

Covid-19 and rural landscape: The case of Italy

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ABSTRACT

Throughout the covid-19 emergency, health authorities have presented contagion data divided by administrative regions with no reference to the type of landscape, environment or development model. This study has been conducted to understand whether there is a correlation between the number of infections and the different rural landscapes of the country. Italy's rural landscape can be classified in four types, according to the intensity of energy inputs used in the agricultural process, socioeconomic and environmental features. Type A includes areas of periurban agriculture surrounding the metropolitan cities, type B areas of intensive agriculture with high concentration of agroindustry, type C hilly areas with highly diversified agriculture and valuable landscape, and type D high hills and mountains with forests and protected areas. Areas A and B are located in the plains, covering 21% of the territory and accounting for 57% of the population. They produce most of the added value, consume high levels of energy and represent the main source of pollution. Areas C and D cover 79% of the territory and 43% of the population. We find that provinces with 10% more type C and D areas exhibit on average 10% fewer cases of contagion. The result is statistically significant, after controlling for demographic, economic and environmental characteristics of the provinces. The pollution produced in more energy-intensive landscape has triggered an intense debate of how to ensure the economic competitiveness of Italian agriculture, without compromising environmental integrity or public health. Our findings speak to this debate, by suggesting that planning for more rural territory with lower energy inputs may come with the added benefit of new development opportunities and decreasing the exposure of the population to covid-19. Cost benefit-analyses should take into account that policies aimed at revitalizing more rural areas may reduce the economic impact of covid-19 and of potential future pandemics.

1. Introduction

In the 14th century, Giovanni Boccaccio escaped the Great Plague that was ravaging Europe by finding shelter in the countryside near Florence. Not only did he and his nine companions survive, but he went on to write about that experience in *The Decameron*, widely considered the first example of western narrative. This paper confirms that Boccaccio chose wisely. People living in more rural areas are less likely to contract covid-19. The surprising element of our findings is that they are not explained away by the lower population density of these areas, or other demographic, economic or environmental characteristics.

Italy has been one of the worst hit countries by covid-19 and since February 2020 has been at the forefront in the fight against the pandemic. The first cases were found in Rome, on 31 January, when tourists returning from China were found positive to the virus. As a first measure, Italian authorities suspended all flights to and from China. On 18 February, an outbreak was identified in Codogno (Lodi), triggering wide media reactions and inducing the Italian government to quarantine the town. The contagion subsequently spread first to the nearby municipalities, and eventually to the whole country. Fig. 1 presents a timeline of the events, together with the spreading of the contagion. On 9 March, the country entered the “phase 1”, a partial lockdown of the

commercial, industrial and entertainment activities. This initially involved only the so-called “red areas” (the most afflicted municipalities), but as of 11 March, in combination with the peak of the infections, it was extended to the entire national territory. After 21 March, these restrictions became stricter, by stopping every activity not deemed absolutely necessary. The “phase 2”, with a gradual return to normal activities, started on 4 May. Since the contagion was not yet eradicated, many activities continued to be subject to restrictions (social distancing, booking requirements and obligation of wearing masks indoors).

Official data about contagion have been collected at province level, with no consideration about the different typologies of the territory. The novel perspective of this study is to link the diffusion of covid-19 to the socio-economic and environmental features of the Italian territory. We do so by collecting and matching data on rural classification of Italian regions, cases of covid-19 infections, as well as demographic, economic and health characteristics of the Italian population. We find that provinces with a greater share of rural territory tend to have significantly less exposure to covid-19, controlling for pollution, population and unemployment. The results are not only statistically significant, but economically relevant: provinces with 10% more share of rural land exhibit on average 10% fewer cases of contagion. This is, to the best of our knowledge, the first scientific contribution to consider

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Trend of COVID-19 cases in Italy

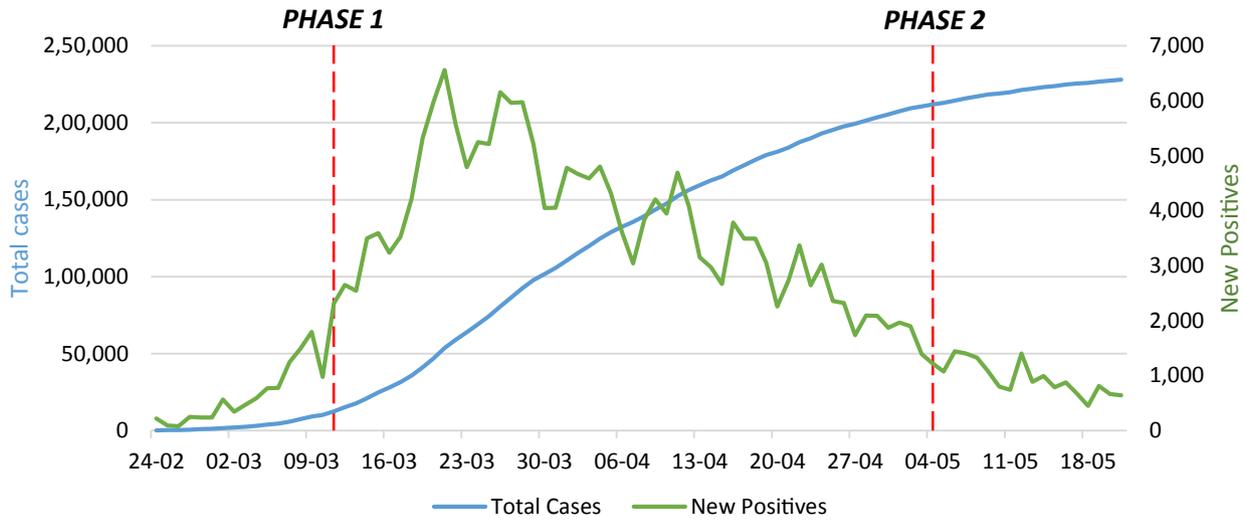


Fig. 1. Chronology of covid-19 infections in Italy.

the problem from this perspective (Torero, 2020).

