO= 1; If it does not belong to PDO= 0
Irrigation	Calibration of the variable for the models: Irrigated = 1; Rainfed = 0

Table 2
Description of the Level 2 variables (Municipal).

Variable	Description	Source
Trading	Number of certified sales enterprises in the municipality	Own elaboration based on certified and authorised wineries in the designations of origin.
Specialisation	If the municipality has most of the Useful agricultural land (UAA) in vineyards. If the value is > 50%, 1 is assigned; if < 50%, 0 is assigned.	Own elaboration based on the Useful agricultural land by crops in 2019 from the Valencian Institute of Statistics.
FEGA	If the municipality receives more CAP aid than the county average, it is assigned a 1; if it receives less, it is assigned 0.	Own elaboration based on Spanish Agricultural Guarantee Fund (2019); Ministry of Agriculture, Fisheries and Food

The dependent variable represented by the planting right granted, which are conditioned by the independent variables. The planting rights of the vineyard register have been classified following the study by Castillo-Valero et al. (2017) into four categories: abandoned plots, new plantings, replanting or maintaining the land unchanged. It is a discrete variable which takes value 0 for plot abandonment; 1 for new planting; 2 for replanting; and 3 for maintaining unchanged.

The independent variables used are distributed over the two levels:

1. Level 1 (plot): Identifies individual plot characteristics (Table 1), calculated from the Valencian Community Wine Register 2020 (Generalitat Valenciana). To transform the variables into discrete variables, the transformations indicated in Table 1 have been carried out.

1. Level 2 (municipality): Conditions of the municipal environment, based on municipal indicators and the payments received from the Spanish Agricultural Guarantee Fund (FEGA) in 2019 The definition of the variables, the transform into discrete variables and sources used are explained in Table 2.

The descriptive statistics of level 1 variables are included in Table 3, with frequencies of each category, minimum, maximum, mean, and standard deviation and finally the Pearson's chi-squared test is conducted to describe the association between the categories established and the variables of level 1.

The plots are of average size (between the 25th and 75th percentile), with no significant differences depending on the producer's decision. The innovation process differs significantly: 39% of the abandoned plots have not any innovation process, while only 1.3% of the plots under maintenance have done. The plots that remained unchanged is the 80%, there are international varieties, while only 33% of the abandoned plots. Modernisation processes on the plots in production have been 18%, 11% and 20% respectively, but not even on 1% of the abandoned plots. Most new plantations belong to PDO, but this is not the case in the other situations. Most of the plots are irrigated, except for the maintained unchanged plots, where only 32.5% are irrigated. Chi-square values indicate that level 1 variables are associated with the planting rights

Table 3
Sample description according to Level 1 variables.

Category	Aband.	New planting	Re-planting	Maint.	Total	Min.	Max.	Mean	SD
No. of plots	1015	3022	31,272	32,019	67,328				
Area (N° of plots)									
Small (l<= 25th percentile)	183	587	5518	6381	12,669	0000	1000	0559	0359
	(18.03%)	(19.42%)	(17.65%)	(19.93%)	(18.82%)				
Medium (25th- 75th per.)	513	1509	14,952	17,565	34,539				
	(50.54%)	(49.93%)	(47.81%)	(54.86%)	(51.30%)				
Large (>= 75th perc.)	319	926	10,802	8073	20,120				
	(31.43%)	(30.64%)	(34.54%)	(25.21%)	(29.88%)				
Innovation (N° of plots)									
Without change (value 0)	399	601	6521	425	7946	0,0	1,5	0,95	0,3923
	(39.31%)	(19.89%)	(20.85%)	(1.33%)	(11.80%)				
Production mode (Value 0.5)	267	33	146	111	557				
	(26.31%)	(1.09%)	(0.47%)	(0.35%)	(0.83%)				
Varietals improve (Value 1)	341	1793	21,145	25,770	49,049				
	(33.60%)	(59.33%)	(67.62%)	(80.48%)	(72.85%)				
Modernising (Value 1.5)	8	595	3460	5713	9776				
	(0.79%)	(19.69%)	(11.06%)	(17.84%)	(14.52%)				
POD (N° of plots)									
Yes (Value 1)	0	1580	6950	235	8765	0	1	0,13	0337
	(0.00%)	(52.28%)	(22.22%)	(0.73%)	(13.02%)				
NO (Value 0)	1015	1442	24,322	31,784	58,563				
	(100.00%)	(47.72%)	(77.78%)	(99.27%)	(86.98%)				
Irrigation (N° of plots),									
Yes	547	1759	17,733	10,419	30,458	0	1	0,45	0498
	(53.89%)	(58.21%)	(56.71%)	(32.51%)	(45.24%)				
No	468	1263	13,539	21,600	36,870				
	(46.11%)	(41.79%)	(43.29%)	(67.46%)	(54.76%)				
Variable X-Variable Y	**Chi–sq**			**Contingency coefficient**			**p-value**		
Planting right-Area	2287.280			0.181			0.000		
Planting right-Innovation	15,422.831			0.432			0.000		
Planting right-POD	10,874.066			0.373			0.000		
Planting right-Irrigation	3979.870			0.236			0.000		

Table 4
Descriptive statistics of level 2 variables.

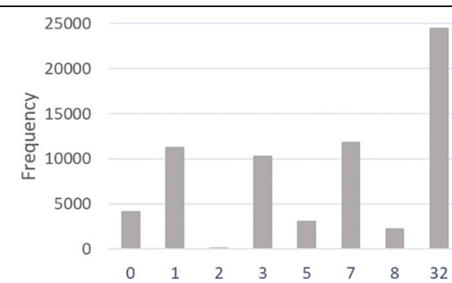
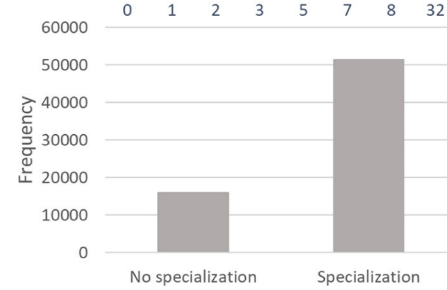
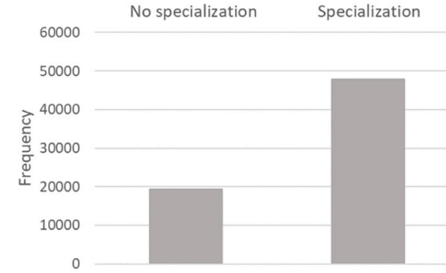
Variables	N	Min	Max	Mean	Std. Deviation	Frequency
Trading	67,328	0	32	13,97	13,789	
Specialisation	67,328	0	1	0,76	0425	
FEGA	67,328	0	1	0,71	0453	

Table 5
Moran's autocorrelation index I.

	Moran's index	*z-value*	*p-value*
Abandoned	0.484	4.0293	0.003
New planting	0.173	2.6550	0.017
Replanting	0.103	1.4560	0.086
Maintained unchanged	0.449	3.8474	0.004

granted (Chi-sq presents a p-value<0.05).

