



Livestock odour dispersion and its implications for rural tourism: case study of Valencian Community (Spain)

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Abstract

Aim of study: To study the relationship between the problem odours caused by livestock farms and the evolution of rural tourism.

Area of study: A coastal region in Spain, the Valencian Community.

Material and methods: The odour emission rates of 4,984 farms have been calculated, and the ambient odour concentration was determined to assess the odour nuisance. The odour concentration was modelled by applying the Gaussian model based on emission data and the most unfavourable meteorological conditions of the 45 climatic stations distributed throughout the analysis area. The dispersion model was implemented in a geographic information system, deducing the municipalities affected using the odour concentration thresholds. Furthermore, the evolution of rural tourism in municipalities was studied during the period of 2006-2017. The relationship between the evolution of rural tourism and the effects of odours is studied by means of a bivariate spatial correlation analysis.

Main results: Pigs are the predominant species in areas with the greatest odour emission problems; ~ 29% of farms can result in annoyances among the population with odour concentrations greater than 5 OU/m³, and 46% of municipalities can be affected by odour problems. These odour nuisances had negative consequences in the municipality where measures were carried out to favour rural development, such as rural tourism. Municipalities were detected in which the problem of odours can be a deterrent to rural tourism, whereas in other municipalities it was observed that minimizing livestock activity can be a method to promote rural tourism.

Research highlights: This study provides a methodology that allows modeling the odour dispersion of livestock and relates its implications to rural tourism. Municipalities have been identified where livestock odours can cause a stagnation of the rural tourism income.

Additional key words: odour emissions; rural areas; spatial autocorrelation; Gaussian dispersion model

Authors' contributions: Both authors participated in all stages of the work, including the conception and design of the research, the revision of the intellectual content and the drafting of the paper.

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Introduction

Livestock keeping are a direct source of nuisances in the form of odour emission rates, which have gradually increased because of the progressive intensification of livestock farming. All livestock farms are susceptible to odour problems, regardless of size. The management and handling of manure and slurry, as well as the animals themselves, contribute to odours that are dispersed into the atmosphere. Odours affect nearby dwellings and populations, causing adverse effects for citizens (Sucker *et al.*, 2008; Aatamila *et al.*, 2011), such as nuisance, negative effects on human health and depreciation of property prices (Cai *et al.*, 2011; Brancher *et al.*, 2017). These

negative externalities affect agents that are not linked to the activity and who do not derive any direct benefit from it, thereby contributing to a significant increase in complaints to local authorities (Henshaw *et al.*, 2006; Lin *et al.*, 2006; Romain *et al.*, 2013).

Furthermore, European policy reforms have evolved in search of a model that allows for the recognition in rural areas of functions such as the conservation of the environment and the rural landscape and the contribution of these functions to the development of a balanced territory; such functions are recognized in addition to the production functions of agriculture and livestock. This multifunctionality favours the development of tourism-related activities in rural areas, such as an activity that generates

new income and promotes the conservation of the rural environment (Fortuin *et al.*, 2009; Gulickx *et al.*, 2013; Olaizola *et al.*, 2015), as has occurred in a large number of European rural areas (Willemen *et al.*, 2008; Gulickx *et al.*, 2013; Solsona Monzonís, 2014).

The confluence of these two phenomena in rural areas with intensive livestock farms creates disjunctive effects. The growing evolution of rural tourism accentuates the problem of odours emitted by livestock farms, resulting in complaints to the livestock sectors of the affected municipalities.

There are currently no specific regulations establishing air quality criteria for odours. Schauburger *et al.* (2013) considered separating farms from the population to avoid high thresholds of odour as a variable for the management of livestock activity. Brancher *et al.* (2017) described the criteria considered to refer to odours throughout the world. In Europe, Council Directive 96/62 on ambient air quality assessment and management (EC, 1996) did not mention the nuisance caused by odoriferous molecules. The Netherlands, Germany and the United Kingdom have developed the most advanced standards: NER, Netherlands Emission Guidelines for Air; TA Luft, Technical Instructions for Air Quality Control; and IPPCH4, Integrated pollution prevention and control horizontal guidance for odour, assessment and control respectively. These standards are guidelines that limit odour emission rates for each activity and establish acceptable air quality criteria.

In Spain, the Valencian Community (VC) is considered a dynamic region in terms of urban and industrial development, population growth and agricultural activities. According to Yepes (1995), the VC has a double territorial personality of coastline and mountain, and this topography has a considerable influence on the distribution of population and economic activity in the VC and enables coastal tourism to be complemented by inland tourism so that each form of tourism can benefit the other. On the coast, tourism and the residential phenomenon have limited the agricultural sector, in many cases supplanting it. However, in the inland mountain areas, policies have been designed to make rural societies more dynamic, preserving their values and potential, halting the deterioration of their landscapes and correcting the negative effects generated by practices that do not respect the environment. In short, this is a region where the spatial dynamics of tourism have been conditioned by the geographical area where the activity takes place (Solsona Monzonís, 2014).

The estimation of odour problems in livestock farms has been analysed using Geographic Information Systems (GIS). In the study of land use planning, in any aspect that is addressed, the geographical component is fundamental. GIS intervene in a multitude of territorial research studies with different objectives, such as solving problems of

land planning and management (Amador & Dominguez, 2005; Vanhaverbeke & Clodt, 2006; Rich *et al.*, 2018; Yamashita & Hoshino, 2018) and providing the capacity to predict and evaluate their impact (Molina-Ruiz *et al.*, 2011; Amadou *et al.*, 2018).

The aim of this study is to estimate the number of municipalities affected by this problem by estimating the odour units (OU/m³) of the geographical areas and the evolution of rural tourism in the VC, and then to analyse whether there is a spatial relationship between these two variables. The initial hypothesis is that there are municipalities where the problems caused by odours in livestock farms are holding back the growth of rural tourism in the area and possibly causing the stagnation of the population's income.

Material and methods

Study area and characteristics of the livestock farms and tourism sector

An extensive description of the study area and study of livestock farms can be found in Calafat *et al.* (2015) and Gallego *et al.* (2019). The VC has a total of 542 municipalities spread across the three provinces; all of the municipalities of the VC have been included in the study.

Otherwise, rural tourism, considered as tourist activity carried out in rural areas, is made up of the integrated leisure offer, characterized by contact with the natural environment. It also facilitates interaction with the local society through which it is managed (Generalitat Valenciana, 2006). In the VC, tourism in 2017 represented 13.2% of GDP and 14.4% of regional employment (Exceltur, 2018); the rural environment presents a great diversity of spaces rich in landscapes (22 natural parks, 4 marine reserves, 8 protected landscapes, 71 municipal natural parks and one natural monument (BOE, 1995), and potential for the practice of tourist activities.

In the VC the influence of tourism depends on the location of the territory. Therefore, mass tourism concentrates in coastal areas (beach tourism) and have low livestock activity. In contrast, the interior areas of the study area have high livestock activity and tourism is based on the offer of rural houses and hostels in small municipalities (it is not mass tourism) where there are no hotels as in the coastal area. Therefore, this study considers only rural tourism in rural areas, which are the areas with livestock activity that do not contain hotels, which are linked to coastal areas with mass tourism where livestock activity is practically non-existent.

Throughout the VC, rural tourism is concentrated in the province of Castellón, which has the largest number

Table 1. Evolution of the percentages of places in rural houses and hostels in the Valencian Community (VC)

Provinces ⁽¹⁾	1996	2017	2017-1996
Rural houses			
Alicante	32.42	26.88	26.70
Castellón	60.94	40.24	39.56
Valencia	6.64	32.88	33.75
Hostels			
Alicante	23.91	25.40	25.65
Castellón	69.13	23.94	16.59
Valencia	6.96	50.65	57.76

⁽¹⁾ VC is divided administratively into three provinces: Castellón, Valencia and Alicante

of rural houses and hostels. Valencia and Alicante, on the other hand, have seen the greatest increase in supply in the last 20 years (Table 1).

The policies that mainly regulate the evolution of rural tourism in the VC come from three different areas, developed through the LEADER initiative (of the European Commission), the PRODER Rural Development Policy (of the Spanish Government) and aid from the Regional Administration, such as aid for the rehabilitation of rural housing for tourist accommodation. Two VC rural development programs co-financed by the European Agricultural Fund for Rural Development (EAFRD) have been developed, one for the period of 2007-2013 and the other for 2014-2020 (EC, 2015, 2017). In the last report, which presents the evolution of the areas included in the LEADER Programs, it is observed that practically all the areas included in the first period continue to be included in the second. Only a few larger municipalities, or those with positive demographic trends, leave the objective of the new LEADER Axis. This indicates that, despite the successive periods of public intervention (LEADER, LEADER II, LEADER PLUS and PRODER), the most depopulated territories of this region persist, even today, in this situation of demographic and economic crisis. For this reason, it is highlighted that the new development strategies to be defined should include proposals with greater innovative effort and the search for new approaches that allow for qualitative progress with respect to the starting situation and that allow for an increase in awareness of the importance of tourism together with a greater business dynamic.