Understanding the current composition of the Italian territory requires to briefly recalling the changes it went through over the past few decades (see Fig. 2). The period after World War II has been characterized by an increasing exploitation of plains and abandonment of marginal areas (Levers et al., 2018). The abandonment of more than 10 million hectares of agricultural land has resulted in an increase in forests by 8 million approximately (Agnoletti, 2013; ONPR, 2018). The labour force in the agricultural sector went from 42% of the total employment in the after-war period to about the current 4%. These developments have been mirrored by a parallel concentration of the population in urban areas and depopulation of more rural regions (ISTAT, 2018). This is also demonstrated by the reduction of residents in municipalities with less than 10.000 inhabitants, dropping from 45% of the total population in 1951 to 35% in 1971. This trend continued in the following decades, accompanied by a parallel migration from southern to northern regions (De Rubertis, 2019; ISTAT, 2014).

The causes behind these developments are numerous, but to a large extent can be traced to the effects of competition. The need to prosper in an increasingly competitive environment led to the adoption of more specialized cultures, the development of productivity enhancing

techniques and the elimination of traditions such as terracings and low-density systems which were no longer cost effective (Agnoletti et al., 2019). The side effect has been an increase in pollution, as these areas are the main responsible for the production of nitrates, methane and nitrous oxide (Houser et al., 2020). Inverting this trend is part of a larger political debate and requires incentives aimed at ensuring the sustainability of agriculture, without compromising environmental integrity or public health (Tilman et al., 2002).

The findings of this paper speak to this debate by suggesting that cultivating more rural territory with lower energy inputs may come with the added benefit of decreasing the exposure of the population to covid-19 disease. The underlying causes remain unclear. Some studies suggest a relationship with pollution (Wu et al., 2020) or wildlife used as food (Yuan et al., 2020), but more research is needed to confirm our findings at international level and to establish a clearer causal link. However, given the exorbitant costs covid-19 is imposing on our society, preparing for future outbreaks calls for policies that would increase the overall resilience of our system should a new pandemic strike again. Claiming back abandoned land and returning to more landscape friendly cultures should be part of this discussion, as well as re-imagine and re-work agricultural and food systems, perhaps in line with

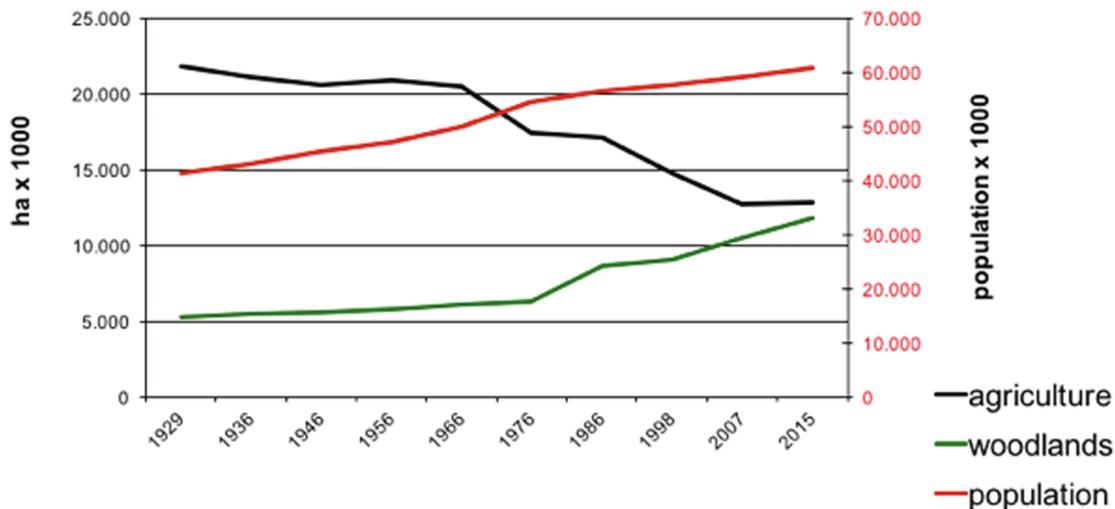


Fig. 2. Population growth and dynamics of the agricultural and forest surfaces in Italy between 1929 and 2015 (Agnoletti, 2013).

different values and strategies (Sanderson, 2020).

The paper is structured as follows. Section 2 describes in greater detail the classification of the Italian territory and its socio-economic and environmental characteristics. It also presents the statistical framework used to analyse the data. Section 3 discusses the results from the regression analysis. Section 4 places our statistical findings into the broader policy discussion. Section 5 concludes.