Table 4 show that 94% of the vineyard plots are in municipalities that have registered sales companies, 76% of the plots are in municipalities with a specialisation in vineyards and 71% are in municipalities that are active in receiving CAP aid.

2.3. Exploratory Spatial Data Analysis (ESDA)

The ESDA methods (Anselin et al., 2006) for evaluating agglomeration effects generated by the decision of winegrowers is used to answer the first research question (H1). Global spatial correlation (or dependence) is a description of spatial characteristics across the region, measured by the Moran I-index,[2] which can be expressed as follows:

$$I = \frac{N}{\sum_i \sum_j w_{IJ}} \frac{\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N} (x_i - \bar{x})^2} i \neq j$$

where N is the number of municipalities, x_i is the area in municipality i, x_j is the area according to the decision of the vine-grower in j, $\bar{x}$ is the average area and w_{ij} is a matrix of spatial weights, which defines whether geographical areas i and j are contiguous or not. The queen criterion was used as a contiguity criterion (Calafat et al., 2015; Calafat and Gallego-Salguero, 2020).

Local spatial autocorrelation (LISA) reveals the similarity or difference between the reference spatial unit and its eigenvalues of adjacent spatial units (Zhang et al., 2020), which allows for identifying, in this case, which municipalities have a higher weight in the overall Moran index. A positively autocorrelated cluster indicates that the percentage of vineyard area in each category is similar in all neighbouring municipalities (high-high or low-low), whereas a negative correlation indicates that, for example, if the percentage of abandoned area in one municipality is high, the opposite is true for neighbouring municipalities (high-low).

2.4. Multinomial logistic multilevel analysis

Multilevel models are applied on data sets that have a hierarchical structure (Gao et al., 2022). It is applied to the wine sector and data at level 1 and level 2 are combined, this being the advantage of these models. The probability of having correlated or non-independent data, when plots in the same municipality tend to show common characteristics, is resolved in these models.

The first step is the preparation and centering data according to Sommet and Morselli (2017). Level 2 predictor variable was used as the grand-mean centred (subtracting the general mean across level 2 units from the predictor variable), whereas a level 1 variable was used as the cluster-mean centred (subtracting the cluster-specific mean of the predictor variable).

[2] The range of values of Moran's I is [− 1, 1]. A value greater than 0 indicates the existence of a positive spatial correlation, a value less than 0 indicates a negative correlation and a value equal to 0 indicates no correlation, i.e. a random distribution. For the results of the analysis, the value significance test was used. At the significance level of 0.05, when the value was greater than 1.96, it indicated a significant positive correlation. Conversely, when the value was below − 1.96, it indicated a significant negative correlation.

The unconditional model (Null model) determines whether there is significant non-independence within groups on the outcome variable. A pre-condition for multilevel modelling is that statistical significance between-group variance exists for the dependent variable (Bliese, 2000). If the Interclass Correlation Coefficient (ICC) is large (about.05 being regarded as a conventional threshold) indicate substantial evidence of clustering and justifies proposing a model with predictors that can help explain this variance (Ronald, 2021).

The following steps include the models with the level 1 and 2 variables and interactions. Model 1 includes only level 1 variables. Model 2 includes the level 1 variables and intralevel interactions (innovation-area, innovation-PDO and innovation-irrigation). Model 3 adds -to Model 2- the level 2 variables. And finally, Model 4 incorporates the cross-level interactions to find out whether innovation in the plots depends on level 2 variables.

Logistic regression models are designed to predict the probability of a case falling into a target group (Y = 1) on a binary outcome variable. Because the probabilities are constrained to 0 and 1, the relationship between the predictors in a model and the outcome is inherently nonlinear (where the predicted probabilities follow an S-shaped curve; logistic curve). To "linearize" the relationship between predictors and the probability of a case falling into the target group, the transformation to a logit was performed using a linear logistic regression model. This model specifies the structural relationships between the independent variables and the predicted logits for each observation. The analysis of the results indicates the changes that may occur in the territory. The Exp (Coefficient) is the expected probability (Y=1, i.e., abandonment, replanting or new planting). To compute the expected probability of a plot of the municipality is abandonment, replanting or new planting is used the equation below (Sommet and Morselli, 2017):

$$P(abandonment, new \quad planting \quad or \quad replanting) = \frac{Exp(Coefficient)}{1 + Exp(Coefficient)}$$

The predicted probabilities from Model 4 were calculated and used to compute the Receiver Operating Characteristic (ROC) curve, and the corresponding area under the ROC curve (AU-ROC). The ROC curve consists of two main axes that represent performance metrics of a binary classification model. The vertical axis of the ROC curve displays sensitivity, which is the true positive rate. Sensitivity indicates the model's ability to correctly identify positive instances, and its value increases as it moves upward on the curve. The horizontal axis represents the false positive rate, which is the complement of specificity. The false positive rate indicates the proportion of negative instances that the model incorrectly classifies as positive. The AU-ROC represents the overall discriminative power of the model across all possible classification thresholds. It quantifies the probability that the model will rank a randomly chosen positive instance higher than a randomly chosen negative instance. The AU-ROC takes a value between 1 and 0.5 where 1 is perfect discrimination and 0.5 the covariates have no predictive power (Ivert et al., 2021).

Lastly, the initial situation can be compared with the predicted values to reflect the tendency established by the multilevel model.

3. Results of the empirical study

3.1. Exploratory spatial data analysis results

The spatial exploratory analysis of the data was carried out with GeoDa 1.20 free software (Anselin et al., 2006). Table 5 shows that the winegrowers' decisions have a marked agglomeration phenomenon at a significance level of 10%, supporting Hypothesis 1. This spatial pattern is closely related to wine terroir. It is a concept that refers to an area in which collective knowledge of the interactions between the environment and viticultural practices is developed, providing distinctive characteristics to the products. Costantini et al. (2016) identify different groupings of Italian winegrowers depending on the viticultural terroir,