Atmospheric dispersion models

During the last few decades, research has been carried out to model the concentration of odours from livestock farms. Initially, only the different chemical components

present in the odours were considered (Zahn *et al.*, 2001; Janes *et al.*, 2004), then environmental conditions such as wind speed, atmospheric stability classes and distance from the odour source were taken into account (Janicke *et al.*, 2012; Lucernoni *et al.*, 2016; Piringer *et al.*, 2016; Guffanti *et al.*, 2018; Oetl *et al.*, 2018).

One of the most relevant studies on odour modelling in livestock farms is the study by Hayes *et al.* (2006), which illustrates a dispersion model to determine the odour impact of intensive poultry production units and the evaluation of separation distances for new facilities. Some European countries (Austria, Germany, Switzerland, Netherlands, etc.) and some North American states or cities (Ontario, Illinois, Purdue, Iowa, etc.) have developed guidelines for the development of dispersion models for the calculation of separation distances. The Austrian model considers the most factors (Guo *et al.*, 2004), including the number of animals, species, housing systems, ventilation systems, manure handling, feeding methods, land use and topography (Janicke *et al.*, 2012; Schauburger *et al.*, 2012b, 2013, 2014; Brancher *et al.*, 2016). Since 1970, the U.S. Environmental Protection Agency (EPA) has developed a series of regulatory programs for the modelling of air quality. It groups air quality (or dispersion) models into different categories: Gaussian (non-reactive pollutants), numerical (if the source is of an urban type with reactive pollutants), statistical (if the chemical and physical processes do not have a clear scientific interpretation or a reliable database is not available), box (if pollutants emitted into the atmosphere are uniformly mixed in a finite volume), or physical (if it involves the use of tunnels, waterways or other means to model fluids).

The choice of the most appropriate model for a given application should be assessed on a case-by-case basis and considering several factors (Capelli *et al.*, 2013). Stationary state models (Gaussian models) are applied when the aim of the study is to look for the most unfavourable

condition. Models that are more sophisticated include parameterizations that are more complex and with a greater number of meteorological variables.

In this study, the Gaussian model was applied to determine the most unfavourable situation. For this purpose, simulations of concentrations of atmospheric pollutants were generated both in the location of farms and in the surrounding area, generating an odour concentration point matrix.

Methodology for calculating farm odour nuisance

The workflow followed for the calculation of odour nuisance of the VC livestock farms can be followed in Fig. 1.

Data input and general procedure

The impact of odour emission rates in the immediate surrounding of the farm depends on the magnitude of the emission rate of the facility, the proximity of sensitive receptors, the local topography and the prevailing meteorological conditions.

To take into account all these aspects and determine the odour emission values generated by the activity, it was necessary to apply mathematical odour dispersion simulation models (Pagans *et al.*, 2010).

STEP 1: DATA INPUTS

Previous work georeferenced the livestock farms of the VC (Gallego *et al.*, 2019), allowing us to know the location of each, with the necessary precision. For geographic referencing, the ETRS89 (European Terrestrial Reference System 1989) was adopted (BOE, 2007).

STEP 2: EMISSION AND SPATIAL ODOUR DENSITY OF LIVESTOCK FARMS

First, the odour emission rate derived from each livestock farm has been calculated, using the emission factors by species and production orientation applicable to livestock farms in the VC, validated in Generalitat Valenciana (2008) (Table 2). Considered emission factors were obtained using samples analysed by dynamic olfactometry from different livestock facilities, which have provided an

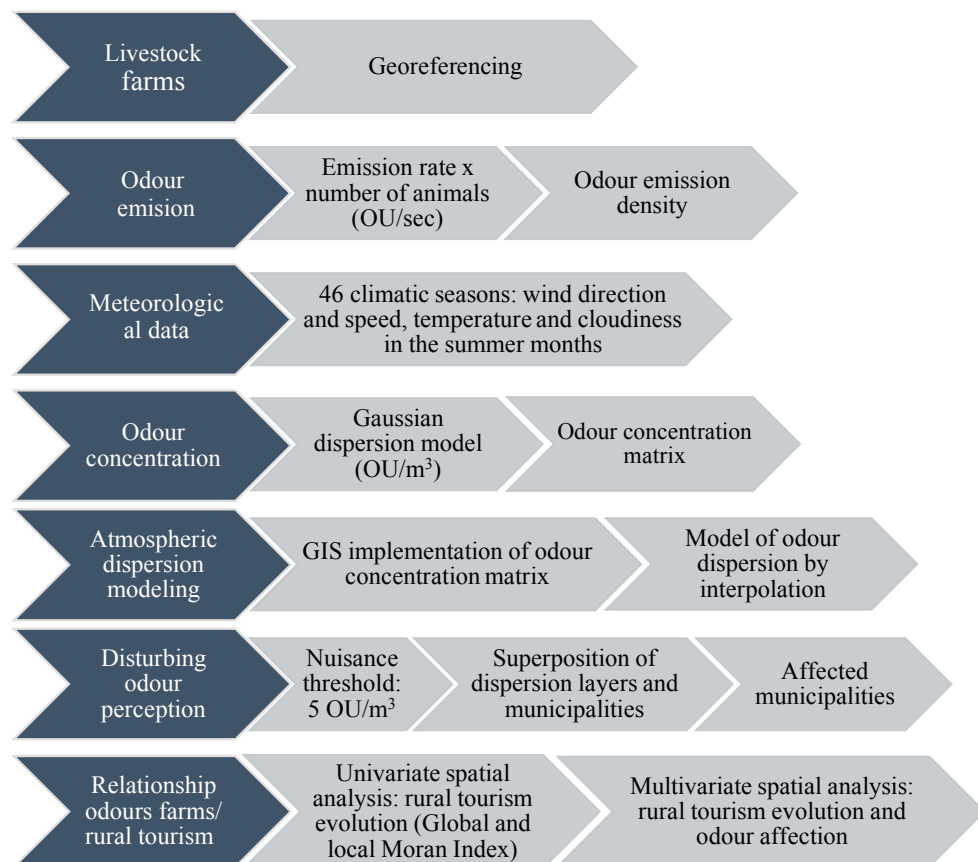


Figure 1. Workflow to obtain odour nuisance and its relationship with the evolution of rural tourism at municipal level.

Table 2. Odour emission factors by species and production orientation

Species	Production orientation	FE Head ⁽¹⁾ (OU/s)
Poultry	Broiler	0.11
	Laying hens in cages	0.49
	Laying hens on the ground	0.39
	Laying hens housed in aviaries	0.24
	Breeding chicks	0.19
Pigs	Transition	4.87
	Fattening	14.67
	Gestation	16.34
	Lactation	41.41
	Dried sows	20.63
	Sows global cycle	19.30
	Boars	26.22
Bovine	Replacement	12.10
	Dairy cow in production	46.48
	Replacement heifer	15.00
	Beef calves	39.73
Sheep	Lactating sheep	7.80
	Replacement sheep	4.68
	Breastfeeding goats	1.95
Goats	Replacement goats	18.84
	Reposition goats	11.30
	Cunningham	5.70
Lamb	Breeding mothers	1.00
	Fattening	0.25
Equine	Animals <12 months	39.73
	Breeders and adults	46.68
	Males	44.20

⁽¹⁾ FE Head: factor emission per animal head, measured in odour units per second (OU/s). *Source:* Generalitat Valenciana (2008).

emission rate per animal unit. In this guide, the values that represent the reality of VC livestock and that are adapted to their production conditions were selected.

The emission rate of each farm was obtained by multiplying the odour emission rate, established for each type of animal, by the total number of animals of the same type in the facility. The normalized values, per unit area, were obtained by interpolation of the sample data from the spatial density of the odour emission.

STEP 3: METEOROLOGICAL DATA

The meteorological information used was based on data of 46 weather stations over the last four years, provided

by the State Meteorological Agency (AEMET) of the Spanish Ministry of Agriculture.

The study was carried out on the dates of higher temperatures, as the temperatures are the climatological factors that most influence the dispersion and concentration of odours and adopt the most unfavourable scenario possible. Specifically, the meteorological data of the summer months of the past four years has been used in the simulation. Data was used daily at 7, 13 and 18 hours regarding: wind direction, temperature, wind speed, low clouds and high clouds.

