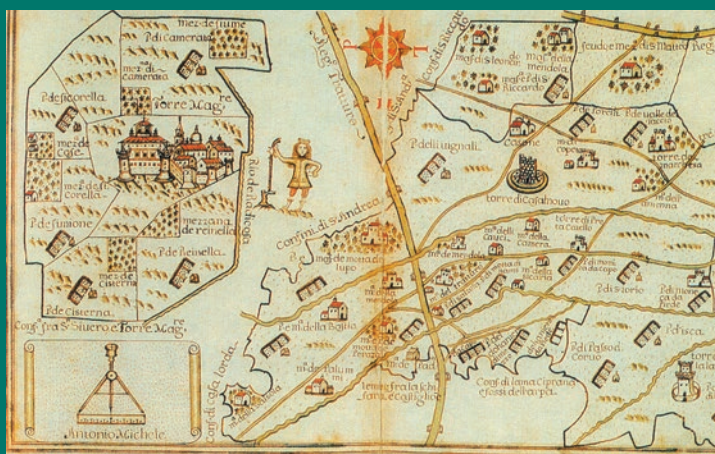# 79
DICEMBRE 2021

A E S T I M U M

SAGGI E CONTRIBUTI

Bio-districts and the territory: evidence from a regression approach *by Chiara Mazzocchi, Luigi Orsi, Carlotta Bergamelli, Alberto Sturla*

The hidden value of non-timber forest products: income contribution of the Basilicata wild truffle *by Mauro Viccaro, Severino Romano, Adele Coppola, Gerardo Vaccaro, Francesco Riccioli, Mario Cozzi*

Buildings' energy performance, green attributes and real estate prices: methodological perspectives from the European literature *by Elena Fregonara, Irene Rubino*

Urban design quality assessment: an approach integrating big data and geostatistical techniques *by Veronica Alampi Sottini, Elena Barbierato, Irene Capecchi, Tommaso Borghini, Claudio Saragosa*

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AESTIMUM

AESTIMUM

INDICE

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TABLE OF CONTENTS

Chiara Mazzocchi[1,*], Luigi Orsi[2], Carlotta Bergamelli[1], Alberto Sturla[3]

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Bio-districts and the territory: evidence from a regression approach

In recent years the bio-districts have been considerably spread in Italy. The bio-district can be defined as a locally rooted multifunctional project with the involvement of farms and institutions. Our research aims at assessing potential relations between territorial, socio-economic features and the presence of bio-districts in an area, by means of a logit regression analysis at municipal scale in Italy. Data have been collected from several sources, among which ISTAT digital databases. Main results show as farms with diversification activities and the presence of Local Action Groups are factors related to the rising of bio-districts in a territory. Moreover, the study highlights the role of bio-districts in disadvantageous and mountain areas, in developing effective territorial governance. In terms of policy implication, CAP 2023-2027 can constitute the ideal bench for testing bio-districts function playing a crucial role in reaching the objective set by the Farm to Fork strategy.

1. Introduction

1.1 Background and research purposes

In recent years the bio-districts have been considerably spread in Italy. Today there are at least 51 Italian bio-districts (Dara Guccione and Sturla, 2021) between established and in the process of being established, characterized by a different level of operations. The bio-district can be defined as a locally rooted multifunctional project (Fanfani et al., 2018) with the involvement of farms and institutions (Municipalities, Regions, Associations). Each institution should be the promoter of initiatives, discussions, elaborations that will lead to measures, to incorporate and coordinate activities meeting the needs of the territory (Sturla, 2018). The objectives are the development of local organic agriculture, the shortening of supply chains, food education and continuous training for operators. Moreover, the scope is to generate income through local products, to help slow down the progressive depopulation phenomena (Mazzocchi et al., 2021) and produce evident benefits in social and economic terms, focusing attention on the profitability and organization of the supply chain (Arru et al., 2019; Sturla, 2018).

The bio-districts have their roots in the concept of industrial districts (Becattini, 1989). After the intuition of Marshall (1842-1924), according to which the economies of scale of large companies can be replaced by the external economies of the districts in which collaborate small businesses (Giuca et al., 2017), Becattini defines the industrial district "as a socio-territorial entity characterized by the active coexistence, in a limited territorial area, of a community and several industrial companies" (Becattini, 1989). Similarly, the peculiarity of agri-food Italian landscapes, consisting of territories with a strong productive specialization and characterized by high concentration of small farms, makes necessary the vertical integration in a system including the transformation, the marketing of products and business management, just like in industrial districts (Sturla, 2020).

Italian legislative decree 228/2001 "Orientation and modernization of the agricultural sector", in article 13, regulates Rural districts and Quality agri-food districts, applying for the first time the concept of "district" to the Italian agricultural system. Therefore, bio-districts could have an advantage compared to the other agricultural districts to foster local development (Carrosio, 2013). According to some scholars (Thomaidis and Papathanasiou-Zuhrt, 2018) local development should be based on the endogenous potential of the territory with an eye to the global system. This neo-endogenous approach, basically consisting in social innovation processes, can be supported by organic agriculture, seen as a complex system of cultural and social values. The contribution of organic agriculture to local development is twofold: organic farming activates the neo-endogenous potential of a territory, involving on the one hand the territorial system in terms of communication of agricultural sustainability, education to respect the environment, environmental protection. Moreover, organic farming works as a catalyst for participation in a territory, as it promotes not only knowledge and skills, but also values (Ruggeri et al., 2020). On the other hand, it includes global aspects, addressing the growing consumer demand for organic farming products. Finally, according to EU, the transition of the European agri-food sector towards a sustainable production and consumption model is a key element of the Green Deal which will be reached by several agricultural approaches, such as precision agriculture, agroecology, agro-forestry, stricter animal welfare standards and organic farming.

Nevertheless, the bio-districts in Italy are a diversified reality, not based on a single model, other than the organic farming values (Sturla, 2020). Italian bio-districts are born for different purposes, have different agricultural characteristics and involve territories that are very diversified one from each other. Our conjecture is that there are common traits that distinguish the bio-districts and some characteristics of the territory which can contribute to the rising and maintenance of this typology of territorial governance. More in detail, we hypothesize the existence of external and internal factors to the agricultural sector related to the presence of bio-districts in a territory. Anyway, at our knowledge, there is a lack of studies focused on bio-districts to analyse the relationship between territorial characteristics and presence of districts. Thus, our research aims at assessing potential relations between territorial, socio-economic features and the presence of bio-districts in an area, by means of a logit regression analysis at a municipal scale

in Italy. The paper is organized as follows. Section 1 details the literature review on bio-districts (1.2) and the regulation aspects (1.3). Section 2 presents methodology and data. The results are shown and discussed in section 3. Section 4 draws conclusions.

1.2 Literature on bio-districts

Following the increase of bio-districts and similar forms of multilevel governance also in Europe, literature on the subject is being developed. However, to date there are still few studies on the subject. The topics dealt with focus mainly on narration or the comparison of case studies (Belliggiano et al., 2019; Favilli et al., 2020; Pugliese et al., 2015; Stotten et al., 2017) on the definition and identification of tools to classify bio-districts and eco-regions (Franco and Pacino, 2015; Pugliese et al., 2016; Zanasi et al., 2020), on the construction of social networks that characterize the bio-districts (Dias et al., 2021), on the implementation of the bio-district tool using the agroecological (Dara Guccione and Sturla, 2021; Gargano et al., 2021; Guareschi et al., 2020) and the circular economy approach (Poponi et al., 2021).

Governance and structure of the first bio-district in Cilento have been analysed by Clemente et al. (2013), eliciting the phases of the organizational and social network building, to define some guidelines for other experiences. Other studies (Belliggiano et al., 2019) have focused on the comparison between bio-districts (Val Camonica, Varese Ligure) highlighting the differences in the agricultural area and landscape characterising the territorial context, by using multivariate analysis. More in detail, Belliggiano et al. (2019) give a distinct partition of the regional territories where the bio-districts are born, selecting the municipalities with affinity to them, for encouraging the replication of bio-districts including them in planning strategies for the future. Awareness of the differences among the Italian bio-districts and the eco-regions in Europe has led Zanasi et al. (2020) to develop an analytical framework in order to find a suitable classification tool to "reorder" these multi-actor governance structures.

In the light of the agroecology concept, some authors have tried to find similarities between Italian multifunctional farms characteristics with agroecological principles, confirming some common points between these two approaches (Gargano et al., 2021), in a bio-district territory. Similarly, Guareschi et al. (2020) investigate if bio-district can contribute to scale-up towards agroecological agriculture in the context of Parma bio-district, finding that it facilitates a relationship between organic and agroecological agriculture, diffusing organic agriculture although some weaknesses of bio-district tool remain, among which the difficulty of governing a territory and participatory processes with many stakeholders. Finally, contributions such as that of Poponi et al. (2021), enrich the panorama of literature by analysing the existing contributions through the interpretative key of the circular economy by taking as a case study the Etruscan Roman Bio-District.

1.3 Italian regulations on bio-districts

An explicit and formal recognition of agricultural districts is given by Legislative Decree 228/2001 (Idda et al., 2002). Legislative Decree 228/2001 "Orientation and modernization of the agricultural sector", in article 13 "Rural districts and quality agri-food districts" defines rural districts and quality agri-food districts. Some researchers (Albisinni, 2010) argue that this decree shows important omissions (e.g., agro-industrial districts (Careri and Saija, 2008)), because it does not consider the great diversity of the agri-food sector, the heterogeneity of supply chains and the different ways of relating to the territory, environment, and local economic system (Sturla, 2019).

The "stability law" n.205, in 2017, tries to fix these omissions. This law establishes the criteria, methods, and procedures for the implementation of interventions and, in art.1 paragraph 499, creates the food districts. Food districts were made for four reasons: firstly, to provide opportunities and resources for the growth and enhancement of both supply chains and territories; secondly, to give impetus to existing districts; thirdly, to encourage the birth of new realities through the possibility of access to dedicated funding; lastly, to highlight the role of the local community and the relationships that can weave with agri-food chains (Fanfani et al., 2018). This law has a fundamental role in the regulatory history because, for the first time (Sturla, 2019), the definition of bio-districts and biological districts is given in article 2 paragraph 449. Until then, bio-districts had organized themselves independently, taking on multiple nuances in the definition and other key aspects: identification, characteristics of agriculture, attention given to the link with the territory, actors involved (Pugliese, 2016).

In advance of national legislation, some individual regions and provinces have made explicit reference to bio-districts, adopting norms that define parametric criteria for their identification, although very different from each other. These regulations have remained in force as established by the above-mentioned law. Currently, four regions and one autonomous province have specific legislation for bio-districts: Liguria (L.R. 66/2009); Sardinia (L.R. 16/2014); Lazio (L.R. 11/2019); Tuscany (L.R. 51/2019), and Independent Province of Trento (L.P. 16/2021). Lazio and Tuscany have a specific law, while in other regions the definition is put within broader laws on organic agriculture (Liguria and Trento) or agriculture in general (Sardinia) (Viganò, 2019). The districts recognized by regional laws respond to stringent parametric criteria. This is because the administrations tend to have a "classic" (or economic) conception of the biological district, in which the presence of productive requirements is the basis for future development actions (Dara Guccione and Sturla, 2021).

The Regional Law 66/2009 of the Liguria Region, the strictest among those issued (Dara Guccione and Sturla, 2021), provides that an organic district to be recognized has the following requirements: at least 13% of the regional organic operators must be present in the area; producers must represent at least 75% of the total number of organic operators; the percentage incidence of organic farms on total farms must be higher than the national and regional incidence of at least 4%; the

percentage incidence of the organic UAA on the total UAA of the area must be at least 6% higher than the national and regional. Moreover, the district must insist on a total area of at least 250 km^2. The Tuscan law also requires that at least 30% of the UAA of the area is cultivated with organic methods and a minimum number of operators and municipalities adhering. Including in the development plan a forecast of the increase of organic UAA is one of the priority criteria for the recognition of bio-districts. Other regional laws are less demanding. The L.R. 11/2019 of the Lazio Region simply establishes a minimum number of partners adhering to the District Agreement (2 farms and 2 municipalities) while the L.R. 16/2014 of the Sardinia Region emphasizes the need for a "presence on site of an economically relevant horizontal supply chain, built from organic production with activities closely interconnected activities concerning production sectors other than the primary one, aimed at the marketing and enhancement of organic production".

Recently, in Trentino, the legislation on organic production has been issued, with the provincial law July 28, 2021, n. 16. Regarding the criteria for the establishment of a bio-district, the law gives only general indications on the characteristics of the territory:

- the significant presence of agricultural products obtained by the organic method;
- the protection of typical local productions and cultivation methods;
- the presence of significant landscape areas, expression of the identity of the territory and/or provincial protected areas;
- the limited use of phytosanitary products.

At the national level, institutions are working to create a common discipline. On January 13th, 2021 the Senate Committee on Agriculture voted unanimously for the approval of the bill on organic farming: ddl n.988 "Provisions for the protection, development and competitiveness of agricultural production, agribusiness and aquaculture with organic method". Article 13 of this law contains specifications about the requirements of the bio-district, its constitution and the action of the subjects involved. It defines the bio-district as "local production systems, even of interprovincial or interregional character, with a strong agricultural vocation in which are significant:

- the cultivation, breeding, processing and food preparation of organic products in accordance with the regulations;
- organic primary production that is located in a supra-municipal territory".

They are also characterized by their environmental value. The law provides that within them there are "landscape relevant areas". Lastly, they are assigned specific purposes to support organic agriculture, both from the point of view of conversion and through the enhancement of local productions.

The experience of bio-districts is not limited to the national territory. Thanks to the initiative of IN.N.E.R. (International Network of Eco-Regions) a similar governance model is present in other European countries[1].

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[1] There are currently four eco-regions in Portugal, two in Spain and two in Slovakia that adopt IN.N.E.R. guidelines (Dara Guccione and Sturla, 2021). IN.N.E.R. is an international network

However, the prototype organic district was born in France, in the Drôme river valley, as a joint initiative of four farmers' cooperatives that have initiated a collective program to develop local organic farming (Stotten et al., 2017). But it is in German-speaking Switzerland that the concept of the biological district as a body capable of initiating an integrated local development process, finds its greatest expression. In addition to these, there are over twenty eco-regions in Austria, although they vary greatly in many ways.

Because of the popularity of this approach, a new regulation on organic farming has been issued (Reg (EU) n. 848/2018), which will become operational as of 1st January 2022. It aims to revise and strengthen the EU rules on organic production and labelling of organic products. In addition, it introduces major innovations, such as group certification, which may facilitate the achievement of the objectives of organic districts and the activities of their operators.

2. Methodology

2.1 Conceptual framework

The study implements an econometric model based on a logit regression, using as a dependent variable the presence of bio-district in the municipalities, a dummy variable, testing socio-territorial and agricultural factors as explanatory variables. In the bio-district the promotion of organic products is combined with the promotion of the territory in order to achieve the development of its economic, social and cultural potential (Triantafyllidis et al., 2019). This can be carried on by involving the territorial actors, such as farmers, associations, institutions. According to Assiri et al. (2021) the presence in a territory of different elements and activities, both material and immaterial, allow the success of bio-districts, where biological and environmental characteristics are immersed in a peculiar economic and social context. Starting from this premise, explanatory variables have been selected, considering economic and social aspects of bio-districts, together with environmental and territorial factors to investigate how these elements are related to the rising of this typology of territorial governance in area. Among explanatory factors, variables related to agriculture features of an area are fundamental, being bio-districts tolls funded on the primary sector. At the same time, studies on industrial districts confirm the recognition of the role played by the territory in development processes and suggest the existence of new variables, not strictly technical, which influence the decisions of economic agents and condition the dynamics of the local socio-economic transformation (Romano, 2000). Thus, we include in the model socio-territorial parameters, since bio-districts start with the aim to develop organic agriculture in areas in which employment supporting measures can strongly help social development.

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of bio-districts which aims to allow an advantageous exchange of experiences between the existing district realities on the European territory, established in December 2014.

Starting from the framework proposed by Assiri et al. (2021), our model comprehends explanatory variables regarding economic, territorial, social aspects, that are grouped into three sets (Table 1): Control variables, Agricultural variables and Socio-territorial variables. Moreover, we included Italian regions as dummy variables, to test the characteristics of each region influencing the existence of bio-districts in municipalities.

The description of the variables is in Table 1. The Control group includes Population density and per capita income variables, which can be considered territorial/economic variables, useful to assess the stability of the model.

The Agricultural variables group includes parameters related to the agricultural characteristics of an area: the presence of organic farms, presence of small farms, farms producing PGI or PDO, direct selling in farms, farmers' age, utilized agricultural area (UAA). We take into consideration the presence of organic farms in the area where bio-districts have taken place. Organic farming is not only a way to produce sustainable food but is the bearer of a value system based on healthiness of productions, environmental care, living ecological system and fairness to the environment (Stotten et al., 2017), thus the presence of organic farms in an area, could foster territorial projects in which organic principles are foundations of the system, as the bio-districts are. Moreover, the territorial development of rural and agricultural areas in Italy could take advantage from organic productions, given the growing market success that organic products have had in the last twenty years, as confirmed by the data regarding the agricultural areas grown organically and the number of farms in constant increase (Sinab, 2021).

Small farms practicing livestock and crops cultivations at small scale can influence the arise of bio-districts, because they are often the target of this kind of regulation system (Sturla et al., 2020). In fact, these farms often opt for alternative solutions for selling their products and solving competitiveness problems (Corsi et al., 2020). According to Mazzocchi et al. (2020), in the past 40 years the Italian trend in farm number records a continuous decrease of small enterprises, those with less than 5 ha, thus they should be the most interested in searching for alternative supply chain system.

Farms producing PDO and PGI products, as well as direct selling farms, should be more sensitive to short supply chains than other typologies of enterprises, and interested to diversify their own activities (Mazzocchi et al., 2020; Monaco et al., 2016). Similarly, bio-districts represents a model to manage food supply chain involving the promotion of the territory, for example by the co-management process between farms and tourist offer in an area (Favilli et al., 2020). So, the existence of these typologies of productions and services in a territory could encourage the bio-districts spread.

Farmers' age is often impacting on farms innovation for the interest of young farmers generation to be involved in new projects having an open-mindedness approach (Mazzocchi et al., 2020). As an example, many studies (Meraner et al., 2015; Rivaroli et al., 2016,) have confirmed a relationship between the young farmers and the diversification degree of farms. Similarly, the young farmers are more prone to organic farming than the old ones because they are usually more inter-

Table 1. Description of variables.

Variable name	Group	Indicator (measure unit)	Source
Bio-district	Dependent variable	presence of bio-district in the municipality (dummy)	CREA, 2021
Population density	Control variable	number of municipality inhabitants/mq of municipality (in/mq)	ISTAT, 2019
Per capita income	Control variable	average income of a municipality (€)	MEF, 2019
Regions	Control variable	belonging of municipality to a Region (dummy)	ISTAT, 2010
UAA	Agricultural variable	utilized agricultural area in each municipality in 2010 (ha)	ISTAT, 2010
Small farms	Agricultural variable	farms in the municipality with less than 2 ha of UAA (number)	ISTAT, 2010
PDO-PGI	Agricultural variable	farms producing PGI or PDO in a municipality (number)	ISTAT, 2010
Farmer's age	Agricultural variable	average of famers' age of a municipality (years)	ISTAT, 2010
Direct selling in farms	Agricultural variable	direct sale farms in each municipality (number)	ISTAT, 2010
Organic farms	Agricultural variable	organic farms in each municipality (number)	ISTAT, 2010
Altitude	Socio-territorial variable	0 = plain municipalities; 1 = hills and mountain municipalities (dummy)	ISTAT, 2010
Non-profit associations	Socio-territorial variable	non-profit associations in a municipality (number)	ISTAT, 2018
LAG	Socio-territorial variable	presence of Local Agricultural Group (LAG) in a municipality (dummy)	CREA, 2021
Unemployment rate	Socio-territorial variable	number of unemployed / number of inhabitants per municipality (index)	ISTAT, 2019

ested to innovative agricultural practices. As a matter of fact, the UAA surface in a territory may influence the rising of bio-districts, because of the availability of agricultural areas in which bio-districts can take place.

Socio-territorial factors are: altitude of the municipality, unemployment rate of the municipality, presence of non-profit associations, presence of Local Action Groups (LAGs). Among the socio-territorial factors, the altitude of the municipality is a proxy of mountain disadvantageous areas (Mazzocchi and Sali, 2021) and can be related to the bio-district localization. Our hypothesis is that municipalities

located in mountain disadvantageous areas are more interested in being included in bio-districts projects. In fact, the idea is to combine nature protection with economic development, for which bio-district approach as a model of territorial governance could be winning (Stotten et al., 2017).

From a socio-economic point of view, rural areas are the most interested in finding new forms of territorial economic development, in places where agricultural space is generally available (Mazzocchi and Sali, 2021). The unemployment rate can influence the rising of bio-districts in disadvantageous areas, to ameliorate working conditions of populations. The presence of non-profit associations may be related to the social capital that allows to develop territorial networks and start projects. In fact, according to Favilli et al. (2020) a bunch of multiple actors work in specific territories to collaborate creating networks, making more efficient the process to facilitate innovation process.

Lastly, we include in the model the Local Agricultural Group (LAG) because it results from a network of active subjects constituting a public-private partnership, which could be functional to the rising of other forms of territorial governance, such as bio-districts. In fact, the reasons for the growth of some local contexts reside precisely in community-type factors (local culture, diffusion of small family businesses, etc.) (Sturla, 2020; Cozzi et al., 2020).

Thus, these parameters could have an impact on the presence of bio-districts in an area, fostering their diffusion.

2.2 Econometric model and data

Our dependent variable measures the event of bio-district formation at the municipality level and this variable is binary in nature (0 = no bio-district presence, 1 = bio-district presence), thus we estimate the likelihood of bio-district formation using a logit model (Rothaermel and Boeker, 2008). Data have been collected from several sources, among which ISTAT digital databases (VI Census of Agriculture, 2010; XV Census of Population and Habitat, 2011), CREA databases and MEF.

The logit regression is a nonlinear regression model used when the dependent variable is dichotomous, to assess the probability that an observation can generate one or the other value of the dependent variable. More in detail, the outcome variable, Y', is the probability of bio-district formation /non-formation based on a nonlinear function with two outcomes. The logit model is estimated by a maximum likelihood procedure with which efficient, consistent and normally distributed estimators are obtained.

We use the following specification:

$$ln\left(\frac{Y'}{1-Y'}\right) = \alpha + \sum \beta_i X_i \tag{1}$$

where α is the constant, X_i is the vector of the independent and control variables for the municipality i and β_i is the vector of coefficients.

We used the *glm* command from the Stats package in the R 4.1.1 software[2] to estimate the logit model.

As a baseline model to which compare our results against, we present the outcome with only the control variables and Regions dummy variables. Indeed, Model 1 in Table 3 reports the effect of the control variables on the dependent variable. Moreover, we have included Italian regions as dummy variables, to test the characteristics of each region influencing the existence of bio-districts in municipalities. Abruzzo region has been selected by the software as the reference level for comparing the results of other Regions. Thus, the results mean the deviation of regions from the baseline. The choice of the Region's dummy variable to be eliminated is made automatically by the software because the results do not change. The elimination of a level from the regression, in our case the Abruzzo dummy variable, is employed exclusively to obtain a baseline from which to comment on the other levels, in our case the other Regions' dummy variables. Furthermore, Abruzzo is one of the Regions with average values as regards the dependent variable, i.e., the presence of bio-districts, so it fits well as baseline.

Model 2 shows the effects of the control variables and Regions dummy variables plus the Agricultural variables group on the dependent variable. The results of the controls and Regions dummy variables plus the Socio-territorial independent factors on the dependent variable are pointed out in Model 3. Finally, Model 4 presents the results for the full model with odds ratios when all variables are included (Regions dummy variables, control variables, agricultural variables, and socio-territorial variables).

The coefficients from the models can be difficult to interpret because they are scaled in terms of logs. Another way to interpret logistic regression models is to use the antilog to estimate the coefficients into odds ratios. This procedure allows for a better understanding and comparison of coefficients in the full model (see Model 4 in Table 3).

We measured the Akaike Information Criterion (AIC) and the log-likelihood to assess the goodness of fit of the logit models. A common way to compare models is using the Likelihood Ratio (LR) test. The LR test evaluates the evidence in the data to support the extra complexity of nested models.

3. Results and discussion

Our sample includes 8,094 Italian municipalities and the descriptive statistics of explanatory variables are shown in Table 2.

In the model all the continuous variables have been considered in their natural logarithm form; for the other variables, we employ the dummy form (LAG, Altitude) or the interval 0-1 (Unemployment rate).

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[2] R is a language and environment for statistical computing and graphics.

Table 2. Descriptive statistics.

Variables	min	max	mean	standard deviation	variance coefficient	observation
Bio-districts	0	1	0.09	0.28	3.28	8094
Population density	0	12224	297.42	634.89	2.13	8094
Per capita income	481920	49314358907	105007624.18	755169820.40	7.19	7854
UAA	0	44973	1588.35	2736.54	1.72	8094
Small farms	0	4599	101.23	222.55	2.20	8094
PDO-PGI farms	0	1023	22.36	55.27	2.47	8094
Farmers' age	0	72	5.49	16.93	3.08	8094
Direct selling farms	0	1069	33.43	64.41	1.93	8094
Organic farms	0	446	5.58	15.92	2.85	8094
Altitude	0	2035	357.53	297.56	0.83	8094
Non-profit associations	0	12436	37.21	203.32	5.46	8094
LAG	0	1	0.62	0.49	0.79	8094
Unemployment rate	3	29.5	9.04	5.21	0.58	7843

The correlation analysis between explanatory variables results in a strong correlation between Income and Non-profit associations variables, and UAA and Organic farms variables, suggesting a similar influence on the dependent variable – bio-district formation; thus, to avoid multicollinearity issues, we have eliminated Non-profit associations and UAA variables from the models.

We have carried out additional tests (see Table 3) to detect possible multicollinearity problems by means of Variance Inflation Factors (VIFs) for all the models and have found multicollinearity not to be a problem, being them lower than the cut-off point of 5 (O'Brien, 2007).

Regressions results are shown in Table 3, with the four models calculated, Model 1, 2, 3 and 4. As highlighted in par. 2, the robustness of our findings is tested by the use of alternative model specifications. As highlighted in Table 3, Model 2, including the Agricultural group variables, performs better than Model 1 (LR test: 42.324(5); AIC: 4,137.68). Similarly, Model 3, comprehending the Socio-territorial group variables, improves significantly compared to Model 1 and also to Model 2, resulting in LR: 97.091(3); AIC: 4,078.92. This means that Socio-territorial group variables have a higher influence than the other group of variables on the dependent, and a better fitting model. Lastly, Model 4 shows the best performance among the alternative specifications, with LR: 152.82(8); AIC: 4,033.19. Thus, Model 4 is the best fitting model of our work.

Following the comments to the result of the full model, starting from Regions' dummy variables. We have included in the models Italian regions, with the aim to assess the influence of the characteristics of each region on the presence of bio-

Table 3. Logistic regression model results.

| | Model 1 | Model 2 | Model 3 | Model 4 | |
| | | | | Full model | |
Dependent variable: Presence of Organic District	Control variables	Agricultural variables	Socio-terr. Variables	Full model	Odds Ratios
Constant	-2.850*** (0.275)	-3.060*** (0.279)	-5.037*** (0.356)	-5.505*** (0.368)	0.004
Small_farms_		-0.001*** (0.0003)		-0.0001 (0.0003)	1.000
PDO-PGI		0.003*** (0.001)		0.004*** (0.001)	1.004
Farmer's_age		0.003 (0.002)		0.003 (0.002)	1.003
Direct selling		0.003*** (0.001)		0.002*** (0.001)	1.001
Organic_farms		0.003 (0.002)		0.002 (0.003)	1.002
Altitude			0.001*** (0.0002)	0.001*** (0.0002)	1.147
LAG			0.524*** (0.119)	0.520*** (0.120)	1.682
Unemployment_rate			0.125*** (0.017)	0.137*** (0.018)	1.682
Population density	-0.002*** (0.0002)	-0.002*** (0.0002)	-0.001*** (0.0002)	-0.001*** (0.0002)	0.999
Per capita income	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	1.000
Basilicata	-13.624 (209.562)	-13.541 (208.521)	-13.523 (208.759)	-13.455 (208.145)	0.000
Calabria	0.780** (0.324)	0.724** (0.329)	-0.543 (0.388)	-0.779* (0.402)	0.459
Campania	0.815** (0.323)	0.848*** (0.324)	0.320 (0.336)	0.299 (0.338)	1.349
Emilia-Romagna	-0.504 (0.451)	-0.565 (0.454)	0.293 (0.459)	0.345 (0.462)	1.412
Friuli Ven. Giu.	0.539 (0.384)	0.656* (0.385)	1.365*** (0.394)	1.610*** (0.397)	5.005
Lazio	0.989*** (0.322)	1.094*** (0.324)	1.304*** (0.325)	1.417*** (0.327)	4.125
Liguria	0.272 (0.405)	0.411 (0.406)	0.608 (0.408)	0.817** (0.410)	2.264
Lombardy	0.865*** (0.295)	1.000*** (0.297)	1.789*** (0.310)	2.048*** (0.315)	7.750
Marche	0.693* (0.369)	0.733** (0.370)	1.164*** (0.373)	1.274*** (0.376)	3.574

Dependent variable: Presence of Organic District

	Model 1	Model 2	Model 3	Model 4	
	Control variables	Agricultural variables	Socio-terr. Variables	Full model	Odds Ratios
Molise	1.893*** (0.337)	2.062*** (0.339)	1.891*** (0.338)	2.057*** (0.340)	7.825
Piedmont	0.439 (0.300)	0.551* (0.302)	0.938*** (0.304)	1.126*** (0.307)	3.083
Apulia	1.598*** (0.325)	1.755*** (0.346)	0.717* (0.375)	0.535 (0.402)	1.707
Sardinia	-2.658** (1.039)	-2.647** (1.039)	-2.885*** (1.043)	-2.868*** (1.043)	0.057
Sicily	2.167*** (0.299)	2.203** (0.306)	0.991*** (0.351)	0.856*** (0.362)	2.353
Tuscany	1.568*** (0.319)	1.442*** (0.322)	2.175*** (0.327)	2.115*** (0.330)	8.287
Tr. Alto Adige	-0.788 (0.496)	-0.914* (0.505)	-0.101 (0.507)	-0.166 (0.516)	0.847
Umbria	-1.515 (1.042)	-1.631 (1.043)	-1.224 (1.043)	-1.324 (1.045)	0.266
Veneto	1.835*** (0.297)	1.875*** (0.300)	2.686*** (0.311)	2.822*** (0.314)	16.818
Observations	7,608	7,608	7,608	7,608	
Log Likelihood	-2,064.003	-2,042.841	-2,015.457	-1,987.595	
Akaike Inf. Crit.	4,170.006	4,137.682	4,078.915	4,033.189	
LR test(Df)		42.324(5)***	97.091(3)***	152.82(8)***	
VIF	1.068	1.706	2.605	2.688	

Notes: *p<0.1; **p<0.05; ***p<0.01; standard errors are in parentheses; regional reference level (omitted) = Abruzzo.

districts in an area. In fact, Regions are characterized by different administrative and legal principles governing the entire regional area, thus potentially influencing the rising and maintenance of bio-districts. As shown in Table 3, several Regions' variables resulted to be significant. Concerning these factors, the regression coefficients show the deviation of each region from the baseline, which in our model is Abruzzo.

Only two regional areas result to have negative signs of the coefficients, Sardinia and Calabria, meaning that belonging to these two regions does not influence the presence of bio-districts in an area if compared to the baseline. In fact, Sardinia counts only one bio-district in its territory, although a second bio-district is now being defined (Sinab, 2020). Other Region variables have coefficients with positive signs. More in detail, we can note a great attention to the bio-district opportunity by many Northern Italian regions, as Lombardy, Piedmont, Veneto, Friuli-Venezia Giulia, and Liguria, resulting in positive coefficients. That is, being in the territory of these Regions positively influences the existence of a bio-district in an area, if compared to the benchmark. Probably, also the geography of these Regions plays a role in influencing the rising of bio-districts, mainly referred to the fact that Northern Regions are characterized by large mountain areas, classified as disadvantageous territories, where bio-district can lead to economic development. Moreover, Liguria is the first Region in which a regional law regulating bio-districts was approved (L.R. 66/2009).

Among the regions of the Central Italy, Tuscany and Marche show a significant positive deviation from the baseline. Tuscany has approved in 2019 its regional law on bio-districts and counts 7 bio-districts in its area, and in Marche region is placed the largest bio-district in Italy and Europe (Federbio, 2021).

Going to the south of the peninsula, among Southern regions only Molise shows a positive deviation from the baseline, probably because it has a small territory extension with a high percentage of rural areas, where 2 bio-districts are born.

The Control variables group includes Population density (coefficient: -0.001; odds ratio: 0.999) and per capita income (coefficient: 0.000; odds ratio: 1.000), remaining stable in all the four models. Only the population density variable shows a negative relationship with the dependent variable, demonstrating a higher probability that bio-districts arise in a territory with low density population. This result is linked to the fact that bio-district is a tool conceived with the aim of developing the rural territory, often characterized by low population density. The urgency to create new economic opportunities in rural areas is also attested by the fact that 40% of the European territory in which 30% of the population lives, is affected, or will be affected by demographic decline in the coming decades, as found by the research project 'Escape', of the ESPON study program (Escape, 2020). Policy actions for declining rural areas should reflect broader social objectives than economic growth, such as inclusion, well-being, community services and an ecological transition, which are objectives very close to those of bio-districts.

Among agricultural factors, PDO-PGI farms and Direct selling in farms have a relationship with the dependent. PDO-PGI variable (coefficient: 0.004; odds ra-

tio: 1.004) includes farms particularly interested in the valorisation of their productions, because they strongly invest in quality (Mazzocchi et al., 2020). Then, farms producing PDO and PGI are more interested in territorial projects that can revitalize the area in which they work, promoting the territory. In fact, as highlighted by Galli et al. (2010) among the objectives included in Reg. 510/2006 denomination of origin productions indirectly should favour the local development of the territory of origin, especially in rural areas, safeguarding their identity and the continuation of traditions and cultural activities related to the product.

Direct selling in farms (coefficient: 0.002; odds ratio: 1.004) variable indicates the farms interested in developing new market channels to implement their income, that can be interested in new socio-economic projects, as bio-districts. Moreover, this variable represents the proximity between producers and consumers and the arising of personal relationships between them (Corsi et al., 2020), which can be the basis for the development of networks capable of supporting the creation and maintenance of bio-districts. The positive relation between this variable and the presence of bio-districts confirms these remarks.

Socio-territorial group includes three statistically significant factors: Altitude (coefficient: 0.001; odds ratio: 1.147), LAG (coefficient: 0.520; odds ratio: 1.682) and Unemployment rate (coefficient: -0.137; odds ratio: 1.682).

Confirming our hypothesis, Altitude is positively related to the bio-districts presence, thus the localization in disadvantageous areas (Mazzocchi & Sali, 2021) seems to influence the rising of this territorial governance structure. In fact, on one hand, bio-district is born to support small farmers, rural communities, rural areas suffering depopulation process, as the mountain and hill areas can be. On the other hand, several mountain areas need a new economic model based on endogenous characteristics of the territory, such as nature, environment, extensive agriculture, traditions; bio-district model comprehends both the involvement of the territorial community carrier of identity, tradition, culture and the issue of nature by stimulating the adoption of organic agriculture techniques.

LAG variable is strongly and positively related to the dependent, thus a network of active subjects as the LAGs encourages the bio-district presence. The presence of LAGs guarantees the development of social networks that connect interest groups, associations, local institutions present in the territory, thus can serve as a basis for the development of bio-districts, confirming our hypothesis. The LAGs are local partnerships functional to the implementation of LEADER actions. Over the years, the LEADER approach to local development "has proved to be an effective tool for promoting the development of rural areas, fully suited to the multisectoral needs of endogenous rural development thanks to its "bottom-up" approach" (Reg UE 1305/2013). In fact, the LEADER approach is also confirmed in the 2023-2027 programming. The bottom-up approach, the need for a public-private partnership, the network of stakeholders and actors that it puts in place for local economic development, makes LEADER a valuable tool for planning and territorial governance.

Lastly, according to the idea that bio-districts should produce evident benefits in social and economic terms, the Unemployment rate is negatively related to

the dependent: that is, where a social fragility in economic terms exists, is more probable the development of bio-districts. In fact, in some areas with bio-districts, there are very important unemployment phenomena, especially among young people (Sturla, 2020). In some cases, the problem of unemployment is strictly linked to legality, also due to the strong presence of migrants who can easily fall prey to the phenomena of illegal hiring. Sturla et al. (2020) affirm as in the case of Valle del Simeto bio-district, one of its objectives is to encourage greater involvement of young people and migrants in the management of farms.