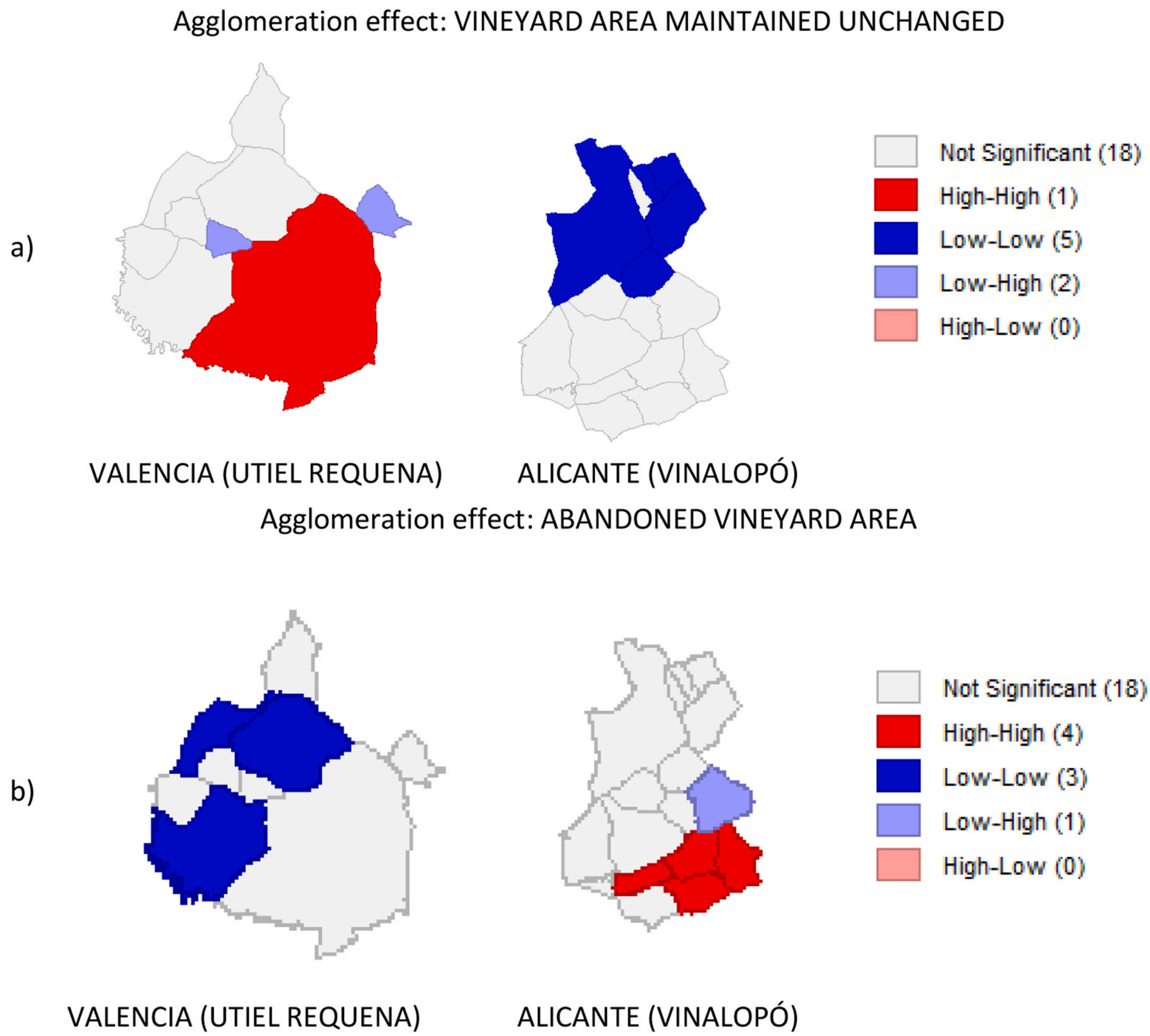


Fig. 3. Local autocorrelation of abandoned and maintained unchanged area.

and the results indicate that the decisions of winegrowers in a municipality in the same viticultural terroir will be closely related to the decisions made by their closest neighbours.

Abandoned areas and areas maintained unchanged have the highest positive spatial autocorrelation values, indicating a higher degree of area agglomeration.

Fig. 3 includes the resulting maps depicting the spatial distribution of local Moran's I indices for each municipality. It represents the spatial similarity between the values of each winegrowers' decision at a specific location and the values of the same variable in neighbouring locations. Each location on the map is coloured according to its local Moran's I value. Areas with high positive autocorrelation are highlighted with more intense colours, while areas with negative autocorrelation or no autocorrelation are represented with softer colours. A positively autocorrelated cluster indicates that the percentage of vineyard area in each category is similar in all neighbouring municipalities (high-high or low-low), whereas a negative correlation suggests that if, for example, the percentage of abandoned area is high in one municipality, it is the opposite for neighbouring municipalities (high-low). The results shown that the effect is different in the two study areas as shown in Fig. 3. The vineyard area that remains unchanged in Valencia (Fig. 3a) is in municipalities with a large area under maintenance, while in Alicante is in municipalities with a small area that remains unchanged. Regarding the abandoned surface area (Fig. 3b), in Valencia there is a predominant agglomeration of municipalities with a small area, and in Alicante is in an extensive abandoned area.

3.2. Multilevel model results

The multilevel model is multinomial, with four categories: abandoning, new plantations, replanting or maintaining unchanged. Maintenance is selected as the reference variable, so the model is interpreted as maintaining unchanged or making changes (abandoning, replanting, or new plantations). Table A1 (Appendix 1) includes the final table of the results of the multilevel multinomial model, including the expected probabilities showing the degree of importance of each variable.

ICC reveals that the percentage of the total variance of the dependent variable attributable to municipality-specific circumstances is 36.8%, 49.7% and 36.4% respectively. Conversely, it indicates that 63,2% for abandonment plots, 50,3% for new planting plots and 63,6% for replanted plots are explained by differences within municipalities. These results can be verified with the variance of the random intercept. The variance decreases progressively from one model to another as the variables are included in the models, showing that variables explain a higher percentage of the variance and a better model fitting. Tables 6, 7 and 8 include the variance of the random intercept and the percentage change from one model to another.

The models in Table 6 show the winegrowers' decision between either maintaining the plot or abandoning it. Model 1 in Table 6 shows that the significant variable is that the plot is irrigated. This variable has

Table 6
Estimation results for winegrowers' decisions: maintenance or abandonment.

	Null Model OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)	Model 4 Expected probability (%)
Level 1 (Individual)						
Intercept	2038	-4435 *	-4507 *	-5315 *	-5573 *	0,40
Area		,454 *	-,228 *	-,232 *	-,253 *	43,69
Innovation		-4237	-3653	-3650	-4199	1,48
PDO		-5585	-6752	-5742	-6644	0,10
Irrigation		-,142 * *	-,357 * *	-,355 * *	-,373 * *	40,79
Intralevel interaction						
Innovation*Area			-,516 * *	-,516 * *	-,766 * *	31,74
Innovation*PDO			4603	4605	4905	99,26
Innovation*Irrigation			-2019 * *	-2018 * *	-2279 * *	9,26
Level 2 (Municipal)						
Trading				-,044	-,033	49,16
Specialisation				-,559	-,599	35,44
Subsides				-,779 *	-1470 *	18,70
Cross-level interaction						
Innovation*Trading					-,041 *	51,03
Innovation*Specialisation					-1000 * *	26,90
Innovation*Subsides					-2344 * *	8,76
Model fit statistics						
N = 67328 plots are nested in K= 25 municipalities						
Number of estimated parameters	3	15	24	33	42	
Deviance (−2 log likelihood)	1025495,307	1232316,01	1345833,04	1346867,14	1346997,99	
LR of model fit		206820,701	113517,03	1034,104	130,844	
Variance of random intercept (R^2)	1915 * *	1838 * *	1744 * *	1,74 * *	1726 * *	
Variance of random intercept variation (%)		4,02	5,11	0,23	0,80	
ICC	0368	0358	0346	0346	0344	

**p-value* > 0.05; * **p-value*> 0.01

Table 7
Estimation results for winegrowers' decisions: maintenance or new planting.