2. Methods

2.1. Classification of the Italian rural landscapes

The Italian Ministry of Food, Agriculture and Forest Policies has classified the Italian rural landscape into four distinct types. It is an official classification, also adopted by the National Observatory for Rural Landscapes, with precise policy objectives and used to allocate funds for specific interventions. The identified categories are:

- A. Urban and periurban rural landscapes
- B. High intensity landscape types
- C. Medium intensity landscape types
- D. Low intensity landscape types

This type of classification is used both in the context of the National Strategic Plan for Rural Development 2007–13, when landscape was introduced for the first time among the objectives of the plan, and the National Strategic Framework of EU Cohesion Policy. These classifications are also relevant in the context of the Common Agricultural Policy and the Biodiversity Strategy towards 2030, especially when spatial information is required to assess the stated objectives.

Classifications based on intensity of agricultural activities, environmental features and economic development is supported by a rich scientific literature, usually measuring intensity as the anthropogenic energy required in the primary crop production (Tieskens et al., 2017; Estel et al., 2016). The intensification of agriculture with high-yielding crop varieties, fertilization and pesticides led to a substantial increase in food production over the past 50 years, but also had damaging environmental consequences. The amount of nitrogen – a major air pollutant contributing, among other things, to the formation of ozone and acid rains – is a frequently used proxy for agricultural intensity (Overmars et al., 2014; Temme and Verborg, 2011; van der Zanden et al., 2016). Land conversion and agricultural intensification alter the biotic interactions and patterns of resource availability in ecosystems. The implications for the local, regional and global environment can be serious (Erb et al., 2013; Rega et al., 2020).

2.1.1. Urban and periurban landscape types

These landscapes comprise 195 municipalities with high average population density (about 1,510 inhabitants per square kilometre), including regional capitals, large metropolitan cities, as well as those areas with high population density and low territorial extension of agriculture. They include 30% of the Italian population and cover 4% of the territory, representing urban and periurban landscapes in the plains of Italy (see light yellow areas in Fig. 3). They are characterized by a strong presence of the tertiary sector and a moderate level of manufacturing activity. Agriculture accounts for 12% of the national added value, mostly concentrated in territories around large urban centres. These areas provide short-range consumer demand for high-quality products, but the quality standards of production are not always up to the demand. Immediately adjacent to the urban fabric, there is a strong concentration of industrial activities, employing 31% of the agro-industrial workforce. Most of these activities require high external energy inputs, putting these areas in the highly energy-intensive category (Tello et al., 2016).

The urban centres are characterized by highly profitable land, with over €5,000 of added value per hectare of Utilized Agricultural Area

(UAA). The high value of the land results in a significant decrease in total agricultural area in favour of urban sprawl. Indirect impacts on farms of these areas include splitting of cultivation units, constraints on agricultural practices due to the proximity of inhabited centres and pollution phenomena caused by non-agricultural sources (Houser et al., 2020).

Proximity to urban centres makes these areas fairly well equipped with services for the population and the economy. Although no data is available at this level of territorial breakdown, these rural areas are those with a greater supply of internet services. The particular orographic and demographic situation leads to the co-habitation of residential and tourist settlements with highly specialized and intensive agricultural activities. They represent important economic and employment realities, but, at the same time, have a significant environmental impact.

2.1.2. High intensity landscape types

This group includes lowland landscapes that are classified as rural, significantly rural or even urbanized rural. They are located in plains and in the immediately adjacent low altitude hill areas, mainly in the northern regions of the country (see green areas in Fig. 2) as the Po river valley. The urban footprint represents 10% of the territory, cultivated areas 80%, forests 7%. They include over 1,782 municipalities, representing over a quarter of the total national population (27%). These areas constitute the backbone of the agro-industrial system: while they account for 24% of the UAA and 29% of the agricultural workers in the country, they produce 38% of the national agricultural added value.

Type B areas are densely populated (313 inhabitants per square kilometre). Its population is relatively younger and growing strongly (more than 10% in the last decade) attracting young people from marginal rural areas and the south of the country. Agricultural and forest areas cover 87% of the territory and there is also a strong specialization in agricultural production and food industry, with a concentration of agro-industrial chains.

The strong agricultural specialization and recent migratory phenomena have led, in some specific areas, to increase competition in the use of primary resources, creating problems of environmental impact and sustainability of agricultural activity. These areas have a higher concentration of zones vulnerable to nitrates, over 35% of the country's total against an area of about 5%, causing river degradation and harming people's respiratory system (Ladrera et al., 2019; Arauzo et al., 2011; Burt et al., 2010). Type B zones include also 6% of the national protected areas that fall within the Natura 2000 network. They are, nevertheless, significantly affected by the strong anthropization of the territory and by the commercial and tourist industry.

2.1.3. Medium intensity landscape types

This typology includes mostly hills and small parts of mountain landscapes, especially in the center of the country, but also in the north and south of Italy. They are mainly or significantly rural and have a good level of diversification of economic activities (see orange areas in Fig. 2). There are 3,084 municipalities, representing about 30% of the Italian population and 33% of the territorial surface. The urbanized area covers 5% of the total territory, agricultural area 62%, forest area 29%. The population has grown by 5.7% in the last decade, but is characterized by a higher aging index. Agriculture plays a significant role, both in terms of surface and employment, even if the intensity of production is more modest than in previous areas (about €2,200 per hectare). In the last decade, this type of landscape has shown strong signs of crisis, significantly losing agricultural area (–12% of UAA and –14% of Total Agricultural Area (TAA), with percentages that drop respectively to –18% and –20% in the less developed regions) and jobs (–27%). The main factors behind these developments are the high production costs and lower profitability due to the morphology of the territory and the presence of traditional agricultural arrangements, such as terraces and polycultures (Barbera and Cullotta, 2016). These