For the characterization of different meteorological data, the mode for wind direction and the arithmetic mean

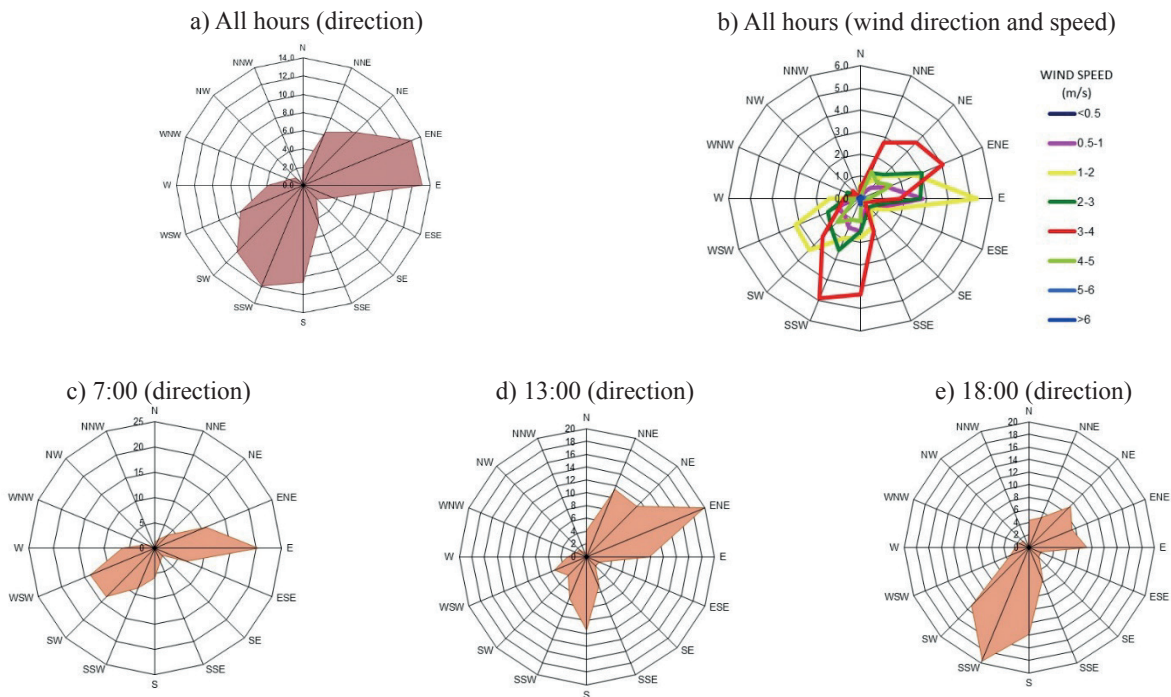


Figure 2. Example of wind rose (% of wind direction frequencies) from the same weather station used in Figures 3 and 4: (a) wind rose with directions of total hours used (%); b) rose of the winds with the directions in function of the speed of the total of hours used; c), d) and e) rose winds of the directions for 7:00, 13:00 and 18:00 hours respectively.

for wind speed and temperature were calculated from the daily data. Fig. 2 shows an example of the wind roses obtained for each of the main directions used from one of the weather stations, which corresponds to the examples of concentration and dispersion shown in Figs. 3 and 4.

STEP 4: CALCULATION OF ODOUR CONCENTRATION. GAUSSIAN METHOD

The Gaussian dispersion model is one of the most widely used models to describe the movement of pollutants in the atmosphere (Schauberger *et al.*, 2012a; Sommer-Quabach *et al.*, 2014; Piringer *et al.*, 2016).

The Gaussian atmospheric dispersion approach was used to assess the impact of the smell of the livestock facilities, in particular the model of Pasquill, obtained from the universal equation of dispersion turbulence and convective transport. Pasquill (1961) proposed a simple method of estimating atmospheric dispersion from continuous point sources, expressed in the equation:

$$C(x, y, z) = \frac{Q}{2\pi U \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2} - \frac{z^2}{2\sigma_z^2}\right) \quad (1)$$

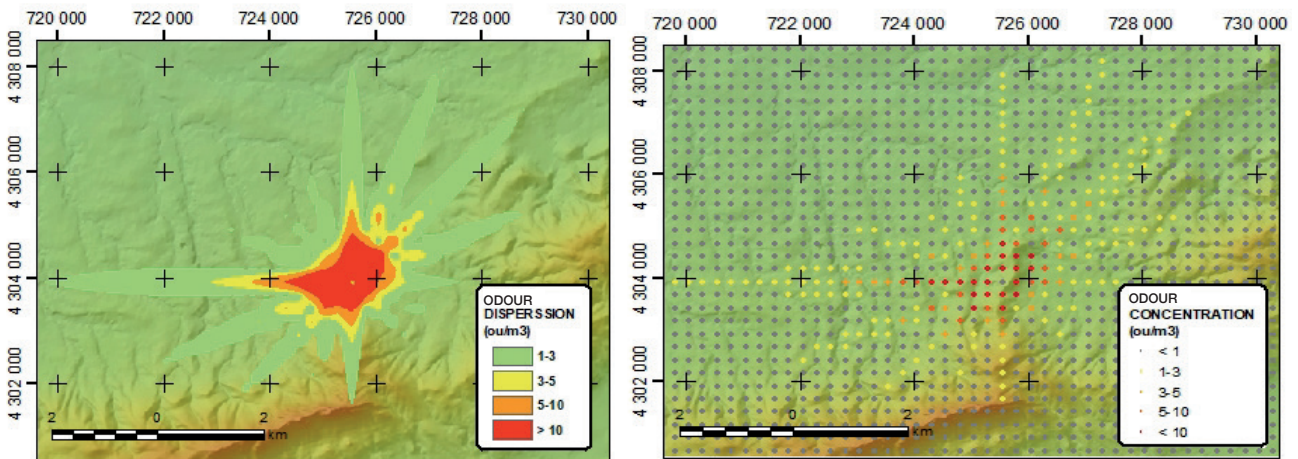


Figure 3. Example of GIS representation of odour concentration and dispersion: a) odour concentration points grid; b) odour dispersion

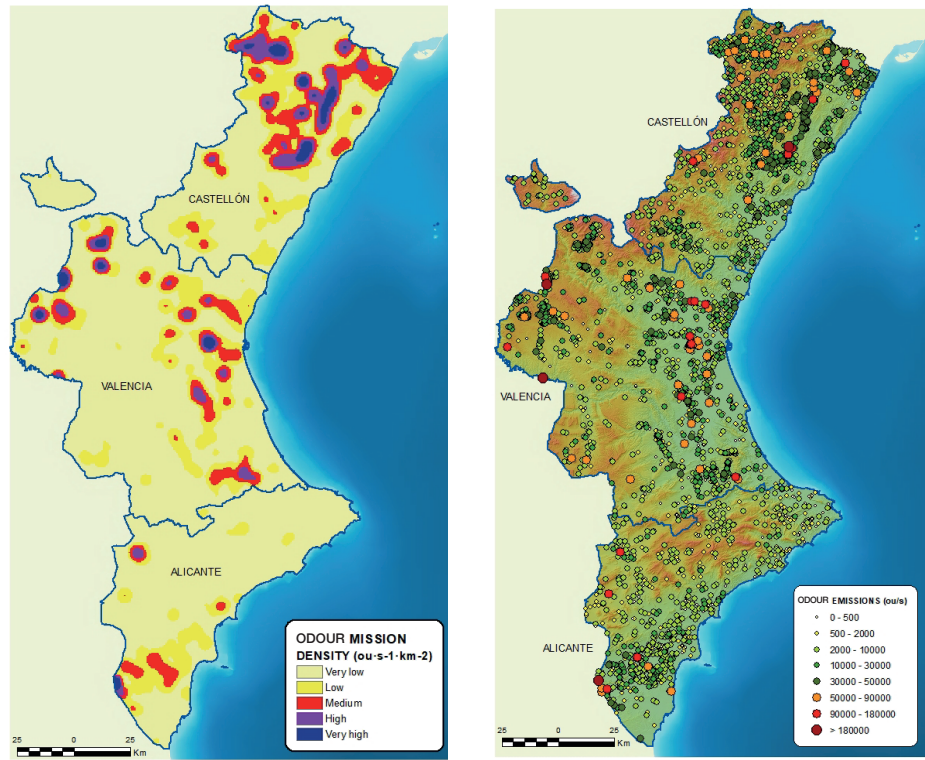


Figure 4. Farm odour emissions (OU/s) and odour emission density (OU/km²): a) map of odour emissions by farm; b) map of odour emission density

where C is the odour concentration (OU·m⁻³) at the receptor location; Q is the odour emission (OU·s⁻¹); U is the horizontal wind velocity (m s⁻¹); and σ_y and σ_z are the atmospheric dispersion coefficients (m). The Gaussian distribution determines the odour plume size on the leeward side, and this depends on the atmosphere stability and its own dispersion in transverse direction.

It is acceptable to assume some simplifying hypotheses when the emission is on a small scale (up to a few kilometres): development of the model for a stationary state; the diffusion of mass is negligible in the direction of the x axis; the wind speed U is considered constant because the variations in the three coordinate axes are very small and can be looked over; the point source is located at $x = 0$ and the effective height of chimney H .