	Null Model OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)	Model 4 Expected probability (%)
Level 1 (Individual)						
Intercept	2976	-3320 * *	-3393 * *	-3211 * *	-3161 * *	4,03
Area		,759 * *	,608 * *	,608 * *	,620 * *	65,02
Innovation		-3172	,104	,108	-,131	46,72
PDO		6392 * *	4912 * *	4912 * *	4933 * *	99,28
Irrigation		2063 * *	2191 * *	2191 * *	2201 * *	90,03
Intralevel interaction						
Innovation*Area			,507	,508	,274	56,80
Innovation*PDO			-,372	-,376	-,203	44,93
Innovation*Irrigation			-3496 * *	-3496 * *	-3773 * *	2,25
Level 2 (Municipal)						
Trading				,027	,022	50,54
Specialisation				-,289	-,153	46,18
Subsides				,204	,289	57,16
Cross-level interaction						
Innovation*Trading					,033 * *	50,81
Innovation*Specialisation					-1229 * *	22,66
Innovation*Subsides					-,688 * *	33,42
Model fit statistics						
N = 67328 plots are nested in K= 25 municipalities						
Number of estimated parameters	3	15	24	33	42	
Deviance (−2 log likelihood)	1025495,31	1232316,0	1345833,0	1346867,1	1346998,0	
LR of model fit		206820,70	113517,03	1034,104	130,844	
Variance of random intercept (R^2)	3248 * *	2976 * *	2912 * *	2,98 * *	2552 * *	
Variance of random intercept variation (%)		8,37	2,15	-2,34	14,36	
ICC	0497	0475	0470	0475	0437	

**p-value* > 0.05; * **p-value*> 0.001

a negative influence, indicating that plots are less probable to be abandoned if irrigated, supporting hypotheses 7. Furthermore, the interaction between innovation and irrigation (Model 2 in Table 6) is also significant and negative, and although it indicates that more modernisation reduces the probability of abandonment, the expected probabilities are higher in Model 1. This result indicates that irrigation is the structural variable that mainly influences the decision of winegrowers, in fact, a plot without irrigation is 41% more probable to be abandoned and, therefore, irrigated plots are more probable to remain unchanged than to be abandoned. In Model 3 (Table 6), obtaining subsidies is added as a significant variable with a negative sign, indicating that CAP subsidies influence winegrowers to maintain their plots and not to abandon them. In Model 4 (Table 6) all interactions are significant and negative, indicating that the effect of the contextual

Table 8
Estimation results for winegrowers' decisions: maintenance or replanting.

	Null Model OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Model 4 OR (95% CI)	Model 4 Expected probability (%)
Level 1 (Individual)						
Intercept	1841	-,198 * *	-,360 * *	-,125 * *	-,094 * *	47,67
Area		,937 * *	,958 * *	,958 * *	,966 * *	72,43
Innovation		-2994 * *	-2743 * *	-2742 * *	-2975 * *	4,85
PDO		4866 * *	3691 * *	3691 * *	3711 * *	97,61
Irrigation		1689 * *	1731 * *	1731 * *	1740 * *	85,07
Intralevel interaction						
Innovation*Area			1248 *	1249 *	1029 * *	73,68
Innovation*PDO			3974 * *	3973 * *	4152 * *	98,45
Innovation*Irrigation			-1384 * *	-1,38 * *	-1641 * *	16,25
Level 2 (Municipal)						
Trading				,064 *	,062	51,55
Specialisation				-,765	-,727	32,61
Subsides				-,345	-,280	43,05
Cross-level interaction						
Innovation*Trading					,029 * *	50,74
Innovation*Specialisation					-,925 * *	28,37
Innovation*Subsides					-,896 * *	28,98
Model fit statistics						
N = 67328 plots are nested in K= 25 municipalities						
Number of estimated parameters	3	15	24	33	42	
Deviance (−2 log likelihood)	1025495,3	1232316,0	1345833,0	1346867,1	1346997,9	
LR of model fit		206820,70	113517,03	1034,104	130,844	
Variance of random intercept (R^2)	1887 * *	1841 * *	1855 * *	1,84 * *	1694 * *	
Variance of random intercept variation (%)		2,44	0,33	-0,27	7,93	
ICC	0364	0359	0358	0359	0340	

**p-value* > 0.05; * **p-value*> 0.001

variables is conditioned by the innovation carried out on the plot. That is, in municipalities with trading firms, high productive specialisation and/or higher subsidies received, fewer plots are abandoned if innovations take place. These results support hypotheses 2, 3 and 4, but depend on the innovation on the plots. The expected probabilities indicating the highest possibility of changes occur in the interaction between innovation and trading enterprises, indicating that changes will influence more than half of the cases.

The decision between maintaining the farm or establishing new plantings is shown in Table 7, where the coefficients indicate the probability of the grower establishing new plantings versus maintaining unchanged. Model 1 shows the positive and statistically significant influence of three individual variables: size, PDO membership and irrigation, indicating that they are variables that encourage new plantings, supporting Hypotheses 5, 6 and 7. The expected probabilities are very high for PDO belonging, irrigation and size (99% and 65% respectively), indicating that these variables have a high influence on winegrowers' decisions towards new plantings. Model 2 (Table 7) adds the innovation-irrigation interaction with a negative and significant value, showing that the negative effect of irrigation on switching to new plantings is conditional on plot innovation. So, irrigated, and modernised (innovation) plots remain unchanged. Unmodernised irrigated plots are more likely to switch to new plantings. In contrast, the expected probabilities are lower than those obtained in Model 1. This indicates that being in PDO and irrigated has a greater influence on the winegrower's decision. These results supports but, nuances, Hypothesis 7. Model 3 (Table 7) does not add significant parameters. Model 4 (Table 7) adds two significant interactions, innovation-trading interaction with a positive influence and innovation-specialisation interaction with a negative influence. The positive effect of the number of trading companies in the municipality towards new plantations is conditioned by the innovation, so that in municipalities with a higher number of sales companies there are more changes towards new plantations in plots that have been modernised. Moreover, the expected probability of this interaction is greater than 50%, indicating that in more than half of the cases the change will take place. The negative effect of productive specialisation is also conditioned by the innovation of the plots, so that in municipalities with high productive specialisation there are no changes in the plots with innovation, influencing more towards change in the plots with a lower degree of innovation. The results of these interactions support Hypotheses 2 and 3 but condition them on the effect of innovation on the plots. The expected probabilities indicating higher probability of change due to the interaction between innovation and trading, indicating that change will influence change in more than half of the cases.