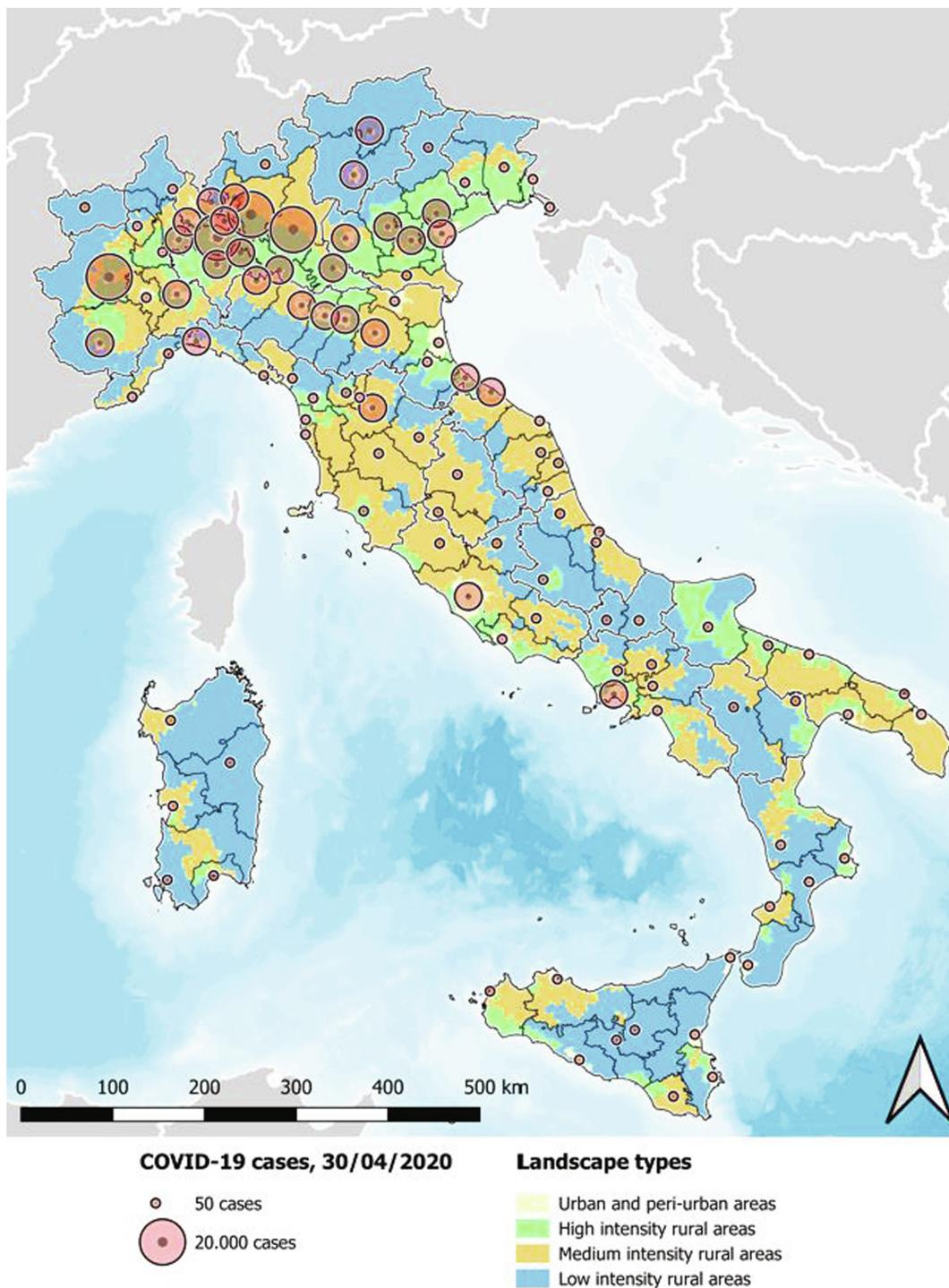


Fig. 3. Map of rural landscape types with the distribution of cases of COVID-19.

problems are compounded by commercial difficulties of promoting the rich variety of typical products, abundant in these areas.

Farmers with alternative income represent 28% of the total also because agriculture in these areas is complementary to other activities and promotes growth of the local economic system in an integrated form. The highly qualified agricultural sector is supported by the presence of highly valued resources such as attractive landscapes, cultural and historical landmarks, as well as typical food and wine. This is confirmed by the fact that more than 83,9% of agritourism firms is located on mountain and hilly areas in Italy. Synergies among these

resources help create an integrated local economic system, with a balanced development of tertiary activities related to tourism, trade and specialized services. These areas can be considered as cultural landscapes, where the term cultural becomes a value-laden concept putting a premium on historical agricultural traditions (Agnoletti, 2013; Antrop, 1997; Bignal and McCracken, 1996; Fischer et al., 2012; Plieninger et al., 2006).