4. Conclusions

At our knowledge few contributions in literature try to assess the characteristics of bio-districts also because they are new governance tools that, most likely, will further be implemented, thanks to the new legal framework of Reg. (EU) No 848/2018 that will be effective from 2022. Main results regard agricultural and socio-territorial factors, because the presence of PDO-PGI productions, Direct selling in farms and presence of LAGs are related to the rising of a bio-district.

 The reason is probably because the development of new market channels for better income and being part of a new socio-economic project, such as bio-districts, are crucial factors for these farms, and the presence of LAGs can be the basis for the development of networks capable of supporting the creation and maintenance of bio-districts. As a matter of fact, whenever a bio-district is not a direct expression of a LAG's development strategy, it is anyway the result of a socio-economic milieu conducive to territorial collaboration, attested by the presence of the LAG. Similarly, the disadvantageous areas as the mountain territory, are the ideal place for the rising of bio-districts, as confirmed by the Altitude variable. According to our results, bio-districts, besides pursuing their core mission of spreading organic production method and supporting small farms, can address different functions and scopes, more related to territorial management and development, thus reinforcing the idea that they could become a reliable subject for the governance of local development according to more inclusive, multi-actor and transdisciplinary approaches.

The upcoming CAP programming period will constitute the ideal bench for testing these functions, although some bio-districts have been already proved as capable of fostering valuable cooperation initiatives to the benefit of the organic supply chain and its actors already in the programming period 2014-2022 (e.g., Val di Vara, Bio Venezia, Colli Euganei). Even though one could argue that bio-districts are not the only type of territorial partnership in the wide panorama of Italian rural development that deserves policy makers' attention, they must be acknowledged as the only cooperation initiatives that is based on a specific set of values (those of organic farming) and, as such, capable of activating actors that go well beyond the agro-food supply chain at the point of involving local administrations, schools, and consumers. This is a point of strength that make them instrumental in connecting local supply chains to local demand, for instance, or for the

adoption of an integrated approach to development policies, where different tools (smart villages, strategies for inner areas, etc) could converge pivoting around the development of organic supply chain and their integration with other economic sectors (Ho.Re.Ca., handicraft and healthcare).

Moreover, bio-districts could play a crucial role in reaching the objective set by the Farm to Fork strategy, by supporting the conversion of small farmers and easing group certification as operationalized by the Reg (EU) No 848/2018. Furthermore, the contents of the EU Biodiversity Strategy also start from a premise: farmers play an essential role in preserving biodiversity. Thus, since organic agriculture also means a bigger environmental protection than conventional agriculture, the diffusion of bio-districts also fulfils the function of putting the EU Biodiversity Strategy into practice. As the bio-districts are gaining greater consideration among policy makers, the analyse proposed in this paper provides the bio-districts analytical bases on which builds their strategies. This work is a first step in this direction, although limited by the scarce availability of updated databases and difficulty in finding deeper information about existing bio-districts. The next step can be the implementation of the model with panel data, once they will be available, in order to be more effective in the investigation of bio-districts dynamics.

References

Albisinni, F. (2010). Distretti e sviluppo rurale: elementi per una lettura delle regole di diritto, *Agriregionieuropa*, 20, 21–25.

Arru, B., Furesi, R., Madau, F. A., & Pulina, P. (2020). "Value portfolio", value creation and multifunctionality: the case study of an Italian wine agritourism farm. Aestimum, 75, 163–181.

Assiri, M., Barone, V., Silvestri, F., & Tassinari, M. (2021). Planning sustainable development of local productive systems: A methodological approach for the analytical identification of Ecoregions. *Journal of Cleaner Production*, 287, 125006.

Becattini, G. (1989). Riflessioni sul distretto industriale marshalliano come concetto socio-economico. *Stato e Mercato*, 25, 111–128.

Belliggiano A., Sturla A., Vassallo M., & Viganò L. (2020). Neo-endogenous rural development in favour of organic farming: Two case studies from Italian fragile areas. *European Countryside*, 12(1), 1–29.

Careri, P., & Saija, R. (2008). Analisi della normativa sui distretti rurali ed agroalimentari. In Gulisano, G., & Marcianò, C. (Eds.). *I distretti rurali in Calabri. Aspetti teorici, metodologici ed applicativi*. Reggio Calabria, KALìT, pp. 35–48.

Carrosio, G. (2013). Social networks and new inhabitants in rural marginal areas. *Scienze Del Territorio*, 1, 201–210.

Clemente, G. F., Pugliese, L., & Valenti, S. (2013). Il distretto biologico: uno strumento innovativo per una governance territoriale sostenibile. *Energia, Ambiente e Innovazione*, 5, 41–44.

CREA (2020). Bioreport 2019, L'agricoltura biologica in Italia. Available at: https://www.crea.gov.it/web/politiche-e-bioeconomia/-/bioreport-2019 (Accessed 4 October 2021).

Corsi, A. (2007). L'agricoltura biologica Piemontese. Un'analisi delle strutture e delle forme di commercializzazione. Supplemento al n. 56 di "Quaderni della Regione Piemonte – Agricoltura" 11/07, 99.

Corsi, S., Mazzocchi, C., & Ruggeri, G. (2020). The coexistence of local and global food supply chains: the Lombardy region case study. *Agriculture*, 10(11), 1–11, 0540.

Cozzi, M., Prete, C., Viccaro, M., Riccioli, F., Fagarazzi, C., & Romano, S. (2021). Towards sustainable and inclusive communities: an integrated approach to assess sustainability in rural areas. *Aestimum*, 81-102.

Dara Guccione, G., & Sturla, A. (2021). Approccio agroecologico e biodistretti, analisi di due casi studio. Available at: https://www.crea.gov.it/web/politiche-e-bioeconomia/-/approccio-agroecologico-e-biodistretti-analisi-di-due-casi-di-studio (Accessed 13 December 2021).

Dias, R.S., Costa, D.V.T.A., Correia, H.E., & Costa, C.A. (2021). Building bio-districts or eco-regions: participative processes supported by focal groups. *Agriculture*, 11(6), 511.

Fanfani, R., Montresor, E., & Pecci, F. (2018). Dai distretti rurali e agroalimentari di qualità ai distretti del cibo. *Rete Rurale Magazine*, 42–43.

Escape (2020). Synthesis report. Available at: https://www.espon.eu/sites/default/files/attachments/ESPON%20ESCAPE%20Synthesis%20Report.pdf (Accessed 4 October 2021).

Favilli, E., Ndah, H.T., & Barabanova, Y. (2020). Multi-actor interaction and coordination in the development of a territorial innovation project: some insights from the Cilento Bio-district in Italy. In *Proceedings of the 13th European International Farming Systems Association (IFSA) Symposium, "Farming systems: facing uncertainties and enhancing opportunities", 1-5 July 2018, Chania, Crete, Greece*, pp. 1–9 ref. 23.

Federbio (2021). Nasce il distretto biologico unico delle Marche, il più grande d'Italia e d'Europa. Available at: https://greenplanet.net/nasce-il-distretto-biologico-unico-delle-marche-il-piu-grande-ditalia-e-deuropa/ (Accessed 4 October 2021).

Franco, S., & Pancino, B. (2015). *Il distretto biologico*. Milano, Franco Angeli.

Galli, F., Carbone, A., Caswell, J.A., & Sorrentino, A. (2010). A multi-criteria analysis for the assessment of the performance of Italian PDO cheeses, In *"L'agricoltura oltre le crisi", Atti XLVII Convegno di Studi SIDEA, 22-25 settembre 2010, Campobasso*.

Gargano, G., Licciardo, F., Verrascina, M., & Zanetti, B. (2021). The agroecological approach as a model for multifunctional agriculture and farming towards the European Green Deal 2030—some evidence from the Italian experience. *Sustainability*, 13(4), 2215.

Giuca, S., Ricciardi, G., Sturla, A., & Vaccaro, A. (2017). Il contributo dell'agricoltura biologica per lo sviluppo sostenibile delle aree rurali. Distretti biologici e sviluppo locale. Risultati preliminari Marzo 2017. Available at: https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/16674 (Accessed 4 October 2021)

Guareschi, M., Maccari, M., Sciurano, J.P., Arfini, F., & Pronti, A. (2020). A methodological approach to upscale toward an agroecology system in EU-LAFSs: the case of the Parma Bio-District. *Sustainability*, 12(13), 5398.

Mazzocchi, C., Orsi, L., Ferrazzi, G., & Corsi, S. (2020). The dimensions of agricultural diversification: a spatial analysis of Italian municipalities. *Rural Sociology*, 85(2), 316–345.

Mazzocchi, C., Orsi, L., & Sali, G. (2021). Consumers' attitudes for sustainable mountain cheese. *Sustainability*, 13(4) 1743.

Mazzocchi, C., & Sali, G. (2021). Supporting mountain agriculture through "mountain product" label: a choice experiment approach. *Environment, Development and Sustainability*, 24(1), 701–723.

Meraner, M., Heijman, W., Kuhlman, T., & Finger, R. (2015). Determinants of farm diversification in the Netherlands. *Land Use Policy,* 42, 767–780.

Monaco, F., Sali, G., Mazzocchi, C., & Corsi, S. (2016). Optimizing agricultural land use options for complying with food demand: evidences from linear programming in a metropolitan area. *Aestimum*, 68, 45–59.

O'Brien, R.M. (2007). A caution regarding rules of thumb for variance inflation factors. *Quality & Quantity*, 41(5), 673–690.

Poponi, S., Arcese, G., Mosconi, E.M., Pacchera, F., Martucci, O., & Elmo, G.C. (2021). Multi-actor governance for a circular economy in the agri-food sector: bio-districts. *Sustainability*, 13(9), 4718.

Pugliese, P., Antonelli, A., & Basile, S. (2015). Full case study report, Bio-Distretto Cilento, Italy. Available at: https://orgprints.org/id/eprint/29252/ (Accessed 4 October 2021).

Rivaroli, S., Bertazzoli, A., Ghelfi, R., & Laghi, A. (2016). Multifunctional farming in Emilia-Romagna region: an analysis through agricultural census data. *New Medit*, 15(2), 37–44.

Romano, D. (2000). I sistemi locali di sviluppo rurale. In Portalupi, D. (Ed.). *L'agricoltura tra locale e globale. Distretti e filiere*. Roma, CNEL, 23, pp. 219–273.

Rothaermel, F.T., & Boeker, W. (2008). Old technology meets new technology: complementarities, similarities, and alliance formation. *Strategic Management Journal*, 29(1), 47–77.

Ruggeri, G., Mazzocchi, C., & Corsi, S. (2020). Drinking biodiversity: a choice experiment on Franciacorta sparkling wines. *British Food Journal*, 122(8), 2531–2549.

Sinab (2020). Nuovi biodistretti: nasce il "Distretto Bio Sardegna". Available at: http://www.sinab.it/bionovita/nuovi-biodistretti-nasce-il-distretto-bio-sardegna (Accessed 4 October 2021).

Stotten, R., Bui, S., Pugliese, P., Schermer, M., & Lamine, C. (2017). Organic values-based supply chains as a tool for territorial development: a comparative analysis of three European organic regions. *International Journal of Sociology of Agriculture and Food,* 24(1), 135–154.

Sturla, A. (2020). L'agricoltura biologica per lo sviluppo territoriale - L'esperienza dei distretti biologici. Available at: https://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/19806 (Accessed 4 October 2021).

Sturla A. (2019). I distretti biologici a supporto delle filiere locali. In *Distretti biologici e sviluppo locale. Linee guida per la programmazione 2021-2027, Rete Rurale Nazionale* 2014-2020. Available at: https://www.reterurale.it/biodistretti (Accessed 4 October 2021).

Sturla, A., Iacono, R., & Licciardo, F. (2018). L'agricoltura biologica e i bio-distretti. L'esperienza della Val Camonica. *EyesReg, Giornale dell'Associazione Italiana Scienze Regionali*, 8(3).

Thomaidis, N., & Papathanasiou-Zuhrt, D. (2019). Heritage tourism and neo-endogenous development: the case of the Black Sea Project "Alector". In Vasile, V. (Ed.), *Caring and sharing: the cultural heritage environment as an agent for change*. Cham, Springer, pp. 51–62.

Triantafyllidis, A., Pietromarchi, A. & Colombo, L. (2019). Veicolazione delle esperienze di biodistretti italiani. I modelli di governance e le buone pratiche dei biodistretti. Available at: https://www.territoribio.it/wp-content/uploads/2019/06/Studio-governance-Biodistretti.pdf (Accessed 15 December 2021).

Viganò, L. (2019). Gli strumenti di programmazione a favore dei bio-distretti. In *Distretti biologici e sviluppo locale. Linee guida per la programmazione 2021-2027, Rete Rurale Nazionale* 2014-2020. Available at: https://www.reterurale.it/biodistretti (Accessed 4 October 2021).

Zanasi, C., Basile, S., Paoletti, F., Pugliese, P., & Rota, C. (2020). Design of a monitoring tool for eco-regions. *Frontiers in Sustainable Food Systems*, 4, 536392.

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The hidden value of non-timber forest products: income contribution of the Basilicata wild truffle

The Basilicata region (South of Italy) is land of truffles where the gastronomic, economic and cultural awareness has developed for this non-timber forest product only in the past decade. Little is known about truffle production and its social, economic and environmental implications. In this article we investigate the Basilicata truffle sector by devoting particular attention to the truffle hunters who gather the truffles from the forests. The data for the analysis were collected through a survey with the aim of describing the gathering activity (people involved, specie and quantities collected, etc.) and assessing its significance as a source of income. Results show that truffles can provide local communities with earning opportunities. However, the truffle sector needs to be protected and enhanced.

1. Introduction

Non-timber forest products (NTFPs), such as berries, mushrooms, nuts, saps and resins, aromatic, medicinal and decorative plant material, can represent an important source of income for rural and forest-dwelling (Angelsen et al., 2014; Shackleton and Pandey, 2014). NTFPs can also improve food security by off-setting seasonality of other food sources both in rural (Tata Ngome et al., 2017) and urban contexts (Clark and Nicholas, 2013), and play an important cultural and spiritual role (Shackleton and Pandey, 2014). In Europe, collected NTFPs represent a total economic value of 23.3 billion euro per year (Lovrić et al., 2020), with a high potential for new income generation, especially in Eastern European countries (Cai et al., 2011; Lovrić et al., 2020) and in Mediterranean region (Blondel, 2006; Masiero et al., 2016). Mainly collected for self-consumption, the total value of sold NTFPs in Europe is estimated at 3.5 billion euro per year, with the highest proportion of value made up of truffles (1.2 billion $€·yr^{-1}$), followed by forest nuts (775 million $€·yr^{-1}$), wild berries (685 million $€·yr^{-1}$) and wild mushrooms (518 million $€·yr^{-1}$) (Lovrić et al., 2020).

Truffles are one of the most famous and the most expensive foods in the world, with prices up to 4000 $€·Kg^{-1}$ (Oliach et al., 2021). Specific growing habitat,

unpredictable growth patterns and growing seasons, unique harvesting methods, limited natural resources, distinctive, desirable flavours highly appreciated in culinary and limited shelf life, altogether strongly contribute to the outstanding economic value of truffles and consequently truffle-based food products (Beara et al., 2021; Patel et al., 2017; Wang and Marcone, 2011). At least 180 species of truffles belonging to the genus *Tuber* (even if only about 13 have any commercial interest) are distributed in Europe, South-East Asia, Australia and North America, while desert truffles (genus *Terfezia* and *Tirmania*) grow mostly in the Middle East region (Patel et al., 2017; Reyna and Garcia-Barreda, 2014). In Europe and Australia, truffles are a multi-million euro industry (Reyna and Garcia-Barreda, 2014), whose importance is demonstrated by the growing diffusion of new activities such as truffle cultivation (Garcia-Barreda et al., 2018; Reyna and Garcia-Barreda, 2014; Samils et al., 2008), truffle tourism (Buntgen et al., 2017), production of new truffle products (Beara et al., 2021; Patel et al., 2017), technical consulting (Samils et al., 2008), not to mention the capacity to stimulates interdisciplinary research (Garcia-Barreda et al., 2019), and the increase of land value in rural areas (Samils et al., 2008).

Italy is one of the main countries for truffle production, processing and trade worldwide, with the largest number of edible truffles of commercial interest (nine species and varieties belonging to the genus *Tuber*), including the well-known Alba white truffle (*Tuber magnatum* Pico) and Norcia black truffle (*Tuber melanosporum* Vittad.). The Italian truffle market stands out locally and internationally (Pampanini et al., 2012), playing an important role for regional economies (Brun and Mosso, 2010; Marone, 2011). The local market refers to traditional food and wine specialties and its territories of origin. Today, truffle represents one of the main products of food and wine tours promoted by different Italian regions. Recent market research conducted by JFC[1] reports that truffle tourism generated a turnover of almost 63 million euro in 2018, due to the presence of foreigner tourists and activities related to truffle gathering and consumption. International trade also represents an important share of the Italian truffle market. In 2018, the economic value of export was about 49.2 million euro for "fresh or chilled truffles" and about 13.7 million euro for "prepared and/or preserved truffles" (ISTAT, 2019).

Despite that, the social, economic and environmental implications of the truffle sector are largely unknown because of a substantial lack of data. Official statistics are scarce and, in any case, not very representative. Indeed, truffle production is represented under the heading "Mushrooms and truffles" without any distinction between the two product categories. According to different authors, a lack of systematic data on NTFPs leads to a lack of awareness of their importance, which leaves them not being fully considered in rural development, forest and land-use related plans and policies (FAO, 2014; Lovrić et al., 2020). For example, Lovrić et al. (2020) highlight that "*If forest management is geared towards optimizing only wood production, this may lead to sub-optimal solutions as this typically involves different management decisions than co-production of wood and of NWFPs*". In the case of truffle,

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[1] JFC is a tourism consultancy and territorial marketing company (online: https://www.jfc.it).

the knowledge of the market and actors involved is fundamental to implement adequate actions to preserve, promote and enhance products and territories (Marone, 2011). Past studies tried to give a comprehensive picture of truffle supply by evaluating national production and its distribution among Italian regions. According to Pampanini et al. (2012), truffles production in Italy was about 81.4 tons in 2007; Umbria and Abruzzo, with annual productions estimated at 25.2 and 21.6 tons respectively, are the most important producing regions, representing 57% of the total. Similar results are reported in Brun and Mosso (2010), that indicated a national production of about 82.2 tons in 2007 with 55 % of the total represented by Umbria and Abruzzo, followed by Marche (9%), Lazio (8%), Toscana (6%) and Molise (6%). However, the available data are underestimated and not updated. Firstly, they mainly refer to formally marketed truffles, and do not take into account informally marketed and those used for self-consumption. Moreover, in the last years, new areas of production are gaining attention and new regions participate in the market.

The Basilicata region (South of Italy) is a land of truffles (Pomarico et al., 2007; Rana et al., 2015), whose gathering, cultivation and trading is regulated by the National Law no. 752 of December 16th 1985 and by the Regional Law no. 35 of March 27th 1995. However, gastronomic, economic and cultural awareness has developed for this NTFP only in the past decade, as demonstrated by the high number of badges issued for gathering activities (constantly growing in recent years) and the presence of truffle hunter associations that count numerous members. As for other Italian regions, the truffle sector can represent an important opportunity for the regional economy. However, little is known about truffle production and its social, economic and environmental implications. For this reasons, in line with other studies conducted in Piemonte (Brun and Mosso, 2010), Toscana e Abruzzo (Marone, 2011), and more recently in Sicilia (Calvo et al., 2020), our work aims to investigate the truffle sector in the Basilicata region, devoting particular attention to the truffle hunters who gather the truffles from the forests. The truffle hunter includes very diversified profiles, from the hobbyist to the professional one (Marone, 2011), according to the aim of the gathering activity and the truffle hunter behavior (types of gathered truffles, occasional versus more constant activity, income function of this activity). In such context, we try to answer the questions (I) who is involved in gathering activity, (II) which truffles and what quantity are collected in terms of weight and economic value, and (III) can truffle represent an important source of income? To that, we conducted a survey involving truffle hunters of Basilicata. The survey was designed to account for one year of truffle gathering in the region. Because the availability of truffle is intrinsically variable, a survey of the truffle hunters may produce estimates of quantities collected that are remarkably different depending on whether the research hits a favourable or an unfavourable year. In this respect, the 2018 season was average and, to some extent, can be taken as representative of a typical year. This can help to provide some useful insights to promote the truffle sector in Basilicata.

2. Materials and methods

2.1 The Basilicata truffle sector: the context

Basilicata is an Italian region located in the south of the country, rich in natural resources, ecosystems with a high value and high amenity landscapes, where the agri-food (Viccaro et al., 2018) and forestry (Viccaro et al., 2019) sector play an important role for the rural economy. The region, characterized by a very heterogeneous territory for cenotics diversity deriving from its great geomorphologic complexity, has been lately discovered to be rich in truffle species (Pomarico et al., 2007; Rana et al., 2015). In the last two decades, several researches have been carried out on biodiversity of hypogeous fungi of Basilicata that, according to Rana et al. (2015), now occupies the first positions among Italian regions for the number of *Tuber* species, varieties or forms (up to 29 of non-edible and edible *Tuber* taxa) naturally growing in its woodlands and Mediterranean scrubland areas (Fig. 1). All the commercial species, varieties and forms of truffles are present in the region, namely *T. brumale* Vittad. and *T. brumale* var. *moschatum* De Ferry, *T. aestivum* Vittad. and *T. aestivum* var. *uncinatum* Chatin., *T. borchii* Vittad., *T. macrosporum* Vittad.,

Figure 1. Basilicata forests by type, management systems and protected areas (source: Viccaro et al., 2019) (Note: forests cover a surface of 354,895 ha, with an index of woodiness equals 35.6%, consisting mainly of oak (51.8%), followed by beech (10%) and Mediterranean scrubland (7.9%)).
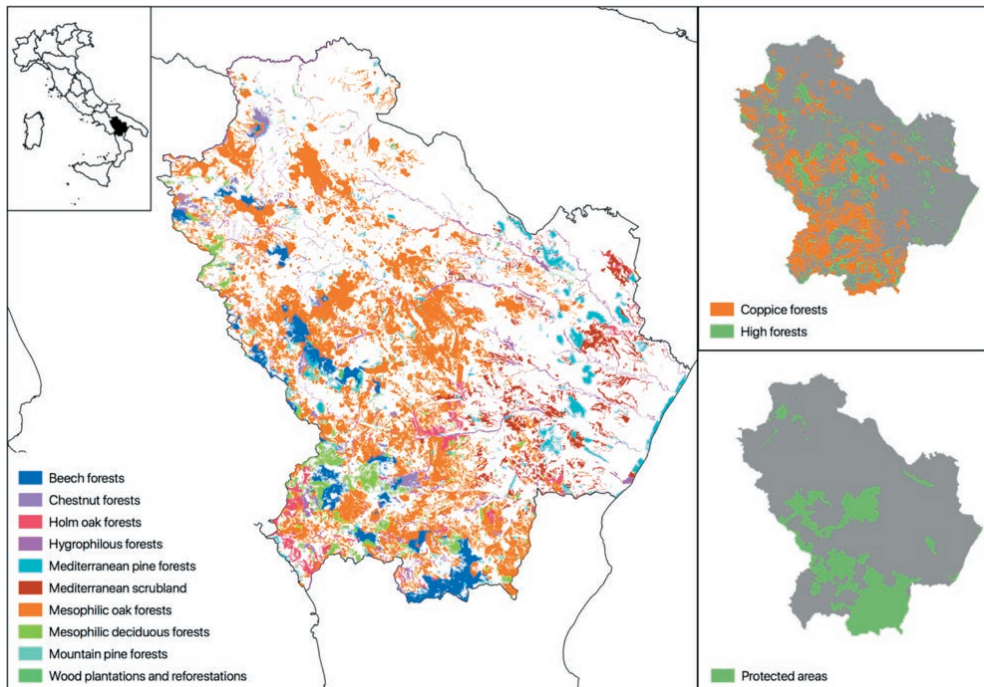
T. mesentericum Vittad., as well as the prized black truffle *T. melanosporum* Vittad. and white truffle *T. magnatum* Pico.

However, in line with the rest of the country, the social, economic and environmental implications of the truffle sector are unknown because of a substantial lack of data. The available data on productions date back to 2007, indicating a total amount of about 1.4 tons (Brun and Mosso, 2010), while information about the final destination of the product – species and relative quantities self-consumed or sold (not only informally but also formally marketed) – is completely missing.

As for the market, the only available data are limited to the number of the main players operating on the supply side, namely the truffle hunters that, based on the number of badges issued for gathering activities, rise from 215 in 2005 to 1652 in 2016, and five industries engaged in truffle collection, processing and sale. However, it is important to point out that we don't know if all the truffle hunters participate in the market due to the presence of possible hobby activities. Moreover, no information about the demand side, represented by catering activities and final consumers, is available.

2.2 *Questionnaire preparation and data collection*

Whether they are hobbyist or professional truffle hunters, very little is usually known about their socio-economic characteristics, their practices, and any return from the activity. So, we ran a survey of truffle hunters of the Basilicata region to identify what types of people engage in gathering truffle, quantifying the time devoted to the activity, the amounts collected, and assessing the economic significance of this source of income.

Data were collected using a questionnaire that was structured in 25 questions and divided into 3 sections, concerning respectively:
1. the sociodemographic information of respondents and general aspects of the gathering activity (personal data, profession, etc.);
2. information on truffle hunting activity (time devoted to and costs incurred in the activity, travel distance, species and amounts collected, etc.);
3. information relating to the marketing and/or processing of the product (final destination, retail and/or wholesale price, etc.).

The first section aims to outline a general profile of the truffle hunter, based on age, profession and motivational characteristics. It also includes questions on different activities performed in natural environments (i.e., fishing, hunting, mushroom gathering, …). In the next section, all the activities related to research and collection are investigated, to know the operating methods and related costs. In this part, there is also a question to evaluate the perception of the state of truffle habitats concerning external disturbance (climate change, land-use change, human activities, etc…). The third part aims to analyse the final destination of the product (self-consumption or sale) to be used for some economic considerations. Finally, an open question is devoted for collecting suggestions to promote and enhance the natural truffle production in the region. The draft questionnaire was

pre-tested twice, firstly with a group of experts of the truffle sector (mycologists, presidents of truffle hunter associations, truffle hunters), and secondly with about ten respondents using the online layout of the questionnaire. The purpose of the pre-testing (Collins, 2003; Lovrić et al., 2020) was to account for a shared understanding of the questionnaires' text, possible missing response categories, and for checking the online version. Pre-testing was performed from September to November 2018.

The survey of the truffle hunters was conducted from January to June 2019, by administering the online version of the questionnaire to members of "*Associazione Micologica dei Sostenitori della Cultura Idnologica Lucana*" (A.M.S.C.I.L), a truffle hunter association that, from 2014, operates to preserve the truffle habitats and valorise the truffle sector in Basilicata. Since people collecting NTFPs from the forest, including truffle hunters, are unwilling to share information about their activities because of a combination of jealously guarding good sites, awareness that they access the resource without a required authorization, and worries about possible changes in regulations (Cai et al., 2011; Marone, 2011), the participation in the survey was incentivized with a prize draw, managed separately to maintain anonymity. The prize consisted of a "vanghetto", a special gathering tool similar to a small shovel. Of the 112 questionnaires handed out, about 66% were returned, but 4 (3.5%) of them were excluded due to incorrect and uncompleted questions. Thus, the analysis was conducted on a total of 70 valid questionnaires which amounts to a 63% response rate.

3. Results

3.1 Truffle hunters and gathering activity in Basilicata

Table 1 presents summary statistics for key socio-economic characteristics of the sample and measures of truffle gathering activity. In line with the total distribution of regional forest areas, the origin of the interviewed sample is almost all of the province of Potenza (94.3%). Almost 93% of the respondents are male and, a great part of interviewees (59%) falls within the age range between 36 and 65 years. The most represented occupations are those of the wages clerk (24%), the worker (23%) and the self-employed (18.6%), followed by "Other" professions (15.7%), pensioners (13%) and students (6%). The greatest part of respondents (64%) has been carrying out truffle hunting for more than 5 years (34% from 5 to 10 years, 30% for more than 10 years), and about 57% of the interviewees declared to be alone when carrying out this activity. 59% of respondents approached the gathering activity due to their inclination towards natural environments, declaring to practice at least one other outdoor activity such as mushroom picking (38%), hunting (14%) or more than one (39%).

As regards the gathering activity, it is carried out only in the province of residence for 44% of the interviewees and in the whole region for 31% of them; only 26% state also to go outside the region. This affects the truffle gathering trips to

Table 1. General statistics of truffle hunters and gathering activity.

A. Truffle hunters' characteristics		
Variable	Description	Relative frequency (%)
Sex	Male	92.9
	Female	7.1
Age	18 - 35	30.0
	36 - 65	58.6
	> 65	11.4
Province of residence	Potenza	94.3
	Matera	5.7
Occupation	Self-employed	18.6
	Worker	22.9
	Wages clerk	24.3
	Student	5.7
	Pensioner	12.9
	Other	15.7
Years of experience	< 1	5.7
	1 - 3	8.6
	3 - 5	21.4
	5 - 10	34.3
	> 10	30.0
Motivations	Delicacy of truffles	7.1
	Contact with nature	58.6
	Down from parents/relatives	15.7
	Profitable business	4.3
	More than one answer	10.0
	Other (research, curiosity, …)	4.3
B. Truffle gathering activity		
Variable	Description	Relative frequency (%)
Gathering area	Province	41.4
	Region	32.9
	In and outside the region	25.7
Days	Up to 10	10.1
	10 - 20	15.9
	21 - 50	26.1
	51 - 100	33.3
	> 100	14.5
Hour per day	< 1	2.9
	2 - 3	64.3
	3 - 5	24.3
	> 5	8.6

the forests which varies from a minimum of 1 km to a maximum of 250 km, with an average of 36 km. The time (hours) dedicated to the gathering activity ranges from a minimum of 1 hour to more than 5 hours per day. However, a very high percentage (64%) declares to devote on average 2-3 hours per day while only 24% of the respondents dedicate 4-5 hours per day. One-third of interviewees dedicate to gathering activity from 51 to 100 days, while 26% of them engage in it from 21 to 50 days. A good percentage (14.5%) even exceeds 100 days, a value that immediately suggests more than the recreational activity.

As shown in Figure 2, the region is particularly suited for black truffles, such as *T. brumale* Vittad., *T. aestivum* Vittad., *T. aestivum* var. *uncinatum* Chatin., *T. macrosporum* Vittad., *T. mesentericum* Vittad., and *T. melanosporum* Vittad. No truffle hunter claims to collect *T. brumale* var. *moschatum* De Ferry. There is a high variability of collected truffle amount among truffle hunters. The *T. aestivum* is the most collected species in the region, all the interviewees declare to collect it and for 13% of them, it represents the only species collected. Quantities range from a minimum of 1 kg to a maximum of 200 kg; the average value per truffle hunter is 34 kg. The *T. aestivum* var. *uncinatum* is another species collected by a large percentage of the respondents (83%), with an average amount of around 10.5 kg, with a minimum value of 0.5 kg and a maximum of 80 kg. The other truffle species collected in Basilicata are the *T. macrosporum* (on average 10.2 Kg per truffle hunter), the *T. mesentericum* (on average 8.3 Kg per truffle hunter), and the *T. brumale* (on average 6.4 kg per truffle hunter). Only 18.5% of the sample collect the prized black truffle (*T. melanosporum*) from the regional forests. The average quantity of the latter is 6.6 kg per truffle hunter. As regards the white truffle species, the *T. borchii* is collected from 51% of the sample with values ranging from 0.1 kg to 30

Figure 2. Species and amount of truffle collected in Basilicata (data expressed in kg, year 2018) (our elaboration on survey data).
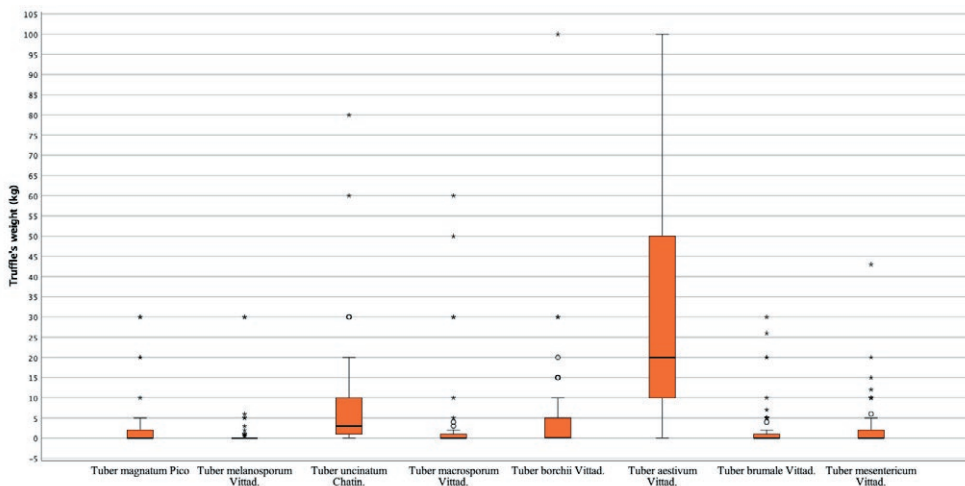
kg (the average quantity is 10 kg), while the *T. magnatum*, the most valuable species by far, is collected by 41% of the interviewees with a minimum value of 0.3 kg and a maximum of 30 kg. For this species, the average annual amount collected is around 4.6 Kg per truffle hunter.

Although only 4% of the interviewees declared to carry out the gathering activity for economic reasons, about 74% of them sell the collected truffles. On average, hunters sell 46% of the collected truffle (with values ranging from a minimum of 20% to the total), while the rest is self-consumed or given away.

The market tends to develop in two ways: wholesale and retail. The first form is the most developed and affects almost all of the products, despite the retail sale it is possible to obtain higher prices because buyers usually require truffle of greater aesthetic and quality. For wholesale, the main buyers are intermediate figures who collect the product subsequently sold to large processing companies, located mainly in the areas of central Italy, or to the markets of northern Italy and abroad. Both for the wholesale and the retail market (Figure 3a), the buyers are mainly local (41% and 50% respectively), followed by regional and national buyers; only a small percentage is represented by international ones. The local final consumers (43%) and the catering sector (28%) represents the main customers (Figure 3b), followed by other figures and tourists. The sale is mainly carried out at home (58.4%), sold for the most part fresh (87%) and the remainder processed (9%) and frozen/deep-frozen (4%). The wholesale and retail prices are reported in Figure 4. There is high variability among species that depends on the characteristics of sold truffles (i.e., size. aesthetic and quality). In general, retail prices are twice as high as wholesale prices. The average prices per kg are (in decreasing order): 1,473 € - T. magnatum; 428 € - *T. melanosporum*; 164.5 € - *T. aestivum* var. *uncinatum*;138 € - *T. borchii;* 137 € - *T. macrosporum;* 106 € - *T. brumale;* 74.5 € - *T. aestivum;* 66 €- *T. mesentericum*.

As regards the main costs associated with the gathering activity (Table 2), they are related to the purchase and care of the dog (fixed costs), and the travel costs (variables costs), the latter according to the number of gathering trips and relative distance. The truffle hunters have declared to have on average two dogs (mini-

Figure 3. Basilicata's truffle market location (a) and final customers (b) (year 2018) (our elaboration on survey data).
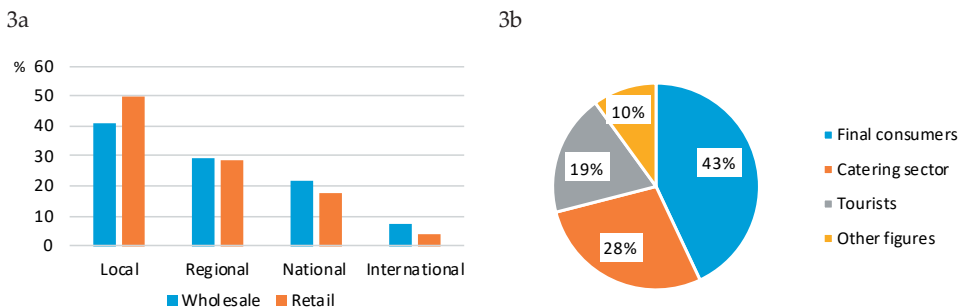
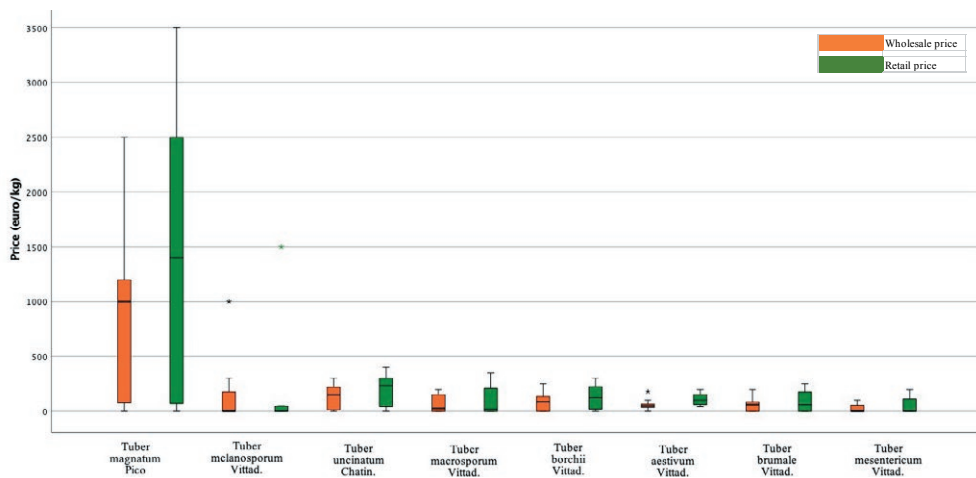Figure 4. Wholesale and retail price of truffle species (euro, year 2018) (our elaboration on survey data).