The decision between maintaining or replanting is shown in Table 8, where the coefficients indicate the probability of the winegrower replanting versus keeping it unchanged. The results are similar to new plantings models. The difference is mainly for the effect of innovation. In this case, in Model 1 (Table 8), innovation has a significant and negative influence, showing that when a plot has been modernised there are no changes, whereas there is more replanting in plots that have not been modernised. In this model the rest of the individual variables are significant and positive, indicating that they have a positive influence on replanting, which supports Hypotheses 5, 6 and 7. The expected probabilities are very high for PDO membership, irrigation, and size (99% and 72% respectively), indicating that these variables have a high influence on the winegrowers' decision to replanting. Model 2 (Table 8) adds two significant and positive interactions, innovation-area and innovation-PDO, i.e., the positive effect of plot size and PDO membership is conditional on innovation. And, also the innovation-irrigation interaction is added with a negative and significant value, showing that the negative effect of irrigation on replanting is conditional on plot innovation, so that irrigated and modernised (innovation) plots remain unchanged and irrigated plots without modernisation are more likely to be replanted. In this case, the expected probabilities are higher than those obtained in Model 1, indicating that the influence of innovation combined with the other variables has a greater influence on the winegrower's decision than if they are evaluated in an uncorrelated way. This was not the case for new plantings. Model 4 (Table 8) nuances the results by adding interactions between innovation and contextualisation variables. An innovation-trading interaction with a positive and significant influence is included, as in the case of new plantings.

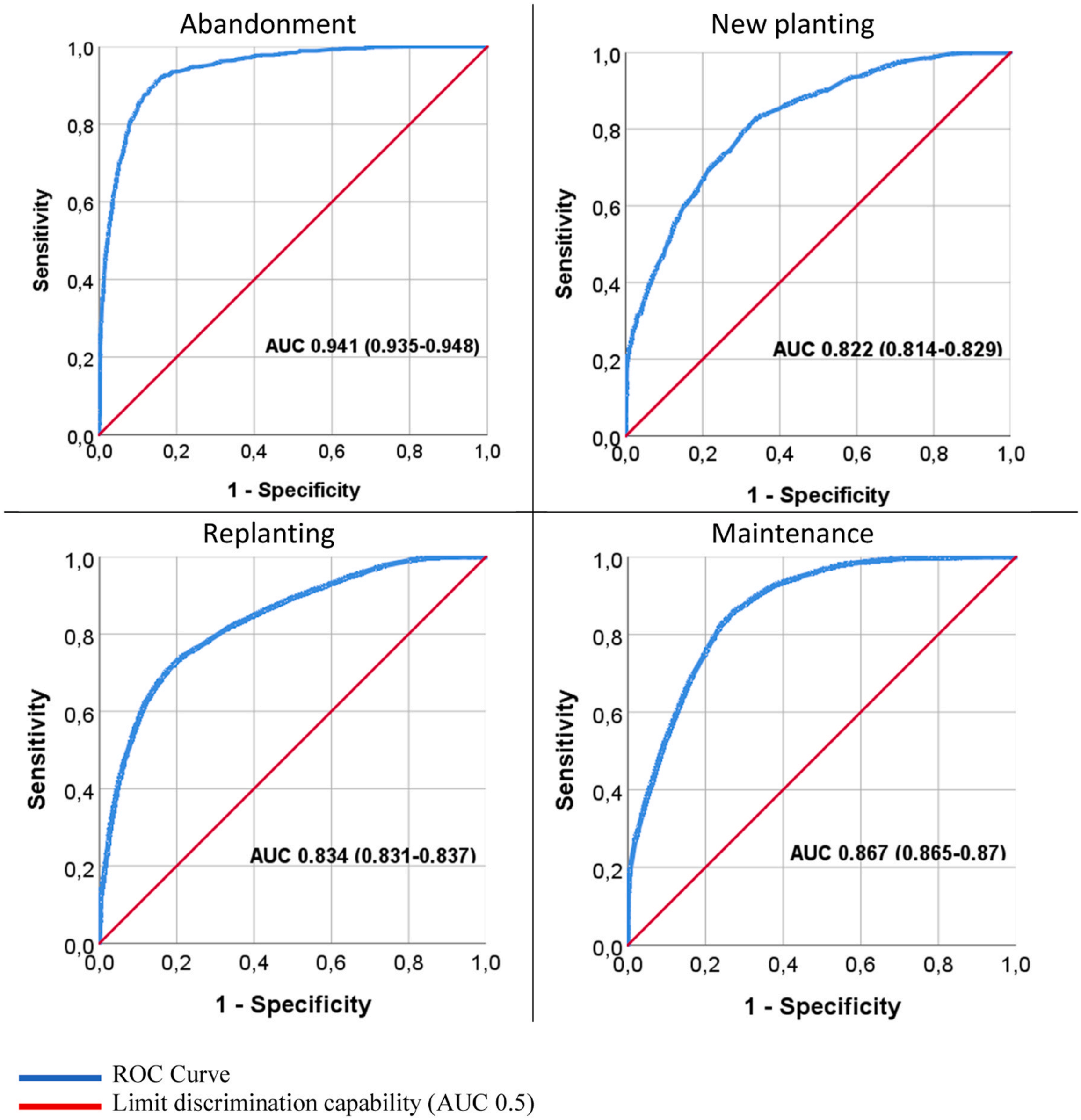


Fig. 4. AUC plotted for the multilevel model.

There are also two significant and negative interactions, innovation-specialisation, and innovation-subsidies, indicating that the effect of specialisation and subsidies is conditional on whether the plots are modernised. These results are in line with Hypotheses 2 and 4 but are conditional on the effects of innovation. The expected probabilities indicating a higher possibility of changes occur in the interaction between innovation and trading enterprises, as is also the case for new plantings.

The results of the ROC analysis for Model 4 demonstrated a remarkable level of predictive accuracy, as depicted in Fig. 4. The ROC curve's vertical axis represents sensitivity, reflecting the model's ability to correctly identify positive instances within the winegrowers' decisions. The values of ROC curve are close to 1 across all winegrowers' decisions, indicating the model's strong discriminatory power. The area under the ROC curve (AU-ROC), which serves as a comprehensive performance metric, further validated the model's effectiveness. Specifically, the AU-ROC of 0.941 for the plot abandonment model suggests the model's outstanding performance in correctly classifying instances related to plot abandonment. Similarly, the AU-ROC values of 0.822, 0.834, and 0.867 for new plantings, replanting, and unchanged maintenance, respectively, highlight the model's strong predictive accuracy in these decision categories.

The results of comparing the initial situation with the predicted by the multilevel model in each municipality indicate the trend established by the multilevel model in each case. The comparison of results for each municipality is included in Appendix 2 Table A2, while Fig. 5 shows which municipalities will experience an increase or decrease in the number of plots for each of the winegrowers' decisions. The result indicates that municipalities in Alicante and Valencia behave differently (Fig. 5), which corroborates Hypothesis 1. In Valencia there is a higher probability of an increase in unchanged plots, but in Alicante there is a higher probability of change. The changes in Alicante are mainly increases in replanting. There are two municipalities in Alicante with a high probability of an increase the number of abandoned plots.