About 23% of Natura 2000 areas of Italy are concentrated in this area, for a total surface of about 10%. The nitrate vulnerable areas instead represent 29% of those identified at national level, with an

incidence on the total area of only 2.3%. The infrastructure is typically rural, limited to roads and railways, with often reduced connections and services. The same goes for telematic infrastructures, with broadband serving only a minority of the population. The reduced specialization of agriculture, less developed infrastructure, the lower urban and industrial concentrations, and the good presence of natural and landscape resources contribute to classify these areas as medium energy-intensity (Marull et al., 2016).

2.1.4. Low intensity landscape types

These areas include 2,865 municipalities, mostly in the mountains and significantly rural high hills in southern Italy, the central and northern mountains with a more markedly rural nature, and some areas of the southern plains and islands (see blue areas in Fig. 2). The urbanized area covers 2% of the territory, the agricultural areas 34% and forests 54%. They are the least densely populated areas of the country (59 inhabitants per square kilometer), characterized by scarce presence of local development processes in all sectors and abandonment by the population (−0.76% in the last decade). The demographic decline in southern regions has been accelerated by migration, particularly from mountain areas, consistent with developments in other European mountain areas (Macdonald et al., 2000). The aging index is far above the national average. Type D areas represent 13% of the population, occupy 46% of the country's territory, 42% of the TAA and 35% of the UAA. They represent 20% of the agricultural workers and 18% of the national added value. The agricultural workers in these areas are around 225,000, the agro-industrial 53,000, the non-agricultural 2.6 million.

The presence of widespread extensive agriculture is accompanied by the presence of most of the Italian forests (69%) and a great variety of natural habitats. These areas are of particular environmental importance, with 68% of Italian protected areas and over 62% of Natura 2000 areas, accounting for more than 2.5 million hectares and an incidence on the total area of over 21%. This contrasts sharply with the rapid agricultural intensification that occurred in Europe and northern Italy after World War II, which sacrificed heterogeneity for more homogeneous and commercially profitable landscapes (Agnoletti, 2013; Bignal and McCracken, 1996; Isselstein, 2003). Only 16% of the nitrate vulnerable areas are located in these areas, with an incidence on the total area of 1%. Type D areas can be classified as low energy-intensity, given their limited industrial, urban and infrastructural development.

Farming is characterized by low levels of profitability of the land (just over €1,000 per hectare of Utilized Agricultural Area) and a low level of production intensification (on an average of 100 ha of Total Agricultural Area only 56 are used). Abandonment processes are particularly intense, especially in the inner mountains. Traditional Mediterranean crops (olive trees, vines, promiscuous arboriculture with arable crops, forest crops) are widespread even if at low productivity and characterized by traditional planting schemes and reduced presence of chemical inputs in the land. The chances of survival and growth of these realities are connected to the local resources. They range from the more effective promotion of typical and quality products, to development based on diversification of local economic activities, and attraction of tourism through environmental resources and cultural landscapes, when not affected by intense abandonment and inappropriate policies (Agnoletti, 2014). This could help alleviate socio-economic problems, such as high unemployment levels, lower disposable income, gap in the provision of services compared to other areas of the country.

Overall, type A and B areas account for 21% of the Italian territory and 51% of the population. They can be described as high energy-intensity areas due to a combination of factors like urban areas, industrial facilities and intensive farming. Type C and D areas, on the other hand, account for 79% of the Italian territory, 43% of the population. They can be classified as low energy-intensity areas.

2.2. Applied statistical analysis

The objective of this study is to understand whether there is a correlation between the different landscape types and the cases of covid-19 contagion. To answer this question, we first match four different databases and next discuss the econometric strategy to analyse the data.

The type of data used and related sources are the following.

- i. **Administrative borders:** the shapefiles available on the website of the Italian statistical agency (ISTAT) provide the administrative borders for towns, provinces and regions. (<https://www.istat.it/it/archivio/222527>)
- ii. **Covid-19:** the website of the Health Ministry provides data on total covid-19 cases for each Italian province. The cut-off date for our analysis is 30 April 2020. (<http://www.salute.gov.it/portale/nuovocoronavirus/dettaglioContenutiNuovoCoronavirus.jsp?area=nuovoCoro%20navirus%20&id=5351&lingua=italiano&menu=vuoto>, last update 30/04/2020)
- iii. **Demographics:** data about population is obtained at province level by ISTAT, as of 2019. (<http://demo.istat.it/index.html>, last update 30/04/2020.)
- iv. **Classification of the Italian rural landscape types:** This classification has been described in the previous section and it is based on data provided by the Ministry of Food, Agriculture and Forest Policies. (<https://www.reterurale.it/psrn>)

A visual representation of the data is presented in Fig. 3. The figure maps the Italian territory into its different landscape types and superimposes the number of covid-19 cases per province. The high correlation between high energy-intensity landscape and contagion is self-evident. We first complement this graphical analysis with a few summary statistics and next proceed to a more formal econometric analysis.

Since the data on contagion are provided at province level, we need to work at this level of aggregation, even though the classification of rural areas is available at a finer degree of precision.

It is worth noting the uncertainty of available official data, particularly pertaining to the true baseline number of infected cases, potentially leading to ambiguous results and inaccurate forecasts (Anastassopoulou et al., 2020).

We impute the contagion cases to the different rural areas following two alternative hypotheses.

- Proportional to the landscape types – We compute for each province the percentage of surface occupied by type A, B, C and D areas and allocate the number of contagion available per province according to this percentage break down. We further divide by the total surface in square kilometres and report the results per 100 km².
- Proportional to the rural population – We compute for each province the percentage of population living in type A, B, C and D areas and allocate the number of contagion available per province according to this percentage break down. We further divide the number of inhabitants and report the results per 10.000 people.