Reduced expression of the Gaussian dispersion model corresponds to the level of the ground:

$$C(x, y, z) = \frac{Q}{\pi U \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2} - \frac{H^2}{2\sigma_z^2}\right) \quad (2)$$

where H is the effective emission height.

Dispersion parameters are determined once the class of turbulence of the atmosphere is defined. This turbulence class defines the ability of the atmosphere to dilute more or less pollution that is being generated by a point source

at a given time. The Pasquill stability classes (Table 3) define six stability levels (Classes A-C, D and E-F represent unstable, neutral and stable conditions, respectively). The more unstable the atmosphere, the greater the dilution. Stability classes are defined for different meteorological situations, characterised by wind speed and solar radiation (during the day) and cloud cover during the night. Once the stability class is defined the parameters of dispersion are determined, which also depend on the distance to the source.

In the present study, the effective emission height is the source height, without considering any over elevation of the odour plume. The atmospheric dispersion coefficients were determined using Eqs. 3 and 4 (Ubeda *et al.*, 2010), depending on atmospheric stability classes (A-F) (Table 4):

$$\sigma_y = a x^p \quad (3)$$

$$\sigma_z = b x^q \quad (4)$$

The methodology used in this study has been validated with field data in the case of a single source, in the same study area, the study of Ubeda *et al.* (2010).

This way, the odour concentration matrix has been obtained around each farm (Fig. 3a).

Table 3. Pasquill categories of atmospheric stability.

Wind speed (m s ⁻¹)	Diurnal insolation ⁽¹⁾			Cloudy conditions ⁽²⁾		
	Strong	Moderate	Weak	Covered (8/8)	Semcloudy (>4/8)	Cloudless (3/8)
<2	A	A-B	B	D		
2-3	A-B	B	C	D	E	F
3-4	B	B-C	C	D	D	E
4-6	C	C-D	D	D	D	D
>6	C	D	D	D	D	D

⁽¹⁾ Categories: A, extremely unstable; B, moderately unstable; C, slightly unstable; D, neutral conditions; E, slightly stable; F, moderately stable. *Source:* Pasquill (1961). ⁽²⁾Cloudy conditions refer to the extent of sky covered by clouds and is expressed in eighths. It is measured by observation, grouping all the clouds, and counting how many eighths (x/8) of the sky they occupy.

Table 4. Parameters used to determine atmospheric dispersion coefficients.

Stability class	σ_y		σ_z	
	a	p	b	q
A	0.3658	0.9031	0.00025	2.1250
B	0.2751	0.9031	0.0019	1.6021
C	0.2089	0.9031	0.2000	0.8543
D	0.1474	0.9031	0.3000	0.6532
E	0.1046	0.9031	0.4000	0.6021
F	0.0722	0.9031	0.2000	0.6020

Modelling was performed using meteorological data from the nearest meteorological station. Total odour concentration around the farm was calculated as a sum of the concentrations of the resulting odour in each direction of the wind by spreadsheet software.

STEP 5: MODELLING ODOUR DISPERSION IN GIS

The odour concentration matrix was implemented in GIS as a point layer (Fig. 3a). A continuous surface of the odour dispersion model of each farm was obtained by interpolation (Fig. 3b).

STEP 6: MUNICIPALITIES' PERCEPTION OF ODOUR NUISANCE

To deduce that farms affect municipalities due to odours, the following odour concentration thresholds have been considered according to the population's perception, according to standard (UNE, 2004):

— Detection threshold: The minimum concentration of odour that can be detected by 50% of the population. The detection threshold is 1 OU/m³.

— Recognition threshold: The minimum concentration of the odour at which 50% of the population can describe the odour. A recognition threshold accepted by the scientific community is defined as 3 OU/m³.

— Nuisance threshold: The concentration at which a small part of the population (<5%) manifests nuisance for at least 2% of the time. The most commonly used is 5 OU/m³.

Odour is classifiable above 5 OU/m³ *i.e.*, it can be identified and can be a source of complaint among the population. Odours are clearly recognizable when the concentration reaches 10 OU/m³, and complaints can also be received.

To analyse this situation in the study area, an overlap was made between the odour dispersion layers and the layer of urban centres, which allows us to know how

many farms can affect each urban centre and the maximum odour density value with which it can be affected. In addition, it is possible to know how many municipalities can be affected by each farm, and for each urban centre, how many farms can affect it and, therefore, the maximum concentration of odour that can be perceived.

STEP 7: RELATIONSHIP BETWEEN ODOUR NUISANCE AND THE EVOLUTION OF RURAL TOURISM AT THE MUNICIPAL LEVEL.

The municipal evolution in VC of rural tourism was based on the variation in the number of places in rural houses and hostels in the period from 2006 to 2017, a period in which the LEADER and PRODER programs were applied.

This analysis is performed in order to assess whether tourism in rural areas is increasing or, on the contrary, decreasing. In addition, the study examines if there is an influence between the evolution of rural tourism between municipalities near each other, *i.e.* if the increase of the rural tourism in a municipality spread to the nearest municipalities; it was carried out by means of an analysis of spatial autocorrelation (Anselin *et al.*, 2006). The study shows if the evolution of rural tourism in a municipality has an overflow effect in neighbouring (showing a positive spatial autocorrelation), favouring the concentration in a given geographical area. Otherwise, if the growth of rural tourism is concentrated on a municipality at the detriment of neighbours' municipalities, it produces the spatial hierarchy phenomenon (negative spatial autocorrelation).

The spatial correlation (or dependence) is calculated from the spatial weights' matrix (also called contact matrix or spatial proximity matrix), which represents the influence relationships of some observations and indicates which spatial units are neighbouring and which are not. It is symbolized with W , it is a matrix square $N \times N$ (where N is the number of spatial units, in this case N being the number of municipalities in the VC), not stochastic, whose elements w_{ij} reflect the intensity of the

interdependence between each pair of municipalities i, j (Moreno & Vayá, 2000). If $w_{ij} = 1$ the two municipalities are contiguous and if $w_{ij} = 0$ otherwise. The elements of the diagonal are 0, since no municipality can be its own neighbour. Subsequently the matrix is normalised in rows. There are different contiguity criteria in practice (Rook criterion if there is a common border; Bishop Criterion if there is a common vertex; Queen Criterion if there is either a common border or vertex). Queen's Criterion was used as a contiguity criterion in this study, due to make up for spatial contiguity by incorporating both the rook and bishop relationships into a single measure (Anselin *et al.*, 2006). Table 5 presents a hypothetical example of a special weight matrix with 5 municipalities, as well as a representation of the Queen's contiguity criteria. The spatial weights matrix allows generate an array of space delay of the explanatory variable (WY), from multiplying the W matrix by a vector of variables, in $N \times 1$ order.

Moran's Index values range from -1 to 1, where -1 means a negative spatial autocorrelation and 1 means a positive spatial autocorrelation. A value of zero indicates a random spatial pattern. The software package used for this index was GeoDa 1.12, developed by Anselin.

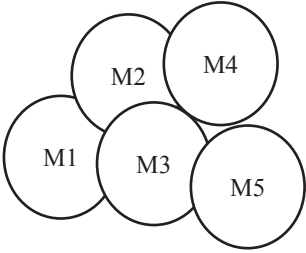
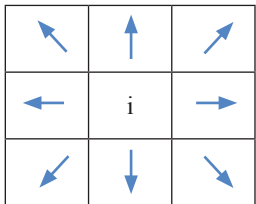
Moran's Index measures spatial autocorrelation using the following equation:

$$I = \frac{N}{\sum_i \sum_j W_{ij}} \frac{\sum_i \sum_j W_{ij} (X_i - \bar{x})(X_j - \bar{x})}{\sum_{i=1}^N (X_i - \bar{x})^2} \quad i \neq j \quad (5)$$

where N is the number of municipalities, X_i is the number of places in rural houses or hostels in i , X_j is the number of places in rural houses or hostels in j , \bar{x} is the mean number of places in rural houses and hostels and W_{ij} is a matrix of spatial weights.

Local Spatial Autocorrelation (LISA) indicates which municipalities have greater weight in index global Moran's Index and which ones are not. LISA map represents the local significant values (Anselin, 1995; Chasco & Fernández, 2008), and classifies the spatial clusters such with

Table 5. Example of the weight matrix and contiguity criterion of the Queen. M: municipality

	M1	M2	M3	M4	M5	
M1	0	1	1	0	0	
M2	1	0	1	1	0	
M3	1	1	0	1	1	
M4	0	1	1	0	1	
M5	0	0	1	1	0	
						<p>Contiguity criterion</p>  <p>Queen</p>

positive autocorrelation (high-high and low-low) and negative autocorrelation (high-low and low-high). A positive autocorrelation cluster indicates that the development of rural tourism has been the same in all the municipalities that are neighbours (high-high or low-low), instead, a negative correlation indicates that if in a municipality the rural tourism has increased, the opposite will have happened in the neighbouring municipalities (high-low).