4. Discussion

The study of the drivers of change affecting farmers has been widely studied in the international literature, with much effort focused on the effects of land abandonment, while few studies have determined the

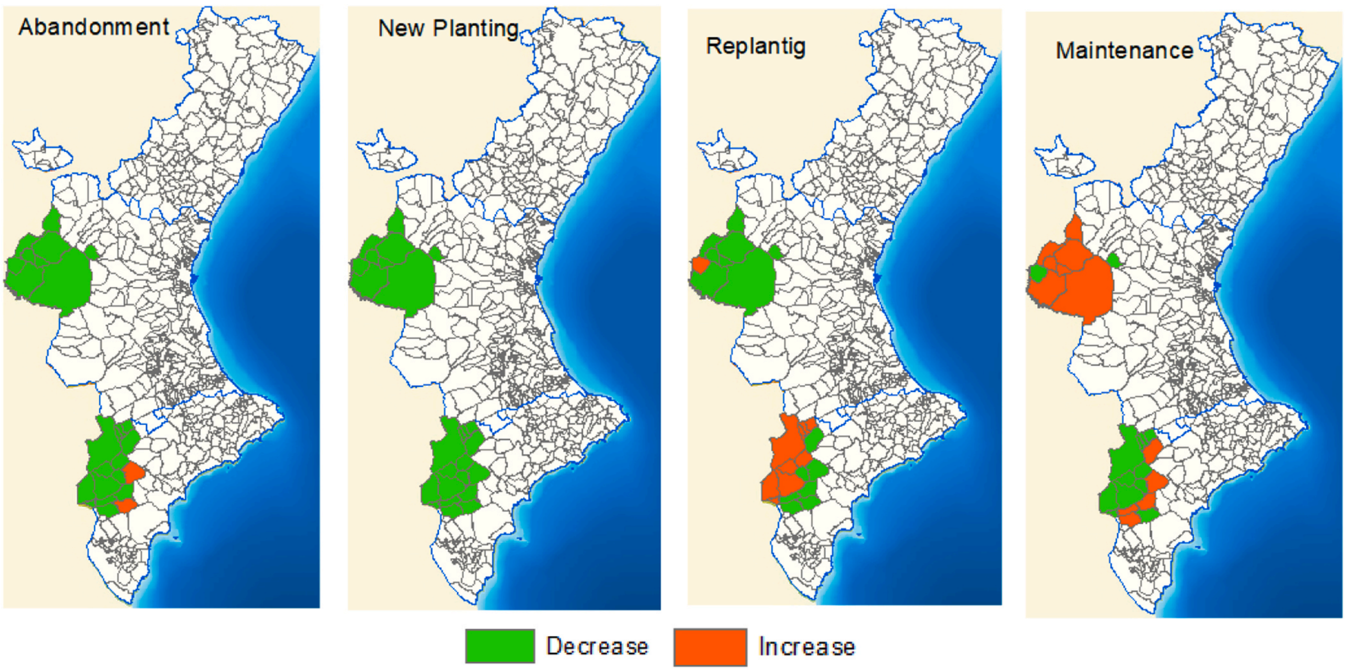


Fig. 5. Multilevel model results at the municipal level.

extent of the drivers of change (Fayet et al., 2022; Lasanta et al., 2017; Movahedi et al., 2021). Therefore, there is consensus in the scientific community in identifying that producers' decisions are due to a combination of internal farm characteristics (individual) and specific local factors related to farm location (contextual) (Castillo-Valero et al., 2017; Lasanta et al., 2017), but it is necessary to advance in identifying the specific importance of each of these drivers, as proposed and developed in this paper. Firstly, we study the spatial dependence (or contagion) between producers' decisions and show that winegrowers' decisions have a marked agglomeration phenomenon, i.e. producers are infected by the decisions of their nearest neighbours, which translates into local dependence, whether to continue with the production of the farm, to make improvements (replanting or new plantings) or even to abandon it, generating environmental and landscape impacts in specific areas, and changes in production with repercussions for the sector. These results are in line with the results of the study by Costantini et al. (2016) which identifies that farmers working in similar environmental contexts are faced with similar viticultural and oenological economic choices and should therefore be considered in studies on the factors influencing producers' decisions, given the importance that influences between producers may have.

Secondly, in the analysis of the specific influence of individual and contextual factors, it is identified that individual structural factors significantly influence producers' decisions to maintain their plots in production or to change. Plot size is undoubtedly an important factor in winegrowers' decisions, as is generally the case in the agri-food sector (Movahedi et al., 2021; Neuenfeldt et al., 2019) influencing as a priority the decision to replant or plant new vineyards. In contrast, it is not a determining factor in the decision to abandon. In this case, it has a more significant influence if the plot is irrigated. In fact, irrigation is a determining factor in all the options and, therefore, it is a key variable to stop abandonment and give stability to the sector. Moreover, when irrigation is combined with innovation, it is observed that, although it is a significant combination, it shows lower expected probabilities of change, which positions irrigation as the key variable in the modernisation of the sector. These results are in line with studies on viticulture and climate change, which identify that, although the vineyard is a crop tolerant to water stress (Riesgo and Gómez-Limón, 2006; Zarrouk et al., 2015), the wine sector is vulnerable to climate change, especially in areas that may suffer excessive water stress (Carroquino et al., 2020). In fact, increased irrigation is one of the adaptation measures to global warming (Fraga et al., 2018), which may imply changes in the geography of wine, such as possible displacement of vineyard locations to other regions. Therefore, an increase in the abandonment of vineyard plots without a change to other crops due to water deficit, and resulting in economic, environmental and landscape consequences in the affected areas.

Another significant individual factor is the PDO membership and its relationship with the quality policy that helps the management of all members of the food chain, coinciding with the studies of Castillo-Valero et al. (2017) and Costantini et al. (2016). In contrast, in our study it is not considered as a deterrent to abandonment but is a variable that does not have a significant influence. PDO membership has a significant and positive effect on the decision of winegrowers to improve their holdings (new planting or replanting). In fact, the importance of this variable in the decision to improve their holdings is the highest, as PDO membership has a 99% chance of influencing new plantings and a 98% chance of influencing replanting.

The last individual factor considered is the innovation carried out on the plot. Innovation is decisive, as indicated in general for the agri-food sector (Giannoccaro and Berbel, 2011), and in particular for winegrowers (Castillo-Valero et al., 2017). However, the results of the study make it possible to establish that not all decisions are influenced in the same way. The results show that it is not a variable with strong direct effects on the winegrower's decision, but it does have important indirect effects by conditioning the response of other variables (individual and contextual), which makes it a variable with geographical dependence. Regarding the interaction between individual variables, innovation combined with irrigation is a significant change that provides stability to the vineyard surface. Again, irrigation is shown to be a key decision variable. The combinations between innovation-plot size and innovation-PDO are decisive for farm improvement decisions, which are essential to reinforce replanting. However, they are not decisive for the promotion of new plantings or abandonment.

Contextual variables influence winegrower behaviour (Castillo-Valero et al., 2017; Lasanta et al., 2017), but mainly conditioned by individual variables. Therefore, the results clarify previous studies. The results of studies conducted in the Rheinland-Pfalz region in Germany

Table A1
Multilevel results.