To further simplify, we report the results in two macro-categories:

- Intensive landscapes: areas A and B
- Non-intensive landscapes: areas C and D

The results are reported in Table 1. It shows that intensive landscape areas have on average a higher number of infected people. The gap between intensive and non-intensive landscapes is more pronounced when contagion is computed proportionally to the areas, than when it is computed proportionally to the population living in those areas. This is not surprising: the population is not homogeneously distributed within the province according to its rural composition, but tends to be more

Table 1
Summary data of COVID-19 infections in different areas.

Typology of rural areas	A. Proportional to areas ^a	B. Proportional to population ^b
National average	67	34
Intensive landscape (A + B)	134	37
Non-intensive landscape (C + D)	49	28

^a Per 100 km².

^b Per 10.000 inhabitants.

concentrated in intensive landscape areas. The second classification takes this partially into account and shows a much lower gap. These descriptive statistics raise three obvious concerns. First, since data on covid-19 is available only at province level, the attribution of cases within the areas of each province is arbitrary (even though the allocation proportional to the population appears to be more plausible). Second, the difference between the intensive and non-intensive landscapes could be entirely explained by the higher population density of the intensive areas, as the drop in column B of Table 1 seems to suggest. Third, is the difference statistically and economically significant?

We address each of these issues simultaneously with the help of a linear regression analysis. The dependent variable to be explained is the number of covid-19 cases per province. The explanatory variables are the percentages of type A, B, C and D per province. We compute these percentages in the two alternative ways already discussed: first as a fraction of the total surface and second as a fraction of the total population. In the empirical analysis, we focus on this second definition, as it provides a more plausible classification and it fits the data better. We also use as controls the average age, the density, the percentage of population relative to the national total, the level of pollution, the rate of unemployment, the percentage of over 65 and the mortality rate. All statistics are computed at province level, with the exception of the level of pollution which is available only at regional level. We refer to the notes at the bottom of Table 2 for a precise definition of each variable. All the data comes from the ISTAT database site (<http://dati.istat.it>).

The data characteristics are summarised in Table 2. The average number of cases is 34 per 10,000 inhabitants, ranging from a minimum of 2.6 registered in Sud Sardegna, to a maximum of 168 in Cremona. Areas A, B, C and D accommodate about 22%, 23%, 35% and 21% of the population, respectively. The average age of the population is 46, with a maximum of 49 in Savona and Genoa and a minimum of 41 in Naples. The most and least densely populated provinces are Naples and Nuoro, respectively. The most and least populous provinces are Rome

Table 2
Summary statistics.

	COVID	A	B	C	D	AGE	DENSITY	POP	POLLUTION	UNEMP	OVER_65	MORTALITY
Mean	34	22%	23%	35%	21%	46	270	0.93%	2%	10%	24%	11
Median	21	20%	11%	32%	7%	46	176	0.64%	0	8%	24%	11
Maximum	168	100%	90%	100%	100%	49.4	2617	7.19%	7%	29%	29%	15
Minimum	2.65	0%	0%	0%	0%	41.8	37	0.14%	0	3%	18%	8
Std. Dev.	32	20	27	32	29	1.64	382	1.02	3%	6%	2%	1

Note: the variables are defined as follows:

- COVID = cases per 10,000 inhabitants by province
- A, B, C, D = percentage of population in each area according to rural classification
- AGE = average age of citizens by province
- DENSITY = inhabitants per square km by province
- POP = percentage of province population, relative to country population
- POLLUTION = percentage of population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year (data available only by region)
- UNEMP = percentage of unemployed relative to the population between 15 and 74 years old
- OVER_65 = percentage of population over 65 years of age
- MORTALITY = deaths over population times 1,000

and Isernia, with 7,19% and 0.14% of the Italian population. The average unemployment is 10%, Crotone has the highest rate (29%) and Bolzano the lowest (3%). The provinces with the highest and lowest percentages of over 65 are Savona (29) and Caserta (18). Finally, mortality rates are highest in Alessandria (18) and lowest in Bolzano (8).

Since type-D areas tend to be scarcely populated, type-C and type-D areas are aggregated into a single category, and we consider in the regression analysis only non-intensive landscape areas. All standard errors are heteroscedasticity consistent, following White (1980). We run regressions at an increasing level of sophistication.

First, to have an initial confirmation of the validity of the results of Table 1, a simple regression is estimated, without controls. These results serve to understand whether the relation between the cases of covid-19 and rural areas found before is also statistically significant:

$$\text{Model1: COVID} = \beta_0 + \beta_1(C + D)$$

Since the sum of the two areas (intensive and non-intensive) is 100 by construction, intensive areas are omitted from the regression and are absorbed by the constant. Estimating Model 1 with (A + B) as regressors instead of (C + D) gives the same value for the coefficient β_1 , but with opposite sign.

Second, one obvious concern is that the energy-intensive areas are also those more densely populated, and therefore more prone to the diffusion of covid-19. To rule this possibility out, we control for a number of variables:

$$\text{Model2: COVID} = \beta_0 + \beta_1(C + D) + \beta_2X$$

where X includes demographic, economic, health and environmental variables.