Subsequently, the bivariate spatial correlation was analysed. In this case, it was examined whether there is autocorrelation among rural tourism variations and odours from the livestock farms. This correlation was held using the concept of global and local spatial bivariate correlation. The number of livestock farms in a municipality according to the emission of odours (OU/m^3) was considered as the explanatory variable in this study and the spatial delay matrix was calculated on the variation of the rural houses in each municipality (WY). In this case it is the values of the global moral bivariate I range from -1 to 1, where -1 means that the evolution of the number of rural houses and hostels and the number of livestock farms in a range of odour evolve at opposite rates (high-low indicates that the houses and hostels have increased in an municipality and in neighbouring municipalities there has been a decrease in the number of farms in a range of odour; low-high indicates that there has been a decrease of rural houses and hostels in an municipality and the number of farms in a range of odour have increased in neighbouring municipalities). A spatial autocorrelation equal to 1 means a positive spatial autocorrelation and the evolution of the number of rural houses and hostels and the number of livestock farms in a range of odour evolve in the same sense.

Results

This study makes a novel contribution of determining and relating two different problems in the same geographical area; also contributes by analysing the implications between key economic sectors for the economic and social development of disadvantaged areas, such as the rural areas within the VC. With the values of the emission factors by species and production orientation, the livestock farms were represented on a map depending on the nuisance thresholds (Fig. 4a) and the odour emission density map was also represented (Fig. 4b). The highest rate of odour emissions came mostly from pig farms, which was the species that produced greater discomfort by its smell. This situation is repeated at intermediate intervals, leading to the conclusion that the pig species is, in addition to be the most annoying, the species that generates the greatest odour emissions in the VC. Likewise, farms with

very high odour emission rates were concentrated in some areas, what causes them to become areas with high odour emission density (Fig. 4b).

The odour concentration was calculated using the Gaussian formula for each of the livestock species farms in the VC. Fig. 5 shows the livestock farms according to the value of the dispersed odour concentration (OU/m^3). Table 6 presents the frequencies of the results obtained. It was observed that 10% of the farms may cause a nuisance to nearby municipalities, as they cause concentrations greater than $5 \text{ OU}/\text{m}^3$, and that 18% may cause a nuisance to most of the population, with concentrations greater than $10 \text{ OU}/\text{m}^3$. Approximately 46% of municipalities may be affected, at some time, by odours emitted by livestock farms, which may cause complaints among the population.

Once the effects of odours were known at the urban centre level, their relationship with rural tourism was analysed and the geographical behaviour of the evolution of rural tourism in the VC was described. The evolution of the number of places offered for rural tourism shows a greater spatial autocorrelation for rural houses than for hostels (Table 7). In the case where the group of

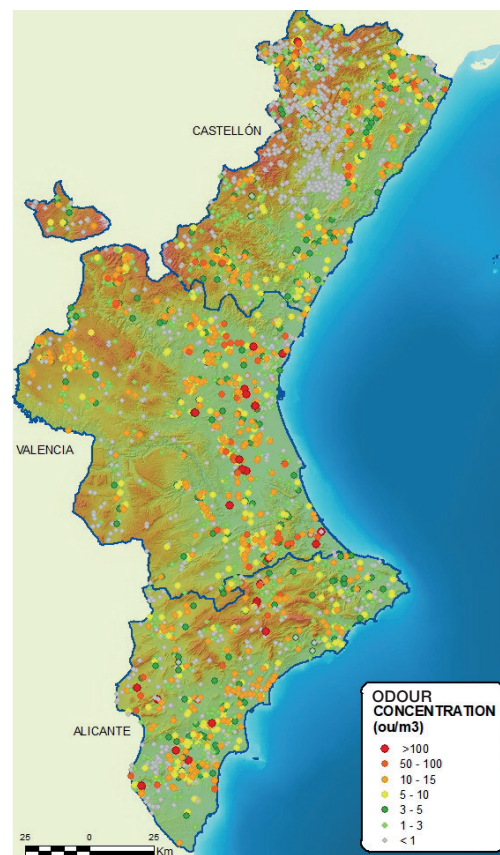


Figure 5. Concentration of dispersed odour (OU/m^3) in all livestock farms according to odour levels

Table 6. Number of farms and municipalities that may be affected by odour problems

Highest concentration (OU/m ³)	No. of farms	No. of municipalities
< 1	2018	52
1-3	1178	272
3-5	363	121
5-10	507	261
>10	918	594

rural houses and hostels showed a positive autocorrelation, mainly for the period from 1996 to 2006, the effects of the European programs of rural development had a contagious effect between the nearest municipalities. On the other hand, over the last decade, the territorial effects of these programs have not produced these effects.

Figure 6 shows the municipalities with the highest levels of spatial autocorrelation. The map in Fig. 6a shows the municipalities, shaded in red, with a high variation in the number of rural houses surrounded by municipalities with the same behaviour. Municipalities shaded in blue are characterized by little variation among rural houses and are surrounded by municipalities with the same trend. Provincial statistics indicate that the province of Castellón is where rural accommodation is concentrated but has had lower growth. Moreover, local spatial autocorrelation indicates that the cluster of municipalities with the greatest contagious effect among their neighbours is concentrated in the interior zone of Castellón (CL1; see Fig. 6) and, therefore, in these municipalities the variables that affect the evolution of rural tourism will be transferred to the neighbours. In the interior of the Valencia province, there is another cluster of municipalities that follow the same trend (CL2 and CL3; Fig. 6).

The global spatial correlation between the variation of rural houses and the number of farms by the odour concentration range indicates a low dependence between the two variables (Table 8). It is remarkable that, in the second period of analysis, there is a negative spatial relationship at all odour levels, which indicates that municipalities that increase/decrease the number of rural houses correspond to municipalities with few/many farms in each range of odour concentration.

The LISA maps are representative of municipalities with a level of significance of $p=0.001$ (Figs. 7 and 8). In the first and second period of rural development funding, for each level of odour concentration, there were few cases of positive local association: high values of both variables, six municipalities mainly in the north of Castellón, which in the first period increased as OU/m³ increased, reaching 12 municipalities. Moreover, the number of municipalities was reduced in the second period. Instead, more complaints can be received due to odour problems from livestock farms in these municipalities, as they are municipalities where rural tourism presents a clear increase and the possibility of generating income for its inhabitants. It was observed that not all the municipalities that were in this situation in the first period repeat

Table 7. Spatial autocorrelation (Moran Index) according to types of rural tourism in the times of the LEADER and PRODER programmes.

	Time periods	Moran Index
Rural houses and hostels	1996-2017	0.257017
	1996-2006	0.308086
	2006-2017	0.003310
Rural houses	1996-2017	0.336208
	1996-2006	0.405790
	2006-2017	0.033605
Hostels	1996-2017	0.085906
	1996-2006	0.080223
	2006-2017	-0.005254

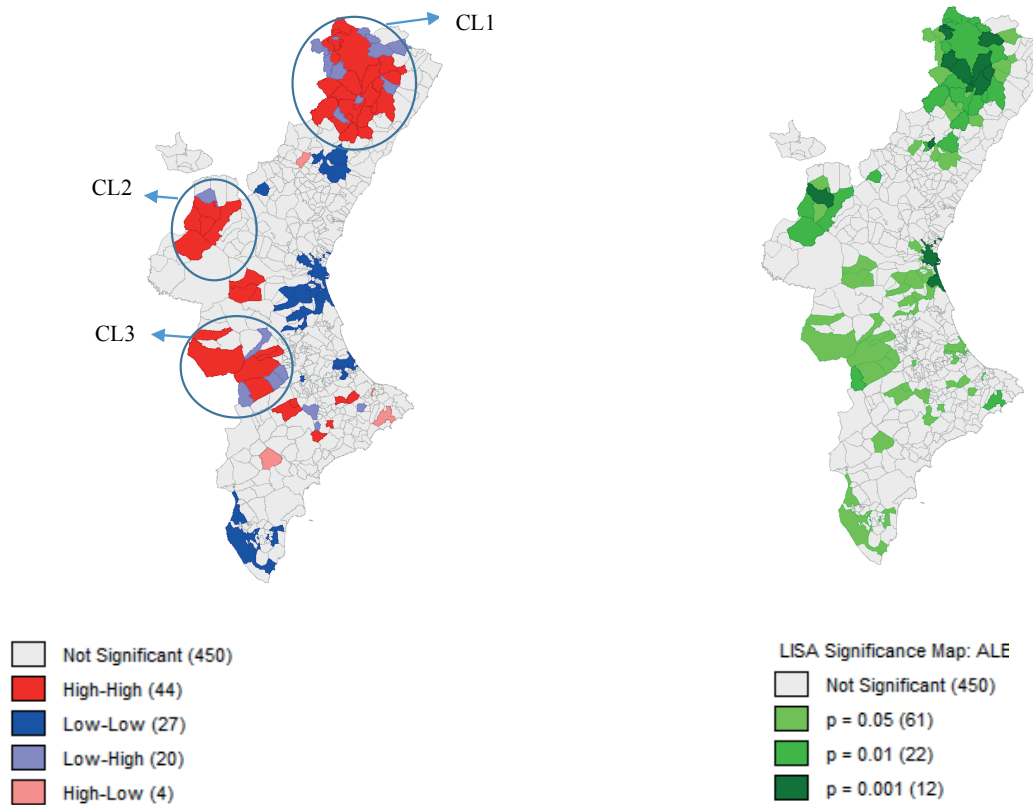


Figure 6. Municipalities with the greatest contribution to the global Moran's Index value and their statistical significance level (*p*-values)

Table 8. Bivariate spatial autocorrelation (Moran Index) according to the evolution of rural houses in the last 20 years and the number of farms according to each odour interval in each municipality.