Plot siuation	Variable	Coeficient	Std. Error	t	Sig.	95% Confidence interval		Exp (Coefficient)	Expected probability		95% Confidence Interval for Exp (Coefficient)	
						Lower	Upper		Value	%	Lower	Upper
Abandonment	*Level 1 (Individual)*											
	Intercept	-5.573	2.8458	-1.958	0.05	-11.151	0.005	0.004	0.004	0.40	1.44E-05	1.005
	Area	-0.253	0.1334	-1.897	0.05	-0.515	0.008	0.776	0.437	43.69	0.598	1.008
	Innovation	-4.199	5.0253	-0.836	0.403	-14.049	5.65	0.015	0.015	1.48	7.92E-07	284.339
	PDO	-6.644	21.4603	-0.31	0.007	-48.706	35.418	0.001	0.001	0.10	7.04E-22	2.4099E+ 15
	Irrigation	-0.373	0.1104	-3.378	0.001	-0.589	-0.157	0.689	0.408	40.79	0.555	0.855
	Intralevel interaction											
	Innovation*Area	-0.766	0.2348	-3.261	0.001	-1.226	-0.305	0.465	0.317	31.74	0.294	0.737
	Innovation*PDO	4.905	38.5796	0.127	0.899	-70.711	80.521	134.962	0.993	99.26	1.95E-31	9.3291E+ 34
	Innovation*Irrigation	-2.279	0.1831	-12.447	0.000	-2.638	-1.92	0.102	0.093	9.26	0.072	0.147
	Level 2 (Municipal)											
	Trading	-0.033	0.0497	-0.67	0.503	-0.131	0.064	0.967	0.492	49.16	0.877	1.066
	Specialisation	-0.599	0.6865	-0.873	0.383	-1.945	0.746	0.549	0.354	35.44	0.143	2.109
	Subsides	-1.47	0.5879	-2.5	0.012	-2.622	-0.318	0.23	0.187	18.70	0.073	0.728
	Cross-level interaction											
	Innovation*Trading	-0.041	0.0161	2.538	0.011	0.009	0.073	1.042	0.510	51.03	1.009	1.075
	Innovation*Specialisation	-1	0.2055	-4.869	0.000	-1.403	-0.598	0.368	0.269	26.90	0.246	0.55
	Innovation*Subsides	-2.344	0.1985	-11.81	0.000	-2.733	-1.955	0.096	0.088	8.76	0.065	0.142
New Planting	*Level 1 (Individual)*								0.040	4.03	0.009	0.192
	Intercept	-3.161	0.7701	-4.105	0.000	-4.67	-1.652	0.042				
	Area	0.62	0.0627	9.889	0.000	0.497	0.743	1.859	0.650	65.02	1.644	2.102
	Innovation	-0.131	0.1612	-0.813	0.416	-0.447	0.185	0.877	0.467	46.72	0.64	1.203
	PDO	4.933	0.0819	60.238	0.000	4.772	5.093	138.771	0.993	99.28	118.193	162.931
	Irrigation	2.201	0.0482	45.697	0.000	2.106	2.295	9.033	0.900	90.03	8.219	9.927
	Intralevel interaction											
	Innovation*Area	0.274	0.2039	1.344	0.179	-0.126	0.674	1.315	0.568	56.80	0.882	1.962
	Innovation*PDO	-0.203	0.2338	-0.867	0.386	-0.661	0.255	0.816	0.449	44.93	0.516	1.291
	Innovation*Irrigation	-3.773	0.1829	-20.627	0.000	-4.132	-3.415	0.023	0.022	2.25	0.016	0.033
	Level 2 (Municipal)											
	Trading	0.022	0.0702	0.311	0.756	-0.116	0.159	1.022	0.505	50.54	0.891	1.173
	Specialisation	-0.153	0.9845	-0.156	0.876	-2.083	1.776	0.858	0.462	46.18	0.125	5.908
	Subsides	0.289	0.8528	0.338	0.735	-1.383	1.96	1.334	0.572	57.16	0.251	7.1
	Cross-level interaction											
	Innovation*Trading	0.033	0.0074	4.4	0.000	0.018	0.047	1.033	0.508	50.81	1.018	1.048
	Innovation*Specialisation	-1.229	0.2168	-5.669	0.000	-1.654	-0.804	0.293	0.227	22.66	0.191	0.447
	Innovation*Subsides	-0.688	0.2101	-3.277	0.001	-1.1	-0.277	0.502	0.334	33.42	0.333	0.758
Replantng	*Level 1 (Individual)*											
	Intercept	-0.094	0.5572	-0.168	0.008	-1.186	0.999	0.911	0.477	47.67	0.306	2.714
	Area	0.966	0.0307	31.501	0.000	0.906	1.026	2.627	0.724	72.43	2.474	2.79
	Innovation	-2.975	0.0635	-46.852	0.000	-3.099	-2.85	0.051	0.049	4.85	0.045	0.058
	PDO	3.711	0.07	53.013	0.000	3.574	3.848	40.902	0.976	97.61	35.657	46.917
	Irrigation	1.74	0.0231	75.365	0.000	1.694	1.785	5.696	0.851	85.07	5.444	5.959
	Intralevel interaction											
	Innovation*Area	1.029	0.1434	7.18	0.000	0.748	1.31	2.799	0.737	73.68	2.113	3.707
	Innovation*PDO	4.152	0.1586	26.189	0.000	3.842	4.463	63.59	0.985	98.45	46.604	86.767
	Innovation*Irrigation	-1.641	0.1205	-13.62	0.000	-1.877	-1.405	0.194	0.162	16.25	0.153	0.245
	Level 2 (Municipal)											
	Trading	0.062	0.0509	1.215	0.224	-0.038	0.162	1.064	0.516	51.55	0.963	1.175
	Specialisation	-0.727	0.702	-1.035	0.301	-2.103	0.649	0.484	0.326	32.61	0.122	1.914
	Subsides	-0.28	0.5863	-0.477	0.633	-1.429	0.869	0.756	0.431	43.05	0.24	2.386
	Cross-level interaction											
	Innovation*Trading	0.029	0.0055	5.27	0.000	0.018	0.04	1.03	0.507	50.74	1.018	1.041
	Innovation*Specialisation	-0.925	0.1369	-6.759	0.000	-1.194	-0.657	0.396	0.284	28.37	0.303	0.518
	Innovation*Subsides	-0.896	0.1372	-6.534	0.000	-1.165	-0.627	0.408	0.290	28.98	0.312	0.534

Probability distribution: Multinomial
Link function: Generalised logit[a]
a. Objective: Plot siuation

(Bognos et al., 2012) and in the Priorat region in Catalonia Spain (Fernández-Aldecua et al., 2017) and Castilla La Mancha (Castillo-Valero et al., 2017) indicate that contextualisation factors, in this case marketing facilities, the productive specialisation of the municipality and CAP aid, condition winegrowers' decisions. The results of this study show that this is an indirect relationship conditioned by the innovation of the plot. If a plot has been modernised (innovation) and is in a municipality with productive specialisation and where CAP aid is actively accessed, it is more likely to maintain the right to the holding than to make changes. In other words, there will be more changes, either towards abandonment or towards productive changes, on modernised plots if they are in municipalities with little productive specialisation and not very dynamic in receiving CAP aid.