Table 2. Fixed and variable costs associated with the truffle gathering activity.

Fixed costs	Unit	Value
Regional tax	€/year	93
Vanghetto*	€/unit	100
Dog		
purchase cost*	€ per dog	1,017
keeping costs	€/year per dog	575
Variable costs	Unit	Value
Travel costs	€/km	0.13

*To calculate the annual costs, we considered an amortisation period of 5 years for the vanghetto and 8 years for the dog.

mum 1, maximum 10). The most represented breed is the "Lagotto romagnolo": 76% of the sample replied to have at least 1 dog of this breed. The average cost of a trained dog was found to be around 1,017 € (67% of the sample released information). However, it is an average value that certainly is influenced by some characteristics such as the lower/higher ability of the dog, breed, experience, etc. The average cost of keeping a dog is around 575 €/year. This value includes the expenses for food, veterinary visits and care, and other costs (e.g., clipping, collars, etc.). The other fixed costs are the payment of the regional tax (93 €/year) and the purchase of the "vanghetto" (about 100 €).

3.2 Truffle hunters' profiles and economic consideration

Considering the average prices and the number of collected truffles in Basilicata in 2018, the economic value (EV) of the collected truffles per hunter is equal to 9,436 €, 42% of which is from prized truffles (*T. magnatum* and *T. melanosporum*). If the truffles collected in other regions are also considered, EV reaches around 13.6 thousand euro. Net of the quantities self-consumed and/or given away, the economic value of the sold truffles is equal 4,341 € (6,264 € with the truffle collected outside the region). However, given the high variability of the quantities and species collected among truffle hunters, the economic relevance of the truffle gathering activity should be better assessed regarding different hunters' profiles. For this reason, we performed a cluster analysis to identify groups that are homogeneous about some truffle gathering characteristics. In particular, we carried out a Twosteps cluster procedure[2] that uses an agglomerative hierarchical clustering method and is adequate when clustering variables are both categorical and continuous. Clustering variables used in the work are the EV of truffle collected, the percentage of EV of prized truffle, the percentage of truffle that is sold, area and range of days of gathering activity. The optimal number of clusters has been based on the Schwarz's Bayesian Criterion (BIC)[3]. Based on BIC, three groups of truffle hunters were identified that can be characterized by the mean values of clustering variables (more frequent values for categorical variables), as well as by the collected sociodemographic and activity information. They can be named as Professional (*Pro hunter*), Semi- Professional (*Semi-pro hunter*) and Hobby hunter (*Hobbyist*) (Table 3).

Pro hunter: young truffle hunter (age 18–35), the professional truffle hunter carries out the gathering activity alone both in the region and outside it, dedicating from 50 to over 100 days per year but generally not more than three hours per day. With three dogs, the amount collected is approximately 105 kg per year (53% of which are for sale). The total economic value is about 20 thousand euro/year, reaching about 33 thousand euro with the amount collected outside the region (56 kg).

Semi-pro hunter: with an age between 35 and 65, the semi-professional truffle hunter prefers to carry out the activity alone, but does not despise the company. He devotes between 21 and 100 days per year to the gathering activity and, unlike the pro hunter, sometimes more than 4 hours per day, preferring the regional territory. With two dogs and just under half of the quantities collected by the pro hunter in the region (about 48 kg), the average EV of collected truffle is equal to 5,763 €. The semi-pro hunter sells 56% of the truffles.

Hobbyist: the hobbyist limits the gathering activity to the province of residence, dedicating no more than 50 days per year and no more than three hours per day.

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[2] This procedure was carried out with SPSS 20

[3] BIC is log-likelihood value obtained, according to the formula -2*log-likelihood + k*npar, where npar represents the number of parameters in the fitted model, and k = log(n) (n being the number of observations). BIC is computed for each potential number of clusters: the "best" clusters solution has the smallest BIC.

Table 3. Cluster statistic.

Profile	n	EV (€)	% EV prized truffle	% Sold	Gathering area	Days
Pro hunter	23	32,778	36.3	53.38	In and outside the region (100%)	50 - more than 100 (65%)
Semi-pro hunter	30	5,763	19.6	56.17	Region (87%)	21 – 100 (77%)
Hobbyist	17	1,556	4.2	18.63	Province (100%)	up to 50 (100%)

Table 4. Species and amount of truffle collected by different truffle hunter profile. Data are expressed in Kg.

	Pro hunter	Semi-pro hunter	Hobbyist	Pro hunter (Outside the region)
T. magnatum Pico	5.96	0.88	0.06	3.87
T. melanosporum Vittad.	3.39	0.25	0.03	3.17
T. uncinatum Chatin.	15.91	6.43	3.12	10.39
T. macrosporum Vittad.	7.35	1.14	0.07	6.22
T. borchii Vittad.	11.48	3.05	0.19	9.26
T. aestivum Vittad.	50.65	33.77	9.47	20.26
T. brumale Vittad.	4.83	1.31	0.56	2.52
T. mesentericum Vittad.	5.04	1.00	2.18	0.78
Total	104.60	47.83	15.67	56.47

With an age between 35 and 65, he prefers to carry out the activity with other people. With only one dog, the amount collected is equal to about 16 kg (EV equal to 1,556 €), which is destined almost exclusively for self-consumption and/or as a gift.

The gathering area and the time dedicated certainly affect the species and the quantities collected (Table 4) and, consequently, their economic value with strong differences between the profiles. Pro hunters collect truffles for an economic value almost six and twenty times higher than that recorded for semi-pro hunters and hobbyists, respectively. 36% of this economic value is represented by valuable species. The pro hunter collects on average more prized truffles (9.35 kg) than the semi-pro hunter (1.13 kg) and the hobbyist (about 0.1 kg), demonstrating greater specialization. Of course, their effort, as well as the costs (i.e., travel costs and costs for dogs), are larger.

It is therefore possible to make some assessments for the economic return of the truffle gathering activity, considering revenues and costs related to the differ-

Table 5. Economic results. Data are expressed in euro.

	Pro hunter	Semi-pro hunter	Hobbyist
Total revenues	17,372	3,227	296
Total cost	2,787	1,729	935
Net income	*14,585*	*1,498*	*-639*

ent truffle hunters' profiles. The annual revenues, namely the economic value of sold truffles, the total annual costs and the net income are shown in Table 5. The costs include the purchase and care of the dog, the travel cost, the annual regional tax and the purchase of a "vanghetto".

Truffle hunters who spend more time in truffle gathering appear to be driven by the possibility of earning some extra income. Time affects results much more than the area in which the gathering activity is carried out. Semi-pro hunters, devoting up to 100 days per year, earn on average 3,227 € (with a net income of 1,498 €), while the pro hunters, with over 100 days, earn on average 17,372 € (with a net income of 14,585 €). Of course, the semi-pro hunters limit the gathering activity only to the region, but if the revenues deriving from the sale of truffles collected outside the regional borders are excluded, the pro hunters still earn on average three times more than the semi-pro hunters (10,628 €), with a net income of 8,923 €. The hobbyists, devoting up to 50 days per year, gather only trivial amounts and their revenues are not even sufficient to cover the costs incurred. They mostly self-consume and/or give away the hunted truffle, and appear to have mostly recreational motivations, confirming what they stated in the survey, that truffle gathering activity is mainly due to their own inclination towards natural environments.

For young professional hunters, the truffle gathering activity seems to represent an important source of income that motivates them to dedicate time and go beyond the regional borders. However, there is no evidence that the type of occupation engraves to the choice of turning to intensive truffle gathering as a source of income.

4. Discussions

The truffle gathering activity in Basilicata can represent, for those who practice it professionally, an important source of income and, for this reason, the sector should be protected and enhanced. According to different studies (FAO, 2014; Lovrić et al., 2020), a lack of systematic data on NTFPs leads to a lack of awareness of their importance, which makes them not being fully considered in rural development, forest and land-use related plans and policies. As a fact, according to what was declared by the truffle hunters themselves, the protection actions should be implemented by local decision-makers and should particularly concern

the protection of natural environments. 84% of the interviewees declared to note variations in the truffle habitats, with a consequent decrease in truffle production. These variations, partly due to climate change, as demonstrated in other studies (Thomas and Büntgen, 2019), and to land-use changes, are attributed to a greater anthropogenic and wildlife pressure (i.e., wild boars). In recent years, the number of badges issued and, therefore, the number of truffle hunters have increased considerably, with greater pressure on the truffle resource which often leads to lower levels of care and protection of the truffle habitats. According to 29% of the respondents, it is above all the inexperience of the truffle hunters that negatively affects these habitats. The interviewees agreed that to protect the regional truffle sector there is the need for greater controls by the supervisory authorities to enforce current legislation, public interventions to reconstitute and/or improve degraded truffle habitats, and the promotion of training courses. In particular, the training and knowledge of the truffle resource are very relevant for preserving the natural environments and guiding the habits of the truffle hunters so that they feel responsible for the truffle resource and its habitats.

Another critical element that emerged from the survey is the poor organization of the actors involved in the collection and marketing of truffles. Most of the time, the product ends up in an undifferentiated market without the right enhancement. As for other Italian regions (Brun and Mosso, 2010; Marone, 2011), the creation of a regional truffle supply chain, which identifies itself with the product of the territory, represents an opportunity to protect and promote the local truffle sector and, consequently, producers, with adequate remuneration, and final consumers, through the safety of the origin of the product. A future implementation of this work could be oriented towards a dedicate marketing plan to promote the above-mentioned truffle chains. This could benefit not only the truffle market, but in general all related activities able to promote the related ecosystem services (e.g., landscape enhancement, biodiversity and hydrogeological protection).

A relevant role for the enhancement of the product and, more generally, of the entire supply chain, is represented by the system of associations and cooperatives that can create critical mass and increase economic results. It constitutes a valid springboard for the development of the sector and can be a useful way to organize the enhancement of the truffle (e.g. using fairs, events, etc.), by framing it in a coordinated pattern of promotion and valorisation of the product and defending its origin. A way to enhance the product is the TAP (Traditional Agri-food Product) recognition, as for it is happening for the "Fragno truffle" in the province of Parma (Italy). Some other new initiatives of interest, from which to draw inspiration, appear to be those of the "Truffle Roads". Oliach et al., (2021) identified strengthening the link between truffles, tourism, and gastronomy as the most important action to be taken. Indeed, tourism and gastronomy linked to production are a new opportunity to promote the truffle sector (Buntgen et al., 2017; Latorre et al., 2021). Another aspect that could help in the promotion of truffles, is the development of the gourmet market, which can be complemented with quality branding to better identify the product. Ensuring that the product consumed comes from a specific territory, understanding the characteristics and expectations

of the collectors, as well as the marketing channels, may soon represent forms of guarantees for the final consumer as well as the basis for careful planning of the production sector. The most suitable tools to achieve these results, therefore, lie precisely in the acquisition of ever greater knowledge of the entire supply chain.

One of the strengths of this work is the analysis of a sector where real data are lacking (in Italy). Many studies analyse the ecosystem services in Italy (Agnoletti et al., 2022; Canedoli et al., 2020; Riccioli et al., 2019, 2020; Salata and Grillenzoni, 2021). However, national statistics provide silvicultural data that essentially refer to timber harvests. Indeed, as stated by Pettenella et al. (2021), for several years, the National statistical institute (ISTAT) has stopped collecting data on the production of non-wood forest products.

So, the added value of this study is to highlight an hidden sector that has been "forgotten" but at the same time is threatened by wildlife. Cozzi et al. (2015, 2019), point out like wild boars represent a serious problem in Basilicata. Therefore, urgent actions to stem the problem are needed to protect the truffle sector.

5. Conclusions

The general objective of the research was to broaden the knowledge on the truffle sector of the Basilicata region, determine its main characteristics, productive and economic consistencies, with the specific aim of providing quantitative elements of evaluation, useful to regional institutions from a perspective of product enhancement. In recent years, in Basilicata, the truffle sector has registered a growing interest; in just over 10 years we have gone from a few hundred truffle hunters with an authorization badge for gathering activities to more than 1600 units. The positive trend in the number of people who have approached the truffle sector can be associated, in large part, with the search for profit and income. In this direction, we tried to answer to three main questions: (i) who is involved in gathering activity? (ii) which truffles and what quantity are collected in terms of weight and economic value? (iii) can truffle represent an important source of income? The answers to these questions reveal the presence of professional truffle hunters in the region, for whom the truffle represents an important source of income.

From the considerations of the economic results obtained, it is desirable to protect the production sector, through the establishment and strengthening of the production and processing chains. These initiatives may be able to connect the various actors and create new opportunities for food services and the tourist sector of the rural areas. A better use of the truffle resource can also be hoped to produce additional value and ensure adequate economic development for the territory. However, what has been stated is only possible following careful planning in the use of this NTFP. A higher level of knowledge, extended in space and time, may be able to safeguard and protect the regional truffle heritage. The reconstitution of degraded truffle fields, improving them with forestation interventions with mycorrhizal plants, carrying out more checks to enforce the legislation in force, are just some of the initiatives to begin to preserve the resource.

The most important objectives to be pursued are the following: (i) protection and promotion of the local products; (ii) protection and safeguarding of the territory; (iii) product certification to protect the consumer.

It is not possible to continue to consider the truffle a product of little economic interest since it is able to provide a rather significant income. Even if in the forests of Basilicata it is present in good quantities and undisputed quality, to date this product doesn't represent an added value for the regional territory and its rural contexts.

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References

Agnoletti, M., Piras, F., Venturi, M., & Santoro, A. (2022). Cultural values and forest dynamics: the Italian forests in the last 150 years. *Forest Ecology and Management*, 503, 119655. https://doi.org/10.1016/J.FORECO.2021.119655

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N. J., Bauch, S., Börner, J., Smith-Hall, C., & Wunder, S. (2014). Environmental income and rural livelihoods: a global-comparative analysis. *World Development*, 64(S1), S12–S28. https://doi.org/10.1016/j.worlddev.2014.03.006

Beara, I., Majkić, T., & Torović, L. (2021). Bioguided design of new black truffle (Tuber aestivum Vittad.) product enriched with herbs and spices. *Lwt*, 138(September 2020), 1–11. https://doi.org/10.1016/j.lwt.2020.110637

Blondel, J. (2006). The "design" of Mediterranean landscapes: a millennial story of humans and ecological systems during the historic period. *Human Ecology*, 34(5), 713–729. https://doi.org/10.1007/s10745-006-9030-4

Brun, F., & Mosso, A. (2010). *Studio delle filiere dei prodotti trasformati a base di tartufo in Piemonte. Mercato, produzioni di qualità e valorizzazione del territorio*. Rapporto finale. Regione Piemonte, Direzione Opere Pubbliche, Difesa del Suolo, Economia Montana e Foreste.

Buntgen, U., Latorre, J., Egli, S., & Martinez-Peña, F. (2017). Socio-economic, scientific, and political benefits of mycotourism. *Ecosphere*, 8(7), e01870. https://doi.org/10.1002/ecs2.1870

Cai, M., Pettenella, D., & Vidale, E. (2011). Income generation from wild mushrooms in marginal rural areas. *Forest Policy and Economics*, 13(3), 221–226. https://doi.org/10.1016/j.forpol.2010.10.001

Calvo, R., Prestifilippo, M., & Venturella, G. (2020). Truffle gathering and trade in the Monti Sicani Regional Park (Sicily, Italy), a new perspective for the local economy and for employment in economically depressed areas. *Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology*. https://doi.org/10.1080/11263504.2020.1845843

Canedoli, C., Ferrè, C., Abu El Khair, D., Comolli, R., Liga, C., Mazzucchelli, F., Proietto, A., Rota, N., Colombo, G., Bassano, B., Viterbi, R., & Padoa-Schioppa, E. (2020). Evaluation of ecosystem services in a protected mountain area: soil organic carbon stock and biodiversity in alpine forests and grasslands. *Ecosystem Services*, 44, 101135. https://doi.org/10.1016/J.ECOSER.2020.101135

Clark, K. H., & Nicholas, K. A. (2013). Introducing urban food forestry: a multifunctional approach to increase food security and provide ecosystem services. *Landscape Ecology*, 28(9), 1649–1669. https://doi.org/10.1007/s10980-013-9903-z

Collins, D. (2003). Pretesting survey instruments: an overview of cognitive methods. *Quality of Life Research*, 12(3), 229–238. https://doi.org/10.1023/a:1023254226592

Cozzi, M., Prete, C., Viccaro, M., & Romano, S. (2019). Impacts of wildlife on agriculture: a spatial-based analysis and economic assessment for reducing damage. *Natural Resources Research*, 28(S1), 15–29 . https://doi.org/10.1007/s11053-019-09469-6

Cozzi, M., Romano, S., Viccaro, M., Prete, C., & Persiani, G. (2015). Wildlife agriculture interactions, spatial analysis and trade-off between environmental sustainability and risk of economic damage. In Vastola, A. (Ed.). *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*. Cham, Springer. (pp. 209–224). https://doi.org/10.1007/978-3-319-16357-4_14

FAO (2014). State of the world's forests 2014: enhancing the socioeconomic benefits from forests. Food and Agriculture Organinization of the United Nations, Rome.

Garcia-Barreda, S., Forcadell, R., Sánchez, S., Martín-Santafé, M., Marco, P., Camarero, J. J., & Reyna, S. (2018). Black truffle harvesting in Spanish forests: trends, current policies and practices, and implications on its sustainability. *Environmental Management*, 61(4), 535–544. https://doi.org/10.1007/s00267-017-0973-6

Garcia-Barreda, S., Sánchez, S., Marco, P., & Serrano-Notivoli, R. (2019). Agro-climatic zoning of Spanish forests naturally producing black truffle. *Agricultural and Forest Meteorology*, 269–270(October 2018), 231–238. https://doi.org/10.1016/j.agrformet.2019.02.020

ISTAT, 2019. Coeweb - Statistiche del commercio estero. Online: https://www.coeweb.istat.it

Latorre, J., de-Magistris, T., Frutos, P. de, García, B., & Martinez-Peña, F. (2021). Demand for mycotourism products in rural forest areas. a choice model approach. *Tourism Recreation Research*, 1–17. https://doi.org/10.1080/02508281.2021.1926749

Lovrić, M., Da Re, R., Vidale, E., Prokofieva, I., Wong, J., Pettenella, D., Verkerk, P. J., & Mavsar, R. (2020). Non-wood forest products in Europe – A quantitative overview. *Forest Policy and Economics*, 116(April), 102175. https://doi.org/10.1016/j.forpol.2020.102175

Marone, E. (2011). *La filiera del tartufo e la sua valorizzazione in Toscana e Abruzzo*. Firenze, Firenze University Press.

Masiero, M., Pettenella, D. M., & Secco, L. (2016). From failure to value: economic valuation for a selected set of products and services from Mediterranean forests. *Forest Systems*, 25(1), e051. https://doi.org/10.5424/fs/2016251-08160

Oliach, D., Vidale, E., Brenko, A., Marois, O., Andrighetto, N., Stara, K., Mart, J., Arag, D., Colinas, C., & Bonet, A. (2021). Truffle market evolution : an application of the Delphi Method. *Forests*, 12, 1174.

Pampanini, R., Marchini, A., & Diotallevi, F. (2012). Il mercato del tartufo fresco in Italia tra performance commerciali e vincoli allo sviluppo: il contributo delle regioni italiane. *Economia Agro-Alimentare*, 3, 11–28.

Patel, S., Rauf, A., Khan, H., Khalid, S., & Mubarak, M. S. (2017). Potential health benefits of natural products derived from truffles: a review. *Trends in Food Science and Technology*, 70, 1–8. https://doi.org/10.1016/j.tifs.2017.09.009

Pettenella, P., Marchetti, M., Motta, M., & Vacchiano, V. (2021). Neanche VAIA resiste all'insostenibile leggerezza delle statistiche forestali. *Forest@ - Journal of Silviculture and Forest Ecology*, 18, 1–4. https://doi.org/10.3832/EFOR3733-017

Pomarico, M., Figliuolo, G., & Rana, G. L. (2007). Tuber spp. biodiversity in one of the southernmost European distribution areas. *Biodiversity and Conservation*, 16(12), 3447–3461. https://doi.org/10.1007/s10531-006-9013-1

Rana, G. L., Mang, S. M., & Camele, I. (2015). Biodiversity of Hypogeous Fungi in Basilicata. In Vastola, A. (Ed.). *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*. Cham, Springer. (pp. 305–310). https://doi.org/10.1007/978-3-319-16357-4_20

Reyna, S., & Garcia-Barreda, S. (2014). Black truffle cultivation: a global reality. *Forest Systems*, 23(2), 317–328. https://doi.org/10.5424/fs/2014232-04771

Riccioli, F., Fratini, R., Marone, E., Fagarazzi, C., Calderisi, M., & Brunialti, G. (2020). Indicators of sustainable forest management to evaluate the socio-economic functions of coppice in Tuscany, Italy. *Socio-Economic Planning Sciences*, 70, 100732. https://doi.org/10.1016/j.seps.2019.100732

Riccioli, F., Marone, E., Boncinelli, F., Tattoni, C., Rocchini, D., & Fratini, R. (2019). The recreational value of forests under different management systems. *New Forests*, 50(2), 345–360. https://doi.org/10.1007/s11056-018-9663-3

Salata, S., & Grillenzoni, C. (2021). A spatial evaluation of multifunctional Ecosystem Service networks using Principal Component Analysis: a case of study in Turin, Italy. *Ecological Indicators*, 127, 107758. https://doi.org/10.1016/J.ECOLIND.2021.107758

Samils, N., Olivera, A., Danell, E., Alexander, S. J., Fischer, C., & Colinas, C. (2008). The socioeconomic impact of truffle cultivation in rural Spain. *Economic Botany*, 62(3), 331–340. https://doi.org/10.1007/s12231-008-9030-y

Shackleton, C. M., & Pandey, A. K. (2014). Positioning non-timber forest products on the development agenda. *Forest Policy and Economics*, 38, 1–7. https://doi.org/10.1016/j.forpol.2013.07.004

Tata Ngome, P. I., Shackleton, C., Degrande, A., & Tieguhong, J. C. (2017). Addressing constraints in promoting wild edible plants' utilization in household nutrition: Case of the Congo Basin forest area. *Agriculture and Food Security*, 6(1), 1–10. https://doi.org/10.1186/s40066-017-0097-5

Thomas, P., & Büntgen, U. (2019). A risk assessment of Europe's black truffle sector under predicted climate change. *Science of the Total Environment*, 655, 27–34. https://doi.org/10.1016/j.scitotenv.2018.11.252

Viccaro, M., Rocchi, B., Cozzi, M., & Romano, S. (2018). SAM multipliers and subsystems: structural analysis of the Basilicata's agri-food sector. *Bio-based and Applied Economics*, 7(1), 19–38. https://doi.org/10.13128/BAE-24046

Viccaro, M., Cozzi, M., Fanelli, L., & Romano, S. (2019). Spatial modelling approach to evaluate the economic impacts of climate change on forests at a local scale. *Ecological Indicators*, 106, 105523. https://doi.org/10.1016/J.ECOLIND.2019.105523

Wang, S., & Marcone, M. F. (2011). The biochemistry and biological properties of the world's most expensive underground edible mushroom: Truffles. *Food Research International*, 44(9), 2567–2581. https://doi.org/10.1016/j.foodres.2011.06.008

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Buildings' energy performance, green attributes and real estate prices: methodological perspectives from the European literature

Buildings' energy efficiency may affect real estate prices, but the literature suggests that the effects of green attributes and Energy Performance Certificate ratings on the value of residential properties in Europe are still variable across contexts. The adoption of methods able to appropriately investigate this issue is thus essential. In this framework and to support future studies, this paper offers a methodological review of scientific works on the topic published in the last five years. Our work does not only represent an update of other reviews, but it originally analyses the papers by a methodological viewpoint. Results highlight a progressive refinement of the research questions and methods adopted. Then, the increasing importance of concepts such as latent variables and green attributes in the real estate pricing process is detected and identified as a field to be furtherly explored. Finally, Structural Equation Modelling is proposed as a promising approach for future studies.

1. Introduction

Residential buildings' energy consumption represents one of the most relevant sources of CO_2 emissions (Chen and Marmolejo-Duarte, 2019; Manganelli et al., 2019; Wilkinson and Sayce, 2020), and the enhancement of energy efficiency has progressively become of paramount importance, as shown for instance by the 2015 UN Sustainable Development Goal 7 – Affordable and Clean Energy, target 7.3, which recommends doubling the global rate of improvement in energy efficiency by 2030 (United Nations General Assembly, 2015).

At the European level, the EU has started to systematically tackle the issue since the early 2000s, with the release of the first Energy Performance of Buildings Directive in 2002 (EPBD-Directive 2002/91/EC). Then, subsequent updates (EPBD-Directive 2010/31/EU; EPBD-Directive 2018/844/EU) and integrations (Commission Delegated Regulation EU, n. 244/2012) aiming at reinforcing and improving the framework have progressively followed.

The urgency of the environmental matter, combined with the enduring existence of a certain slowness in the performance of energy interventions, have recently led the European Commission to strengthen its commitment towards the achievement of a real "green" transition: in fact, the Communication presented from the Commission to the European Parliament on 10th October 2020 and named *"A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives"* (European Commission, 2020) puts at its core a faster and deeper energy

renovation of buildings. Moreover, as outlined by the title of the Communication, in the current socio-economic framework – which has been strongly affected and weakened by the Covid-19 pandemic – energy retrofit and green constructions are valued not only as necessary actions for decarbonization but also as economic leverages: this is a statement that thus contributes to possibly increase the market value of these buildings.

As underlined by scholars and experts in the field, consumption patterns of domestic energy are a multi-dimensional issue involving variables such as climate zones (Chiesa and Fregonara, 2019; Dell'Anna et al., 2019; Fregonara et al., 2020; Taltavull de La Paz et al., 2019), architectural and technological characteristics of the residential units, households' income, behavioural, demographic and socio-economic characteristics of inhabitants (Azizi et al., 2019), cost of energy, fuel and combustive agents and so on (Kamal et al., 2019).

In this framework, the implementation of measures able to address multiple variables can probably represent the most sustainable solution to reach the desired goals; however, it is nonetheless important to underline that the reduction of domestic energy consumption related to heating and cooling needs can be particularly facilitated by: a) retrofit interventions for what concerns the historical and existing housing stock; b) construction of "green" and nearly-zero energy buildings (D'Agostino and Mazzarella, 2019) for what concerns new real estate properties. Technical interventions that aim to improve buildings' energy efficiency include, for instance, thermal coating, solar panels, photovoltaic systems and storage cells, use of insulating materials on horizontal, vertical and oblique perimetral surfaces, installation of energy-efficient windows, doors and skylights, heat pumps, floor heating and cooling, combination with domotics and remote-control systems, etc. (Manganelli et al., 2019). Additionally, it must be mentioned that the upscaling of green policies and energy consumption reduction from the building to the urban and district-based scale has started to emerge (Reynolds et al., 2017).

With exclusive reference to the building level, the implementation of the technical solutions mentioned above usually implies a considerable initial expenditure by households, and in absence of monetary incentives and financial mechanisms the economic viability of these interventions cannot be taken for granted (Brown et al., 2019). However, it is known that these interventions are associated to different and multiple benefits (Kamal et al., 2019; Kerr et al., 2017), such as an enhanced indoor environment (e.g., in terms of thermal comfort, ventilation, acoustic insulation, aesthetics, etc.), lower CO_2 emissions, and also lower heating and cooling running costs during the entire lifecycle of the building. Consequently, it has been advanced that energy efficient houses might thus be desirable by owners, occupants and potential buyers also by an economic point of view.

Given these multiple benefits and considering that – especially for what concerns the existing residential stock – sellers might want to recoup previous expenditures, it has frequently been supposed that energy efficient residential units are associated to higher real estate prices. In other words, it has thus been advanced that higher energy efficiency has a positive effect on properties' values.

However, even though this hypothesis sounds strong and reasonable, the international literature on the topic has not reached an agreement yet (Bisello et al., 2020; Cespedes-Lopez et al., 2019; Marmolejo-Duarte and Chen, 2019; Wilkinson and Sayce, 2020). More precisely, the appreciation of buildings' energy performance and "green" attributes by the real estate market still appears not homogeneous across contexts, and the relationships between energy-related characteristics and residential real estate prices have not proved to be straightforward up to now (McCord et al., 2020b). In fact, despite the increasing attention towards this topic and the progressive growth of scientific articles addressing the issue, results obtained by scholars have been extremely variable (Cespedes-Lopez et al., 2019; Marmolejo-Duarte and Chen, 2019; Wilkinson and Sayce, 2020). This lack of uniformity may be related to contextual factors (e.g., country, location and climate zone in which the buildings are located) and to specific characteristics of the local real estate markets and stocks (e.g., type of buildings, market segments, specific level of energy efficiency considered, etc.). Additionally, it must also be recalled that the measurement of buildings' energy performance is still not consistent throughout EU Member States and that the research perspectives and methods adopted by existing studies may have overall contributed to the variability of the results. Moreover, it is worth mentioning that the situation is constantly evolving, also depending on the incentives, regulatory frameworks and economic measures set up by governments especially in this time of economic crisis. In fact, it is possible that, while the compliance with energy requirements becomes stricter, Governments facilitate retrofits through economic incentives, the awareness about the advantages of energy-efficient buildings increases and the sensitivity towards ecological matters spreads, real estate prices will be affected too.

With respect to green policies promoted at the EU level, the European Green Deal – i.e. a set of policies aiming at making Europe the first net-zero climate impact continent – represents the framework of reference, and significantly it will be financed by one third of the 1.8 trillion euros of the Next Generation EU Recovery Plan and the EU's seven-year budget (European Commission, 2021a). For what concerns single EU countries, an exemplificatory case can be mentioned. For instance, Italy established the so called "Superbonus" (law n. 77, July 2020) during the 2020 Covid-19 crisis, to favour both economic recovery and the achievement of green objectives: in fact, the "Superbonus" encourages the performance of retrofits on buildings respecting given characteristics leveraging on fiscal and economic incentives. However, not only emergency measures but also long-term strategies and action plans have been developed by single EU countries, as recently outlined and analysed by a working document elaborated by the European Commission staff (European Commission, 2021b).

In this framework and through the conduction of a systematic analysis of the most recent peer-reviewed literature, this paper aims to identify the research methods adopted by scholars to explore the relationships between energy efficiency and real estate prices, in order to:

a) provide a methodological overview useful for future applications;

b) detect the research lines and methodological approaches that seem particularly worth exploring through future studies;

c) possibly recognize additional methods that may be particularly suitable to face emerging and promising research issues.

This contribution will take into account only the European context: in fact, whilst different conditions and regulatory frameworks possibly influencing markets and behaviours exist worldwide, the European Union has progressively established for its Member States a set of common directives, as anticipated above. Even though full comparability among EU countries is not possible yet, these Directives nonetheless offer a homogeneous policy background.

Given that in the European context the official document that expresses the energy efficiency degree of a building/building unit is the Energy Performance Certificate (EPC), the literature review will mainly include contributions that investigate the relationships between EPC ratings and real estate prices.

Notice that the work makes reference to the measures taken at the building level to ensure energy efficiency. However, as mentioned above, policies are also shifting attention to other urban and district-based solutions to reach the targets. The reasoning about the potentialities offered by shifting from the single building to the district/territorial scale is interesting, particularly in the case, for example, of the coexistence of different energy sources and technologies for supplying it. The great complexity deriving by enlarging the context can be managed through the definition of policies for the territorial governance and for the energy consumptions reduction, opening the way to other experiences and researches, mainly involving the application of approaches for the evaluation of project energy-economic sustainability (De Paola et al., 2021; Del Giudice et al., 2021a; Del Giudice et al., 2021b). Thus, the present work will focus on the building scale, demanding to future studies the exploration of other scale perspectives.

Overall, this piece of work explores the most recent studies on EPCs and real estate prices by a methodological viewpoint, and it can serve both as a literature review in itself and as a methodological support for further studies that will aim to estimate the effects of energy efficiency on real estate prices. Overall, our work does not only represent an update of previous literature review studies, but it originally analyses the papers by a methodological viewpoint.

The paper is articulated as follows. Section 2 presents a short overview about buildings' energy efficiency and EPCs in EU, as to frame the context of analysis and recall the regulatory framework that is determining energy-related policies in EU countries; in this Section some references to the Italian context are performed too, to empirically exemplify some concepts and applications of the EU Directives. Section 3 describes the materials and methods, while Section 4 illustrates and discusses the selected contributions and obtained results. Finally, Section 5 outlines final remarks and proposes perspectives for future studies.

2. Background: a short overview on the European Union's regulatory framework and policies about buildings' energy efficiency

In order to boost decarbonisation and the green energy transition in the real estate sector, the European Union has released and progressively updated the Energy Performance of Buildings Directive (EPBD-Directive 2002/91/EC). Originally issued in 2002 and then modified with subsequent versions (EPBD-Directive 2010/31/EU; EPBD- Directive 2018/844/EU) and supplements (Commission Delegated Regulation (EU) n. 244/2012), the EPBD has not only introduced minimum energy performance requirements for buildings but it has also established that buildings' energy efficiency is measured and attested by an Energy Performance Certificate (EPC). The EPDB prescribes that an EPC is made available whenever buildings are constructed, sold or rented out (Bisello et al., 2020): in fact, the provision, communication and publication of EPC ratings enhance transparency during transactions of various kinds and they offer precious information to the subjects involved in the operations (e.g., seller, buyer, tenant, intermediaries, etc.).

As known, EPCs summarise the energy efficiency of buildings through a rating scheme; with reference to a country such as Italy, energy labels range for instance from A4 (very efficient) to G (inefficient). Additionally, the EPC also includes suggestions on the technical interventions to be performed to improve the current rating of the building/building unit under consideration. With the aim of improving the rating scheme, the original criteria at the basis of the EPC rating were modified in 2018 (EPBD- Directive 2018/844/EU), and changes have been integrated by Member States in their national legislations in subsequent years.

Then, *"A Renovation Wave for Europe"* (European Commission, 2020) has recently anticipated that further enhancements to the EPC framework will be needed shortly. In fact, the document has underlined that barriers to the energy renovation of buildings exist at several points of the value chain, and that the poor explanation and understanding of the benefits stemming from retrofit (including their measurement and monetisation) definitely represent a major obstacle to renovation. Consequently, the European Commission has identified, among the essential areas of intervention, the strengthening of information, legal certainty (and incentives) for public and private owners and tenants. More precisely, the Commission will revise the EPBD in 2021, and it will propose to *"introduce a stronger obligation to have Energy Performance Certificates alongside a phased introduction of mandatory minimum energy performance standards for existing buildings […]. The impact assessments accompanying these legislative revisions will consider different options in terms of the level, scope and timing of these requirements"* (European Commission, 2020, p. 5).

Moreover, the European Commission will not only propose mandatory minimum energy performance standards as part of the revision of the EPBD by the end of 2021, but it will also propose to update the EPC framework, e.g. encouraging the application of energy performance metering technologies, the creation of a uniform EU machine-readable data format for the EPCs, the improvement (in terms of both availability and accessibility) of EPCs digital repositories and the

possible extension of energy audits requirements to a larger variety of non-residential buildings.

Coherently with the EU guidelines, a European country such as Italy has for instance started to make EPCs mandatory since 2009; additionally, in line with EU directives, the publication of the EPC rating has become compulsory in real estate advertisements since 2012 (Fregonara et al., 2017). The contents of the EPBD 2018 were adopted just recently instead, with the Decreto Legislativo 10/06/2020, n. 48. With reference to repositories publicly available, an overview of the number of EPCs progressively issued and of associated ratings can be currently freely accessed on the SIAPE- Sistema Informativo sugli Attestati di Prestazione Energetica website (https://siape.enea.it/). As mentioned in the Introduction, other EU countries have developed frameworks and long-term strategies promoting buildings' energy efficiency too.