	Odour concentration (OU/m ³)	Moran Index
Rural houses	< 1	0.3326800
1996-2006	1-3	0.1358580
	3-5	0.1891390
	5-10	0.1789220
	10-50	0.2070790
	50-100	0.1493630
	> 100	-0.0498380
	Rural houses	< 1
2006-2017	1-3	-0.0724050
	3-5	-0.0596544
	5-10	-0.0700574
	10-50	-0.0684552
	50-100	-0.0623618
	> 100	-0.0111484

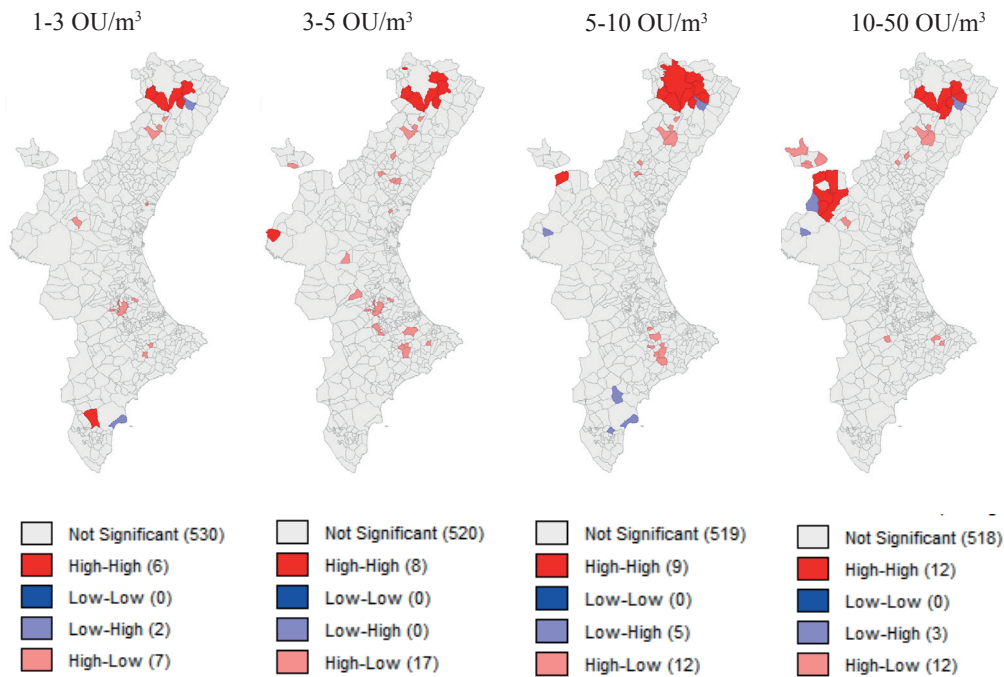


Figure 7. Bivariate local spatial autocorrelation between rural house evolution from 1996 to 2006 (first period of rural development programs in the Valencian Community) and odour concentration according to the degree of nuisance. Categories: Positive autocorrelation: High-High (Low-Low): High (Low) increase in rural tourism in municipality *i* and High (Low) increment in the number of livestock farms in neighbouring municipalities, in each odour range. Negative autocorrelation: Low-High (High-Low): Low (High) increase in rural tourism in municipality *i* and High (Low) increment in the number of livestock farms in neighbouring municipalities, in each odour range

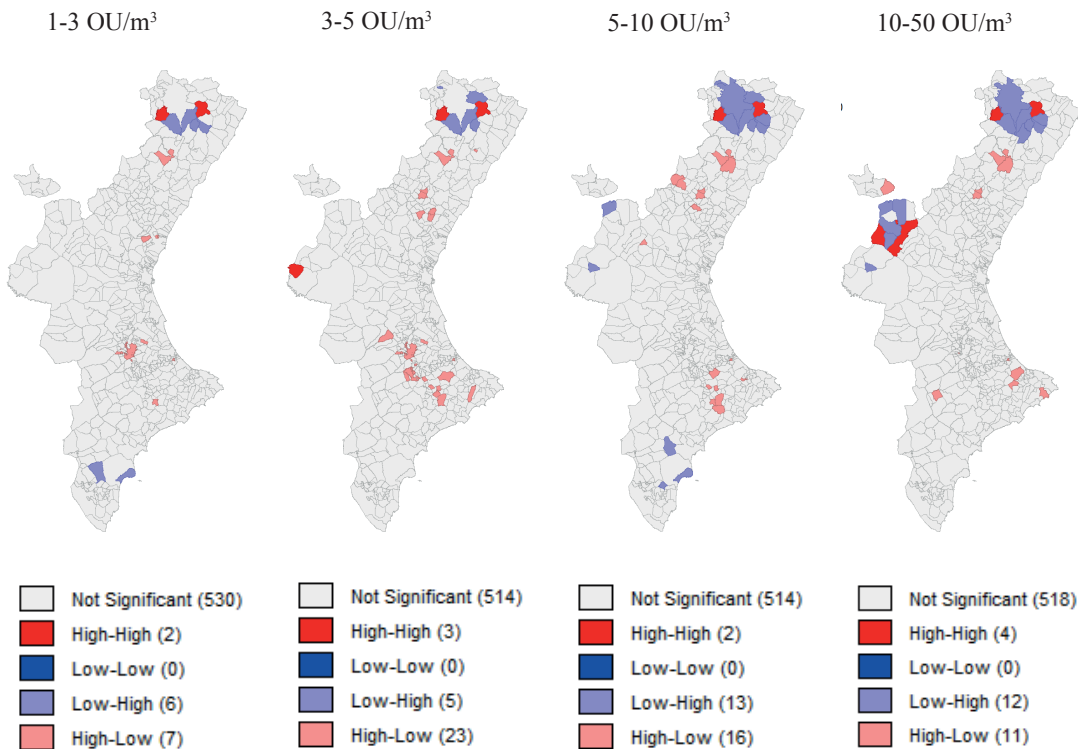


Figure 8. Bivariate local spatial autocorrelation between the evolution of the rural house from 2006 to 2017 (second period of the rural development program in the Valencian Community) and odour concentration according to the degree of nuisance.

in the second period. In fact, the majority municipalities changed to a situation of low-high values; they have become municipalities with a low growth of rural houses and a high number of farms with odour nuisances, which indicates that they are municipalities where livestock activity continues to predominate over tourism.

The number of municipalities with dissimilar values, mainly high-low, increased with a greater concentration of odour. They were characterized by being municipalities in which rural tourism grows (growth of rural houses) and had few livestock farms in each odour range, up to levels of 50 OU/m³, which is a threshold of high nuisance. In other words, they were municipalities with few odour-generating livestock farms where rural tourism is growing. In the two periods analysed, the number of municipalities with these characteristics increased, being more pronounced in the second period.

Municipalities with low and high values were characterized by low growth of rural tourism and a high number of farms in all ranges of odour concentration. In other words, they were municipalities where the tourism sector does not displace the livestock sector. In the first period, the number of municipalities was scarce, but in the second period, it was higher as the concentration by odour increased.

Discussion

Livestock odours are a very demanding analytical challenge due to their chemical complexity and the low concentrations of individual compounds. In the study by Boers *et al.* (2016), it was indicated that age and education do not truly have a significant influence on the perception of odour nuisance. Instead, exposure to odour is the main driver for odour nuisance. For this reason, it is essential to know the odour exposure at the urban centre level, linking the possible odour-generating sources. At the European level, the odours generated by livestock farms and their consequences on the surrounding population, the environment and local economies are not regulated. In Spain, there is no legislation that can be applied to the whole territory. This lack of legislation hinders possible action and the development of efficient techniques for its reduction.