Third, we relax the assumption of linear relationship, by adding quadratic and cubic terms of the control variables. We have also added the share of population older than 65, as older people have been disproportionately affected by covid-19. The specification takes the following form

$$\text{Model3: COVID} = \beta_0 + \beta_1(C_1 + D_1) + \beta_2X + \beta_3X^2 + \beta_4X^3$$

where X stands for the control variable whose nonlinearity is being tested and we allow for nonlinearity in more control variables.

Fourth, given that our data is collected with reference to provinces, which can be measured as points in space, we consider also spatial variables. The concern addressed here is that the relationship between covid-19 and the control variables may be entirely explained by the proximity with the epicentre of the contagion. For instance in Italy, one of the worst hit regions was Lombardy, a region with a high share of

energy-intensive landscape. It is reasonable to suspect that neighbouring provinces may have been more exposed to covid-19 than those further away, as our Fig. 1 visually confirms. Spatial information can be incorporated in numerous ways. There is a large literature on spatial econometrics discussing alternative parsimonious specifications (see Le Sage, 1999, for a comprehensive review). Spatial econometrics can be quite involved, requiring non-standard estimation techniques, due to the endogeneity of the dependent variables (see Le Sage, 2008, for a recent review). In this paper, we adopt a simple approach which makes direct use of the latitude-longitude coordinates associated with the provinces included in our analysis. Denoting with Z_m and Z_p the spatial coordinates of a province (where m stands for meridian and p for parallel), we compute the Euclidean distance from the province of Bergamo as $D = \sqrt{(Z_m - Z_m^0)^2 + (Z_p - Z_p^0)^2}$, where (Z_m^0, Z_p^0) denote the coordinates of Bergamo. We chose Bergamo as reference point, as it was the worst hit province of Italy. We then augmented the model with this distance as an additional variable:

$$\text{Model4: COVID} = \beta_0 + \beta_1(C_1 + D_1) + \beta_2X + \beta_3D$$

where again X stands for the generic control variable.

Since the number of possible regressors can be very large and we have a relatively small sample of observations, we use the Akaike Information Criterion (AIC) and the adjusted R^2 for model selection purposes. The best model minimises the AIC and maximises the adjusted R^2 .

3. Results

All the results of our econometric analysis are reported in Table 3, which is structured as follows. The dependent variable is always COVID, while the control variables used in the analysis are reported in the first column on the left. Although many alternative specifications have been estimated, we report in this table only six of them, labelled in the first row according to the model typology. For each coefficient, we report the ordinary least square (OLS) value, with the robust standard errors in parenthesis. Statistical significance at 1%, 5% and 10% levels is denoted by three, two and one star respectively. Coefficients without stars are not statistically significant at conventional confidence levels. The last two rows of the table report the AIC and adjusted R^2 .

The simplest possible specification is Model 1. The coefficient associated with the non-intensive landscape areas is negative (-0.29) and statistically significant at 1%. The interpretation is that provinces with

a higher share of non-intensive landscape areas tend to have lower cases of covid-19. Taken at face value, this result says that if one were to increase C and D areas by 10%, one should on average observe 2.9 less covid-19 cases per 10,000 inhabitants (=0.29*10). Since the average number of overall covid-19 cases is 34 per 10,000 inhabitants (see Table 1), this corresponds to almost a 10% decrease. The result is therefore not only statistically significant, but also economically meaningful.

Model 2 includes various control variables to provide a first check that the negative correlation found so far is not spurious. Adding demographic, economic and health data substantially increases the fit of the model, as can be seen by the adjusted R^2 jumping from 0.08 to 0.50. Adding these controls reduces by about a half the coefficient associated with the non intensive areas (-0.15), which however remains significant at the 10% level. Of the control variables, only the levels of pollution and unemployment appear to be statistically significant, implying that provinces with higher levels of pollution and lower levels of unemployment tend to be more affected by covid-19. This result is intuitive and consistent with the punchline of this paper: more energy intensive areas tend to be more polluted and characterised by lower levels of unemployment. The result of this regression says that the landscape composition of the provinces continues to be negatively correlated with covid-19 infection rates over and above their levels of pollution and economic activity. Under Model 2A, we have selected the variables which minimise the AIC, a standard way to perform model selection in econometrics. Although we have not performed a systematic search across all possible model specifications, Model 2A improves over Model 2, as can be seen by the lower AIC and higher adjusted R^2 . Our coefficient of interest, $C + D$, remains negative and statistically significant at 10%.

Model 3 considers robustness to non linearities. We have added square and quadratic terms of some of the control variables (age, density and pollution), as well as the share of inhabitants over 65. The coefficient associated with the non intensive areas is still negative and with a higher statistical significance (it is now significant at 1%). Model 3A optimises the non linear variables using the AIC criterion. We notice that the fit of this non linear model is not as good as that of Model 2A.

Finally, Model 4 addresses non linearities by taking into account spatial dependence by adding the distance of each province from Bergamo as explanatory variable. The distance is significant and with the expected negative sign: provinces further away from Bergamo tend to have lower rates of covid-19 infection. Results (not reported here)

Table 3
Linear regressions.