Overall, the growing relevance of the topic at the international level has favoured the flourishing of a significant amount of studies focusing on buildings' energy efficiency, including contributions that aim to analyse the effects of EPCs and single "green" attributes on residential real estate prices. Recent articles have provided comprehensive overviews on the state of the art (Bisello et al., 2020; Khazal and Sønstebø, 2020; Marmolejo-Duarte et al., 2020; Marmolejo-Duarte and Chen, 2019), but the literature on the topic is still proliferating, and numerous articles have been published in the last few years. To pursue the research objectives outlined in the Introduction, the rest of the article will investigate the methods and results stemming from a systematic review of the most recent peer-reviewed contributions on the topic.

3. Materials and methods

The aim of this piece of work is to highlight the methodological perspectives recently adopted by scholars to investigate the relationships between buildings' energy performance and real estate prices. In order to reach this goal and capture the most updated methodological approaches, we performed a structured literature review, focusing only on scientific works indexed on the Scopus database and published in the last 5 years, i.e. between 2016 and 2020. This time frame was selected since it is a timespan frequently adopted in literature review studies aiming at investigating the recent state of the art on a defined topic (see, for instance, Tavares Thomé, 2016). Additionally, considering that EU Member States have integrated the prescriptions of the EPBD 2010 – which makes EPCs mandatory for all European buildings (Barreca et al., 2021) – at a different pace, we supposed that the articles published in this timeframe could most likely capture the effects of the energy efficiency regulations on the real estate markets better than less recent studies.

For the years 2016-2017 we capitalized on the searches already conducted by other authors (Bisello et al., 2020; Khazal and Sønstebø, 2020; Marmolejo-Duarte et al., 2020; Taltavull de La Paz et al., 2019), who recently integrated a literature review section in their empirical works: on the basis of their results, appropriate

contributions were thus included in our analysis. With respect to previous studies, our work does not provide an in-depth analysis of a single method (e.g. regression, spatial analysis, etc.), but rather a more comprehensive review of the methodologies recently adopted by scholars in the analysed literature.

For what concerns the years 2018-2020, an original and *ad hoc* search was performed instead. In line with the work of other researchers (Bisello et al., 2020), we retrieved on-topic contributions through a systematic search on the Scopus database (https://www.scopus.com, last accessed on 31st January 2021), inputting as keywords "Energy Performance Certificates" OR "EPC" AND "price" OR "housing market". This initial search returned more than 120 contributions. Obtained titles were then screened, and only articles focusing on the European context and on the effects of EPC/ "green" attributes on the residential real estate market were selected for analysis. Given that the focus of the study is the residential real estate market, articles concerning EPCs and the rental sector (Bian and Fabra, 2020; Cajias et al., 2019; Chegut et al., 2020; Collins and Curtis, 201; Cornago and Dressler, 2020; Franke and Nadler, 2019; Fuerst et al., 2020; Heffernan et al., 2021; Khazal and Sønstebø, 2020; Pommeranz and Steininger, 2021) were thus not included in the review. However, they represent an interesting and emerging field of research and they could constitute the core of a specific contribution on the topic. Articles focusing on the cost-effectiveness of the interventions or on contexts other than Europe (see, for instance, Baldini et al., 2020 and Dell'Anna and Bottero, 2021 respectively) were not analysed as well. Articles that during the screening phase emerged as useful for the contextualisation of the debate (e.g. articles analysing the willingness to pay for specific green interventions and attributes) are nonetheless cited in the text (see, for instance, Aydin et al., 2019, D'Alpaos and Bragolusi, 2020; Marmolejo-Duarte et al., 2020d).

Finally, some contributions published in early 2021 and/or presenting 2021 as publication year but already available in late 2020 were included in the analysis, with the aim of providing the most updated state of the art. Figure 1 provides an overview of the workflow followed to conduct the study.

Coherently with the research objectives outlined in the Introduction, it was decided to analyse the selected contributions according to the following fields*: a) city and country of application; b) size of the data sample; c) timeframe to which the data analysed in the contributions referred to; d) type of real estate price under investigation; e) methods adopted by researchers to conduct the study; f) synthesis of major findings*.

The fields *a), b)* and *c)*, together with the reference to the contribution in the form Author-Year, mainly aimed at contextualising the study (e.g., by a geographic and temporal perspective, as well as at specifying the data under study). *d)* aimed at identifying the type of price considered by authors: in fact, prices are not only a very important variable (since in most cases they constitute the dependent variable), but they are also an object of debate in the estimative discipline (Curto et al., 2012). Consequently, it was deemed appropriate to specify their nature through a dedicated field. Even though some authors used the log version of prices, this was not specified in the analysis. *e)* aimed at identifying the methods adopted by researchers and it represents the core of the study. Field *f)* was

Figure 1. Workflow followed to perform the literature review presented in the study.
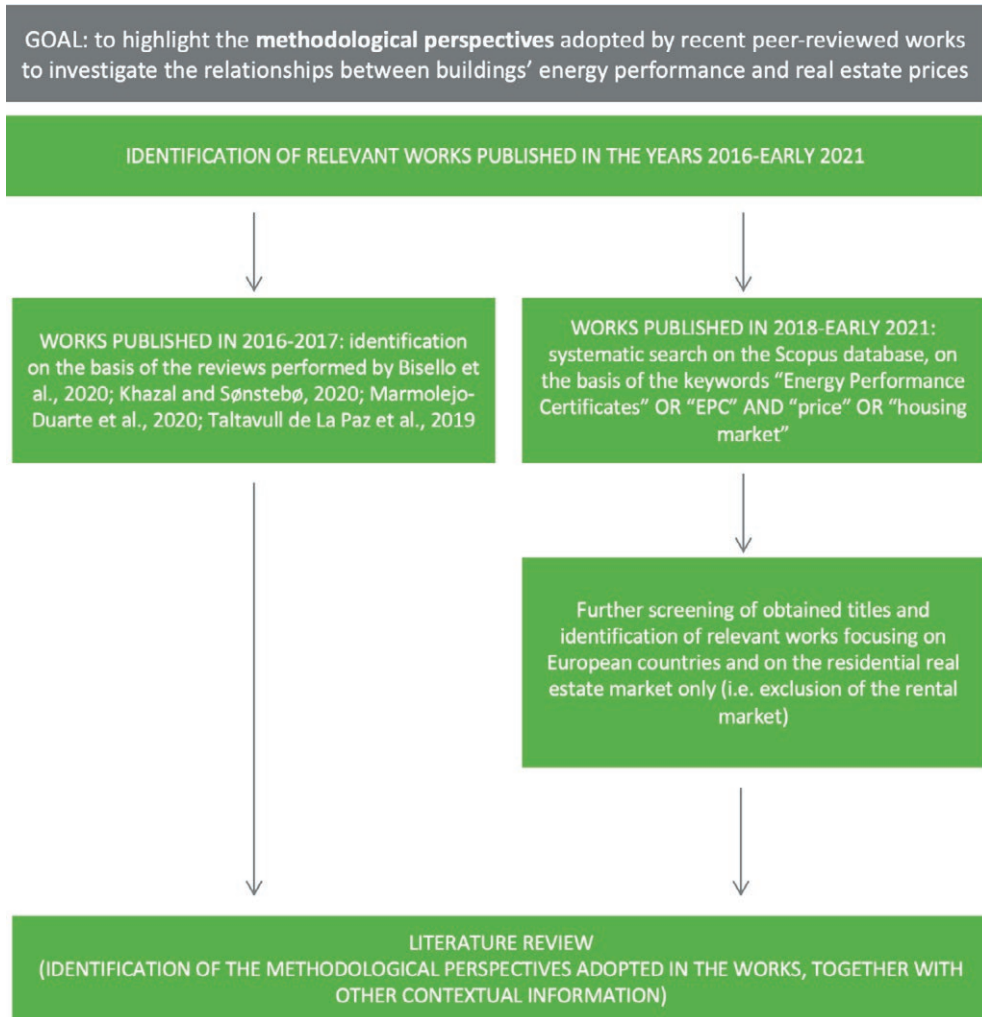
Source: authors' own elaboration.

included to offer a synthesis of the major findings, without the claim of providing a complete account of all the results reported in the contributions.

Information was overall summarised into a table and then analysed according to the research questions of our study.

4. The influence of Energy Performance Certificates (EPCs) on real estate prices: results from recent studies

Coherently with the methods described in the previous section, a total of 26 contributions were included in the review. Table 1 functions as reference for the analysis and it provides a systematic synthesis of the information collected.

4.1 Location, geographic scale, property types and sample sizes

The examined contributions covered different European countries, ranging from Mediterranean to Northern and Eastern Europe (Figure 2). More precisely, 7 studies analysed Italian cities, 7 addressed Spanish contexts, 3 focused on Belfast (Northern Ireland), 2 on Sweden, 1 on Portugal, 1 on Wales, 1 on Denmark, 1 on Finland (Helsinki area), 1 on Oslo (Norway), 1 on Dublin (Ireland) and 1 on Bucharest (Romania); additionally, one study included a desk review of EU case-studies (Figure 2). The recent publication of papers focusing on Mediterranean countries seems to indicate that a certain gap in the literature evidenced by other scholars (Dall'Anna et al., 2019) – i.e. the prevalence of studies focusing on Northern Europe – has started to be at least partially reduced. However, the results stemming from our research highlighted that a certain unbalance in the literature still exists, since not all EU countries were equally represented in the works emerged from the application of the workflow described in Section 3.

Overall, the geographic scale selected by authors varied: the urban (i.e. single cities), intra-urban (i.e. sub-portions of cities), metropolitan (i.e. main city and surrounding municipalities), territorial (e.g. province) and national (i.e. country) scales were overall explored. Additionally, a couple of studies considered two cities as object of analysis, especially to perform comparisons (Dell'Anna et al., 2019; Manganelli et al., 2019).

In line with the object of the research, all articles analysed residential units. However, some exclusively focused on apartments located in multi-family buildings (Chen and Marmolejo-Duarte, 2019; Cespedes-Lopez et al., 2020; Dell'Anna et al., 2019; Fuerst et al., 2016b; Marmolejo-Duarte, 2016; Marmolejo-Duarte and Chen, 2019; Marmolejo-Duarte et al., 2020; Taltavull et al., 2017), whereas others exclusively considered single family-houses (Jensen et al., 2016; Wahlström, 2016; Wilhelmsson, 2019). Choices were usually justified by authors in light of the characteristics of the local housing stock (i.e. most frequent type of building).

Sample sizes varied too, and they seemed to depend both on specific research questions and available datasets. Considered timeframes were not homogeneous as well, and they ranged from one or few months to several years. Contributions usually included in the analysis datasets referring up to 2-3 years before publication, even though some studies analysed older (Evangelista et al., 2020; Fuerst et al., 2016b; Jensen et al., 2016; Marmolejo-Duarte and Chen, 2019; Marmolejo-Duarte et al., 2020; McCord et al., 2020; Wahlström, 2016) or more recent data (Bottero et al., 2018; Dell'Anna et al., 2019).

Table 1. Recent articles that analyse the influence of "green" variables and EPC ratings on residential real estate prices: background, methods and main findings.

Authors and year	City and country	Data sample: size	Data sample: year	Price type included in the models	Methods	Major findings
Barreca et al., 2021	Turin (Italy)	2,092 residential units	2015-2018	Listing prices	Hedonic Price Model (OLS), Spatial Error Models	The study pointed out that low EPC ratings (i.e. E, F and G) significantly and negatively affected housing prices; high EPC ratings (i.e. B, A1, A2, A3 and A4) had a lower but positive influence instead. Then, the building category and the housing unit maintenance level resulted to particularly influence prices. With reference to the spatial dimension, different spatial clusters resulted to behave as different sub-markets. With respect to previous studies (Fregonara et al, 2014; Fregonara et al, 2017), price premiums increased.
Bisello et al., 2020	Bolzano (Italy)	849 residential units	March 2018	Listing prices	Hedonic Price Model (OLS), then combined with spatial specifications	All other characteristics being equal, authors found a price premium in excess of 6% moving from the worst EPC rating ("G") to the best ("A"). A spillover effect exerted by retrofitted properties on nearby properties was detected too.
Bottero et al., 2018	Turin (Italy)	15,295 residential properties	2015- Q1 2018	Listing prices	OLS, Multiplicative exponential model, Linear and nonlinear spatial error model, Linear and nonlinear spatial autoregressive model	Through a variety of models combining the OLS-Hedonic Price Model and spatial econometrics, authors estimated the willingness to pay for a specific type of residential unit characterized by "E" EPC rating. Additionally, authors underlined that level of maintenance plays an important role in the price formation process.
Cespedes-Lopez et al., 2020	Province of Alicante (Spain)	52,939 observations (multi-housing properties), of which, 9,194 included information on energy qualification	Period June 2017 – May 2018	Listing prices	Hedonic Price Model (OLS)	The study highlighted that, for the multi-family housing properties under study, a positive relationship between EPC ranking and listing prices did not exist.
Chen and Marmolejo-Duarte, 2019	Barcelona Metropolitan Area (164 municipalities) (Spain)	3,246 apartments for 2014 and 3,246 apartments for 2016 (total: 6,492)	2014-2016	Listing prices	Spatial Error Hedonic Model	Price premiums were found for "A" ranked homes in 2014 and "B, C, D" ranked homes in 2016. Additionally, authors highlighted that "A" ranked homes located in peripheries where new completions were developed; "B" , "C" and "D" were found in more central locations in neighbourhoods of wealthy population, instead.

Authors and year	City and country	Data sample: size	Data sample: year	Price type included in the models	Methods	Major findings
Dell'Anna et al., 2019	Barcelona (Spain) and Turin (Italy)	3,224 (Barcelona) and 15,288 (Turin) apartments mainly in multi-family buildings	2014-2018	Listing prices	Hedonic Price Model (OLS), then combined with spatial specifications	Authors found that in Barcelona each step of EPC ranking allowed a + 2% in the total listing price, with an increase of 12% passing from a rank G to A. In Turin, the found percentage was +6.8% instead. Then, the correction of the spatial autocorrelation allowed to improve the model fitting; corrected percentages were 1.88% for Barcelona and 6.33% for Turin.
Evangelista et al., 2020	Portugal	256,000 residential properties	2009-2013	Sales prices	Hedonic Price Model and quantile regressions	Authors found a price premium for energy efficiency, which was more pronounced for apartments (13%) than for houses (5 to 6%). Additionally, these price premiums tended to increase from 2009 to 2013.
Fregonara et al., 2017	Turin (Italy)	879 transactions of old properties	2011-2014	Transaction prices and listing prices	Hedonic Price Model (OLS)	Authors highlighted that EPC labels had no impact on prices of apartments in old buildings, which were characterized by mid-to-low energy performance.
Fuerst et al., 2016a	Wales	191,544 transactions	2003-2014	Transaction prices	Hedonic Price Model (OLS)	The study highlighted a positive price premium for EPC rating A/B (+12.8%) compared to dwellings rated D. Statistically significant discounts were found for E and F ratings instead (-3.6% and -6.5 %, respectively).
Fuerst et al., 2016b	Helsinki metropolitan area (Finland)	6,203 observations (apartmentsonly)	2009-2012	Transaction prices	Hedonic price Model (OLS)	A statistically significant 3.3% price premium for apartments in the top three energy-efficiency categories was found. This percentage amounted to 1.5% when a set of detailed neighbourhood characteristics were included.
Jensen et al., 2016	Denmark	A sample derived from delimitations applied to a total of 117,483 observations (single-family houses)	1st January 2007-1st July 2010; 1st July 2010-October 2012	Sale prices	Regression analysis	Authors found that EPC rating had an impact on sale prices. Before the implementation of the EPBD in 2010 the effect was modest, but it increased significantly in the period 2010-2012.

Authors and year	City and country	Data sample: size	Data sample: year	Price type included in the models	Methods	Major findings
Manganelli et al., 2019	Bari and Acri (Italy)	101 real estate units located in the central area of Bari, 43 in the suburban area of Bari and 39 in Acri	Recent years	Purchase and sale prices	Categorical regression – Alternating Least Squares Model	Authors found that in the most valuable areas (e.g. city centre of Bari) energy efficiency plays only a secondary role in the value formation process, whilst location is of primary importance. For what concerns the increase of value when shifting from a lower EPC rating to the next, authors found that the last jump (i.e. from B to A) was the one evaluated by the market as the most important.
Marmolejo-Duarte, 2016	Metropolitan area of Barcelona (Spain)	4,248 apartments (multifamily dwellings)	2014	Listing prices	Hedonic Price Model (OLS)	The study highlighted that an improvement from an EPC G rating to an A rating increased the value by 5.11 %.
Marmolejo-Duarte and Chen, 2019	Municipalities around the Barcelona area (Spain)	3,479 apartments (multifamily dwellings)	First quarter of 2015	Listing prices	OLS, also applied to different clusters of apartments (i.e. market segments)	Different EPC rating affected older dwellings, while it played a null role in the price formation for apartments with amenities and active-comfort systems. "A" rating exerted a +12.2% price premium for the most expensive, central and well-endowed segment and an impact of + 33.2% for the cheaper segment (apartments with worse active air conditioning, poor architectural quality and located in working-class neighbourhoods).
Marmolejo-Duarte et al., 2020	Municipalities around the Barcelona area (Spain)	5,497 apartments	April 2016	Listing prices	OLS and Geographically Weighted Regression	Authors found a premium equal to 1.7% for each EPC ranking. By a spatial perspective, apartments registering the largest impact of energy efficiency were located in peripheral areas mainly populated by medium and low-income residents and characterized by a less-differentiated housing stock (with respect to wealthier areas).
McCord et al., 2020	Belfast (Northern Ireland)	1,478 properties	Q3 2013-Q3 2014	Transacted prices	OLS, Geographically Weighted Regression and Spatial Lag Model	Different EPC effects were detected with regard to different property types, age of construction and location. Authors found that a capitalization effect was not always present, since high prices did not always connotate superior energy efficiency. Additionally, authors found a composite effect of EPC and heating type (gas heating), underlining that the actual impact of EPC on prices need to be evaluated carefully.

Authors and year	City and country	Data sample: size	Data sample: year	Price type included in the models	Methods	Major findings
McCord et al., 2020a	Belfast (Northern Ireland)	3,797 residential achieved sales	Q3 2017- Q3 2018	Transacted prices	Binary logit regression models in conjunction with a Polytomous Universal Model	Authors did not find evidence of an increased probability of a growth in sales price with higher EPC rating. Overall, results seemed to suggest the presence of a complex and dynamic relationship between the nature of the property type (i.e. apartments, terrace houses, detached and semi-detached houses, etc.) and its energy efficiency and sales price.
McCord et al., 2020b	Belfast (Northern Ireland)	1,478 residential achieved sales	Q2 2018-Q1 2019	Transacted prices	OLS and Quantile Regressions Models	Authors found that the effects of EPC-ratings were not constant or significant across the entirety of the pricing structure, with premiums existing in the higher EPC-rated properties at the higher levels of the price distribution. Authors identified potential EPC scores as a variable affecting market values too.
Morano et al., 2020	Bari (Italy)	200 residential properties	2016-2017	Selling prices	Evolutionary Polynomial Regression	"Extreme" labels (i.e. A and G) exerted the highest contribution on selling prices: whereas label A had a positive effect on prices (+ 27%), G had an approximately similar but negative effect (– 27%).
Olaussen et al., 2017	Oslo (Norway)	Residential properties	1st January 2000-31st December 2014 (EPC mandatory since 1st July 2010)	Transaction prices (bidding context)	Hedonic Price Model (OLS)	Authors found that price premium was not related to EPCs. They also evidenced the problem of omitted variables being correlated with the energy label. Authors hypothesized a correlation between EPC and aesthetics too.
Stanley et al., 2016	Dublin (Ireland)	Residential homes	2009-2014	Listing prices	Hedonic Price Model (OLS)	Authors estimated that a 1-point improvement in the 15-point scale from G to A1 yields a list price increase of 1 %.
Taltavull et al., 2017	Bucharest (Romania)	16,443 observations (apartments)	2013-2015	Listing prices	Hedonic Price Model (OLS) and STAR GLS model	Authors found that energy efficiency is associated to a price premium in two (out of 5) areas of the city. The estimated green premium for the overall city is +3.5%.
Taltavull de La Alicante Paz et al., 2019	Alicante (Spain)	Around 9,000 residential properties	Since 2013	Listing prices	Pool- OLS and Instrumental Variables Hedonic Models	Authors found a partial green premium when energy-efficiency improvements increase the EPC rating from G to F (+1.8%) and from F to E (+1.1%). Additionally, different green premiums were found for properties located in different climatic areas, with intermediate zones manifesting the highest green premium.

Authors and year	City and country	Data sample: size	Data sample: year	Price type included in the models	Methods	Major findings
Wahlström, 2016	Sweden	77,000 observations (single-family homes)	2009-2010	Selling prices	Hedonic Price Model (OLS)	Authors found a price premium for housing attributes that improve the energy efficiency and not for energy consumption in itself.
Wilhelmsson, 2019	Sweden	More than 100,000 single-family housing	2013-2018	Transaction prices	Hedonic Price Model and quintile regression; spatial autoregressive models	The author found that the price difference between the A-C EPC labelled houses and the D-G labelled group was small and not statistically significant. Additionally, EPC impact on prices was found for all housing price segments; the impact percentage was almost the same for all segments. Impact was higher in Northern parts of the country instead.
Wilkinson and Sayce, 2020	EU-based case studies	Desk review of 21 contributions	2008-2020	Mostly listing prices	Mostly Hedonic Price Analysis (OLS)	Energy efficiency (expressed through EPC ratings) has started to impact on value, but it is small compared to other value drivers. Additionally, empirical findings seemed to point towards the emergence of a "brown" discount rather than a green premium, especially in the long-term trend.

Figure 2. Effects of EPC ratings on real estate prices in Europe: countries covered by recent peer-reviewed articles.

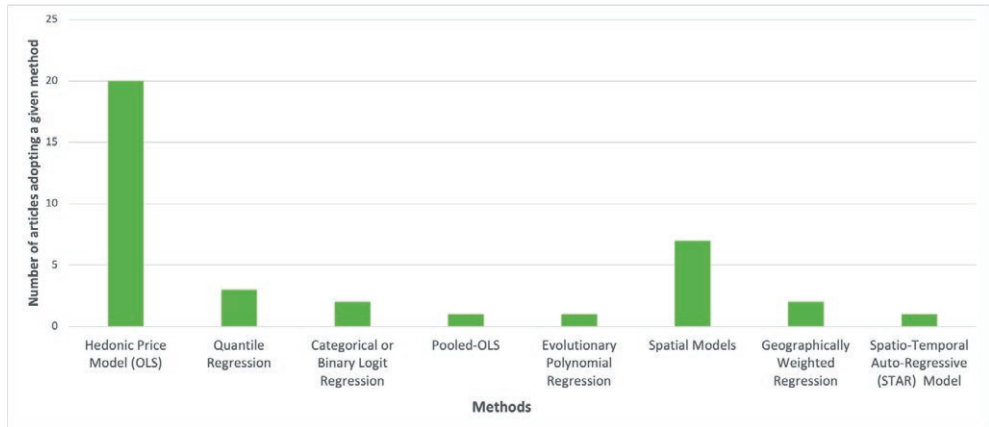Source: authors' own elaboration.

4.2 Price types

With reference to prices, the selected articles largely considered listing prices. In fact, as known, listing price is frequently the only variable that stands for the value of the real estate asset that can be easily accessed (e.g. through real estate agencies and online real estate portals). Since some studies have underlined that they can be considered as a proxy for actual transaction prices (Curto and Fregonara, 2012; Malpezzi 2003 in Stanley et al., 2016) and that they play an important role in price prediction (Knight, 2002 and Horowitz, 1992 in Barreca et al., 2021),

they are an appropriate variable to be analysed. However, it might be useful to remind that listing prices are especially able to reflect the value of the residential unit as either perceived by the seller or calculated by the intermediary: they thus particularly report the point of view of the offer/supply side (Taltavull del la Paz et al., 2019). Conversely, actual transaction prices are the result of a negotiation process, and they might better reflect not only the value of the residential units and of its characteristics (including "green" variables) as estimated by the supply side, but also the value attributed by the demand side. Thanks to the availability of specific data sources, a certain number of articles was nonetheless able to analyse transaction prices (Fregonara et al., 2017; Fuerst et al., 2016a; McCord et al., 2020; McCord et al., 2020a; McCord et al., 2020b; Whilelmsson, 2019). Interestingly, one article included transaction prices derived from a perfectly competitive bidding context, where potential *"buyers compete with open bids, and the highest wins the auction"* (Olaussen et al., 2017, p. 248). Other authors considered speed of sale (Aydin et al., 2019) and time on the market (Fregonara et al., 2017; Fuerst et al., 2016b) as dependent variable instead; even though the investigation of these variables is out of the scope of this review, it can be stated that they are particularly interesting too, since they suggest to what extent the characteristics of the residential unit are able to meet the demand's needs.

4.3 Methods and major findings

With reference to the methods and models adopted, the selected contributions included the following ones: Hedonic Price Model (Cespedes-Lopez et al., 2020; Fregonara et al., 2017; Fuerst et al., 2016a; Fuerst et al., 2016b; Marmolejo-Duarte, 2016; Olaussen et al., 2017; Stanley et al., 2016; Wahlström, 2016; Wilkinson and Sayce, 2020), OLS and quantile regression (Evangelista et al., 2020; McCord et al., 2020b; Whilhelmsson, 2019), Pooled-OLS and Instrumental Variables Hedonic Models (Taltavull de La Paz et al., 2019), regression (Jensen et al., 2016) and multivariate analysis (Brounen et al., 2020), categorical regression (Manganelli et al., 2019), binary logit regression models in conjunction with a Polytomous Universal Model (McCord et al., 2020a), Evolutionary Polynomial Regression (Morano et al., 2020), Hedonic Price Model (HPM) combined with spatial specification (Barreca et al., 2021; Bisello et al., 2020; Bottero et al., 201; Dell'Anna and Bottero, 2021; Dell'Anna et al., 2019), Geographically Weighted Regression (Marmolejo-Duarte et al., 2020; McCord et al., 2020) and spatio-temporal autoregressive models (Taltavull et al., 2017). Overall, HPM and regressions frequently remain the core of the methods adopted – in line with what already noted by other researchers (Molina et al., 2019) – even though many studies have applied approaches that represent an evolution of the basic OLS approach (Figure 3). For instance, spatial approaches aim to take into account into regressions possible spatial autocorrelation patterns, and they can generally take the form of either Spatial Lag Models or Spatial Error Models. In the considered context of application, quantile regressions usually aim at detecting different EPC effects on price distributions instead.

Figure 3. Methods adopted by recent peer-reviewed articles investigating the effects of EPC ratings on real estate prices in Europe: frequencies.

Source: authors' own elaboration.

The well-established Hedonic Price Method (HPM-OLS) (Curto and Fregonara, 2019; Fregonara et al., 2014; Fregonara et al., 2017; Molina et al., 2019) was applied for instance by M. F. Cespedes-Lopez and colleagues (Cespedes-Lopez et al., 2020); interestingly, these authors found that a positive relationship between EPC-labels and prices did not exist for multi-family properties in the province of Alicante (Spain), and that sellers tended not to disclose the EPC label of the property. This phenomenon was interpreted by authors in light of a variety of reasons, including the following ones: owners' desire to sell their energy-inefficient properties at prices similar to "greener" comparable assets, lack of sanctions for owners not disclosing EPC ratings, absence of compensations for the investments required to improve EPC rating, and a generalized negative attitude towards interventions aimed at improving energy efficiency.

HPM was also applied in a study investigating the Welsh real estate market (Fuerst et al., 2016a): in this case authors highlighted a positive price premium for A/B ratings (+12.8%) compared to dwellings rated D. Statistically significant discounts were found for E and F ratings instead (- 3.6% and – 6.5 %, respectively).

The employment of the HPM to the metropolitan area of Helsinki (years 2009-2012) pointed out a statistically significant + 3.3% price premium for apartments in the top three energy-efficiency categories, reduced to 1.5% when considering detailed neighbourhood characteristics (Fuerst et al., 2016b).

Regression and OLS allowed other authors too to identify various premium prices for residential units characterized either by a certain energy efficiency level (Jensen et al., 2016; Marmolejo-Duarte, 2016; Stanley et al., 2016) or by housing attributes that improve the energy efficiency (Wahlström, 2016).

Analysing through the HPM approach a Norway real estate dataset covering the 2000-2014 period, some researchers did not find a price premium related to

EPCs instead. Interestingly, they also evidenced the problem of omitted variables being correlated with the energy label. Authors then hypothesized a correlation between EPC and aesthetics too (Olaussen et al., 2017).

In the context of a more extensive work focusing on cost-benefit analysis of interventions finalized to improve buildings' energy efficiency, B. Manganelli and colleagues (Manganelli et al., 2019) estimated the marginal prices associated to different EPC ratings in three different contexts by the means of categorical regressions (i.e. an approach that treats EPC as a categorical variable in the realm of an iterative regression model called the alternating least squares model); authors found that in the most valuable areas (e.g. city centre of Bari) energy efficiency plays only a secondary role in the value formation process, whilst location is of primary importance. For what concerns the value increase when shifting from a lower EPC rating to the next, authors found that the last jump (i.e. from B to A) was the one evaluated by the market as the most important.

Pooled-OLS and Instrumental Variables Hedonic Models were applied by other authors (Taltavull de La Paz et al., 2019) to the entire province of Alicante – which extends over different climate zones- instead: researchers found a partial green premium when energy-efficiency improvements increased the EPC rating from G to F (+1.8%) and from F to E (+1.1%). Additionally, different green premiums were found for properties located in different climatic areas, with intermediate zones manifesting the highest green premium. For authors, this pattern indicated the existence of a higher sensibility in regions with greater weather instability.

OLS and quantile regressions were used for instance by R. Evangelista and colleagues (Evangelista et al., 2020) to analyse a large set of sales prices referring to Portugal (years 2009-2013). Overall, authors did find a price premium for energy efficiency, which was more pronounced for apartments (13%) than for houses (5 to 6%). Additionally, authors reported that these price premiums tended to increase from 2009 to 2013. Then, conditional quantile regressions were applied to detect the impact of energy efficiency over the distribution of residential property prices: results highlighted the existence of a price premium for energy efficiency across the entire spectrum of prices; moreover, authors reported that the impact of energy efficiency seemed quite stable across the quantiles.

Quantile regression was applied also by M. Whilelmsson (Whilhelmsson, 2019) when analysing a large data set of real estate transaction prices (more than 100,000 observations) in Sweden. By a methodological perspective, the author also addressed the selection bias issue (i.e. risk that there is a different probability that observations are included in the sample under study) through the propensity score method, considering dwellings with an A-C EPC rating as "treatments" and with D-G EPC ratings as control group. Then, spatial autoregressive models were applied too. In synthesis, it was found that the price difference between the treatment group and the control group was small and not statistically significant. Additionally, the author found that the impact of high energy performance on prices was present in all housing price segments and that the percentage was almost the same for all segments. With reference to location, a higher impact was found for Northern parts of the country instead.

OLS and quantile regression have been recently experimented also by M. McCord and colleagues (McCord et al., 2020b) in the context of Belfast's real estate market. Like the work presented above (Whilelmsson, 2019), their research stands out since the study does not analyse listing prices but actual transacted prices, thus offering a perspective that best incorporate the value attributed by the demand side too. Through this approach authors found that the effects of EPC-ratings were not constant or significant across the entirety of the pricing structure, with premiums existing in the higher EPC-rated properties at the higher levels of the price distribution. The article continues stressing that the relationship between energy performance and property value is not straightforward, and that the market may value not only actual EPC scores but also EPC potential scores; in other words, *"if the current score is good, purchasers pay a little more than otherwise. If the current score is poor but potential score is good, they pay up and move on. If the current score is poor and potential score is poor, then a discount is evidenced"* (McCord et al., 2020b, p. 429). With reference to potential scores, authors advanced the existence of a "latent" attribute able to both positively affect the highest price segments of the B-rated energy-efficient properties (i.e. presence of price premium) and negatively affect the properties with the lowest ratings (i.e. presence of a "brown discount").

Latent relationships between EPC scores and real estate prices were explored by the University of Ulster (McCord et al., 2020a) also through binary logit regression models specified in conjunction with a Polytomous Universal Model; the aim of the work was to examine the likelihood of EPC ratings falling within a particular property type and the likelihood of any pricing effects. Results did not show evidence of an increased probability of a growth in sales price for units with higher EPC ratings. Overall, logit and ordinal regression-based methodologies were applied to evaluate the inter-relationships between property characteristics, EPCs and value; results seemed to suggest the presence of a complex and dynamic relationship between the nature of the property type (i.e. apartments, terrace houses, detached and semi-detached houses, etc.) and its energy efficiency and sales price.

A. Bisello and colleagues (Bisello et al., 2020) analysed the listing prices of a sample of residential properties located in Bolzano (Italy) by the means of the Hedonic Price Method, then performing spatial specifications: overall, authors found a price premium in excess of 6% moving from the worst EPC rating ("G") to the best ("A"), being equal all the other characteristics. Additionally, they detected a spillover effect exerted by retrofitted properties on nearby residential units, highlighting that this might represent an additional benefit of energy-efficiency interventions.

A spatial approach was already followed by F. Dell'Anna and colleagues (Dell'Anna et al., 2019) for the analysis of a sample of apartments located in the cities of Barcelona (Spain) and Turin (Italy); in this case, authors found that in Barcelona each step of EPC ranking allowed a + 2% in the total listing price while in Turin the calculated percentage was +6.8% instead. Then, the correction of the spatial autocorrelation allowed authors to improve the model fitting: corrected percentages were 1.88% and 6.33% respectively. Authors also concluded that while in Barcelona air conditioning and swimming pool were particularly valued by the

market, in Turin (which is characterised by a different climate zone and a cooler weather) EPC ratings resulted to have a higher importance instead.

With reference to the effects of EPCs on the real estate market of Turin, other authors (Barreca et al., 2021) have more recently found that low EPC ratings (i.e. E, F and G) significantly and negatively affected housing prices; high EPC ratings (i.e. B, A1, A2, A3 and A4) had a lower but positive influence instead. Authors performed Spatial Error Models, and they found that different spatial clusters resulted to behave as different sub-markets. Interestingly, authors also noted that, compared to previous studies (Fregonara et al, 2014; Fregonara et al., 2017), price premiums increased: in fact,

the analysis of 2011-2014 data actually highlighted that EPC labels had no impact on prices of local apartments located in old buildings (Fregonara et al., 2017).

The effects of EPC ratings on the real estate market of Turin were explored by the means of spatial econometrics by M. Bottero and colleagues (Bottero et al., 2018) too: among multiple results, authors particularly underlined that level of maintenance plays an important role in the price formation process.

M. McCord and colleagues (McCord et al., 2020) analysed the prices registered for real estate transactions in the Belfast Metropolitan Area through a variety of methods, including Geographically Weighted Regression and Spatial Lag Models. Overall, different EPC effects were detected for different property types, age of construction and location. Authors found that a capitalization effect was not always present, since high prices did not always connotate superior energy efficiency. Additionally, authors found a composite effect of EPC and heating type (gas heating), underlining that the actual impact of EPC on prices need to be evaluated carefully.

In a study focusing on Bucharest, some authors (Taltavull et al., 2017) applied a spatio-temporal auto-regressive approach and they found that energy efficiency was associated to a price premium in two (out of 5) areas of the city. The estimated green premium for the overall city was +3.5%.

Through a Spatial Error Hedonic Model, A. Chen and C. Marmolejo-Duarte (Chen and Marmolejo-Duarte, 2019) found that price premiums were associated to "A" ranked homes in 2014 and "B, C, D" ranked homes in 2016 in the Barcelona metropolitan area. Additionally, authors highlighted that "A" ranked homes were located in peripheries where new completions were developed; "B", "C" and "D" were found in more central locations in neighbourhoods of wealthy population, instead.

C. Marmolejo-Duarte and colleagues (Marmolejo-Duarte et al., 2020) applied a Geographically Weighted Regression approach to the analysis of EPC marginal prices for apartments located in the Barcelona area (Spain) and they found a premium equal to 1.7% for each EPC ranking. However, authors explained that energy efficiency overall remained one of the less important variables in the real estate pricing process. Interesting, authors reported that the premium found when analysing April 2016 data (i.e. almost three years after the inclusion of EPC ranking in real estate advertisements became mandatory in Spain) nearly doubled the premium reported for data referring to November 2014: this seems to reinforce what we stated in the Introduction, i.e. that it is likely that the appreciation of buildings' energy efficiency by the market will change coherently with regulatory frame-

works and the evolving degree of awareness concerning the vast realm of energy efficiency. Following a spatial approach, authors also found that the apartments registering the largest impact of energy-efficiency were located in peripheral areas mainly populated by medium and low-income residents. In wealthier areas, other characteristics of the apartments seemed to influence the market instead. On this point, C. Marmolejo-Duarte and A. Chen (Marmolejo-Duarte and Chen, 2019) already warned about the necessity of retrofit subsidies in order to mitigate possible negative effects generated by energy requirements on vulnerable social segments: in fact, through an OLS analysis applied to a set of 3,479 apartments located in the Barcelona area (Spain), they found that the "A" EPC rating exerted the maximum effect in the market segment characterized by poor architectural quality and located in working-class neighbourhoods, i.e. a context where only few subjects might be able to perform interventions finalized to enhance energy-efficiency.