In general, different types of models can be used to simulate the dispersion of pollutants into the atmosphere. Among them, Gaussian models, for which turbulent dispersion is parameterized with empirical coefficients (Gifford, 1959; Pasquill, 1961; Smith, 1995). This stationary state model (Gaussian models) is applied when the aim of the study is to look for the most unfavourable condition. Models that are more sophisticated include parameteriza-

tions that are more complex and with a greater number of meteorological variables. Many studies analyse the livestock farm odour problems of the farms mediating Gaussian models (Capelli *et al.*, 2013; Danuso *et al.*, 2015; Piringier *et al.*, 2016).

In the study presented, the entire territory of the VC and livestock farms with more than one livestock unit have been included in the analysis, thus 4984 farms were included in the study. In contrast, the number of considered farms in most of the studies of odours in livestock farms is lower (Schauberger *et al.*, 2012a; Romain *et al.*, 2013; Sommer-Quabach *et al.*, 2014), even in many of them only one farm is analysed to study, either, the composition of odour concentration in detail, or the odours of the same farm in several geographical locations (Schauberger *et al.*, 2014; Wu *et al.*, 2016). Other studies include several buildings in farms (Henshaw *et al.*, 2006; Hernandez *et al.*, 2012), but the number of observations is also lower than the ones considered in this study. The amount of data used determines both the objectives of the study and the results, and, in this case, makes the results of the concentrations and dispersion of odours not comparable with other studies.

The methodology developed can be applied to other regions and extended to consider additional environmental variables, such as the concentration of nitrates or other atmospheric pollutants that cause odours. In addition, other geographical and livestock criteria could be incorporated to influence the growth of rural tourism. Implementing the results of GIS techniques allows for the geographical detection of the most problematic areas in the territory.

The results obtained allowed the identification of the hot spot in municipalities where the complaints to the local institutions increased due to livestock odour. In this municipality cluster, that is increasing the rural tourism, the effects of livestock odours may suppose a restraint for rural tourism. Against this, groups of municipalities are evidenced where the livestock sector predominates over tourism and the complaints of the neighbours may not increase for this reason. In conclusion, the initial hypothesis is fulfilled in municipalities that increase rural tourism, due to problems caused by odours in livestock which can cause a stagnation of the population's income.

Finally, the results obtained make it possible to inform and facilitate decision-making in the design and application of sectorial and social policies by the public administrations, which are responsible for the management of livestock activities and the territory. In addition, another line of future research is the identification of suitable geographical locations for new livestock farms that guarantee the necessary production of food and produce an improvement of activities and incomes in areas at risk of depopulation (such as the interior areas of the CV) and do not

restrain the development of booming economic sectors, such as rural tourism.

References

- Aatamila M, Verkasalo PK, Korhonen MJ, Suominen AL, Hirvonen MR, Viluksela MK, Nevalainen A, 2011. Odour annoyance and physical symptoms among residents living near waste treatment centres. *Environ Res* 111: 164-170. <https://doi.org/10.1016/j.envres.2010.11.008>
- Amador J, Dominguez J, 2005. Application of geographical information systems to rural electrification with renewable energy sources. *Renew Energ* 30: 1897-1912. <https://doi.org/10.1016/j.renene.2004.12.007>
- Amadou ML, Villamor GB, Kyei-Baffour N, 2018. Simulating agricultural land-use adaptation decisions to climate change: An empirical agent-based modelling in northern Ghana. *Agric Syst* 166: 196-209. <https://doi.org/10.1016/j.agsy.2017.10.015>
- Anselin L, 1995. Local indicators of spatial association-LISA. *Geograph Anal* 27: 93-115. <https://doi.org/10.1111/j.1538-4632.1995.tb00338.x>
- Anselin L, Syabri I, Kho Y, 2006. GeoDa : An introduction to spatial data analysis. *Geograph Anal* 38 (1): 5-22. <https://doi.org/10.1111/j.0016-7363.2005.00671.x>
- BOE, 1995. Ley 11/1994, de 27 de diciembre, de espacios naturales protegidos de la Comunidad Valenciana. *Boletín Oficial del Estado (España)*, BOE-A-1995-3325.
- BOE, 2007. RD 1071/2007, de 27 de julio, por el que se regula el sistema geodésico de referencia oficial en España. *Boletín Oficial del Estado (España)*, 35986-35989.
- Boers D, Geelen L, Erbrink H, Smit LAM, Heederik D, Hooiveld M, Yzermans CJ, Huijbregts M, Wouters IM, 2016. The relation between modeled odor exposure from livestock farming and odor annoyance among neighboring residents. *Int Arch Occup Environ Health* 89: 521-530. <https://doi.org/10.1007/s00420-015-1092-4>
- Brancher M, Schauburger G, Franco D, De Melo Lisboa H, 2016. Odour impact criteria in south American regulations. *Chem Eng Trans* 54: 169-174.
- Brancher M, Griffiths KD, Franco D, de Melo Lisboa H, 2017. A review of odour impact criteria in selected countries around the world. *Chemosphere* 168: 1531-1570. <https://doi.org/10.1016/j.chemosphere.2016.11.160>
- Cai L, Koziel JA, Zhang S, 2011. Odorous chemical emissions from livestock operations in United States. *Int Conf on Remote Sens Environ Transport Eng, IEEE*, pp: 532-535. <https://doi.org/10.1109/RSETE.2011.5964331>
- Calafat C, Gallego A, Quintanilla I, 2015. Integrated geo-referenced data and statistical analysis for dividing livestock farms into geographical zones in the Valencian Community (Spain). *Comput Electron Agric* 114: 58-67. <https://doi.org/10.1016/j.compag.2015.03.005>
- Capelli L, Sironi S, Del Rosso R, Guillot JM, 2013. Measuring odours in the environment vs. dispersion modelling: A review. *Atmos Environ* 79: 731-743. <https://doi.org/10.1016/j.atmosenv.2013.07.029>
- Chasco C, Fernández G, 2008. Análisis de datos espacio-temporales en geomarketing: difusión espacial del lanzamiento de un nuevo producto. *Invest Market* 98: 56-61.
- Danuso F, Rocca A, Ceccon P, Ginaldi F, 2015. A software application for mapping livestock waste odour dispersion. *Environ Model Softw* 69: 175-186. <https://doi.org/10.1016/j.envsoft.2015.03.016>
- EC, 1996. Council Directive 96/62/EC of September 27, 1996 on ambient air quality assessment and management
- EC, 2015. Programa de desarrollo rural de la Comunitat Valenciana Cofinanciado por FEADER para el periodo 2007-2013. European Commission. <http://www.avfga.gva.es/es/pdr-cv-2007-2013>
- EC, 2017. Programa de desarrollo rural de la Comunitat Valenciana Cofinanciado por FEADER para el periodo 2014-2020.pdf. European Commission. <http://www.avfga.gva.es/es/pdr-cv-2014-2020>
- Exceltur, 2018. Perspectivas turísticas. 65-2018. <https://www.exceltur.org/perspectivas-turisticas/>
- Fortuin FTJM, Omta SWF, 2009. Innovation drivers and barriers in food processing. *Br. Food J* 111 (8): 839-851.
- Gallego A, Calafat C, Segura M, Quintanilla I, 2019. Land use policy land planning and risk assessment for livestock production based on an outranking approach and GIS. *Land Use Policy* 83: 606-621. <https://doi.org/10.1016/j.landusepol.2018.10.021>
- Generalitat Valenciana, 2006. El turismo rural en la Comunitat Valenciana. Conselleria de Turisme.
- Generalitat Valenciana, 2008. Guía técnica para la gestión de las emisiones odoríferas generadas por las explotaciones ganaderas intensivas [Technical guide for the management of odour emission rates generated by intensive livestock farms].
- Gifford F, 1959. Statistical properties of a fluctuating plume dispersion model. *Adv Geophys* 6: 117-137. [https://doi.org/10.1016/S0065-2687\(08\)60099-0](https://doi.org/10.1016/S0065-2687(08)60099-0)
- Guffanti P, Pifferi V, Falciola L, Ferrante V, 2018. Analyses of odours from concentrated animal feeding operations: A review. *Atmos Environ* 175: 100-108. <https://doi.org/10.1016/j.atmosenv.2017.12.007>