The models obtained indicate that the aid programme for the sector is a relevant factor in preventing the abandonment of vineyards, showing that it affects the winegrower's decision between abandoning

Table A2
Initial and predict situation at level municipal.

Municipality	Initial situation					Predict situation					Variation			
	Abandon	New Planting	Replant	Maint.	Total	Abandon	New Planting	Replant	Maint	Total	Abandon	New Planting	Replant	Maint.
Algueña	34	1	334	182	551	0	0	436	115	551	-34	-1	102	-67
Aspe	162	5	33	2394	2594	244	0	0	2350	2594	82	-5	-33	-44
Beneixama	6		51	59	116	0	0	58	58	116	-6	0	7	-1
Biar	15	1	58	91	165	0	1	54	110	165	-15	0	-4	19
Campo de Mirra	3	6	53	20	82	0	5	67	10	82	-3	-1	14	-10
Cañada	1	11	55	39	106	0	11	56	39	106	-1	0	1	0
Elda	0	0	2	24	26	0	0	2	24	26	0	0	0	0
Hondón de las Nieves	41	8	147	756	952	0	3	92	857	952	-41	-5	-55	101
Monóvar/ Monòver	77	36	1036	482	1631	0	0	1255	376	1631	-77	-36	219	-106
Novelda	88	0	119	2015	2222	64	0	80	2078	2222	-24	0	-39	63
Petrer	10	0	7	109	126	14	0	0	112	126	4	0	-7	3
Pinós (el)/ Pinoso	199	29	1766	441	2435	88	0	2184	163	2435	-111	-29	418	-278
Romana (la)	80	5	286	918	1289	1	0	267	1021	1289	-79	-5	-19	103
Salinas	18	5	257	121	401	0	0	313	88	401	-18	-5	56	-33
Sax	14	0	154	167	335	0	0	182	153	335	-14	0	28	-14
Villena	74	69	1237	389	1769	0	15	1620	134	1769	-74	-54	383	-255
Camporrobles	18	160	1146	1333	2657	0	18	994	1645	2657	-18	-142	-152	312
Caudete de las Fuentes	6	156	845	1117	2124	0	27	835	1262	2124	-6	-129	-10	145
Chera	0	0	3	21	24	0	0	3	21	24	0	0	0	0
Fuenterrobles	4	115	719	660	1498	0	12	586	900	1498	-4	-103	-133	240
Requena	20	1408	12735	10296	24459	0	454	12517	11488	24459	-20	-954	-218	1192
Sinarcas	14	152	719	894	1779	0	36	695	1048	1779	-14	-116	-24	154
Utiel	69	477	5619	5667	11832	0	108	4932	6792	11832	-69	-369	-687	1125
Venta del Moro	54	300	3207	2964	6525	0	52	2872	3601	6525	-54	-248	-335	637
Villargordo del Cabriel	8	78	684	860	1630	0	16	831	783	1630	-8	-62	147	-77
Total	1015	3022	31272	32019	67328	411	758	30931	35228	67328	-604	-2264	-341	3209

Appendix 3. Abreviations

PDO: Protected Designations of Origin
CAP: Common Agricultural Policy
LISA: Local spatial autocorrelation
ICC: Interclass Correlation Coefficient
ROC curve: Receiver Operating Characteristic curve
AU-ROC: Area Under the ROC curve
OR (95% CI): Odds Ratios and 95% Confidence Intervals

or maintaining the vineyard in 18.7% of cases. In other words, abandonment would be higher in 19% of cases in the absence of aid. Furthermore, it affects the winegrower's decision in 8.76% of the cases if the effect of the aid is conditional on the degree of innovation of the plots showing that 8.76% of the cases will abandon on plots where innovation has taken place. Moreover, support has a strong influence on change options (33.42% on new plantings and 28.98% on replantings), but only on plots with innovation, being a driver for modernisation of the sector. Therefore, the contextual aspects should not be considered separately, but conditioned to the individual characteristics of the plots, being more convenient the definition of policies that consider together the individual and contextual contexts.

5. Conclusion

Winegrowers' decisions should be studied considering factors at different territorial scales, since, as has been shown with spatial analysis methods, producers' decisions have a contagion effect between the decisions of producers and their neighbours. Individual variables (larger plot size, innovation, PDO membership and being irrigated) are the drivers of vineyard area, with irrigation having the greatest overall influence, and is expected to be decisive in the face of climate change projections. The promotion of measures to guarantee water supply could be an important stabilising element for the wine sector in semi-arid areas such as the one in this study. The combination of size and PDO membership with innovation mainly reinforces the decision to replant but is not as important for the decision to abandon the farm. The elements that slow down the abandonment of plots are the guarantee of irrigation and the combination of innovation and contextual variables, mainly the combining of modernised plots in municipalities with trading options. PDOs are factors that dynamize the territory and achieve productive concentrations, encouraging winegrowers to replant, but they are not sufficient to halt abandonment, as is the guarantee of irrigation.

The results obtained suggest that policy measures in this sector should focus on climate change mitigation in areas with excessive water stress, given the relevance of irrigation in the abandonment of plots. These policy measures should be able to support PDOs in orienting the sector towards both productivism and multifunctional and ecosystem restoration, especially in these semi-arid areas. To effectively promote innovation, it is important to go beyond farm modernization and technological advancements and prioritize social aspects that foster collaboration and cooperation among farmers, such as joint land management initiatives. By reinforcing innovative practices, we can support farm expansion and enhance the modernization of plots through increased innovation. This, in turn, can help reduce land abandonment and create favourable conditions for new plantings and replanting.

Other measures aimed at income diversification in the sector through PDOs, such as activities promoting wine culture, have the potential to enhance producers' incomes by advancing land use multifunctionality and ecoculture improvement of landscapes. To encourage ecotourism around wine culture, it is necessary to implement measures that promote biodiversity conservation, adopt sustainable agricultural practices, restore degraded landscapes, ensure sustainable water management, and promote environmental education. These measures aim to achieve a harmonious balance between wine production and the preservation of natural ecosystems, ultimately promoting sustainability and the preservation of biological diversity.

The results open a line of research for the application of similar methodological approaches in other countries or at different territorial scales, to highlight both the physical potential and the limitations of the vineyard soil and to improve the territorial planning of the different production systems. Similar approaches could also be applied to other quality crops, such as olive oil, coffee, or cheese production, which use quality labels such as PDOs. Moreover, the study of the abandonment of vineyard plots could be opened with the incorporation of business pressures for agricultural land such as the wind or solar industry that have intensified in the last decade.

CRediT authorship contribution statement

Consuelo Calafat-Marzal: Conceptualization, Data curation, Formal analysis, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing, Investigation, Resources, Visualization. **Aurea Gallego-Salguero:** Data curation, Methodology, Visualization, Writing – review & editing. **Veronica Piñeiro:** Data curation, Formal analysis, Methodology, Supervision, Writing – review & editing.

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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). She is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs.

Data availability

The authors do not have permission to share data.

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Appendix 1. Summary table of the results of the multilevel analysis

Table A1.

Appendix 2. Multilevel model results at the municipal level Summary table of the results of the multilevel analysis

Table A2.

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