P. Morano and colleagues (Morano et al., 2020) analysed the contribution of the energy performance component on the prices of two hundred residential properties sold in 2016-2017 in Bari (Italy) by the means of a data-driven technique employing a genetic algorithm aimed to identify the best functional expressions. More specifically, authors applied the Evolutionary Polynomial Regression approach and the model obtained pointed out that the "extreme" labels (i.e. A and G) were the ones which were able to exert the highest contribution on selling prices. Authors also noted that the properties associated to an A-label were either new or recently renovated, whereas G EPC labels were associated to properties characterized by a low level of maintenance and/or to be restructured yet.

With reference to the relationship between EPC and another interesting variable (i.e. speed of sale), E. Aydin and colleagues (Aydin et al., 2019) highlighted that, for what concerns a large sample of single-family homes in the Netherlands (i.e. 876,000 observations referring to the period 2008-2016), energy-rated homes sold faster than non-energy-rated homes. In the case of a sample of apartments located in the Helsinki metropolitan area (Fuerst et al., 2016b), it was found a slightly shorter time on market for the high-rated units and a longer period for the E-rated apartments (compared with the average energy class D). However, coefficients were statistically insignificant. A very low explanatory power of EPCs on the variable time on the market was found by E. Fregonara and colleagues (Fregonara et al., 2017) when investigating the 2011-2014 Turin's real estate market instead.

A stated preference approach was then used by some authors to investigate the willingness to pay for improving the energy efficiency of homes (Marmolejo-Duarte et al., 2020d) in Barcelona (Spain): results overall highlighted divergent sensibilities of respondents according to their demographic and socio-economic conditions, awareness of EPC scheme and environmental issues and so on.

Then, it must be mentioned that the relationships between green attributes and residential real estate prices have been studied considering not only the overall energy performance of residential units but also the presence of specific green attributes such as -for instance- photovoltaic plants installations. As an example, C. D'Alpaos and M. Bragolusi (D'Alpaos and Bragolusi, 2020) investigated the topic

through a contingent valuation approach, showing that participants were inclined to pay a premium price for solar homes.

In the context of a study with a broader aim, V. R. M. Lo Verso and colleagues (Lo Verso et al., 2014) investigated the willingness to pay an extra price for houses characterised by enhanced indoor environmental quality and by attributes allowing energy savings, instead: authors found that nearly 40% of the questionnaire participants declared to be keen on paying up to 25% more for a house with characteristics allowing energy savings; the percentage of questionnaire participants that expressed to be willing to pay the same extra price (+ 25%) for a house with enhanced indoor environmental quality amounted to 26% instead. Interestingly, authors overall underlined the rise in the market of a new sensitivity towards environmental and energy issues.

Building on these findings, it can be advanced that the conduction of studies able to capture the revealed and/or stated preferences for retrofit or retrofitted residential units (e.g. through the measurement of the willingness to pay for specific products/ interventions and/or through the analysis of transacted prices) could represent a valuable area of study, especially if investigations are carried out taking into account the socio-economic characteristics and green attitudes of the subjects involved: in fact, these studies will allow to express in monetary terms the multidimensional values associated to green interventions.

4.4 Research trends and perspectives: a synthesis

Overall, the review of the articles included in the analysis seems to highlight the presence of some trends in the most recent peer-reviewed literature. A synthesis is presented below, together with some comments for future research:

1) the spatial scale of the studies varies, and analysed samples included data at the intra-city and city level, but also at the metropolitan, regional and national level. Overall, this variety is a signal of the multiplicity of the research questions explored by authors, and future studies should be able to identify the most appropriate geographic scale in relation to the perspectives set by the research questions. In this process the availability of appropriate datasets is not irrelevant: in fact, the nature and extension of datasets can either facilitate or prevent the development of specific lines of research;

2) the type of housing solution under study is well explained by some authors, whereas in other cases the composition of the sample appears less detailed. Whereas studies focusing on Northern Europe countries have frequently explored the relationship between EPC ratings and single-family houses, recent papers on Mediterranean countries have particularly analysed apartments located in multi-family dwellings. In general terms, the future provision of details on the characteristics of the local housing stock and on the prevalent building type would enrich contextualisation and the interpretation of results;

3) with reference to the type of residential solution, some authors reported a greater effect for apartments with respect to houses (Evangelista et al., 2020), but

the relationship between the property type, its energy efficiency and prices seems overall complex and it requires further development (McCord et al., 2020a). Since single-family houses would be particularly eligible for the integration of renewable energy sources, future studies could also try to investigate the relationship possibly occurring between this specific green attribute and the appreciation manifested by the market;

4) contributions analyse the relationships between EPCs and real estate prices referring to different timeframes (i.e. length of the time span under consideration) and different years. The peculiarities of each study seem related to reasons internal to the research but in some occasions they might also be related to available datasets. In general, the reasons behind the selection of certain timeframes should be always clarified by authors and reference to the regulatory framework in force during the investigated timeframes should be always made explicit too. In fact, this would help monitor whether different energy-related policies are associated to some effects in terms of real estate prices; additionally, it would be interesting to capture the time span that is necessary for the market to acknowledge these policies and translate them into detectable price effects;

5) as an extension of the point above, it must be evidenced that in some cases (Barreca et al., 2021; Evangelista et al., 2020; Jensen et al., 2016) authors have reported that price premiums for energy-efficient residential units tended to increase through time, especially for what regard certain EPC classes (e.g. units with higher ratings). This pattern seems particularly interesting and it would be beneficial to explore whether this trend will expand and grow, also in relation to the implementation of new green policies and the possible spread of green awareness. In this framework, to perform consistent studies with a diachronic perspective, the regular retrieving of data would be recommendable. The exploration of the socio-economic and behavioural characteristics of "green-buyers", as well as the monitoring of the evolution of "green value systems" and the detection of possible "green imitative behaviours" would be interesting too. Additionally, an analysis that combines green attributes, transaction prices and possibly buyers' profiles might help better understand in monetary terms to what extent environmental benefits are valued (especially in the case that a clear economic advantage is not associated to retrofit interventions);

6) comparative studies – that observe for instance cities located in different climate zones (Dell'Anna et al., 2019), cities with a similar environmental context (Manganelli et al., 2019), but also different city-areas (Barreca et al., 2021; Taltavull et al., 2017)- have started to emerge, thus extending the research perspectives and the investigation of differences/commonalities between multiple contexts. These types of studies, in addition to enriching the general literature framework, will especially allow to better reflect on the role played by variables such as the geographical and climate zone, the building type, the maintenance level of the housing stock, the socio-economic characteristics of the neighbourhood etc. However, it must be recalled here that housing energy efficiency is calculated and categorised heterogeneously by EU Member States, and a step towards additional comparative studies would be the development of a standardised EPC rating model (Dell'Anna

et al., 2019). Making explicit the regulatory framework in force during the investigated timeframes would be essential for comparative studies analysing cities of different countries: in fact, it is known that the translation of the European Directives into national legislations does not occur simultaneously in all EU Member States. Then, it must be recalled here that, also at the country level, some differences in energy requirements (e.g. at the regional level) may exist; moreover, at the country level climate differences commanding different energy needs exist too (Chiesa and Fregonara, 2019; Fregonara et al., 2020). As a consequence, when performing comparative studies, all these peculiarities should be taken into account;

7) the analysis of listing prices (rather than transaction prices) is still frequent. Even though listing prices can be considered as a good proxy for the value of real estate assets, this suggests that the studies performed so far have probably mainly captured the value of green attributes as perceived by the sellers and/or the real estate intermediaries (supply side). This seems to indicate that, apart from research questions, elements that may greatly influence the investigation of the phenomenon are the nature and availability of data: as a consequence, further studies should try to investigate transaction prices whenever possible and, in order to reach this goal, partnerships with real estate agencies or other actors (in compliance with privacy and local legal regulations) should be encouraged. Other types of studies that have estimated the value attributed to green attributes by potential buyers (demand side) are the ones that have applied contingent evaluation instead;

8) the recent literature confirms that homogeneous effects of EPCs on real estate prices have not been detected yet. In some cases, extreme classes (i.e. A and G) tended to exert the greatest effects on prices (positively and negatively respectively), but in some occurrences a higher positive effect was progressively registered not only for A-rated units but also for units labelled with B, C or D. In other cases, a similar increase of value was registered for every jump from one class to the next. With reference to transaction prices, some authors found that the effects of EPC-ratings were not constant or significant across the entirety of the pricing structure. These results highlight a great variety of patterns, and the specificities behind these phenomena should be deepened, considering a range of different characteristics. At the same time, it must be mentioned that recent studies have also started to explore the role possibly played by single green attributes or by variables related to specific energy-related facilities (e.g. air conditioning, type of heating, etc.), thus enriching the list of intrinsic characteristics (e.g. brightness, floor, elevator, etc.) usually investigated in the real estate literature (Lo Verso et al., 2014);

9) even though the Hedonic Price Model-OLS approach still prevails, the most recent articles tended to employ methods able to answer more specific and refined research questions. For instance, recent studies aimed to explore the spatial dimension (e.g. applying spatial statistics, Geographically Weighted Regression, spatio-temporal autoregressive analysis, etc.) or the relationship between EPCs ratings and specific pricing segments (e.g. employing quantile regressions). The further development of these approaches would allow to better articulate the discourse on EPCs ratings and real estate prices, possibly identifying differentiation patterns in relation to variables such as location, type of buildings, age of con-

struction, presence of certain intrinsic characteristics of the residential unit, pricing distribution, etc. Future studies could also try to hypothesize and test cause-effect relationships between variables;

10) recent studies have identified new variables that may affect the market, such as potential EPC scores (McCord et al., 2020b), i.e. the energy efficiency level that could be obtained after retrofit. This variable appears to be of particular interest especially at this specific time, since EU Governments are providing economic incentives for retrofit, and the potential EPC scores could thus be particularly valued by potential buyers.

Moreover, some authors have underlined the necessity to investigate whether effects on prices are truly exerted by EPCs or rather by the presence of specific attributes/green attributes or even by a combination of EPC and specific technical characteristics (McCord et al., 2020b). Additionally, some authors have highlighted the problem of omitted variables possibly correlated with the energy label (Olaussen et al., 2017). These perspectives of research appear to be particularly promising, and the implementation of methods able to calculate the different effects exerted by a variety of variables and by a combination of variables could enrich the research framework and better address refined research questions.

In light of these considerations, a possible path towards the expansion of the research perspectives outlined above could be represented by the investigation of latent variables possibly affecting real estate prices. More precisely, future studies could follow approaches able to explore the relationships between latent variables, characteristics of the residential units (included EPC ratings) and real estate prices. Among available methods, an approach that seems particularly suitable and worth exploring is Structural Equation Modelling (SEM). SEM is a multivariate statistical approach that allows to study latent (i.e. not directly observable) variables, to estimate direct and indirect effects and to test hypothesized cause-effects relationships between variables. SEM capitalises on techniques such as factor analysis, path analysis and simultaneous regressions (Bollen, 1991; Corbetta, 1992; Ullman and Bentler, 2013; Wang and Wang, 2020). Mainly applied in Econometrics, social sciences and economics, SEM is an approach that has already been employed to study the real estate pricing process so far (Bravi and Fregonara, 1996; Freeman and Zhao, 2019; Liu and Wu, 2009; Manganelli, 2001; Manganelli and Morano, 2001), but the integration of green attributes and energy efficiency among analysed variables has not been systematically explored yet. As a consequence, testing the potentialities of SEM with reference to the topic mentioned above could represent an enrichment to this field of research, both in terms of possible results and methods adopted.

5. Conclusions

The present article has outlined that, despite homogeneous effects of energy efficiency levels on real estate prices have not been detected, some trends in the most recent peer-reviewed literature focusing on European contexts can be iden-

tified. Overall, they mainly regard the refinement of the research questions performed and the research methods consequently adopted, with a special attention towards the analysis of the spatial component and the identification of different effects on various housing segments and pricing distributions.

If studies on the effects of EPCs ratings have been performed since the establishment of the first EPBD, the relevance of the topic has progressively assumed increasing importance, and the statements presented by the European Commission in the document *"A Renovation Wave for Europe- greening our buildings, creating jobs, improving lives"* (European Commission, 2020) induce to advance that in the near future further studies will be needed, especially to monitor the effectiveness of EU and national policies, evaluate concurrent effects (e.g. on real estate values, environmental indicators, etc.) and then take further action.

Even though EPBDs have provided a common framework to the European context so far, Member States have nonetheless implemented energy efficiency guidelines at a different pace and in different ways, making the comparison of results hardly straightforward. The revision of the EPCs and the creation of accessible databases prospected by the *Renovation Wave* will probably facilitate the monitoring of the energy efficiency of European buildings and the provision of useful and usable data instead.

Since the *Renovation Wave* conceives retrofit not only as a set of interventions finalised to reach environmental goals and decarbonisation but also as an economic leverage able to create green jobs, in future studies it will be interesting to analyse whether retrofit will have an economic reflection also on another facet of the exchange economy, namely real estate prices. In this context, an area of research may regard for instance the identification of green premiums and brown discounts associated to specific EPC ratings, building types and their location. Considering location not only in terms of geographic and climatic position but also as an element to which socio-economic variables are ascribed would allow to extend the discourse on a socio-economic level too. In these reflections, considerations should be particularly made on the effects that policies and economic incentives have on the most fragile segments of the population, which seem to have been affected by brown discounts so far.

The evolution and progressive refinement of research questions have led scholars to apply different methods, ranging from the well-established Hedonic Price Model to spatial analyses and different regression approaches. Given that effects on real estate prices might be exerted not only by EPCs as such but also by a combination of EPC and other characteristics, future studies could experiment the application of Structural Equation Modelling, i.e. a statistical approach that allows to estimate direct and indirect effects, as well as to study latent (i.e. not directly observable) variables and cause-effects relationships.

Concerning future research, the perspective is threefold. Firstly, a further review work will be done considering the cyclical variability of prices and the market dynamics which can influence not only the models results but also the selection of the appropriate model itself. Specifically, the availability of significant data samples, in view of the number of transactions, could allow a comparative explo-

ration of the models implied and eventually to increase the number of contributions also from further Member States involved in the academic research. Secondly, speaking about the methodological exploration, a further research work will be done exploring the potentialities of SEM, which emerged – as said before – as a particularly promising procedure. Given its peculiarities, the application of this approach could then also be extended to a macro-level, to investigate possible effects induced by energy-related policies. On the basis of the literature described in previous paragraphs, an "Energetic Quality" latent variable (encompassing comfort, as well as savings and environmental benefits) could be hypothesized. By the means of SEM, future studies could try to investigate this variable through measurable indicators, as well as to detect the effects exerted by identified variables on the real estate pricing process.

Thirdly, it must be considered that the present work has assumed the building scale perspective and, thus, a wider exploration is necessary considering that the issues explored, in many cases, involve the district-territorial scale, and, implicitly, the urban governance and policies which are strictly related to the energy-environmental sustainability.

The urban metabolism has to be adaptive to today's challenges – i.e. environment, climate change, economy –, and possible solutions for the reuse/retrofit of existing structures and infrastructures need to be adaptive to today and future changes too. The design of the solutions will include the urban context, considering private/public spaces in a sustainable perspective, from the neighbourhood scale to the building scale. The balance between architecture and environment will be the core for the definition of design strategies and related technologies, including buildings' green attributes. In this framework, their impact on pricing processes and real estate market dynamics will need to be detected with the appropriate models.

References

Aydin, E., Correa, S. B., & Brounen, D. (2019). Energy performance certification and time on the market. *Journal of Environmental Economics and Management*, 98, 102270. https://doi.org/10.1016/j.jeem.2019.102270

Azizi, S., Nair, G., & Olofsson, T. (2019). Analysing the house-owners' perceptions on benefits and barriers of energy renovation in Swedish single-family houses. *Energy and Buildings*, 198, 187–196. https://doi.org/10.1016/j.enbuild.2019.05.034

Baldini, M., Brøgger, M., Jacobsen, H. K., & Wittchen, K. B. (2020). Cost-effectiveness of energy efficiency improvements for a residential building stock in a Danish district heating area. *Energy Efficiency*, 13(8), 1737–1761. https://doi.org/10.1007/s12053-020-09889-x

Barreca, A., Fregonara, E., & Rolando, D. (2021). EPC Labels and Building Features: Spatial Implications over Housing Prices. *Sustainability*, 13(5), 2838. https://doi.org/10.3390/su13052838

Benefield, J. D., Hefner, F., & Hollans, H. (2019). Green certifications in residential real estate: Discounted cost savings or name recognition? *Journal of Real Estate Literature*, 27(2), 143–158.

Bian, X., & Fabra, N. (2020). Incentives for information provision: Energy efficiency in the Spanish rental market. *Energy Economics*, 90, 1-10. https://doi.org/10.1016/j.eneco.2020.104813

Bisello, A. (2020). Assessing multiple benefits of housing regeneration and smart city development: The European project Sinfonia. *Sustainability (Switzerland)*, 12(19), 1–28. https://doi.org/10.3390/su12198038

Bisello, A., Antoniucci, V., & Marella, G. (2020). Measuring the price premium of energy efficiency: A two-step analysis in the Italian housing market. *Energy and Buildings*, *208*. https://doi.org/10.1016/j.enbuild.2019.109670

Bollen, K. A. (1989). *Structural equations with latent variables*. New York, NY: Wiley.

Booker, Y. (2020). Assessing the impact of the intensifying UK minimum energy efficiency standards (MEES) on regional office rental values. *International Journal of Urban Sciences*, 24(2), 152–172. https://doi.org/10.1080/12265934.2019.1651669

Bottero, M., Bravi, M., Dell'Anna, F. & Mondini, G. (2018). Valuing buildings energy efficiency through hedonic Prices Method: are spatial effects relevant? *Valori e Valutazioni*, 70, 27–39.

Bravi, M. and Fregonara, E. (1996). Structural Equations in Real Estate Appraisal. In *5th Annual International Real Estate Conference*, AREUEA – American Real Estate and Urban Economics Association 23rd-25th May 1996, Orlando, Florida.

Brounen, D., Groh, A. M., & Haran, M. (2020). The value effects of green retrofits. *Journal of European Real Estate Research*, 13(3), 301–319. https://doi.org/10.1108/JERER-12-2019-0049

Brown, D., Sorrell, S., & Kivimaa, P. (2019). Worth the risk? An evaluation of alternative finance mechanisms for residential retrofit. *Energy Policy*, 128, 418–430.

Cajias, M., Fuerst, F., & Bienert, S. (2019). Tearing down the information barrier: The price impacts of energy efficiency ratings for buildings in the German rental market. *Energy Research & Social Science*, 47, 177–191. https://doi.org/10.1016/j.erss.2018.08.014

Cespedes-Lopez, M.-F., Mora-Garcia, R.-T., Perez-Sanchez, V. R., & Perez-Sanchez, J.-C. (2019). Meta-analysis of price premiums in housing with energy performance certificates (EPC). *Sustainability (Switzerland)*, 11(22), 2–59. https://doi.org/10.3390/su11226303

Chegut, A., Eichholtz, P., Holtermans, R., & Palacios, J. (2020). Energy Efficiency Information and Valuation Practices in Rental Housing. *Journal of Real Estate Finance and Economics*, 60(1–2), 181–204. https://doi.org/10.1007/s11146-019-09720-0

Chen, A., & Marmolejo-Duarte, C. (2019). *How different are dwellings whose energy efficiency impacts price formation?* 603(4), 1–10. https://doi.org/10.1088/1757-899X/603/4/042015

Chiesa, G., & Fregonara, E. (2020). Energy and Economic Analyses for Supporting Early Design Stages: Introducing Uncertainty in Simulations. In Littlewood, J., Howlett, R. J., Capozzoli, A. & Jain, L. C. (Eds.), *Sustainability in Energy and Buildings*, Vol. 163. Singapore, Springer, pp. 49-63.

Collins, M., & Curtis, J. (2018). Rental tenants' willingness-to-pay for improved energy efficiency and payback periods for landlords. *Energy Efficiency*, 11(8), 2033–2056.

Corbetta, P. (1992), *Metodi di analisi multivariata per le scienze sociali*. Bologna, Il Mulino.

Cornago, E., & Dressler, L. (2020). Incentives to (not) disclose energy performance information in the housing market. *Resource and Energy Economics*, 61, 1–13. https://doi.org/10.1016/j.reseneeco.2020.101162

Curto, R., & Fregonara, E. (2019). Monitoring and analysis of the real estate market in a social perspective: Results from the Turin's (Italy) Experience. *Sustainability (Switzerland)*, 11(11), 1–22. https://doi.org/10.3390/su11113150.

Curto, R., Fregonara, E. & Semeraro, P. (2012). Asking prices vs Market Prices: An Empirical Analysis. *Territorio Italia*, 12, 53–72.

D'Agostino, D., & Mazzarella, L. (2019). What is a Nearly zero energy building? Overview, implementation and comparison of definitions. *Journal of Building Engineering*, 21, 200–212.

D'Alpaos, C., & Bragolusi, P. (2021). The Market Price Premium for Residential PV Plants. In Bevilacqua, C., Calabrò, F., & Della Spina, L. (Eds.), *New Metropolitan Perspectives. NMP 2020. Smart Innovation, Systems and Technologies*, Vol. 178. Cham, Springer, pp. 1208-1216. https://doi.org/10.1007/978-3-030-48279-4_112

de La Paz, P. T., Perez-Sanchez, V. R., Mora-Garcia, R.-T., & Perez-Sanchez, J.-C. (2019). Green premium evidence from climatic areas: A case in Southern Europe, Alicante (Spain). *Sustainability (Switzerland)*, 11(3), 1–29. https://doi.org/10.3390/su11030686

De Paola P., Del Giudice V., Massimo D.E., Del Giudice F.P., Musolino M. & Malerba A. (2021) Green Building Market Premium: Detection Through Spatial Analysis of Real Estate Values.

A Case Study. In Bevilacqua C., Calabrò F., Della Spina L. (Eds.) *New Metropolitan Perspectives. NMP 2020. Smart Innovation, Systems and Technologies*, Vol. 178. Cham, Springer, pp. 1413-1422.

Del Giudice V., Massimo D.E., De Paola P., Del Giudice F.P. & Musolino M. (2021a) Green buildings for post carbon city: Determining market premium using spline smoothing semiparametric method. In Bevilacqua C., Calabrò F., & Della Spina L. (Eds.) *New Metropolitan Perspectives. NMP 2020. Smart Innovation, Systems and Technologies*, Vol. 178. Cham, Springer, pp. 1227-1236.

Del Giudice V., Massimo D.E., Salvo F., De Paola P., De Ruggiero M. & Musolino M. (2021b) Market Price Premium for Green Buildings: A Review of Empirical Evidence. Case Study. In Bevilacqua C., Calabrò F., & Della Spina L. (Eds.) *New Metropolitan Perspectives. NMP 2020. Smart Innovation, Systems and Technologies*, Vol. 178. Cham, Springer, pp. 1237-1247.

Dell'Anna, F., & Bottero, M. (2021). Green premium in buildings: Evidence from the real estate market of Singapore. *Journal of Cleaner Production*, 286, 1–14. https://doi.org/10.1016/j.jclepro.2020.125327

Dell'Anna, F., Bravi, M., Marmolejo-Duarte, C., Bottero, M. C., & Chen, A. (2019). EPC green premium in two different European climate zones: A comparative study between Barcelona and Turin. *Sustainability (Switzerland)*, 11(20), 1–21. https://doi.org/10.3390/su11205605

European Commission (2021a). A European Green Deal. Striving to be the first climate-neutral continent. Retrieved from: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en. Last accessed 22nd June 2021.

European Commission (2021b). Preliminary analysis of the long-term renovation strategies of 13 Member States. Retrieved from: https://ec.europa.eu/energy/sites/default/files/swd_commission_preliminary_analysis_of_member_state_ltrss.pdf. Last accessed 22nd June 2021.

European Commission (2020). *A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives.* Communication from the European Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels, 14th October 2020. Retrieved from: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1603122220757&uri=CELEX:52020DC0662. Last accessed 5th March 2021.

European Commission. Joint Research Centre. (2018). *Energy efficiency, the value of buildings and the payment default risk.* Publications Office. https://data.europa.eu/doi/10.2760/267367

Evangelista, R., Ramalho, E. A., & Andrade e Silva, J. (2020). On the use of hedonic regression models to measure the effect of energy efficiency on residential property transaction prices: Evidence for Portugal and selected data issues. *Energy Economics*, 86, 1–14. https://doi.org/10.1016/j.eneco.2020.104699

Franke, M., & Nadler, C. (2019). Energy efficiency in the German residential housing market: Its influence on tenants and owners. *Energy Policy*, 128, 879–890.

Freeman, J. and Zhao, X. (2019). An SEM Approach to Modeling Housing Values. In C. H. Skiadas and J.R. Bozeman (Eds.), *Data Analysis and Applications 1: Clustering and Regression, Modeling-estimating, Forecasting and Data Mining*, 2, pp.125-135.

Fregonara, E., Ferrando, D. G., & Chiesa, G. (2021). Economic Valuation of Buildings Sustainability with Uncertainty in Costs and in Different Climate Conditions. In Bevilacqua, C., Calabrò, F. & Della Spina, L. (Eds.), *New Metropolitan Perspectives. NMP 2020. Smart Innovation, Systems and Technologies*, Vol. 178. Cham, Springer, pp. 1217–1226. https://doi.org/10.1007/978-3-030-48279-4_113

Fregonara, E., Rolando, D., & Semeraro, P. (2017). Energy performance certificates in the Turin real estate market. *Journal of European Real Estate Research*, 10(2), 149–169. https://doi.org/10.1108/JERER-05-2016-0022

Fregonara, E., Rolando, D., Semeraro, P., & Vella, M. (2014). The impact of Energy Performance Certificate level on house listing prices. First evidence from Italian real estate. *Aestimum*, 65, 143-163. https://doi.org/10.13128/AESTIMUM-15459

Fuerst, F., McAllister, P., Nanda, A., & Wyatt, P. (2016a). Energy performance ratings and house prices in Wales: An empirical study. *Energy Policy*, 92, 20–33.

Fuerst, F., Oikarinen, E., & Harjunen, O. (2016b). Green signalling effects in the market for energy-efficient residential buildings. *Applied Energy*, 180, 560–571.

Fuerst, F., Haddad, M. F. C., & Adan, H. (2020). Is there an economic case for energy-efficient dwellings in the UK private rental market? *Journal of Cleaner Production*, 245, 1–34. https://doi.org/10.1016/j.jclepro.2019.118642

Goldberger, A.S. (1972). Structural equation methods in the social sciences. *Econometrica*, 40, 979–100.

Heffernan, T. W., Daly, M., Heffernan, E. E., & Reynolds, N. (2021). The carrot and the stick: Policy pathways to an environmentally sustainable rental housing sector. *Energy Policy*, 148, 1–14. https://doi.org/10.1016/j.enpol.2020.111939

Heffernan, T. W., Heffernan, E. E., Reynolds, N., Lee, W. J., & Cooper, P. (2020). Towards an environmentally sustainable rental housing sector. *Housing Studies*, 36(3), 397-420. https://doi.org/10.1080/02673037.2019.1709626

Horowitz, J.L. (1992). The role of the list price in housing markets: Theory and an econometric model. *Journal of Applied Economics,* 7, 115–129.

Jensen, O. M., Hansen, A. R., & Kragh, J. (2016). Market response to the public display of energy performance rating at property sales. *Energy Policy*, 93, 229–235.

Kamal, A., Al-Ghamdi, S. G., & Koc, M. (2019). Revaluing the costs and benefits of energy efficiency: A systematic review. *Energy Research and Social Science*, 54, 68–84.

Kerr, N., Gouldson, A., & Barrett, J. (2017). The rationale for energy efficiency policy: Assessing the recognition of the multiple benefits of energy efficiency retrofit policy. *Energy Policy*, 106, 212–221.

Khazal, A., & Sønstebø, O. J. (2020). Valuation of energy performance certificates in the rental market – Professionals vs. Nonprofessionals. *Energy Policy*, 147, 1–11. https://doi.org/10.1016/j.enpol.2020.111830

Knight, J.R. (2002). Listing price, time on market, and ultimate selling price: Causes and effects of listing price changes. *Real Estate Economics*, 30, 213–237.

Liu, Y., & Wu, Y. X. (2009). Analysis of residential product's value based on structural equation model and hedonic price theory. In *2009 International Conference on Management Science and Engineering*, pp. 1950-1956, IEEE.

Lo Verso, V. R. M., Fregonara, E., Caffaro, F., Morisano, C. & Peiretti, G. M., (2014). Daylighting as the Driving Force of the Design Process: from the Results of a Survey to the Implementation into an Advanced Daylighting Project. *Journal of Daylighting*, 1, 36-55.

Malpezzi, S. (2003). Hedonic pricing models: a selective and applied review. In O'Sullivan, Tony, Gibb, Kenneth (Eds.), *Housing Economics and Public Policy: Essays in honour of Duncan Maclennan*, 2003. Blackwell.

Manganelli, B. (2001). Un sistema di equazioni strutturali per la stima di masse di immobili. *Genio Rurale Estimo e Territorio*, 2, 54-64.

Manganelli, B. & Morano, N. (2001). Comparative performance of structural equations system and neural networks for real estate appraisal. In *Preceeding of the 7th SIGEF Congress, New Logics For the New Economy*. Roma, Edizioni Scientifiche Italiane.

Manganelli, B., Morano, P., Tajani, F., & Salvo, F. (2019). Affordability assessment of energy-efficient building construction in Italy. *Sustainability*, 11(1), 1–17. doi:10.3390/su11010249

Marmolejo-Duarte, C. (2016). La incidencia de la calificación energética sobre los valores residenciales: Un análisis para el mercado plurifamiliar en Barcelona. *Informes de La Construcción*, 68(543), 156.

Marmolejo-Duarte, C., García-Hooghuis, A., & Masià, A. G. (2020). How much and why are we willing to pay for energy-efficient homes? A stated preferences analysis in Barcelona. *Architecture, City and Environment*, 14(42), 1–16. https://doi.org/10.5821/ace.14.42.9215

Marmolejo-Duarte, Carlos, & Chen, A. (2019). The Uneven Price Impact of Energy Efficiency Ratings on Housing Segments and Implications for Public Policy and Private Markets. *Sustainability*, 11(2), 372. https://doi.org/10.3390/su11020372

Marmolejo-Duarte, Carlos, Chen, A., & Bravi, M. (2020). Spatial Implications of EPC Rankings Over Residential Prices. In Mondini, G., Oppio, A., Stanghellini, S., Bottero, M. & Abastante, F. (Eds.), *Values and Functions for Future Cities. Green Energy and Technology*. Cham, Springer, pp. 51–71. https://doi.org/10.1007/978-3-030-23786-8_4

McCord, M., Davis, P., McCord, J., Haran, M., & Davison, K. (2020a). An exploratory investigation into the relationship between energy performance certificates and sales price: A polytomous universal model approach. *Journal of Financial Management of Property and Construction*, 25(2), 247–271. https://doi.org/10.1108/JFMPC-08-2019-0068

McCord, M., Haran, M., Davis, P., & McCord, J. (2020b). Energy performance certificates and house prices: A quantile regression approach. *Journal of European Real Estate Research*, 13(3), 409–434. https://doi.org/10.1108/JERER-06-2020-0033

McCord, M., Lo, D., Davis, P. T., Hemphill, L., McCord, J., & Haran, M. (2020). A spatial analysis of EPCs in The Belfast Metropolitan Area housing market. *Journal of Property Research*, 37(1), 25–61.

Morano, P., Rosato, P., Tajani, F., & Di Liddo, F. (2020). An Analysis of the Energy Efficiency Impacts on the Residential Property Prices in the City of Bari (Italy). In Mondini, G., Oppio, A., Stanghellini, S., Bottero, M. & Abastante, F. (Eds.), *Values and Functions for Future Cities. Green Energy and Technology*. Cham, Springer, pp. 73–88.

Olaussen, J. O., Oust, A., & Solstad, J. T. (2017). Energy performance certificates – Informing the informed or the indifferent? *Energy Policy*, 111, 246–254.

Pommeranz, C., & Steininger, B. I. (2021). What Drives the Premium for Energy-Efficient Apartments – Green Awareness or Purchasing Power? *Journal of Real Estate Finance and Economics*, 62, 220-241.

Reynolds, J., Rezgui, Y., & Hippolyte, J. L. (2017). Upscaling energy control from building to districts: Current limitations and future perspectives. *Sustainable Cities and Society*, 35, 816-829.

Stanley, S., Lyons, R. C., & Lyons, S. (2016). The price effect of building energy ratings in the Dublin residential market. *Energy Efficiency*, 9(4), 875–885.

Taltavull, P., Anghel, I., & Ciora, C. (2017). Impact of energy performance on transaction prices: Evidence from the apartment market in Bucharest. *Journal of European Real Estate Research*, 10(1), 57–72.

Taltavull de La Paz, P., Perez-Sanchez, V., Mora-Garcia, R.-T., & Perez-Sanchez, J.-C. (2019). Green Premium Evidence from Climatic Areas: A Case in Southern Europe, Alicante (Spain). *Sustainability*, 11(3), 686.

Thomé, A. M. T., Scavarda, L. F., & Scavarda, A. J. (2016). Conducting systematic literature review in operations management. *Production Planning & Control*, 27(5), 408–420.

Ullman, J. B. & Bentler, P. M (2013). Structural Equation Modeling. In Weiner, I. B. (Ed.), *Handbook of Psychology*, 2nd Edition, Wiley, pp. 661-690.

United Nations General Assembly (2015). *The 2030 Agenda for Sustainable Development.* https://sdgs.un.org/2030agenda. Last accessed 25th February 2021.

Wahlström, M. H. (2016). Doing good but not that well? A dilemma for energy conserving homeowners. *Energy Economics*, 60, 197–205.

Wang, J., and Wang, X. (2020). *Structural equation modeling: Applications using Mplus* (Second edition). Wiley.

Wilhelmsson, M. (2019). Energy performance certificates and its capitalization in housing values in Sweden. *Sustainability (Switzerland)*, 11(21). https://doi.org/10.3390/su11216101

Wilkinson, S. J., & Sayce, S. (2020). Decarbonising real estate: The evolving relationship between energy efficiency and housing in Europe. *Journal of European Real Estate Research*, 13(3), 387–408.

Zancanella, P., Bertoldi, P., Boza-Kiss, B., (2018). Energy efficiency, the value of buildings and the payment default risk, EUR 29471 EN, Luxembourg, Publications Office of the European Union.

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Assessing the perception of urban visual quality: an approach integrating big data and geostatistical techniques

Human well-being is affected by the design quality of the city in which they live and walk. This depends primarily on specific physical characteristics and how they are aggregated together. Many studies have highlighted the great potential of photographic data shared on the Flickr platform for analyzing environmental perceptions in landscape and urban planning. Other researchers have used panoramic images from the Google Street View (GSV) web service to extract data on urban quality. However, at the urban level, there are no studies correlating quality perceptions detected by social media platforms with spatial geographic characteristics through geostatistical models. This work proposes the analysis of urban quality in different areas of the Livorno city through a methodological approach based on Geographical Random Forest regression. The result offers important insights into the physical characteristics of a street environment that contribute to the more abstract qualities of urban design.

1. Introduction

It is well known that people live well in environments that they recognize and perceive as pleasant, comfortable, and safe. Human well-being is influenced by the physical characteristics of the surrounding urban space and how they aggregate with each other (Alexander et al., 1977; Lynch, 1960). European cities are generally built in different periods with distinctive architectural styles. The visual quality of the urban space for each era and for each zone of the city is influenced by different variables. In the various zones of the city, the visual quality of urban spaces can be explained by geographical and morphological macro-elements, such as coastlines, waterways or hills. These characteristics influence the visual quality of urban spaces in limited areas and not of the whole urbanized area.

According to Radovic (2003) the physical structure of the city implies "a complex set of built elements, space and environment, units and assemblages, which united and connected in an integrated urban system, create the atmosphere and environment for the complex processing of urban life". Therefore, visual percep-

tion, understood as the subjective presentation of objective reality, has always been a complex and highly sensitive issue in the architectural and urban design process. Resources and visual effects play a dominant role in the identification of cultural, socio-economic, identity and communal values of the built environment, as the value and meaning of the built space is manifested predominantly through the subjective view of that space (Perovic & Folic, 2012).