- Gulickx MMC, Verburg PH, Stoorvogel JJ, Kok K, Veldkamp A, 2013. Mapping landscape services: A case study in a multifunctional rural landscape in the Netherlands. *Ecol Indic* 24: 273-283. <https://doi.org/10.1016/j.ecolind.2012.07.005>
- Guo H, Jacobson L, Schmidt D, Nicolai R, Janni K, 2004. Comparison of five models for setback distance determination from livestock sites. *Can Biosyst Eng* 46 (6): 17-25.
- Hayes ET, Curran TP, Dodd VA, 2006. A dispersion modelling approach to determine the odour impact of intensive poultry production units in Ireland. *Bioresour Technol* 97: 1773-1779. <https://doi.org/10.1016/j.biortech.2005.09.019>
- Henshaw P, Nicell J, Sikdar A, 2006. Parameters for the assessment of odour impacts on communities. *Atmos Environ* 40: 1016-1029. <https://doi.org/10.1016/j.atmosenv.2005.11.014>
- Hernandez G, Trabue S, Sauer T, Pfeiffer R, Tyndall J, 2012. Odor mitigation with tree buffers: Swine production case study. *Agric Ecosyst Environ* 149: 154-163. <https://doi.org/10.1016/j.agee.2011.12.002>
- Janes KR., Yang SX, Hacker RR, 2004. Single-component modelling of pig farm odour with statistical methods and neural networks. *Biosyst Eng* 88: 271-279. <https://doi.org/10.1016/j.biosystemseng.2004.04.004>
- Janicke U, Müller WJ, Both R, Trukenmüller A, 2012. Comment on “Empirical model derived from dispersion calculations to determine separation distances between livestock buildings and residential areas to avoid odour nuisance” by G. Schaubberger, R. Schmitzer, M. Kamp, A. Sowa, R. Koch, W. Eckhof, F. Eichler. *Atmos Environ* 50: 385-386. <https://doi.org/10.1016/j.atmosenv.2011.12.010>
- Lin XJ, Barrington S, Nicell J, Choinière D, Vézina A, 2006. Influence of windbreaks on livestock odour dispersion plume in the field. *Agric Ecosyst Environ* 116: 263-272. <https://doi.org/10.1016/j.agee.2006.02.014>
- Lucernoni F, Tapparo F, Capelli L, Sironi S, 2016. Evaluation of an odour emission factor (OEF) to estimate odour emissions from landfill surfaces. *Atmos Environ* 144: 87-99. <https://doi.org/10.1016/j.atmosenv.2016.08.064>
- Molina-Ruiz J, Martínez-Sánchez MJ, Pérez-Sirvent C, Tudela-Serrano ML, García-Lorenzo ML, 2011. Developing and applying a GIS-assisted approach to evaluate visual impact in wind farms. *Renew Energ* 36: 1125-1132. <https://doi.org/10.1016/j.renene.2010.08.041>
- Moreno R, Vayá E, 2000. Técnicas econométricas para el tratamiento de datos espaciales: La econometría espacial. Universitat de Barcelona, Col UB 44, manuals.
- Oetl D, Kropsch M, Mandl M, 2018. Odour assessment in the vicinity of a pig-fattening farm using field inspections (EN 16841-1) and dispersion modelling. *Atmos Environ* 181: 54-60. <https://doi.org/10.1016/j.atmosenv.2018.03.029>
- Olaizola AM, Ameen F, Manrique E, 2015. Potential strategies of adaptation of mixed sheep-crop systems to changes in the economic environment in a Mediterranean mountain area. *Livest Sci* 176: 166-180. <https://doi.org/10.1016/j.livsci.2015.03.012>
- Pagans E, Domínguez R, van Harreveld AP, 2010. Gestión de impactos por emisiones odoríferas procedentes de actividades ganaderas. Int. Workshop on Anaerobic Digestion of Slaughterhouse Waste; Bonmatí A, *et al.* (Eds.), pp: 23-32.
- Pasquill F, 1961. The estimate of the dispersion of windborne material. *Met Mag* 90: 33.
- Piringer M, Knauder W, Petz E, Schaubberger G, 2016. Factors influencing separation distances against odour annoyance calculated by Gaussian and Lagrangian dispersion models. *Atmos Environ* 140: 69-83. <https://doi.org/10.1016/j.atmosenv.2016.05.056>
- Rich KM, Rich M, Dizyee K, 2018. Participatory systems approaches for urban and peri-urban agriculture planning: The role of system dynamics and spatial group model building. *Agric Syst* 160: 110-123. <https://doi.org/10.1016/j.agry.2016.09.022>
- Romain AC, Nicolas J, Cobut P, Delva J, Nicks B, Philippe FX, 2013. Continuous odour measurement from fattening pig units. *Atmos Environ* 77: 935-942. <https://doi.org/10.1016/j.atmosenv.2013.06.030>
- Schaubberger G, Piringer M, Jovanovic O, Petz E, 2012a. A new empirical model to calculate separation distances between livestock buildings and residential areas applied to the Austrian guideline to avoid odour nuisance. *Atmos Environ* 47: 341-347. <https://doi.org/10.1016/j.atmosenv.2011.10.056>
- Schaubberger G, Schmitzer R, Kamp M, Sowa A, Koch R, Eckhof W, Eichler F, Grimm E, Kypke J, Hartung E, 2012b. Empirical model derived from dispersion calculations to determine separation distances between livestock buildings and residential areas to avoid odour nuisance. *Atmos Environ* 46: 508-515. <https://doi.org/10.1016/j.atmosenv.2011.08.025>
- Schaubberger G, Lim TT, Ni JQ, Bundy DS, Haymore BL, Diehl CA, Duggirala RK, Heber AJ, 2013. Empirical model of odor emission from deep-pit swine finishing barns to derive a standardized odor emission factor. *Atmos Environ* 66: 84-90. <https://doi.org/10.1016/j.atmosenv.2012.05.046>
- Schaubberger G, Piringer M, Heber AJ, 2014. Odour emission scenarios for fattening pigs as input for dispersion models: A step from an annual mean value to time series. *Agric Ecosyst Environ* 193: 108-116. <https://doi.org/10.1016/j.agee.2014.04.030>

- Smith RJ, 1995. A Gaussian model for estimating odour emissions from area sources. *Math Comput Model* 21: 23-29. [https://doi.org/10.1016/0895-7177\(95\)00048-7](https://doi.org/10.1016/0895-7177(95)00048-7)
- Solsona-Monzonis J, 2014. Análisis prospectivo del turismo rural: El caso de la comunitat valenciana. *Cuad Tur*: 313-334.
- Sommer-Quabach E, Piringer M, Petz E, Schaubberger G, 2014. Comparability of separation distances between odour sources and residential areas determined by various national odour impact criteria. *Atmos Environ* 95: 20-28. <https://doi.org/10.1016/j.atmosenv.2014.05.068>
- Sucker K, Both R, Bischoff M, Guski R, Winneke G, 2008. Odor frequency and odor annoyance. Part I: assessment of frequency, intensity and hedonic tone of environmental odors in the field. *Int Arch Occup Environ Health* 81: 671-682. <https://doi.org/10.1007/s00420-007-0259-z>
- Ubeda Y, Ferrer M, Sanchis E, Calvet S, Nicolas J, López PA, 2010. Evaluation of odour impact from a landfill area and a waste treatment facility through the application of two approaches of a Gaussian dispersion model. *Proc 5th Bienn Conf Int Environ Model Softw Soc iEMSs 1*: 322-331. <https://scholarsarchive.byu.edu/cgi/viewcontent.cgi?article=2473&context=iemssconference>
- UNE, 2004. UNE-EN 13725:2004 Air quality - Determination of odour concentration by dynamic olfactometry.
- Vanhaverbeke W, Clodt M, 2006. Open innovation in value networks. In: *Open innovation: Researching a new paradigm*; Chesbrough H, Vanhaverbeke W, West J (Eds.). Oxford Univ Press, pp: 258-281. <https://doi.org/10.1093/acprof:oso/9780199682461.003.0015>
- Willemen L, Verburg PH, Hein L, van Mensvoort MEF, 2008. Spatial characterization of landscape functions. *Landsc Urban Plan* 88: 34-43. <https://doi.org/10.1016/j.landurbplan.2008.08.004>
- Wu C, Liu J, Zhao P, Piringer M, Schaubberger G, 2016. Determination of the odour concentration and odour intensity of a mixture of odorous substances by chemical concentrations: A comparison of methods. *Chem Eng Trans* 54: 283-292. <https://doi.org/10.1016/j.atmosenv.2015.12.051>
- Yamashita R, Hoshino S, 2018. Development of an agent-based model for estimation of agricultural land preservation in rural Japan. *Agric Econ* 164: 264-276. <https://doi.org/10.1016/j.agsy.2018.05.004>
- Yepes V, 1995. Turismo sostenible en el interior de la Comunidad Valenciana: posibilidad de un desarrollo turístico complementario al del “sol y playa”. *Papers de Turisme* 17: 75-87.
- Zahn JA, DiSpirito AA, Do YS, Brooks BE, Cooper EE, Hatfield JL, 2001. Correlation of human olfactory responses to airborne concentrations of malodorous volatile organic compounds emitted from swine effluent. *J Environ Qual* 30: 624-634. <https://doi.org/10.2134/jeq2001.302624x>