Many studies have focused on researching visual perception using photographic data shared on social platforms (Alampi Sottini et al., 2018; Dunkel, 2015; Quercia et al., 2014; Zhou et al., 2015), others have used indicators to obtain information on urban visual quality using panoramic images from the Google Street View (GSW) web service (Yin and Wang, 2016), but, at the urban level, there are no studies that correlate perceptions of visual quality detected by social media platforms with spatial geographic characteristics through geostatistical models.

Therefore, this paper proposes a geostatistical approach using Geographical Random Forest regression on the Tuscan city of Livorno. this has been analysed city because allows us to assess the visual quality of urban space in very diverse geographical areas. In fact, despite its relatively small size, the city of Livorno consists of a rather heterogeneous mosaic of neighbourhoods with peculiar characteristics due to different construction periods. For this reason, it is an appropriate study area to test a first version of the model to assess the visual quality of urban spaces.

The proposed methodological approach consists of 3 macro-phases: the first one aims at obtaining the indices that compose the urban visual quality perceived by users using photos shared on Flickr; the second one involves calculating the indicators that constitute the urban visual quality using data from both Google Street View, LiDAR data and geographic data; the last one consists in applying two geostatistical models a global random forest and a geographic random forest to differentiate the results for each neighbourhood of the city.

The objective of the study is to test the proposed methodological approach by understanding its strengths and weaknesses and to understand what methodological aspects are needed for the spatial component in the regression models used. The final goal is to provide useful information not only to researchers but also to public and private sectors to develop projects, standards and guidelines to improve the visual quality of urban design in cities.

2. Literature review

Many scholars over time have focused on understanding what visual elements citizens positively perceive as they walk and experience their cities, in order to obtain the indices that make up an image of spaces in which there was a constant observer-environment relationship (Lynch, 1960). The visual perception of architecture and urban planning of cities throughout history has been studied by multiple theorists (Arnheim, 1977; Cullen, 1959; Ittelson, 1960; Lynch, 1960; Rossi, 1966; Spreiregen, 1965; Stea, 1978; Winters, 1999), who not only indicated the im-

portance of the human-environment relationship, but also the importance of creating images in the memory of the users themselves.

According to Ewing and Handy (2009; 2006), the visual quality of an urban design depends on physical characteristics such as the sidewalk width, street width, traffic volume, tree canopy, building height, and number of people. Gavrilidis et al. (2016) selected six urban landscape components for visual assessments and used a five-level Likert scale to visually evaluate each of the six landscape components. Talavera-Garcia and Soria-Lara (2015) developed an alternative walking index called the quality of pedestrian level of service (Q-PLOS), based on the visual quality of urban design for pedestrians, and its relationship with walking needs. However, one major limitation with developing such urban design indicators is that they require unfeasible or inefficient large-scale field observations in terms of time and cost. Recently, Yin and Wang (2016) explored the potential of big data and big data analytics with respect to the current approaches to measuring streetscape features. By applying machine learning algorithms on Google street view (GSV) imagery, the authors objectively generated three measures for visual enclosures.

However, there remains a methodological limit in the literature in regard to identifying an efficient model for relating the perception of well-being deriving from the visual quality of urban space to its physical and architectural characteristics (as measured with the above-mentioned dimensions and indicators).

Lately, with the evolution of Internet, several approaches have been developed for using the so-called big data (Jin et al., 2010) made available by the "social media" platforms.

The correlation between perceived urban landscape quality and the density of photo data shared on the Flickr platform has been demonstrated by numerous studies. Dunkel (2015) highlighted the usefulness of information associated with photos shared on for analyzing environmental perceptions in landscape and urban planning. Zhou et al. (2015) automated the detection of places of interest in multiple cities based on the spatial and temporal characteristics of Flickr images.

Some authors used questionnaires as a complementary survey to the density of data shared on Flickr. Quercia et al. (2014) correlated the emotions stated by the questionnaires with the emotional perception of some paths in London. Similarly, Alampi Sottini et al. (2018) in a research in Livorno used a questionnaire administered via virtual reality headset based on differential semantics techniques and found a correlation between perceived emotion and snapshot point density of shared photographs. Recent studies have used panoramic images taken from Google Street View (GSV) web service to extract urban quality data. In a pioneering work, Naik et al. (2014) correlated the safety perception in the city with indices deriving from Gabor-like filters calculated on a sample of over 1 million Google Streetview. Doersch et al. (2012) used linear Support-Vector Machines to automatically extract representative architectural elements from Google Street View images in Paris and Prague. Steinmetz et al. (2019) used GSV to detect 40, mainly binary, micro-scale features, which influence the walkability of a city, and used them to create a tool to measure the visual quality of urban space. Zhou et

al. (2019) combined street view data with deep learning technologies and mapped residents' perception of walkability in Shen Zhen, China.

Geographic information shared on the internet by different sources (social media platforms, geographic internet services such as google street view, etc.) is an important resource for studying the city's characteristics, which explain the visual perception of urban quality. However, the plethora of existing studies leaves some important gaps. First of all, at the urban level, there are no studies that correlate the visual perception of quality detected by social media platforms with the geographical spatial characteristics through geostatistical models. These studies, widespread in natural and rural environments (for a review see Oteros-Rozas, 2018), are difficult to carry out in cities as a single model cannot explain the importance of the features that define the quality of spaces throughout the urban surface.

While in natural and rural contexts, the statistical model Random Forest (RF) has been used in multiple researches due to its excellent performance (Genuer et al., 2008; Gromping, 2009; Probst et al., 2019; Strobl et al., 2008), in the urban context there are very few studies that manage to apply it, because a single model cannot explain the importance of the characteristics that define the quality of spaces throughout the urban area.

The most interesting application has been adopted in the field of geography with Geographic Weighted Regression (GWR), which is an adaptation of linear regression to be more suitable for spatial data (Fotheringham et al., 2003),

and later with Geographic Random Forest (GRF), applying the same principle to RF (Georganos et al., 2019). GRF is a relatively recent concept used in the environmental field, but it has great potential as it allows selecting the most meaningful indicators for different areas of the city.

For these reasons, we proposed a methodological approach that combines two versions of the random forest (RF) model: traditional for predictive purposes and geographical for exploration purposes.

## 3. Materials and methods

3.1 Study area

Livorno is a town in the region of Tuscany, in the central Italy. Until the second half of the sixteenth century Livorno was only a small village around a cove. In the 16th century the Medici family contributed in a decisive way to the development of Livorno and its port system with the intention of making it the main seaport of Tuscany. Bernardo Buontalenti was therefore commissioned to design a new fortified city around the original nucleus of Livorno, with an imposing system of moats and bastions that gave the city a pentagonal shape (Figure 1 number 1). A following expansion took place at the beginning of the XVII century with the realization of a new quarter called Venezia Nuova, because of the presence of many canals (Figure 1 number 2). The growth of the city outside the pentagonal walls began in 1700, with the duke Pietro Leopoldo (Figure 1 number 3). In the

nineteenth century Livorno became a destination for seaside tourism and an elegant waterfront was created that transformed the ancient villages of Ardenza and Antignano into neighbourhoods (Figure 1 number 4). In the Fascist period Livorno became a city and an industrial port and this made necessary the construction of new residential quarters for workers called Sorgenti and Corea (Figure 1 number 5). In the middle of 1900 there was the last consistent urban expansion of the city with the creation of modern suburbs (Figure 1 number 6).

We believe that Livorno is an appropriate study area for our methodology for the following reasons.

1) It is relatively small and this has allowed us to reduce computer processing time in the application of Deep Learning based models.

Figure 1. Study area.
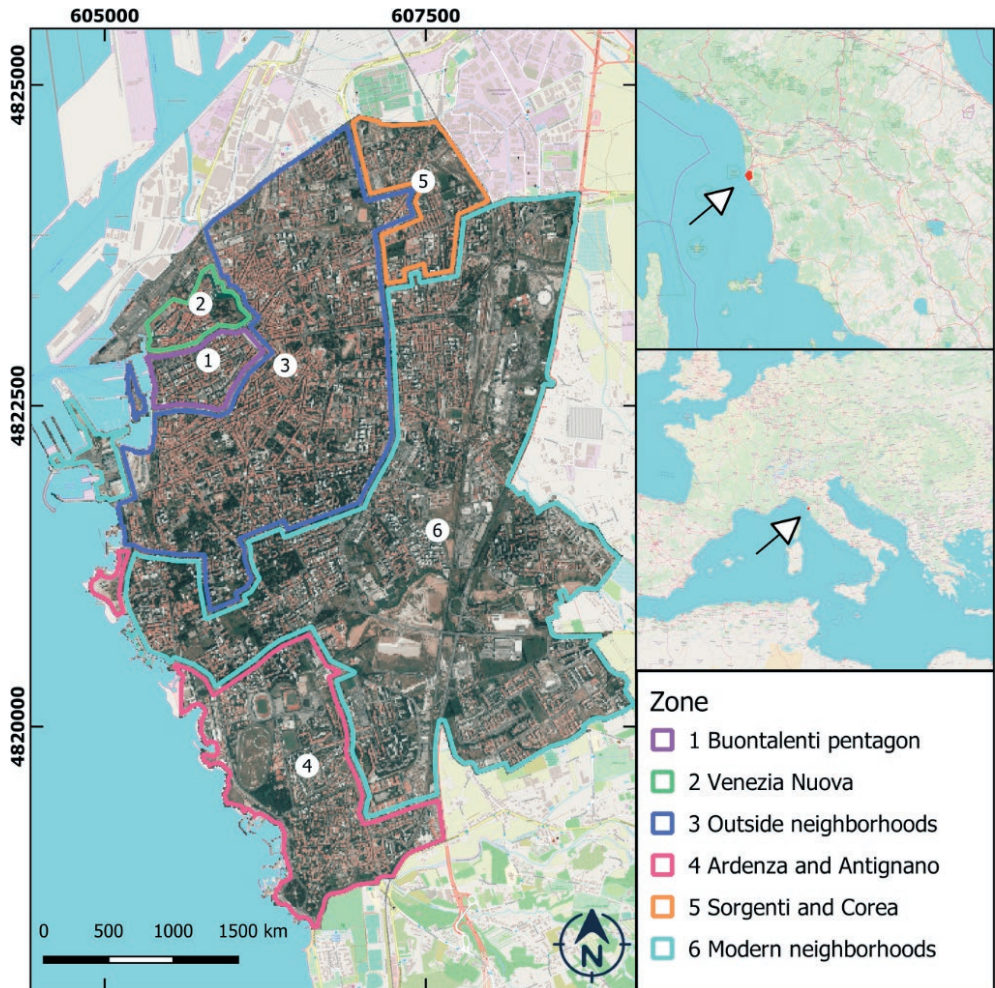
2) It presents a heterogeneous mosaic of neighbourhoods built in different eras, thus with peculiar characteristics.
3) Presents macro-spatial characteristics that are found in many other cities, such as waterfront. The perimeter of the study area only includes the urbanized territory of the municipality, as the topic of this study focuses on urban quality. Thus, industrial areas to the north of the city have been excluded, as well as some neighbouring areas that are too far from the city center, and those bordering rural areas.

3.2 Methods

The proposed methodology is synthetically divided into the following four macro phases. Each of them is characterized by specific micro phases detailed in subsequent sections.
1. Assessment of the perception of urban visual quality: the visual quality of urban spaces was obtained by calculating of the density map of the photo shooting points shared on Flickr (variable depending on the geostatistical model).
2. Calculation of the urban visual quality indicators: using different methodologies to obtain indices that built urban visual quality (dependent variables of the geostatistical model).
3. Geostatistical model estimation: a global Random Forest (RF) model for predictive purposes and a local Geographic Random Forest (GRF) model for exploration purposes, to understand which are the most significant indices of urban visual quality for the whole city and which are the most important dimensions that characterize the visual perception of the different urban neighbourhoods. Figure 2 shows a flowchart of the work.

3.2.1 Assessment of the perception of urban visual quality

Previous research showed that the information contained in the social platform of Flickr can be used to assess the perceived quality of urban spaces. The download of the geographical coordinates of the photo shotting points shared on Flickr is characterized by the following steps.
1) Download through an R language program based on Flickr API the metadata of the shooting points of photos shared from 2005 to 2018. The downloaded data were: photo code, owner code, geographic coordinates, date, time, title, TAG description, geo_context parameter.
2) Selection of photos taken outdoors by setting the "geo_context parameter" in the API to "outdoors".
3) Unification of all photos taken by the same user on the same date and with the exact coordinates.
4) Selection of images not related to urban quality by filtering tags with specific keywords.
5) Selection of photos taken with daylight, using the Flickr API to know the date

Figure 2. Flowchart of the work.
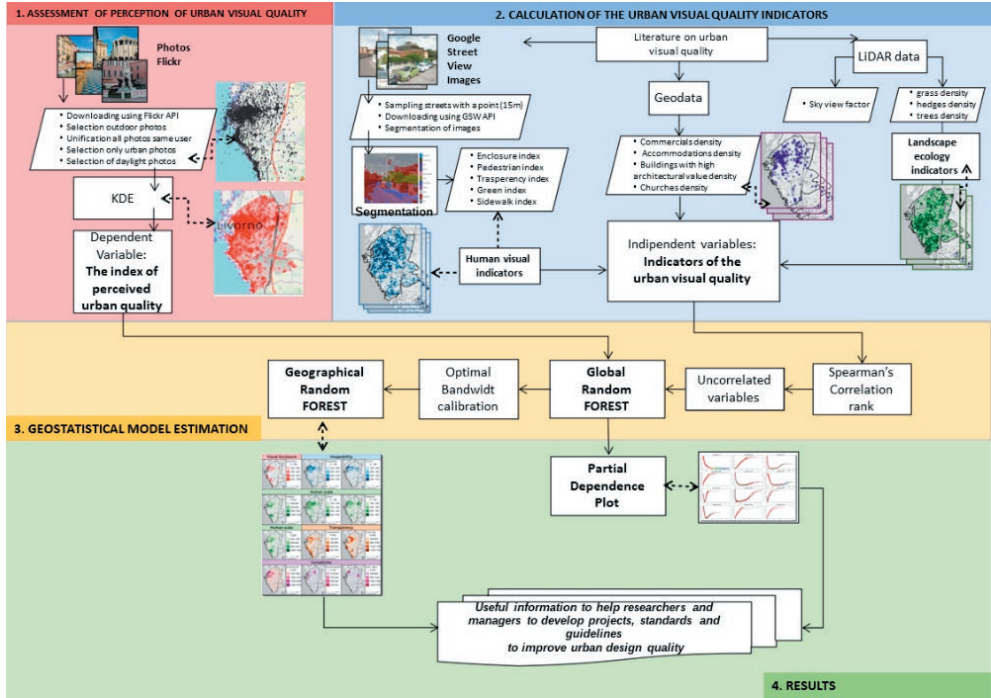
and time of the shot. The time of sunset was calculated using the R {suncalc} library.

The final geo-database of points was transformed into a density surface, using a kernel density estimation analysis (KDE) (Chen and Shaw, 2016).

To calculate the probability that a photo could be taken in a given location, we performed a kernel density analysis for the data, using the geographical locations of the photos. The kernel density was used to estimate the intensity of the points, by creating a smooth surface using a bivariate probability density function. The kernel estimator is defined as:

$$f(x) = \frac{1}{nh} \sum_{i=1}^{n} K \frac{x - x^i}{h} \tag{1}$$

Here, n is the total number of points, h is the bandwidth that determines the amount of smoothing, K is the kernel function, x is the location of the estimation, and xi is a known point location.

The kernel function K can have different forms. The triangular function we used in the analysis is given below:

$$K = \begin{cases} \frac{b - |x - x^i|}{b^2} & x \epsilon [x^i - b, x^i + b] \\ 0 & otherwise \end{cases} \tag{2}$$

The case under study used a triangular Kernel with a bandwidth b = 50 m. The kernel was then overlapped with a 100-meter side hexagonal grid, chosen because of its topological and geometric properties (Feick and Robertson, 2015; Patil, et al., 2000). The size of the grid was identified by applying the Abstract Method (Stamps III, 2001) according to the number of blocks in the study area.

$$r = \sqrt{\frac{S}{0.866 \cdot NB}} \tag{3}$$

where r is the radius of the grid, S is the total area of the area, NB is the number of blocks.

3.2.2 Calculation of the urban visual quality indicators

In the vast amount of literature on urban design quality and structural properties, we referred to the classification of the indicators proposed by Ewing and Handy (2009). According to their study, visual quality indicators were divided into the following five conceptual categories.

(a) Visual enclosure. Outdoor spaces are defined and shaped by vertical elements, which interrupt viewers' lines of sight. Christopher Alexander et al. (1977, p. 106) stated that «an outdoor space is positive when it has a distinct and definite shape, as definite as the shape of a room, and when its shape is as important as the shapes of the buildings which surround it». According to this definition, visual enclosure indicators are: sky view factor and enclosure index.

(b) Imageability. Kevin Lynch (1960, p. 9) defines imageability as the quality of a physical environment that evokes a strong image in an observer: "it is that shape, color, or arrangement which facilitates the making of vividly identified, powerfully structured, highly useful mental images of the environment".

(c) Human scale. Following Ewing and Handy (2009, p. 77), «Human scale refers to a size, texture, and articulation of physical elements that match the size and proportions of humans and, equally important, correspond to the speed at which humans walk. Building details, pavement texture, street trees, and street furniture are all physical elements contributing to human scale».

(d) Transparency. "Transparency refers to the degree to which people can see or perceive what lies beyond the edge of a street and, more specifically, the degree to which people can see or perceive human activity beyond the edge of a street." (id., p. 78).

(e) Complexity. "Complexity results from varying building shapes, sizes, materials, colours, architecture and ornamentation" (id., p. 79) but also "The presence and activity of people add greatly to the complexity of a scene" (id., p. 80).

According to the above and also using additional indicator classifications found in the bibliography (Ewing et al. 2006; Gavrilidis et al. 2016; Talavera-Garcia and Soria-Lara, 2015; Yin and Wang, 2016), we selected the following quality indicators in our study (Bernetti et al., 2020):

(a) Visual enclosure: sky view factor; enclosure index.
(b) Imageability: pedestrian index; distance from churches; pavement index.
(c) Human scale: grass density, hedges density, trees density, green index, side-walk index.
(d) Transparency: transparency index, distance from coast-line.
(e) Complexity: distance from commercials; distance from accommodation land use; distance from buildings with high architectural value.

Most of these indicators selected are based on data available on the Internet. The remaining were based on geodatabases made available by public administrations. The methodologies used to calculate our indicators are the following:

– Deep learning segmentation was applied to the enclosure index, pedestrian index, cyclist index, road crowdedness index, building crowdedness index, and transparency index.
– Landscape ecology indicators for the grass density, hedges density and trees density.
– Kernel Density Estimation for urban points of interest (POIs) defined as commercials, accommodations, buildings with high architectural value, and churches.
– Sky View Factor was applied to LIDAR data.
– GIS application for coastline distance.

3.2.2.1 Human Visual Indicators

To efficiently detect the streetscape of the city of Livorno through images taken from the GSV platform, we sampled all the streets of Livorno with a point every 15 meters. Adopting a 60° field of view (FOV) (similar to human, Yin and Wang, 2016) to cover a 360° panoramic view of the surrounding environment, we downloaded 6 images with azimuth = 0, 60, 120, 180, 240 and 300 for each sampled point. Sampling was carried out using procedures based on GRASS and R.

A segmentation procedure was applied to the images obtained. Segmentation of an image in digital image processing is the process of partitioning an image into meaningful regions. It is used to obtain a more compact representation, to extract objects or as a tool for image analysis and allows you to partition digital images into sets of pixels. To segment the GSV images we employed a pre-trained network of MATLAB software based on the Deeplabv3 + network trained using a collection of images containing street level views obtained while driving (Brostow et al. 2009). To facilitate training, CamVid's 32 original classes have been grouped into 11 classes as follows: "Sky", "Building", "Pole", "Road", "Sidewalk", "Tree", "Symbol Sign", "Fence", "Car", "Pedestrian" and "Cyclist".

Based on the theories and recent literature mentioned above, we proposed a method to evaluate four indicators related to the visual quality of urban design, and to calculate the indices for each GSV photo. The indices calculated were as follows (Bernetti et al., 2020).

1. Enclosure index (Encl), defined as the degree to which streets and other public spaces are visually defined by buildings, walls, trees, and other elements.

Usually, people positively perceive an urban space when they are able to recognize a distinct shape defined by vertical elements that interrupt their view (Alexander et al., 1977). It was calculated using the following equation:

$$Encl = \frac{\sum_1^6 Bn + \sum_1^6 Tr + \sum_1^6 Pol}{\sum_1^6 Rd + \sum_1^6 Pv} \tag{4}$$

where *Bn* is the number of building pixels; *Tn* is the number of tree pixels; Rd is the number of road pixels; *Pv* number of pavement pixels, and *Polis* is the number of road signs pixels.

2. Pedestrian and cyclist, index (Ped), defined as the degree to which people can see or perceive human activity: The perception of other people makes the environment more comfortable and safe.

$$Ped = \frac{\sum_1^6 Bc + \sum_1^6 Pd}{\sum_1^6 Car} \tag{5}$$

where *Bc* is the number of bicyclist pixels; *Pd* is the number of pedestrian pixels; and *Car* is the number of car pixels.

3. Transparency index (Trp), defined as the degree to which people can see what lies beyond the edge of a street or other public space. The wide view ensures that people can observe objects that are far away, allowing observers not only to recognize the world around them but also to feel safer moving around in the environment.

$$Trp = \frac{\sum_1^6 Sky}{\sum_1^6 TotPix} \tag{6}$$

Where *Sky* is the number of sky pixels and *TotPix* is the total pixel number in the image.

4. Green index (Green), defined as the extent to which the visibility of street vegetation can influence pedestrian psychological feelings. The therapeutic effects of natural environments is well-known and extensively reported in the literature. Several cities have been equipped with healing gardens and green roads for restoration from stress (Pouya et al., 2015).

$$Green = \frac{\sum_1^6 Veg}{\sum_1^6 TotPix} \tag{7}$$

where*Veg* number of vegetation pixels.

5. Sidewalk index (Sidewalk), defined as the extent to which the visibility of pavement and fences influences pedestrian psychological feelings:

$$Sidewalk = \frac{\sum_1^6 Pav + \sum_1^6 Fenc}{\sum_1^6 Road} \tag{8}$$

where *Pav* is the number of pavement pixels and *Fenc* is the number of fences pixels.

3.2.2.2 Landscape ecology indicators

The indicators used in our analysis were the percent density of grassland, hedgerows, urban forest in each hexagon of the grid. The indicators were calculated using multispectral and lidar remote sensing data according to the methodology defined by Barbierato et al. (2019).

Urban vegetation cover was identified through normalized difference vegetation index (NDVI) analysis, taking into account only healthy vegetation extracted based on NDVI values greater than or equal to 0.2 (Rodgers III et al., 2009).

The result was presented as a Boolean map with a resolution of 1 m (similar to LiDAR data), in which the value of 0 indicated the absence of vegetation, and a value of 1 indicated its presence. The results were spatialized on the hexagonal grid. As urban green areas are characterized by various types of vegetation with different ecologic and perceptive functions, we distinguished these types according to their height values.

To obtain the height of the vegetation, we made an overlay operation between the NDVI binary map and a normalized digital surface model generated from LIDAR data. The result of this operation was a raster map divided into three height classes. The first class (from 0 to 0.40 m) represented grass, the second (from 0.40 to 3 m) was classified as hedges, and the third (greater than 3 m) was classified as trees.

The indicators we used were the percentages of green landscapes of class i (P_i) with i = {grass, hedges, trees}. The former allowed us to understand the percentage of plant cover of each grid hexagon. The operation is as follows:

$$P_i = \frac{\sum NDVI_{j,i}}{H} \qquad (9)$$

In the above, $NDVI_{j,i}$ is the j-th pixel in the NDVI raster map classified on class i, and H is the total hexagon area.

3.2.2.3 Kernel density estimation (KDE) of the urban points of interest (POIs)

We have identified commercial, housing, churches and buildings of high architectural value as urban Points of Interest (POI). The location of the POIs was taken from the OpenStreetMap (OSM) database.

We calculated the territorial density of the POIs using a KDE procedure. KDE has been widely used in POI data analysis (Li et al. 2013). Lian et al. (2014) demonstrated that through KDE, it is possible to identify areas of influence of POIs, as related to areas of activity of the users. The POIs derived from OSM were implemented in density maps by applying a triangular KDE with a bandwidth of 500 m. The results were spatialized on the hexagonal sampling grid.

In according to Chan et al. (2021), the equation is the following:

$$K(q, p_i) = \max(1 - \frac{1}{b} * dist(q, p_i), 0) \qquad (10)$$

where b and $dist(q,p_i)$ denote the bandwidth of the triangular kernel function and Euclidean distance, respectively.

3.2.2.4 The sky-view factor

Sky-View Factor (SVF) indicates the portion of the sky that is visible from an observation point. The higher the SVF, the greater the heat loss to the atmosphere. Sky-View Factor (SVF) is a widely used parameter to describe urban climatology at high resolution scales, several studies have employed SVF as a parameter of urban design quality (Lindberg and Grimmond, 2010; Nasrollahi and Shokri, 2016; Yang et al. 2007). We calculated SVF through Quantum GIS software with the urban multi-scale environmental predictor (UMEP) plug-in (Lindberg et al. 2017) by superimposing reconstructing through Lidar data the 3D model of the city of Livorno.

3.2.2.4 GIS application to calculate coastline distance

The coastline distance is an index was calculated with Qgis software using the public administration geodatabase data. The coastline, with its promenade represents a significant geographical macro-characteristic for the visual perception of the local quality of the urban space.

3.2.3 Geostatistical model estimation

The regression models used the Flickr photo density indicator as the dependent variable, and the urban design quality indicators as independent variables. For this purpose, we combined two versions of the random forest (RF) model: traditional and geographical.

The RF regression model has some advantages over traditional statistical methods: it allows to treat complex relationships between predictors that can arise with large amounts of data, and is able to process nonlinear relationships between predictive variables. The main limitation is the difficulty in the direct interpretation of the results, since the explicit ensemble model is represented by hundreds (sometimes thousands) regression trees. To overcome this difficulty, Friedman (2001) proposed the use of partial dependence plots, allowing for visualization of a suitable RF model through its mapping from feature space to prediction space. Welling et al. (2016) proposed a new methodology called "forest floor" using feature contributions (FC), a method to decompose trees by splitting features and then performing projections. The advantages of the forest floor approach over the partial dependence plots are that the interactions are not masked as averaging. As a result, interactions that are not visualized in a given projection can be located. Forest floor was implemented in the {foresFloor} library in the statistical programming language R (Team, 2015).

Even though RF is a well-functioning and generalizable algorithm, the vast majority of its implementations are not spatialized. Georganos et al. (2021) proposed a geographical implementation of the RF, called the geographical RF (GRF), as a disaggregation of RF in the geographical space in the form of local sub-models.

The equation for a typical GRF model is:

$$y_i(u) = f\big(\beta_{0,i}(u_i, v_i)x_{i,0}, \beta_{1,i}(u_i, v_i)x_{i,1}, \cdots, \beta_{m,i}(u_i, v_i)x_{m,}, e\big) \tag{11}$$

In the above, $\beta_{m,i}(u_i, v_i)$ is the non-linear prediction of an RF model calibrated on location i and u_i, v_i are the coordinates, e is an error term and $x_i \ldots x_n$ are the independent variables (indices). The area in which the sub-model operates is called the neighborhood (or kernel), and the maximum distance between a data point and its kernel is called the bandwidth (Brunsdon, 1998). The bandwidths for geographical models can be user-specified, or can be determined via automated procedures (e.g., cross-validation), provided an objective function exists (Akaike, 1973; Fotheringham, 2018; Hurvich, 1998). With the data set organized on a regular hexagonal tessellation, we set an adaptive kernel bandwidth to include the N hexagons closest to the observation/calibration hexagon. We estimated the bandwidth using the Akaike information criterion.

To avoid overfitting problems, we used two distinct approaches. We set a large number of trees (500), with 5 variables each and maximum number of terminal node trees in the forest equal to 4 (Cutler et al. 2012; Fotheringham and Park, 2018; Scornet, 2017). We then extracted three sub-datasets from the original dataset: a training set (70% of total observations), used for learning the RF model; a validation set (15% of total observations) for verification of model parameters and a test set (15% of total observations) evaluation of model performance. Unlike RF, we used the GRF as a purely exploratory (rather than predictive) tool. GRF is a local decomposition of the RF and, therefore, the results can be mapped using the entire data set without training/test divisions (for better visualization), to study the local importance of the individual indicators and the performance distributions of the local models. The global and geographical RF models were calculated using the R library {randomForest} and {SpatialML} packages, respectively. The procedures are available as supplementary material.

4. Results

4.1 Assessment of the perception of urban visual quality

The raw database contained approximately 23,063 photo localizations taken in the period from 2005–2017, and the final filtered database contained 11,008 observations. Figure 3 shows a dependent variable map based on the KDE Flickr photo index.

Figure 3. Map of the dependent variable.
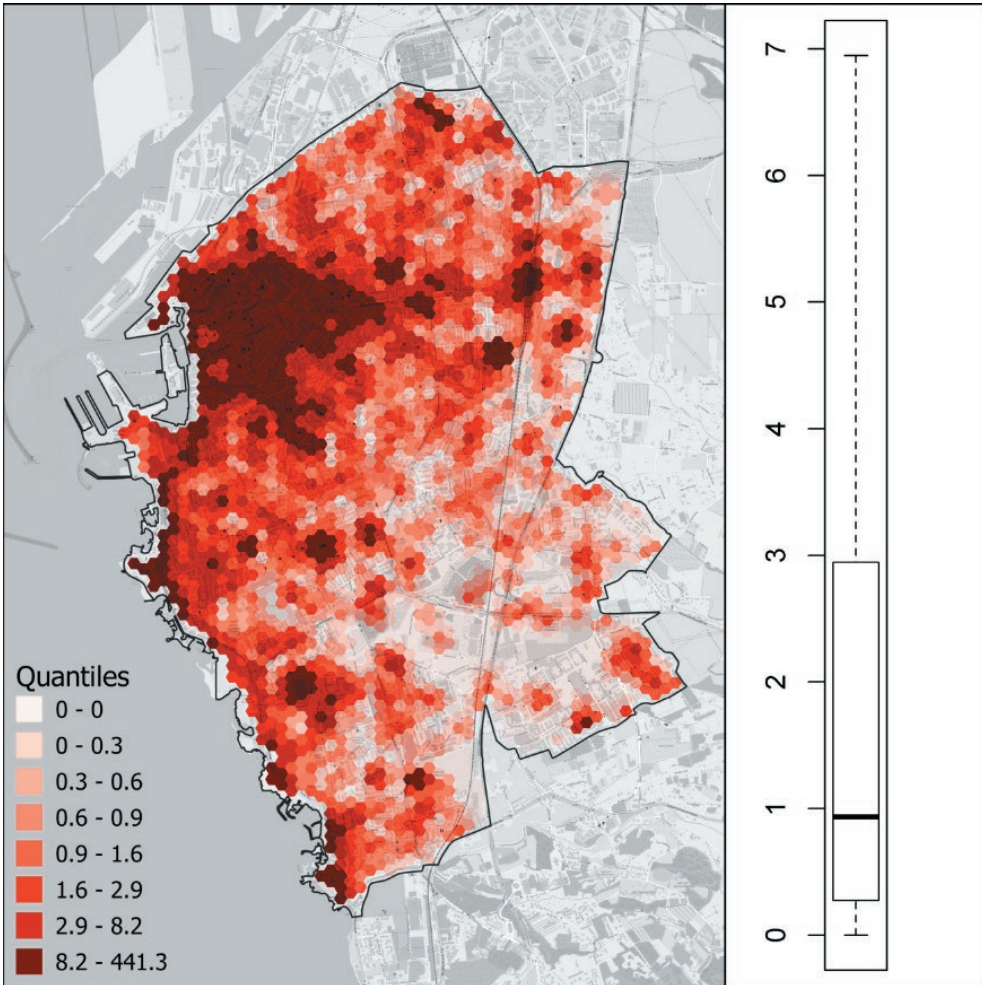
The index recorded a maximum value of 26.07 photo/m^2 with an average value of 3.33 photo/m^2, a median value of 0.93 photo/m^2, and first and third quartiles of 0.27 and 2.94 photo/m^2, respectively. Thus, the data had a very asymmetrical frequency distribution.

4.2 Calculation of the urban visual quality indicators

Using the Googleway library, we downloaded 17,196 geo-tagged images, relating to 2,866 sampling points acquired in 2018. Figure 4 shows an example of the segmentation process.

Figure 4. Example of segmentation process.
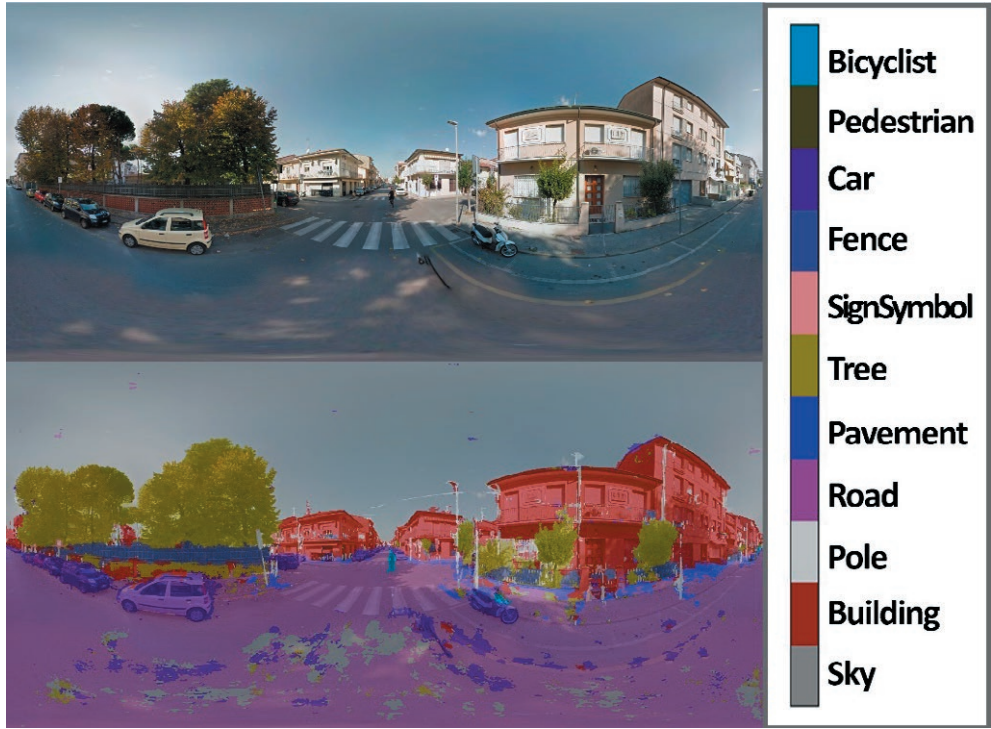
Figure 5. Maps of the indices calculated through the segmentation of the GSV images.
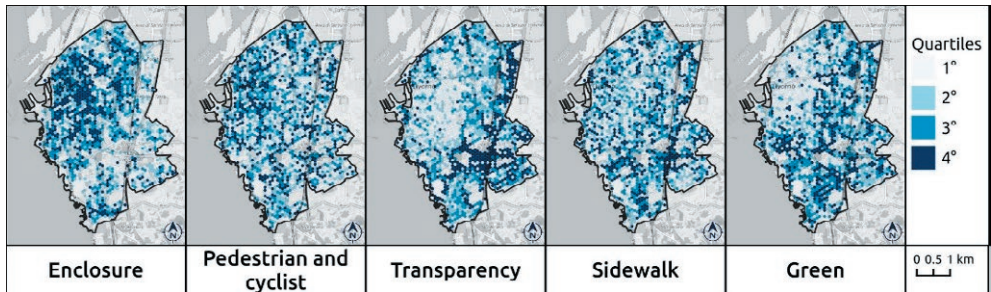

Figure 5 shows the maps of the indices calculated via the segmentation of the GSV images.

Figure 6 shows the maps of the three landscape indices. Figure 7 shows the density indices of the buildings intended to influence the perceived quality of the urban environment. Lastly, Figure 8 shows the two geographical indices linked to the "visual enclosure" and "transparent" dimensions.

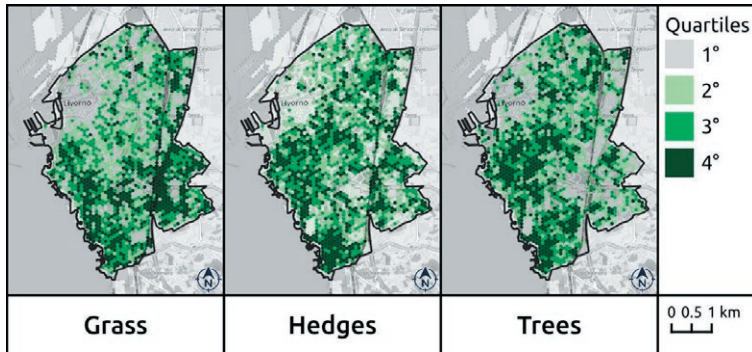Figure 6. Maps of landscape ecology indices.
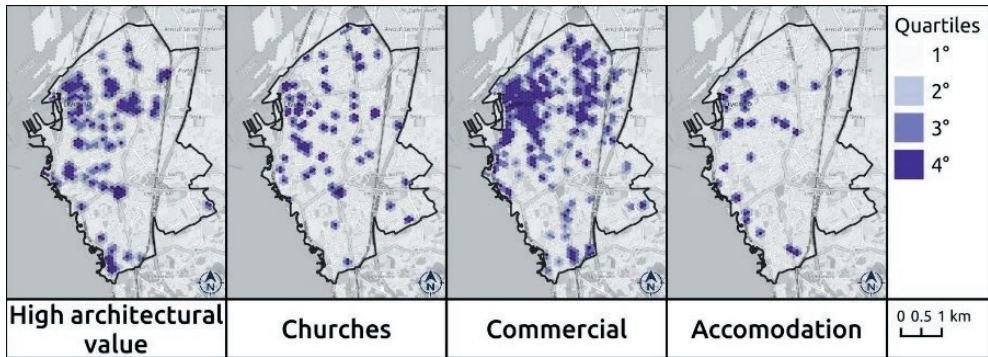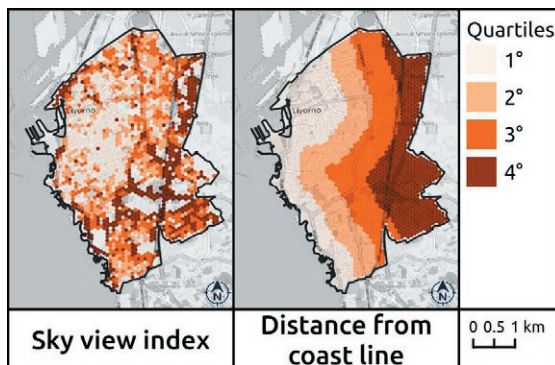

Figure 7. Maps of density indices.

Figure 8. Maps of sky view factor (SVF) and of distance from coastline.

4.3 Random forest (RF) models

The first step in the RF algorithm was to test for multicollinearity between variables using Spearman's degree of correlation. We kept all variables that

showed Spearman's correlation below 0.7, a limit used in the literature in applying random forest models using GIS (Chen et al., 2018; Kamusoko & Gamba, 2015). Variance Inflation Factor (VIF, Table 1) analysis also shows that there is no multicollinearity among the independent variables, as all VIFs are less than 10 (Kim, 2019). Table 1 shows the VIF values for each index.

The final set of 12 variables is the following:
a) Visual enclosure: enclosure index.
b) Imageability: pedestrian index; churches density.
c) Human scale: hedges density, trees density, green index, sidewalk index.
e) Transparency: transparency index, distance from coastline.
e) Complexity: commercial land use density; accommodation land use density; density of buildings with high architectural value.

The global (non-geographical) RF model had a McFadden pseudo R-square value of 0.911 for the training set, 0.56 for the testing set, and 0.566 for the validation set (Table 2). These results can be considered satisfactory on a general level. The most important predictors, in decreasing order of the percent increase in mean squared error (% increase in MSE) and node purity, are shown in Table 2. The variable that contributes most to explaining the perception of urban visual quality in the global model is the distance from the coastline, followed by the commercial land use density and the hedges density.

Figure 9 illustrates the partial dependency plots for each predictor. The partial dependency diagram shows the marginal effect that a predictor has on the expected result of a model. A partial dependency graph can show whether the relationship between the dependent variable and the predictor is linear, monotonous or more complex. Most of the graphs show non-linear relationships of the dependent variable in relation to the predicted perception of urban quality.

Table 1. Variance Inflation Factor.

| Index	VIF
Pedestrian	7.877074
Trees density	6.611743
Hedges density	5.297603
Green index	4.918989
Enclosure index	4.048282
Sky view factor	3.995972
Sidewalk index	3.779627
Commercial land use density	3.765017
Churches density	3.586181
Coast distance	2.728047
Density of building with high architectural value	2.482175
Accommodation land use density	1.697885

Table 2. Results of the non-geographical random forest (RF) regression model.

Predictor	% IncMSE	Node Purity
Coast distance	103.04	30,090.52
Commercial land use density	50.82	12,289.57
Hedges density	27.81	7,133.00
Density of building with high architectural value	26.75	5,904.94
Trees density	20.90	5,216.73
Green index	13.19	4,918.20
Transparency index	17.56	3,770.87
Sidewalk index	6.57	3,171.20
Enclosure index	10.59	3,117.37
Pedestrian index	8.16	2,752.35
Churches density	4.30	1,319.50
Accommodation land use density	6.44	1,236.92
Residual Sum of Squares	7551.707	
Pseudo R-squared Training set	0.91	
Pseudo R-squared Validation set	0.56	
Pseudo R-squared Testing set	0.57	
Moran index Global model	0.53	

For example, the graph shows that the effect of coastline on quality perception is geographically localized. In fact, the curve decreases rapidly to zero less than 1 km from the sea. Similarly, an increase in the density of churches and buildings with high architectural value is associated with an increase in urban quality perception. Interestingly, some variables seem to have partial dependency plots with two distinct segments. For example, the green index, edge density, sidewalk index, and transparency index have a decreasing trend followed by an increasing trend, and this can be explained by the fact that the presence of these two variables has positive effects on the perception of the visual quality of a city, but only beyond a certain threshold value. Another interesting result is obtained in the case of the enclosure index. The partial dependence graph shows that the perception of urban spaces is correlated to two cases: null or very low enclosure index values (typically in the promenade) and enclosure index values equal to about 5-7 (typical of the central areas of the city). Beyond this value, the observations (represented by small colored circles) are very scattered and, therefore, the model does not give reliable indications.

We tested the spatial distribution of the global model residues and found a Moran index of 0.53, indicating the presence of spatial autocorrelation. This justified the use of a local GRF model to identify the variations in the importance of the predictors in space.

Figure 9. Plots for the random forest (RF) variables. Panel titles designate which variable is being plot along the x-axis: (CoastDist) distance from coastline, (ComDen) Commercial land use density, (Green) Green index, (ArchDen) Density of buildings with high architectural value, (Hedges) Hedges density, (Sky) Transparency index, (Encl) Enclosure index, (Trees) Trees density, (Ped) Pedestrian index, (VisPav) Sidewalk index, (ChDen) Churches density, (AccDen) Accommodation density. Panel titles also include the R2 (leave-one-out goodness of fit) of the average feature contribution line (denoted in black). The color gradient is applied in all panels along the distance from the coastline, passing through red-yellow-green-blue with increasing distance.
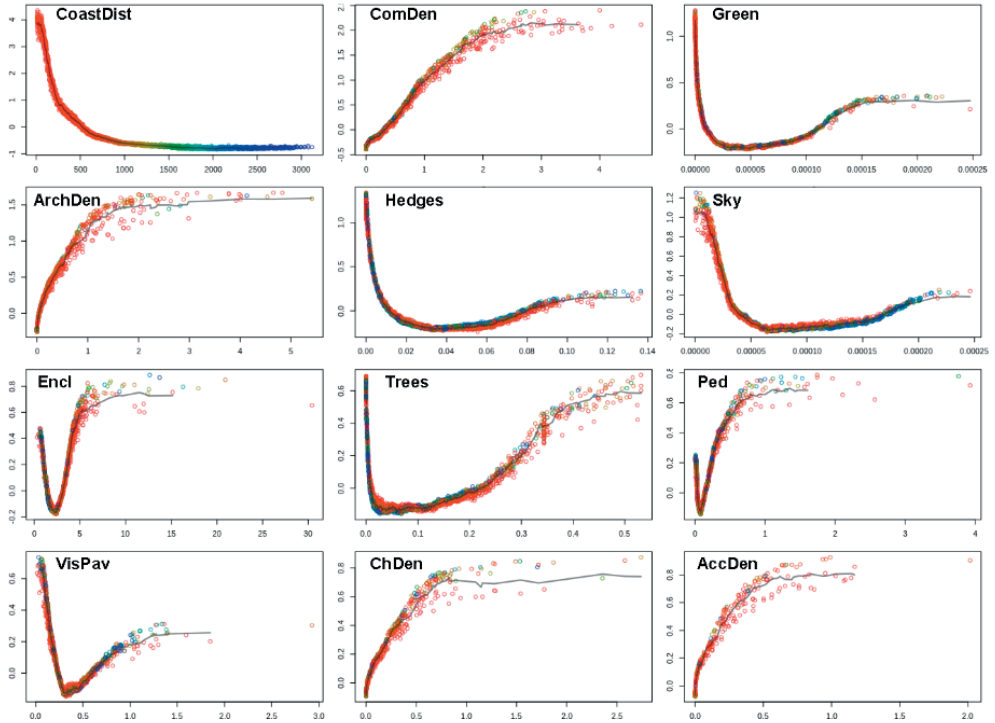
The results of the bandwidth optimization suggested an optimal bandwidth of 95 cells (i.e., for each of the 2,517 cells, a local RF model should be calibrated using data from the nearest 95 cells). The use of the GRF model reduced the spatial autocorrelation of the residues, with a Moran index of 0.17, and a pseudo R-square value equal to 93%. Figure 10 and 11 and Table 3 show respectively the geographical variation, boxplots and the statistics of the purity index of the indicators. The geographic model is therefore overall consistent with the global model. The results of the geographic model confirm the importance of the explanatory variables in terms of purity index for all positions. The R square improves from 0.91 to 0.93.

Notably, there is a strong degree of spatial interaction between each predictor, whereas the importance of each predictor varies consistently through space. At the level of individual geographic location, we obtain very diverse results relative to the ranking of the importance of the variables. The importance of the predic-

Figure 10. Geographical variation of predictors of the geographic RF (GRF) model.
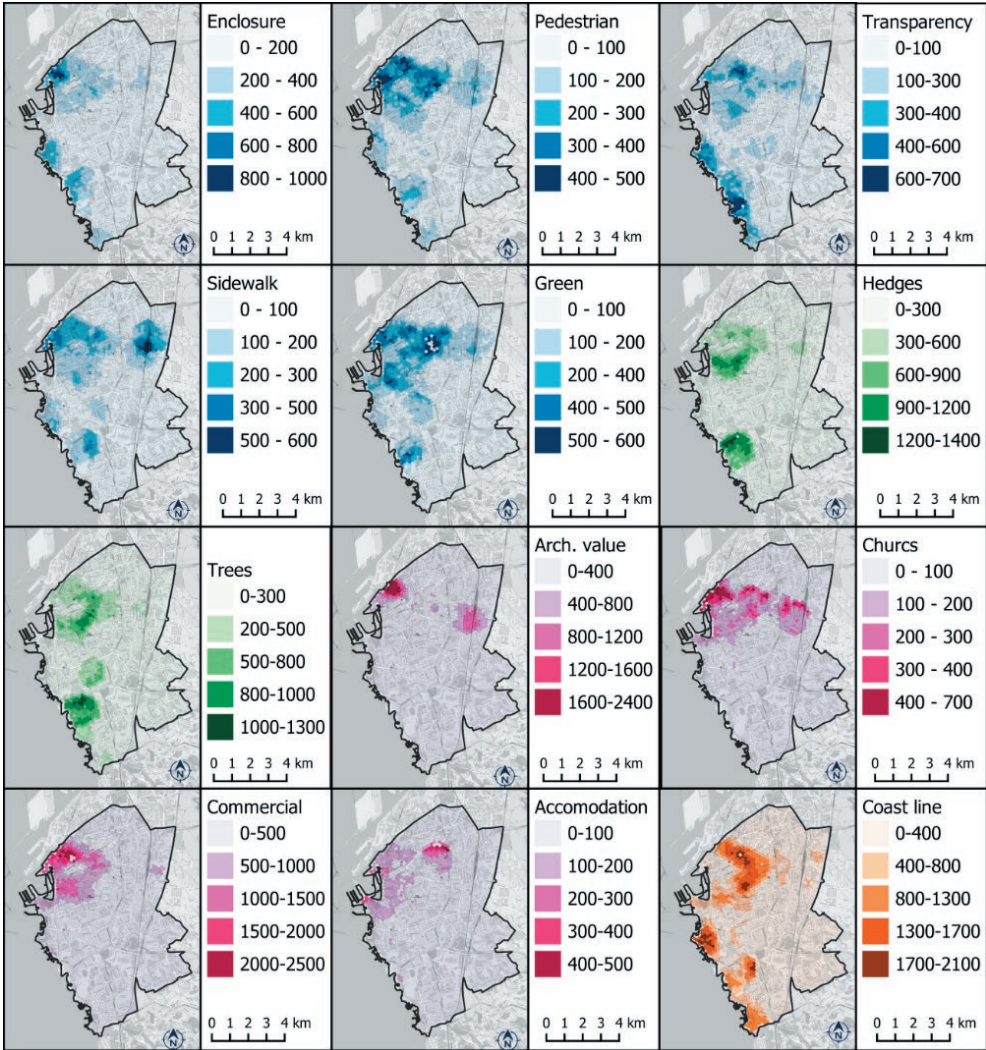
tors is generally highest in areas with a greater density of photos, but with important variations among the predictors, especially in relation to the north-south gradient of the study area. Interestingly, both transparency variables seem to be more important near the coastline. Moreover, the two imageability indices appear to be strongly more predictive over the historical center of the city. Similarly, the rest of the predictive variables formulate unique spatial patterns.

More specifically, comparing Figure 2 with Figure 10, we can see how the different neighborhoods of Livorno show importance of the dimensions of urban quality strongly differentiated. The Buontalenti neighborhood has high val-

Figure 11. Boxplot of purity index of predictors in geographical RF (GRF) regression model.
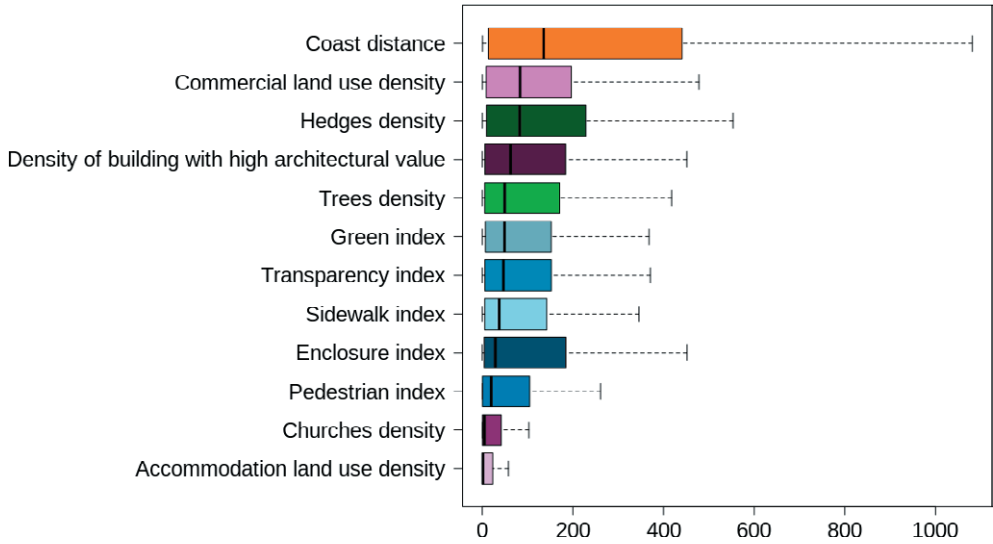

Table 3. Results of the geographical RF (GRF) regression model.

| Predictors	Purity index			
	Min	Max	Mean	StD
Coast distance	0.79	2,232.39	315.11	423.52
Commercial land use density	0.00	2,604.24	192.20	361.75
Hedges density	0.52	1,455.72	170.86	244.55
Density of buildings with high architectural value	0.46	1,309.07	164.82	217.50
Trees density	0.21	732.39	113.42	133.36
Green index	0.00	2,291.88	112.93	253.59
Transparency index	0.34	668.38	108.33	131.80
Sidewalk index	0.33	1,024.51	106.14	139.69
Enclosure index	0.26	567.36	89.84	103.71
Pedestrian index	0.28	595.58	86.61	102.20
Churches density	0.00	605.35	48.26	89.82
Accommodation land use density	0.00	639.11	31.33	66.19
Statistical parameters of Geographical Random Forest				
Residual Sum of Squares (Predicted)	5895.932			
Pseudo R-squared %	93.058			
Moran index	0.17			

ues of the purity index for all indices related to the human scale. The Venezia Nuova neighborhood is characterized by a multidimensional urban quality with high importance of the Visual Enclosure, Imageability and Complexity indices. In the neighborhoods outside the pentagonal city the urban quality is corelated to the indices of transparency near the promenade, similarly to the neighboring neighborhood of Ardenza, which is also characterized by the importance of the indices of human scale density of hedges and density of trees. The modern neighborhoods have only a few indices with significant importance values: sidewalk, density of churches and density of architectural value. Finally, the Sargenti and Korea neighborhoods show low urban quality with no indices with appreciable importance.

5. Discussions

We combined two different RF models: a global model for predictive purposes and a local model for exploration purposes, to select the most significant indicators for different areas of the city of Livorno. The study here offers important information on the geometric, physical and environmental variables of an urban environment that contribute to more abstract qualities. The significant characteristics had the expected relationships with the other findings present in the literature, although many others proved to be statistically not significant despite initial expectations. of city design.

For instance, Figure 12 shows some case studies referring to the different periods of historical expansion of the city. The zone of the pentagon of Buontalenti (see also Figure 1) is characterized by a greater correlation between perceived urban quality and the presence of urban greenery (both trees and hedges). The perception of the quality of the spaces in the Old Venice (Figure 1 and 12) is instead related to the commercial density index and the enclosure index. Therefore, in this part of the city it may be appropriate to implement urban projects for the redevelopment and maintenance of the facades and to improve the visual quality of the shops. The neighbourhoods outside the pentagon of Buontalenti (Figure 1 and 12) do not reveal urban quality elements such as to influence the perception of spaces. On the other hand, the neighbourhoods of modern expansion (Figure 1 and 12), despite having an urban layout similar to the previous one, appear to have a higher perceived quality due to the widespread presence of modern buildings but of architectural value. Finally, as regards the Ardenza zone (Figure 1 and 12), the analysis confirms the correlation between the perceived quality of public spaces and the characteristic indicators of the seaside promenade: distance from the coastline and the presence of urban greenery (trees and hedges). The results of this study can be used in different of ways. Municipal planners and administrators can achieve a more detailed and complete understanding of an urban environment. The map can provide good support for the definition of urban planning policies.

Figure 12. Some case studies of indicators correlated with urban quality.
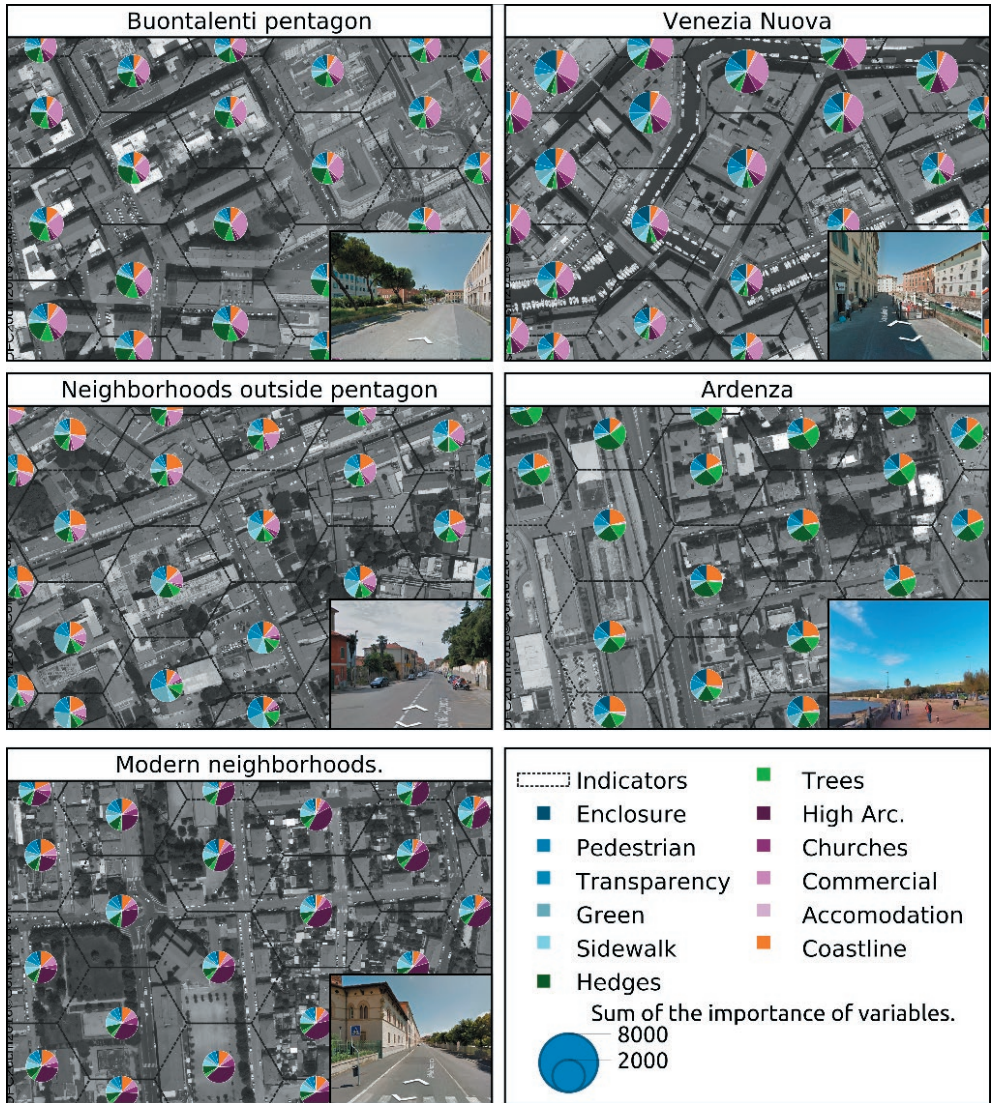
6. Conclusions and future developments

The proposed approach is able to provide useful information to identify and evaluate the geometric, physical and environmental characteristics of public spaces that most determine the perceived urban visual quality at the planning scale.

We believe that our study has helped to demonstrate that the perceived quality of the city is influenced by many physical, geometric and environmental vari-

ables in a complex way. From a general point of view, data shared by social media combined with data deriving from Google's Internet services and remote sensing data can provide a useful tool to improve our understanding of the relationship between humans and the urban environment.

Another advantage is the ability of using publicly available data with a much lower cost if compared to a traditional analogous survey through questionnaires. A survey through questionnaires can evaluate a greater number of subjective variables, for example linked to the sentiment that arouses perception. However, this study clearly has some limitations.

The method has been tested on a small city and this allowed to have acceptable processing times, but for larger cities there are two possible solutions that will be implemented in the future development of the research. The first is to tile the study area; since the methodology is based on a local geographical model, this should not affect the estimation of the model parameters. A second solution would be to use a reduced sample of images downloaded from GSV. The pros and cons of the two hypotheses will have to be evaluated. In the future both methods will be applied in Florence to verify their advantages and limitations.

Furthermore, other limitations are related to the characteristics of social media data. Social media are not only about young people, but it seems that only this social group is actively involved, older people may be mostly recipients of content and not its creators. Moreover, the Flickr platform does not allow to obtain social and personal information about the individual user in order to segment visual preferences by age groups and other social variables.

An additional weakness is that the presence of autocorrelation was tested only by Moran's index calculation. Further investigations will be needed to test for the presence of spatial heterogeneity through measures of similarity between associations of values (covariance, correlation or difference) and associations in space (contiguity), including Lagrange multiplier tests (LM-lag and LM-error). The results of these tests could allow us to compare the results obtained through GRF models with other spatial regression models, such as the Spatial Lag Model (SLM) or the Spatial Error Model (SEM).

After all, the results of the methodology can help to implement more efficient sample designs, stratifying the city in relation to the importance of the indicators used as independent variables, thus reducing the sample size and therefore the costs. The synergistic implementation of the two methodologies will constitute a first future development of this research to give useful information to help researchers and managers to develop projects, standards and guidelines to improve urban visual quality in the cities.

References

Adams, M. A., Ryan, S., Kerr, J., Sallis, J. F., Patrick, K., Frank, L. D., & Norman, G. J. (2009). Validation of the Neighborhood Environment Walkability Scale (NEWS) items using geographic information systems. *Journal of Physical Activity and Health*, 6(s1), S113–S123.

Akaike, H. (1973). Information Theory and an Extension of the Maximum Likelihood Principle. In Parzen, E., Tanabe K., & Kitagawa G. (Eds). *Selected Papers of Hirotugu Akaike*. Springer Series in Statistics (Perspectives in Statistics). New York, NY, Springer.

Alampi Sottini, V., Barbierato, E., Bernetti, I., Capecchi, I., Cipollaro, M., Sacchelli, S., & Saragosa, C. (2018). Urban landscape assessment: a perceptual approach combining virtual reality and crowdsourced photo geodata. *Aestimum*, (73), 147–171.

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A Pattern Language*. Oxford University Press.

Arnheim, R. (1969). *Visual Thinking*. Berkeley, University of California Press.

Asihara, Y. (1983). *The Aesthetic Townscape*. Cambridge, MA, MIT Press.

Barbierato, E., Bernetti, I., Capecchi, I., & Saragosa, C. (2019). Remote sensing and urban metrics: an automatic classification of spatial configurations to support urban policies. In *Earth Observation Advancements in a Changing World,* Torino, Italy, p. 187. Italian Society of Remote Sensing.

Bernetti, I., Alampi Sottini, V., Bambi, L., Barbierato, E., Borghini, T., Capecchi, I., & Saragosa, C. (2020). Urban niche assessment: an approach integrating social media analysis, spatial urban indicators and geo-statistical techniques. *Sustainability*, 12(10), 3982.

Breiman, L. (2001). Random forests. *Machine learning*, 45(1), 5–32.

Brostow, G. J., Fauqueur, J., & Cipolla, R. (2009). Semantic object classes in video: a high-definition ground truth database. *Pattern Recognition Letters*, 30(2), 88–97.

Brunsdon, C., Fotheringham, S., & Charlton, M. (1998). Geographically weighted regression. *Journal of the Royal Statistical Society: Series D*, 47(3), 431–443.

Cerin, E., Saelens, B. E., Sallis, J. F., & Frank, L. D. (2006). Neighborhood Environment Walkability Scale: validity and development of a short form. *Medicine & Science in Sports & Exercise*, 38(9), 1682–1691.

Chan, T. N., Ip, P. L., U, L. H., Tong, W. H., Mittal, S., Li, Y., & Cheng, R. (2021). KDV-Explorer: A near real-time kernel density visualization system for spatial analysis. *Proceedings of the VLDB Endowment*, 14(12), 2655–2658.

Chen, J., & Shaw, S. L. (2016). Representing the spatial extent of places based on Flickr photos with a representativeness-weighted Kernel Density Estimation. In Miller, J., O'Sullivan, D., & Wiegand, N. (Eds). *Geographic Information Science*. GIScience 2016. Lecture Notes in Computer Science, vol 9927. Springer, Cham.

Chen, W., Zhang, S., Li, R., & Shahabi, H. (2018). Performance evaluation of the GIS-based data mining techniques of best-first decision tree, random forest, and naïve Bayes tree for landslide susceptibility modeling. *Science of the total environment*, 644, 1006–1018.

Chen, L. C., Zhu, Y., Papandreou, G., Schroff, F., & Adam, H. (2018). Encoder-decoder with atrous separable convolution for semantic image segmentation. In *Proceedings of the European conference on computer vision* (ECCV) (pp. 801–818).

Cullen, G. (1959). *Townscape*. London, Architectural Press.

Cutler, A., Cutler, D. R., & Stevens, J. R. (2012). Random forests. In Zhang, C., & Ma, Y. (Eds). *Ensemble Machine Learning*. Boston, MA, Springer. (pp. 157–175).

Doersch, C., Singh, S., Gupta, A., Sivic, J., & Efros, A. A. (2012). What makes Paris look like Paris?. *ACM Transactions on Graphics*, 31(4), 101.

Duncan, D. T., Aldstadt, J., Whalen, J., Melly, S. J., & Gortmaker, S. L. (2011). Validation of Walk Score® for estimating neighborhood walkability: an analysis of four US metropolitan areas. *International Journal of Environmental Research and Public Health*, 8(11), 4160–4179.

Dunkel, A. (2015). Visualizing the perceived environment using crowdsourced photo geodata. *Landscape and Urban Planning*, 142, 173–186.

Ewing, R., & Handy, S. (2009). Measuring the unmeasurable: urban design qualities related to walkability. *Journal of Urban Design*, 14(1), 65–84.

Ewing, R., Handy, S., Brownson, R. C., Clemente, O., & Winston, E. (2006). Identifying and measuring urban design qualities related to walkability. *Journal of Physical Activity and Health*, 3(s1), S223-S240.

Feick, R., & Robertson, C. (2015). A multi-scale approach to exploring urban places in geotagged photographs. *Computers, Environment and Urban Systems*, 53, 96–109.

Fotheringham, A. S., & Park, B. (2018). Localized spatiotemporal effects in the determinants of property prices: a case study of Seoul. *Applied Spatial Analysis and Policy*, 11(3), 581–598.

Fotheringham, A. S., Brunsdon, C. and Charlton, M. (2003). *Geographically weighted regression: the analysis of spatially varying relationships.* Chichester, John Wiley & Sons.

Friedman, J. H. (2001). Greedy function approximation: a gradient boosting machine. *Annals of statistics*, 29(5), 1189–1232.

Gavrilidis, A. A., Ciocănea, C. M., Niţă, M. R., Onose, D. A., & Năstase, I. I. (2016). Urban landscape quality index–planning tool for evaluating urban landscapes and improving the quality of life. *Procedia Environmental Sciences*, 32, 155–167.

Genuer, R., Poggi, J.M. and Tuleau, C. (2008). Random Forests: some methodological insights, *arXiv,* arXiv:0811.3619. Available at: https://arxiv.org/pdf/0811.3619.pdf (Accessed 1 July 2021).

Georganos, S., Grippa, T., Gadiaga, A.N., Linard, C., Lennert, M., Vanhuysse, S., Mboga, N., Wolff, E., & Kalogirou, S. (2019). Geographical random forests: a spatial extension of the random forest algorithm to address spatial heterogeneity in remote sensing and population modelling. *Geocarto International,* 36(2), 1–16.

Georganos, S., Grippa, T., Niang Gadiaga, A., Linard, C., Lennert, M., Vanhuysse, S., Mboga, N., Wolff, E., & Kalogirou, S. (2021). Geographical random forests: a spatial extension of the random forest algorithm to address spatial heterogeneity in remote sensing and population modelling. *Geocarto International*, 36(2), 121–136.

Gibson, J. J. (1979). The Ecological Approach to Visual Perception. Boston:Houghton Mifflin.

Gromping, U. (2009). Variable importance assessment in regression: linear regression versus random forest. *The American Statistician*, 63(4), 308–319.

Hauthal, E., & Burghardt, D. (2016). Using VGI for analyzing activities and emotions of locals and tourists. In *Proceedings of the Link-VGI Workshop in Connection with the AGILE,* June 14, 2016, Helsinki, Finland.

Hurvich, C. M., Simonoff, J. S., & Tsai, C. L. (1998). Smoothing parameter selection in nonparametric regression using an improved Akaike information criterion. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 60(2), 271–293.

Hyun, C. U., Lee, J. S., & Lee, I. (2013). Assessment of hydrogen fluoride damage to vegetation using optical remote sensing data. *International Society for Photogrammetry and Remote Sensing Spatial Inf. Sci.*, XL-7/W2, 115–118.

IGM, I. (2015). Airplane equipped with an UltraCam XP aerial digital cam-era installed on a gyro-stabilized mount. In *Pattern Recognition: 7th Mexican Conference*, MCPR 2015, June 24-27, 2015, Mexico City, Mexico Proceedings (Vol. 9116, p. 145). Cham, Springer.

Ittelson, W. H. (1960). *Visual Space Perception*. New York, Springer.

Jin, X., Gallagher, A., Cao, L., Luo, J., & Han, J. (2010). The wisdom of social multimedia: using Flickr for prediction and forecast. In *Proceedings of the 18th ACM international conference on Multimedia*, October 2010, ACM (pp. 1235–1244).

Kamusoko, C., & Gamba, J. (2015). Simulating urban growth using a Random Forest-Cellular Automata (RF-CA) model. *ISPRS International Journal of Geo-Information*, 4(2), 447–470.

Kim, J. H. (2019). Multicollinearity and misleading statistical results. *Korean Journal of Anesthesiol.* 72, 558–569.

Li, L., Goodchild, M. F., & Xu, B. (2013). Spatial, temporal, and socioeconomic patterns in the use of Twitter and Flickr. *Cartography and geographic information science*, 40(2), 61–77.

Lian, D., Zhao, C., Xie, X., Sun, G., Chen, E., & Rui, Y. (2014, August). GeoMF: joint geographical modeling and matrix factorization for point-of-interest recommendation. In *Proceedings of the 20th ACM SIGKDD international conference on Knowledge discovery and data mining*, August 2014, ACM (pp. 831–840).

Lindberg, F., & Grimmond, C. S. B. (2010). Continuous sky view factor maps from high resolution urban digital elevation models. *Climate Research*, 42(3), 177–183.

Lindberg, F., Grimmond, C. S. B., Gabey, A., Huang, B., Kent, C. W., Sun, T., & Chang, Y. Y. (2017). UMEP-An integrated tool for city-based climate services. In *21ST International Congress of Bio-*

meteorology, September 3-6, 2017, Durham, United Kingdom (p. 51). International Society of Biometerology.

Lynch, K. (1960). *The image of the city*. Cambridge, MIT Pres.

Moura, F., Cambra, P., & Gonçalves, A. B. (2017). Measuring walkability for distinct pedestrian groups with a participatory assessment method: A case study in Lisbon. *Landscape and Urban Planning*, 157, 282–296.

Naik, N., Philipoom, J., Raskar, R., & Hidalgo, C. (2014). Streetscore-predicting the perceived safety of one million streetscapes. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition Workshops* (pp. 779–785).

Nasrollahi, N., & Shokri, E. (2016). Daylight illuminance in urban environments for visual comfort and energy performance. *Renewable and Sustainable Energy Reviews*, 66, 861–874.

Oteros-Rozas, E., Martín-López, B., Fagerholm, N., Bieling, C., & Plieninger, T. (2018). Using social media photos to explore the relation between cultural ecosystem services and landscape features across five European sites. *Ecological Indicators*, 94, 74–86.

Patil, G. P., Myers, W. L., Luo, Z., Johnson, G. D., & Taillie, C. (2000). Multiscale assessment of landscapes and watersheds with synoptic multivariate spatial data in environmental and ecological statistics. *Mathematical and Computer Modelling*, 32(1-2), 257–272.

Tenerelli, P., Demšar, U., & Luque, S. (2016). Crowdsourcing indicators for cultural ecosystem services: a geographically weighted approach for mountain landscapes. *Ecological Indicators*, 64, 237–248.

Peng, X., & Huang, Z. (2017). A novel popular tourist attraction discovering approach based on geo-tagged social media big data. *ISPRS International Journal of Geo-Information*, 6(7), 216.

Perovic, S., & Folic, N. K. (2012). Visual perception of public open spaces in Niksic. *Procedia-Social and Behavioral Sciences*, 68, 921–933.

Pouya, S., & Dem˙Irel, Ö. (2015). What is a healing garden?. *Akdeniz Üniversitesi Ziraat Fakültesi Dergisi*, 28(1), 5–10.

Probst, P., Wright, M. N., & Boulesteix, A. L. (2019). Hyperparameters and tuning strategies for random forest.

Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery, 9(3), e1301.

Quercia, D., Schifanella, R., & Aiello, L. M. (2014). The shortest path to happiness: Recommending beautiful, quiet, and happy routes in the city. In *Proceedings of the 25th ACM conference on Hypertext and social media,* September 2014, ACM (pp. 116-125).

Radovic, R. (2003). *Forma grada: osnove, teorija i praksa*. Beograd, Orion art; Novi Sad, Stylos.

Rodgers III, J. C., Murrah, A. W., & Cooke, W. H. (2009). The impact of hurricane Katrina on the coastal vegetation of the Weeks Bay Reserve, Alabama from NDVI Data. *Estuaries and Coasts*, 32(3), 496–507.

Rossi, A. (1966). *The Architecture of the City*. Cambridge, The MIT Press.

Scornet, E. (2017). Tuning parameters in random forests. In *ESAIM: Proceedings and Surveys*, 60 (pp. 144–162).

Segal, M., & Xiao, Y. (2011). Multivariate random forests. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, 1(1), 80–87.

Spreiregen, P. D. (1965). *Urban design: the architecture of towns and cities*. New York, McGraw-Hill.

Stamps III, A. E. (2001). Evaluating enclosure in urban sites. *Landscape and Urban Planning*, 57(1), 25–42.

Stea, D. (1978). Environmental perception and cognition: toward a model for :mental maps. In Kaplan, R., & Kaplan, S. (Eds.). *Humanscape: environment for people*. Boston, MIT Press.

Steinmetz-Wood, M., Velauthapillai, K., O'Brien, G., & Ross, N. A. (2019). Assessing the microscale environment using Google Street View: the virtual systematic tool for evaluating pedestrian streetscapes (virtual-STEPS). *BMC Public Health*, 19(1), 1–11.

Strobl, C., Boulesteix, A. L., Kneib, T., Augustin, T. Zeileis, A. (2008). Conditional variable importance for random forests. *BMC bioinformatics*, 9(1), 307.

Talavera-Garcia, R., & Soria-Lara, J. A. (2015). Q-PLOS, developing an alternative walking index. A method based on urban design quality. *Cities*, 45, 7–17.

Team, R. C. (2015). *R: A language and environment for statistical computing*. Vienna, Austria, R Foundation for Statistical Computing.

Walden-Schreiner, C., Leung, Y. F., & Tateosian, L. (2018). Digital footprints: incorporating crowdsourced geographic information for protected area management. *Applied Geography*, 90, 44–54.

Welling, S. H., Refsgaard, H. H., Brockhoff, P. B., & Clemmensen, L. H. (2016). Forest floor visualizations of random forests. *arXiv*, arXiv:1605.09196. Available at https://arxiv.org/pdf/1605.09196.pdf (Accessed 1 July 2021).

Winters, N. B. (1986). *Architecture is elementary: visual thinking through architectural concepts*. Salt Lake City, Gibbs Smith Publishers.

Yang, P. P. J., Putra, S. Y., & Li, W. (2007). Viewsphere: a GIS-based 3D visibility analysis for urban design evaluation. *Environment and Planning B: Planning and Design*, 34(6), 971–992.

Yin, L., & Wang, Z. (2016). Measuring visual enclosure for street walkability: using machine learning algorithms and Google Street View imagery. *Applied geography*, 76, 147–153.

Yoshimura, N., & Hiura, T. (2017). Demand and supply of cultural ecosystem services: use of Geo-tagged photos to map the aesthetic value of landscapes in Hokkaido. *Ecosystem Services*, 24, 68–78.

Zhou, H., He, S., Cai, Y., Wang, M., & Su, S. (2019). Social inequalities in neighborhood visual walkability: using Street View imagery and deep learning technologies to facilitate healthy city planning. *Sustainable Cities and Society*, 50, 101605.

Zhou, X., Xu, C., & Kimmons, B. (2015). Detecting tourism destinations using scalable geospatial analysis based on cloud computing platform. *Computers, Environment and Urban Systems*, 54, 144-153.

Zuniga-Teran, A. A., Orr, B. J., Gimblett, R. H., Chalfoun, N. V., Going, S. B., Guertin, D. P., & Marsh, S. E. (2016). Designing healthy communities: A walkability analysis of LEED-ND. *Frontiers of Architectural Research*, 5(4), 433–452.

Rassegna giurisprudenziale

(a cura di Nicola Lucifero)

AGRICOLTURA

CGUE, 16/12/2021, C-225/20, Euro Delta Danube SRL contro Agenţia de Plăţi şi Intervenţie pentru Agricultură – Centrul Judeţean Tulcea
Rinvio pregiudiziale – Agricoltura – Politica agricola comune – Regolamento delegato (UE) n. 640/2014 – Regime di aiuto per superficie – Pagamento unico per superficie – Criteri di ammissibilità – Contratto di concessione di terreni agricoli – Cambiamento d'uso di tali terreni senza l'assenso del concedente – Utilizzo per scopi agricoli di superfici destinate ad attività di piscicoltura – Differenza tra la superficie dichiarata e la superficie determinata – Sovradichiarazione – Sanzioni amministrative
L'articolo 2, paragrafo 1, punto 23, e l'articolo 19, paragrafi 1 e 2, del regolamento delegato (UE) n. 640/2014 della Commissione, dell'11 marzo 2014, che integra il regolamento (UE) n. 1306/2013 del Parlamento europeo e del Consiglio per quanto riguarda il sistema integrato di gestione e di controllo e le condizioni per il rifiuto o la revoca di pagamenti nonché le sanzioni amministrative applicabili ai pagamenti diretti, al sostegno allo sviluppo rurale e alla condizionalità, come modificato dal regolamento delegato (UE) 2016/1393 della Commissione, del 4 maggio 2016, devono essere interpretati nel senso che non prescrivono, nell'ambito del regime di pagamento unico per superficie, che siano inflitte sanzioni amministrative per sovradichiarazione ad un richiedente di aiuti agricoli perché utilizza per fini agricoli superfici concessegli per la piscicoltura senza il consenso del concedente a un siffatto cambiamento di destinazione d'uso di dette superfici, laddove tale richiedente disponga, per quanto riguarda queste superfici, di un'autonomia sufficiente ai fini dell'esercizio della sua attività agricola.

CGUE, 14/10/2021, C-373/20, A.M. contro Dyrektor Z. Oddziału Regionalnego Agencji Restrukturyzacji i Modernizacji Rolnictwa,
Rinvio pregiudiziale – Agricoltura – Politica agricola comune – Regimi di sostegno diretto – Norme comuni – Regime di pagamento unico – Regolamento (CE) n. 1120/2009 – Articolo 2, lettera c) – Nozione di "pascoli permanenti" – Avvicendamento delle colture – Inondazioni naturali e periodiche dei prati e dei pascoli situati in una zona di protezione speciale della natura
L'articolo 2, lettera c) del regolamento (CE) n. 1120/2009 della Commissione, del 29 ottobre 2009, recante modalità di applicazione del regime di pagamento unico di cui al titolo III del regolamento (CE) n. 73/2009 del Consiglio che stabilisce norme comuni relative ai regimi di sostegno diretto nell'ambito della politica agricola comune e istituisce taluni regimi di sostegno a favore degli agricoltori, deve essere interpretato nel senso che non sono esclusi dalla nozione di «pascolo permanente», ai sensi di tale disposizione, prati o pascoli situati

in una zona di protezione speciale e che sono soggetti ad allagamenti e inondazioni naturali e periodiche, dato che tali allagamenti e inondazioni non possono, di per sé, portare a un «avvicendamento delle colture» sui terreni interessati, ai sensi di detta disposizione.

CGUE, 6/10/2021, C-119/20, Līga *Šenfelde* Contro Lauku atbalsta dienests
Rinvio pregiudiziale – Politica agricola comune – Finanziamento da parte del Fondo europeo agricolo per lo sviluppo rurale (FEASR) – Programma nazionale di sviluppo rurale 2014-2020 – Regolamento (UE) n. 1305/2013 – Articolo 19, paragrafo 1, lettera a) – Aiuti all'avviamento di imprese per i giovani agricoltori – Aiuti allo sviluppo delle piccole aziende agricole – Cumulo degli aiuti – Possibilità di rifiutare il cumulo
1) L'articolo 19, paragrafo 1, del regolamento (UE) n. 1305/2013 del Parlamento europeo e del Consiglio, del 17 dicembre 2013, sul sostegno allo sviluppo rurale da parte del Fondo europeo agricolo per lo sviluppo rurale (FEASR) e che abroga il regolamento (CE) n. 1698/2005 del Consiglio, deve essere interpretato nel senso che esso non osta a che un agricoltore, il quale abbia beneficiato dell'aiuto all'avviamento di imprese per lo sviluppo di piccole aziende agricole, previsto alla lettera a), punto iii), della disposizione sopra citata, possa cumulare tale aiuto con l'aiuto all'avviamento di imprese per i giovani agricoltori, contemplato dalla lettera a), punto i), della medesima disposizione, a condizione che sia rispettato l'importo massimo dell'aiuto concesso, quale previsto dal paragrafo 6 di tale articolo.
2) L'articolo 19, paragrafo 1, del regolamento n. 1305/2013 deve essere interpretato nel senso che esso non osta a una normativa nazionale in forza della quale la concessione dell'aiuto all'avviamento di imprese per lo sviluppo di piccole aziende agricole, previsto alla lettera a), punto iii), di detta disposizione, esclude l'ottenimento dell'aiuto all'avviamento di imprese per i giovani agricoltori, contemplato dalla lettera a), punto i), di quest'ultima.

CGUE, 8/07/2021, C.J. contro Région wallonne
Rinvio pregiudiziale – Agricoltura – Fondo europeo agricolo per lo sviluppo rurale (FEASR) – Regolamento (UE) n. 1305/2013 – Regolamento delegato (UE) n. 807/2014 – Insediamento dei giovani agricoltori – Sviluppo delle aziende agricole – Aiuti all'avviamento d'impresa per giovani agricoltori – Condizioni d'accesso – Equivalenza – Insediamento in qualità di capo non unico dell'azienda – Massimali – Fissazione – Criteri – Produzione standard dell'azienda agricola
Gli articoli 2, 5 e 19 del regolamento (UE) n. 1305/2013 del Parlamento europeo e del Consiglio, del 17 dicembre 2013, sul sostegno allo sviluppo rurale da parte del Fondo europeo agricolo per lo sviluppo rurale (FEASR) e che abroga il regolamento (CE) n. 1698/2005 del Consiglio, in combinato disposto con gli articoli 2 e 5 del regolamento delegato (UE) n. 807/2014 della Commissione, dell'11 marzo 2014, che integra talune disposizioni del regolamento (UE) n. 1305/2013 del Parlamento europeo e del Consiglio sul sostegno allo sviluppo rurale da parte del Fondo europeo agricolo per lo sviluppo rurale (FEASR) e che introduce disposizioni transitorie, devono essere interpretati nel senso che non ostano a una normativa nazionale in forza della quale il criterio di determinazione del massimale che consente ad un giovane agricoltore, che si insedia in qualità di capo non unico dell'azienda, di accedere agli aiuti all'avviamento d'impresa, è quello della produzione lorda standard dell'intera azienda agricola, e non soltanto della quota di tale giovane agricoltore in tale azienda.

Cass. civ., Sez. II, Ordinanza, 30/06/2021, n. 18570
Riforma fondiaria - Assegnazione - Morte dell'assegnatario prima del riscatto - Subentro dell'erede nel rapporto di assegnazione - Requisiti - Momento determinativo - Morte dell'assegnatario e momento della decisione della relativa controversia - Persistenza - Necessità - Prova
In tema di riforma agraria, l'art. 7 della l. n. 379 del 1967 stabilisce i requisiti - che devono esistere al momento dell'apertura della successione e persistere fino a tutto il tempo della decisione - per la designazione di colui che subentra "iure proprio" all'assegnatario deceduto prima dell'esercizio del diritto di riscatto, senza comunque prescindere dal criterio principale dell'abitualità del successore medesimo nella coltivazione della terra, che deve sussistere sia al momento della morte dell'assegnatario che in quello in cui si chiede il subentro e la cui prova va fornita in concreto, non essendo sufficienti all'uopo certificazioni o altre attestazioni amministrative. Dimostrata dall'erede la sussistenza di tali requisiti al momento dell'apertura della successione, se ne presume la permanenza fino alla decisione mentre, ove si accerti che nessuno dei contendenti è in possesso del requisito dell'abitualità nella lavorazione manuale della terra, il giudice è tenuto a pronunciare, anche in difetto di domanda in tal senso da parte dell'ente concedente, il rientro delle terre nella disponibilità di quest'ultimo.

T.A.R. Sardegna Cagliari, Sez. II, 02/07/2021, n. 51
Agricoltura – agevolazioni – suini – equiparazione cinghiali
In materia di sostegni e aiuti agli allevatori, la normativa primaria di riferimento individua quali possibili destinatari del contributo, riferendosi in via generale agli allevamenti di "suini", senza alcuna esclusione degli allevamenti di cinghiali, la cui esclusione risulterebbe del tutto irragionevole alla luce della sostanziale equivalenza tra le due specie, prima di tutto sotto il profilo delle esigenze di miglioramento delle condizioni di allevamento, obiettivo principale del contributo. Pertanto qualsivoglia bando finalizzato all'assegnazione dei predetti sostegni è ovviamente tenuto a rispettare le disposizioni previste nella normativa vigente.

ALIMENTI

CGUE, 9/9/2021, Comité Interprofessionnel du Vin de Champagne contro GB
Rinvio pregiudiziale – Agricoltura – Protezione delle denominazioni d'origine e delle indicazioni geografiche – Carattere uniforme ed esaustivo – Regolamento (UE) n. 1308/2013 – Articolo 103, paragrafo 2, lettera a), punto ii) – Articolo 103, paragrafo 2, lettera b) – Evocazione – Denominazione di origine protetta (DOP) "Champagne" – Servizi – Comparabilità dei prodotti – Uso della denominazione commerciale "Champanillo"
1) L'articolo 103, paragrafo 2, lettera b), del regolamento (UE) n. 1308/2013 del Parlamento europeo e del Consiglio, del 17 dicembre 2013, recante organizzazione comune dei mercati dei prodotti agricoli e che abroga i regolamenti (CEE) n. 922/72, (CEE) n. 234/79, (CE) n. 1037/2001 e (CE) n. 1234/2007 del Consiglio, deve essere interpretato nel senso che protegge le denominazioni di origine protetta (DOP) da condotte relative sia ai prodotti che ai servizi.

2) L'articolo 103, paragrafo 2, lettera b), del regolamento n. 1308/2013 deve essere interpretato nel senso che l'«evocazione» di cui a tale disposizione, da un lato, non richiede, quale presupposto, che il prodotto che beneficia di una DOP e il prodotto o il servizio contrassegnato dal segno contestato siano identici o simili e, dall'altro, si configura quando l'uso di una denominazione produce, nella mente di un consumatore europeo medio, normalmente informato e ragionevolmente attento e avveduto, un nesso sufficientemente diretto e univoco tra tale denominazione e la DOP. L'esistenza di un tale nesso può risultare da diversi elementi, in particolare, dall'incorporazione parziale della denominazione protetta, dall'affinità fonetica e visiva tra le due denominazioni e dalla somiglianza che ne deriva, e anche in assenza di tali elementi, dalla vicinanza concettuale tra la DOP e la denominazione di cui trattasi o ancora da una somiglianza tra i prodotti protetti da tale medesima DOP e i prodotti o servizi contrassegnati da tale medesima denominazione.

3) L'articolo 103, paragrafo 2, lettera b), del regolamento n. 1308/2013 deve essere interpretato nel senso che l'«evocazione» di cui a tale disposizione non è subordinata all'accertamento dell'esistenza di un atto di concorrenza sleale, dal momento che tale disposizione istituisce una protezione specifica e propria che si applica indipendentemente dalle disposizioni di diritto nazionale in materia di concorrenza sleale.

CGUE, 11/11/2021, C-388/20, Bundesverband der Verbraucherzentralen und Verbraucherverbände – Verbraucherzentrale Bundesverband eV contro Dr. August Oetker Nahrungsmittel KG

Rinvio pregiudiziale – Regolamento (UE) n. 1169/2011 – Informazioni ai consumatori sugli alimenti – Articolo 9, paragrafo 1, lettera l) – Dichiarazione nutrizionale – Articolo 31, paragrafo 3, secondo comma – Calcolo del valore energetico e delle quantità di sostanze nutritive – Possibilità di fornire tali informazioni per l'alimento dopo la preparazione – Presupposti – Articolo 33, paragrafo 2, secondo comma – Espressione per porzione o per unità di consumo

L'articolo 31, paragrafo 3, secondo comma, del regolamento (UE) n. 1169/2011 del Parlamento europeo e del Consiglio, del 25 ottobre 2011, relativo alla fornitura di informazioni sugli alimenti ai consumatori, che modifica i regolamenti (CE) n. 1924/2006 e (CE) n. 1925/2006 del Parlamento europeo e del Consiglio e abroga la direttiva 87/250/CEE della Commissione, la direttiva 90/496/CEE del Consiglio, la direttiva 1999/10/CE della Commissione, la direttiva 2000/13/CE del Parlamento europeo e del Consiglio, le direttive 2002/67/CE e 2008/5/CE della Commissione e il regolamento (CE) n. 608/2004 della Commissione, deve essere interpretato nel senso che tale disposizione si applica esclusivamente agli alimenti che richiedono una preparazione e la cui modalità di preparazione è predeterminata.

ANIMALI

CGUE, 02/09/2021, C-579/19, Association of Independent Meat Suppliers, Cleveland Meat Company Ltd, contro Food Standards Agency,

Rinvio pregiudiziale – Tutela della salute – Regolamento (CE) n. 854/2004 – Articolo 5, paragrafo 2 – Regolamento (CE) n. 882/2004 – Articolo 54, paragrafo 3 –

Norme in materia di igiene per gli alimenti di origine animale – Ispezione post mortem della carcassa e delle frattaglie – Veterinario ufficiale – Bollatura sanitaria – Diniego – Carne dichiarata inidonea al consumo umano – Diritto di ricorso avverso una decisione del veterinario ufficiale – Tutela giurisdizionale effettiva – Articolo 47 della Carta dei diritti fondamentali dell'Unione europea

1) Il regolamento (CE) n. 854/2004 del Parlamento europeo e del Consiglio, del 29 aprile 2004, che stabilisce norme specifiche per l'organizzazione di controlli ufficiali sui prodotti di origine animale destinati al consumo umano, come modificato dal regolamento (CE) n. 882/2004 del Parlamento europeo e del Consiglio, del 29 aprile 2004, e il regolamento n. 882/2004 devono essere interpretati nel senso che essi ostano a una normativa nazionale in forza della quale, se un veterinario ufficiale rifiuta di apporre un bollo sanitario su una carcassa e il proprietario di tale carcassa non è d'accordo con tale decisione, il veterinario ufficiale è tenuto ad adire un giudice affinché questi decida, nel merito e sulla base di prove peritali dedotte da ciascuna parte, se la suddetta carcassa soddisfi o meno i requisiti di sicurezza alimentare, senza poter formalmente annullare le decisioni del veterinario ufficiale né ordinare la revoca degli effetti di tali decisioni.

2) L'articolo 54 del regolamento n. 882/2004, in combinato disposto con il considerando 43 di quest'ultimo e alla luce dell'articolo 47 della Carta dei diritti fondamentali dell'Unione europea, deve essere interpretato nel senso che esso non osta a una normativa nazionale secondo cui la decisione adottata dal veterinario ufficiale, ai sensi dell'articolo 5, paragrafo 2, del regolamento n. 854/2004, come modificato dal regolamento n. 882/2004, di non apporre un bollo sanitario su una carcassa può essere oggetto soltanto di un controllo giurisdizionale limitato, nell'ambito del quale il giudice adito può annullare detta decisione per qualsiasi motivo che la renda illegittima, comprese le ipotesi in cui detto veterinario abbia agito per uno scopo diverso da quello per cui i suoi poteri gli sono stati conferiti, non abbia applicato i criteri giuridici adeguati o la sua decisione sia priva di fondamento o sia non suffragata da elementi di prova sufficienti.

Cass. pen., Sez. IV, Sentenza, 26/10/2021, n. 41140

Delitti - Furto - Circostanze aggravanti - Animali (abigeato) - Furto di capi di bestiame raccolti in gregge o in mandria - Valutazione della sussistenza della mandria - Criteri

Per il reato di furto commesso sui capi di bestiame riuniti in gregge o in mandria di cui all'art. 625, n. 8, cod. pen., la determinazione della sussistenza dei requisiti propri della mandria è rimessa all'apprezzamento del giudice, il quale deve tenere presente l'oggetto della tutela penale della norma, cioè la salvaguardia della economia e del patrimonio zootecnico.

T.A.R. Lazio Roma, Sez. III quater, 26/08/2021, n. 9395

Animali – allevamento – profilassi - competenza

Le iniziative in materia di contenimento di malattie infettive e diffusive presso gli allevamenti situati nei territori degli Stati membri, individuati mediante decisioni comunitarie, sono riconducibili alla materia di legislazione esclusiva dello Stato, atteso che attengono alla profilassi internazionale e riguardano profili incidenti sulla tutela dell'ecosistema, anch'essa riservata alla legislazione statale.

CACCIA E PESCA

Corte cost., 06/07/2021, n. 138

Esercizio venatorio da appostamento temporaneo - Obbligo di rimozione del materiale usato per la costruzione dell'appostamento al venir meno del consenso del proprietario o conduttore del fondo - Previsione che il consenso si intende validamente accordato nel caso in cui non esiste un formale diniego. Paesaggio - Modifiche alla legge regionale n. 4 del 1999 - Norme in materia di foreste e di assetto idrogeologico - Sistemazioni idraulico-forestale e idraulico-agraria - Limitazioni nei terreni vincolati - Introduzione di categorie di opere non soggette ad alcun titolo abilitativo. Ambiente - Modifiche alla legge regionale n. 35 del 2006 - Misure di salvaguardia in ambito venatorio nelle Zone di Protezione Speciale [ZPS] - Divieto di esercizio dell'attività venatoria nel mese di gennaio, con l'eccezione della caccia da appostamento fisso e temporaneo e in forma vagante, nonché della caccia agli ungulati, per due giornate settimanali a scelta del cacciatore.

È fondata la questione di legittimità costituzionale sollevata in relazione all'art. 2, comma 1, 6 e 9 della legge della Regione Liguria 19 maggio 2020, n. 9 che ha aggiunto, nella parte finale dell'art. 29, comma 13, della legge della Regione Liguria 1° luglio 1994, n. 29 (Norme regionali per la protezione della fauna omeoterma e per il prelievo venatorio), un ulteriore periodo ai sensi del quale "il consenso si intende validamente accordato nel caso in cui non esiste un formale diniego". La disposizione impugnata è ritenuta in contrasto con la riserva di competenza legislativa allo Stato in materia di «ordinamento civile» di cui all'art. 117, secondo comma, lett. l), Cost. in quanto, consentendo ai cacciatori di mantenere, se il proprietario non manifesta espressamente il suo dissenso, sul fondo altrui il materiale utilizzato per la costruzione degli appostamenti temporanei, inciderebbe sulle facoltà dominicali garantite dall'art. 832 c.c. Invero la disciplina del diritto di proprietà attiene alla competenza esclusiva dello Stato in materia di ordinamento civile e l'ordinamento del diritto privato si pone quale limite alla legislazione regionale, in quanto fondato sull'esigenza, sottesa al principio costituzionale di eguaglianza, di garantire sul territorio nazionale l'uniformità della disciplina dettata per i rapporti tra privati. Il limite dell'ordinamento civile, quindi, identifica un'area riservata alla competenza esclusiva della legislazione statale e comprende i rapporti tradizionalmente oggetto di codificazione. Nel caso in esame, la norma impugnata nell'aggiungere nella parte finale dell'art. 29, un ulteriore periodo, introduce una presunzione di consenso del proprietario del fondo al mantenimento su di esso del materiale usato per la costruzione degli appostamenti temporanei, che eccede i limiti del legittimo intervento del legislatore regionale, invadendo la competenza riservata allo Stato nella materia "ordinamento civile".

IMPOSTE, TASSE E CONTRIBUTI

CGUE, 28/10/2021, C-221/20

Rinvio pregiudiziale – Fiscalità – Direttiva 92/83/CEE – Accise – Birra – Articolo 4, paragrafo 2 – Possibilità di applicare aliquote ridotte di accisa alla birra prodotta

dalle piccole birrerie indipendenti – Considerazione di due o più piccole birrerie come una unica piccola impresa indipendente – Obbligo di trasposizione

L'articolo 4, paragrafo 2, seconda frase, della direttiva 92/83/CEE del Consiglio, del 19 ottobre 1992, relativa all'armonizzazione delle strutture delle accise sull'alcole e sulle bevande alcoliche deve essere interpretato nel senso che uno Stato membro che attua la possibilità, prevista all'articolo 4, paragrafo 1, di tale direttiva, di applicare aliquote ridotte di accisa alla birra prodotta da piccole birrerie indipendenti non è, per questa ragione, tenuto a considerare come una unica piccola impresa indipendente due o più piccole birrerie che cooperano e la cui somma di produzione annuale non supera i 200 000 ettolitri.

T.A.R. Campania Salerno, Sez. I, 09/12/2021, n. 2656
Contributi europei – indebite percezioni - sospensione - durata
Stante la natura cautelare della misura di cui all'art. 33, comma 1, del D.Lgs. n. 228/2001, inerente alla sospensione dell'erogazione di contributi comunitari, secondo cui "i procedimenti per erogazioni da parte degli Organismi pagatori sono sospesi riguardo ai beneficiari nei cui confronti siano pervenute da parte di organismi di accertamento e di controllo, notizie circostanziate di indebite percezioni di erogazioni a carico del bilancio comunitario o nazionale, finchè i fatti non siano definitivamente accertati" il relativo provvedimento non deve prevedere un termine finale, in quanto nell'impianto normativo l'efficacia temporale della sospensione non è rigidamente predeterminata, ma risulta ancorata all'esito dei definitivi accertamenti dei fatti posti a fondamento della misura.

Cons. Stato, Sez. II, 29/10/2021, n. 7273
Contributi europei – indebite percezioni - sospensione – natura del potere - comunicazione di avvio del procedimento – non dovuta.
a) Il provvedimento di sospensione dell'erogazione dei contributi, ex art. 33, comma 1, D.Lgs. n. 228/2001, avendo carattere cautelare, non necessita della previa comunicazione di avvio del procedimento.
b) La misura della sospensione dell'erogazione dei contributi avvenuta in violazione dell'art 33 del D.Lgs. n. 228/2001D.Lgs. 18/05/2001, n. 228 ha valenza meramente cautelare ed interinale ed è espressione di un potere discrezionale dell'amministrazione in ordine alla valutazione della consistenza delle notizie circostanziate di indebita percezione di contributi. Dalla valenza meramente cautelare dell'istituto in esame discende che non sono necessarie né la corrispondenza fra le erogazioni per le quali pende giudizio in sede penale e quelle di cui è stata disposta la sospensione, né l'identità tra i soggetti coinvolti nelle "notizie circostanziate" e quelli che operano attualmente per il soggetto colpito dalla sospensione. La sospensione è comunque frutto di valutazione ampiamente discrezionale, e l'apertura di indagini penali e la relativa richiesta di rinvio a giudizio da parte del p.m. garantiscono, in astratto, quel minimo livello di riscontro dei fatti, che consente di adottare il provvedimento cautelare.

Cons. Stato, Sez. III, 12/07/2021, n. 5281
AGEA – Registro nazionale dei debiti – iscrizione a ruolo delle somme - equiparazioneInizio modulo

Fine modulo
In tema di riscossione del prelievo supplementare nel settore del latte, l'individuazione del responsabile del relativo procedimento coincide con l'individuazione del responsabile dell'iscrizione a ruolo, atteso che, a seguito dell'affidamento all'AGEA dell'intero procedimento di riscossione in tale settore, avvenuto con la L. n. 228 del 2012, (cd. legge di Stabilità 2013) la successiva emissione della cartella, da parte dello stesso ente, è atto esecutivo dell'unitario procedimento di riscossione avviato con l'iscrizione a ruolo, non esistendo alcuna separazione tra il procedimento di iscrizione a ruolo (di competenza dell'ente creditore) e quello di emissione della cartella (di competenza del concessionario della riscossione), come invece avviene per la riscossione per le imposte sui redditi. Deve, quindi, ritenersi che nel procedimento di riscossione del prelievo supplementare nel settore latte, poichè esso è interamente affidato al creditore AGEA, l'individuazione del responsabile del procedimento coincida con l'individuazione del responsabile della iscrizione a ruolo, in quanto le successive emissioni e notificazioni, da parte dello stesso Ente, non sono che atti esecutivi dell'unitario procedimento di riscossione avviato con l'iscrizione a ruolo.

PARCHI E AREE PROTETTE

Cons. Stato, Sez. VI, 06/07/2021, n. 5152
Parchi – Interventi ed autorizzazioni – nulla osta - Ente Parco
Il rilascio di concessioni ed autorizzazioni relative ad interventi, impianti ed opere all'interno di un parco è sottoposto al preventivo nulla osta dell'Ente parco attraverso il quale si verifica la conformità tra le disposizioni del piano e del regolamento e l'intervento.

PRELAZIONE E RISCATTO

Cass. civ., Sez. VI - 2, Ordinanza, 03/11/2021, n. 31490
Prelazione – contiguità tra fondi – nozione – contiguità funzionale - esclusione
Il diritto di prelazione e riscatto del coltivatore diretto proprietario del terreno confinante, previsto dall'art. 7, L. n. 817 del 1971, integrando una limitazione della circolazione della proprietà agricola e dell'autonomia negoziale, spetta solo nel caso di fondi confinanti in senso giuridicamente proprio, ovvero caratterizzati da contiguità fisica e materiale, per contatto reciproco lungo la comune linea di demarcazione, non potendo essere esteso alla diversa ipotesi della c.d. contiguità funzionale (fra fondi separati ma idonei ad essere accorpati in un'unica azienda agraria), con la conseguenza che deve escludersi la configurazione di tale "contatto" ove i due fondi siano separati da un corso d'acqua demaniale.

Cass. civ., Sez. III, 20/09/2021, n. 25351
Nuovo affitto – diritto di prelazione – violazione - condizioni
In tema di affitto a coltivatore diretto, la lesione del diritto di prelazione riconosciuto al conduttore, in caso di nuovo affitto, dall'art. 4 bisL. 03/05/1982, n. 203, 4-bis. - Diritto di prelazione in caso di nuovo affitto. della l. n. 203 del 1982, inserito dall'art. 5 del d.lgs.

n. 228 del 2001, presuppone che il locatore: a) abbia ricevuto offerte di affitto da parte di terzi; b) non abbia comunicato all'affittuario, almeno novanta giorni prima della scadenza del contratto, le offerte ricevute; c) abbia concesso il fondo in affitto a terzi entro sei mesi dalla scadenza stessa. Siffatte condizioni, poiché il diritto di prelazione costituisce una limitazione della libertà legale di contrarre, devono essere provate dal titolare del diritto stesso, dovendosi escludere sia che il legislatore abbia inteso stabilire una presunzione assoluta secondo cui i contratti di affitto stipulati entro i sei mesi dalla scadenza del precedente rapporto siano l'effetto dell'accettazione di proposte risalenti ad epoca anteriore ai novanta giorni precedenti, sia che sussista, in capo al locatore, l'obbligo di comunicare le proposte contrattuali pervenutegli dopo la scadenza del predetto termine di novanta giorni, nonché quelle pervenute nei sei mesi successivi alla scadenza del contratto.

Cass. civ., Sez. II, Sentenza, 29/07/2021, n. 21757
Diritto di prelazione - Riscatto - Rimborso del prezzo all'acquirente - Obbligo di corresponsione degli interessi e della rivalutazione monetaria - Esclusione - Fondamento
Nel caso di retratto agrario, il retraente è tenuto a versare esattamente il medesimo prezzo indicato nel contratto di vendita stipulato in violazione del diritto di prelazione, senza interessi e rivalutazione monetaria, atteso che, prevedendo l'art. 8, comma 6, della l. n. 590 del 1965, per l'ipotesi di esercizio del diritto di riscatto, che, anche ove sia sorta controversia giudiziale, il prezzo debba essere versato nel termine di tre mesi dal passaggio in giudicato della sentenza di accoglimento dell'azione di riscatto, prima della scadenza di tale termine l'obbligazione è inesigibile e, quindi, è inidonea a generare interessi ai sensi dell'art. 1282 c.c.

Cass. civ., Sez. II, Ordinanza, 14/07/2021, n. 2007
Prelazione – esercizio – presupposti – soggettivi e oggettivi
Ai fini dell'esercizio della prelazione agraria, è necessario non solo che l'interessato rivesta la qualifica di coltivatore diretto, ma anche che coltivi direttamente il fondo adiacente a quello posto in vendita o quello condotto in fitto, non essendo sufficiente che eserciti altrove l'attività di agricoltore, in quanto l'intento perseguito dal legislatore è l'ampliamento dell'impresa coltivatrice e non l'acquisto della proprietà della terra da parte di qualsiasi coltivatore diretto. La qualità di agricoltore, nel senso anzidetto, non può desumersi da elementi formali, quali gli elenchi redatti dal Servizio contributi agricoli unificati (SCAU), poiché detta certificazione, rilasciata a fini essenzialmente assistenziali, è idonea soltanto a fornire elementi indiziari.

RITROVATI VEGETALI E PRIVATIVE

CGUE, 14/10/2021, C-186/18, José Cánovas Pardo SL contro Club de Variedades Vegetales Protegidas
Rinvio pregiudiziale – Privativa comunitaria per ritrovati vegetali – Regolamento (CE) n. 2100/94 – Articolo 96 – Calcolo del termine di prescrizione dei ricorsi contemplati agli articoli 94 e 95 – Dies a quo – Data della concessione della privativa comunitaria nonché della presa di conoscenza dell'atto e dell'identità dell'autore

– Data della cessazione del comportamento di cui trattasi – Atti successivi – Atti continuati – Limitazione agli atti posti in essere più di tre anni prima

1) L'articolo 96 del regolamento (CE) n. 2100/94 del Consiglio, del 27 luglio 1994, concernente la privativa comunitaria per ritrovati vegetali, deve essere interpretato nel senso che il termine di prescrizione di tre anni previsto da tale disposizione per i ricorsi contemplati agli articoli 94 e 95 di detto regolamento inizia a decorrere, indipendentemente dalla circostanza che l'atto di infrazione di una varietà protetta perduri e dalla data in cui tale atto è cessato, a partire dalla data in cui, da un lato, la privativa comunitaria per ritrovati vegetali è stata definitivamente concessa e, dall'altro, il titolare della privativa comunitaria ha preso conoscenza dell'esistenza di tale atto e dell'identità del suo autore.

2) L'articolo 96 del regolamento n. 2100/94 deve essere interpretato nel senso che sono prescritti solo i ricorsi contemplati agli articoli 94 e 95 di tale regolamento, relativi a un insieme di atti di infrazione di una varietà protetta, che sono stati proposti più di tre anni dopo che, da un lato, la privativa comunitaria per ritrovati vegetali è stata definitivamente concessa e che, dall'altro, il titolare ha preso conoscenza dell'esistenza di ciascuno degli atti, facenti parte di tale insieme di atti, considerato singolarmente nonché dell'identità del loro autore.

USI CIVICI

Cass. civ., Sez. III, Sentenza, 21/10/2021, n. 29344
Usi civici - In genere - Terreno gravato da uso civico - Concessione in godimento a privati mediante locazione - Validità - Condizioni - Fattispecie
La concessione in godimento a privati mediante contratto di locazione di terreni gravati da uso civico è valida a condizione che la destinazione concreta impressa al bene sia conforme all'esercizio del predetto uso e la stessa sia temporanea e tale da non determinare l'alterazione della qualità originaria del bene. In mancanza di tali requisiti - l'onere di provare i quali grava sulla parte che intende far valere in giudizio diritti derivanti dal contratto - quest'ultimo è nullo per contrasto con norma imperativa. (In applicazione del principio, la S.C. ha annullato la sentenza di appello che aveva ritenuto validamente concesso in locazione un immobile appartenente al demanio civico senza accertare la concreta destinazione impressa ad esso con il contratto).

Cass. civ., Sez. II, Ordinanza, 09/09/2021, n. 24390
Usi civici - Procedimento - Prove - Accertamento usi civici - Principio "ubi feuda, ibi demania" - Prova - Contenuto - Distinzione tra usi posteriori e antecedenti al 1800 - Usi su terre ex feudali - Prova documentale - Necessità - Oggetto – Fondamento.
Nel giudizio di accertamento di usi civici, in forza del disposto dell'art. 2 della legge n. 1766 del 1927 e del principio "ubi feuda ibi demania", la prova dell'esistenza, natura ed estensione di usi esercitati anche posteriormente al 1800 può essere offerta con ogni mezzo istruttorio, mentre per quelli il cui esercizio sia cessato anteriormente al 1800 deve essere data esclusivamente mediante documenti propri del diritto feudale, che dimostrino non l'atto formale di investitura e di concessione del feudo, ma la natura ex feudale delle terre

e l'esistenza di un feudo abitato, da ciò direttamente derivando la sussistenza degli usi originari, ossia di quelli necessari secondo i bisogni della popolazione e la natura delle terre, i quali costituiscono il giuridico attributo della feudalità di un determinato territorio abitato.

INDICE

€ 15,00