Dependent variable: COVID						
	Model 1	Model 2	Model 2A	Model 3	Model 3A	Model 4
C + D	-0.29 (0.09)***	-0.15 (0.08)*	-0.14 (0.07)*	-0.31 (0.1)***	-0.27 (0.08)***	-0.14 (0.07)*
AGE		-0.37 (4.85)		1145 (1925)		
DENSITY		-0.01 (0.01)		-0.01 (0.04)		
POP		-2.36 (1.69)	-3.66 (1.74)**			-3.71 (1.67)**
POLLUTION		5.48 (1.19)***	5.55 (1.09) ***	3.37 (7.05)		5.31 (1.12)***
UNEMP		-2.42 (0.51)***	-2.23 (0.35) ***			-1.74 (0.38)**
OVER_65		0.76 (4.20)		6.43 (4.06)	3.00 (0.88)***	
MORTALITY		2.87 (3.44)				
AGE ²				-24 (42)		
AGE ³				0.18 (0.31)		
DENSITY ²				-3E-5 (4E-5)	-3E-5 (1E-5)**	
DENSITY ³				1E-8 (1E-8)	1E-8 (6E-9)**	
POLLUTION ²				-3.52 (3.05)		
POLLUTION ³				0.59 (0.33)*	0.16 (0.02)***	
DISTANCE						-2.39 (1.01)**
Obs	107					
AIC	9.71	9.15	9.09	9.32	9.24	9.09
Adjusted R ²	0.08	0.50	0.52	0.43	0.45	0.52

Note: White (1980) robust standard errors in parenthesis. ** denotes significance at 5% level, *** significance at 1%.

are robust to breaking the measure in short and long distances. Although statistically significant, adding the distance increases the fit of the model only marginally, since the AIC and adjusted R^2 are only slightly better than those of Model 2A (the numbers are identical, as the improvement is at the level of the third decimal). More importantly for the discussion of this paper is that the coefficient associated with $C + D$ is still negative and still statistically significant.

Overall, we can conclude that our econometric analysis points to a robust relationship between the composition of the Italian rural landscape and covid-19 infection rates. One important caveat is that correlation does not imply causation. Many other factors, not considered in our analysis, may be responsible for this correlation. For instance, these regions are also characterised by colder temperatures and higher humidity levels, which in turn may be correlated with the share of energy-intensive areas and exposure to covid-19. More research is needed to shed light on the true causal links behind our findings.

4. Discussion

The COVID-19 pandemic has led to the publication of numerous articles in many fields of study. The most analysed topics are related to the economic impact of the pandemic on the agricultural market, both from a global point of view (Elleby et al., 2020) or from a local point of view (Villulla, 2020; Weersink et al., 2020; Kumar et al., 2020), including articles considering food production (Torero, 2020). Some studies have also linked the expansion of the intensive agriculture to the increasing insurgence of the zoonotic infection like the COVID-19, underlying the consequence of the deforestation process that reduces the distance between the humankind and the wild animals (Baudron and Liégeois, 2020). There are studies investigating the spatial and temporal distribution of the infection, but without taking into account the type of agricultural landscape (Xie et al., 2020; Kuebart and Stabler, 2020). The attempt of this research is to offer another point of view, crossing the spatial distribution of the infection with the type of agricultural landscape, in order to find a possible correlation between the spread of the virus and the intensity level of the agricultural landscape.

From this point of view, our empirical analysis reveals the presence of a strong negative correlation between less energy-intensive landscapes and covid-19. These results are confirmed by a more formal regression analysis and are robust to a variety of controls, such as demographic, economic, health and environmental variables, as well as potential non linearities and spatial dependence. The results are even more striking if one considers that the population of less energy-intensive provinces is on average older and according to the most recent medical research more vulnerable to the virus (Williamson et al., 2020).

The ultimate causes behind the strong negative correlation remain unknown and more research is needed on an international scale to confirm the statistical results of this paper and to find possible scientific explanations. What is certain is that energy-intensive areas are also more vulnerable to pollution by nitrates, methane and emissions of nitrous oxide (Houser et al., 2020) and they are also contributing to ecosystem simplification, loss of ecosystem services and species extinctions (Tilman et al., 2001). Independently of whether there is a causal link between pollution and covid-19, incentives for a more sustainable agriculture are needed to meet the demands of improving yields without compromising environmental integrity or public health (Tilman et al., 2002). The presence of the strong correlation between energy-intensive landscapes and contagion unearthed in this paper should provide an additional rationale for the scientific and political communities to rethink the relationship between humans and their territory.

From the environmental point of view, the potential of low-energy agriculture should be acknowledged by policy-makers and the general public, as already suggested in the past (Bignal and McCracken, 1996). Protecting European landscapes and biotopes of high natural

conservation value requires low-intensity farming. Maintaining farmers in rural areas would contribute to reducing hydrogeological risk and the loss of fertility due to the abandonment of traditional agricultural practices (Agnoletti et al., 2019). It would also foster sustainable quality food resources, one of the most important assets of the Italian rural economy (ISMEA, 2018), and reduce the tendency to import raw material from abroad. Most of this farmland has little political clout, with decisions often shaped by farm businesses lobbying at European and national levels. The positive externalities associated with the conservation and correct management of the landscape resources should weigh in the economic assessment of rural development strategies.

This discussion is intimately linked to the broader issue of which actions are best suited to help the Italian economy emerging from the severe recession triggered by the pandemic. Many economists think that the most expansionary fiscal policy at the current juncture is investment in health research, because until a cure is available, people continue to be afraid to resume their normal life. Even if large subsidies are granted to sustain their livelihood, chances are that they will go unspent because they are paralyzed with fear (Summers, 2020). From this perspective, policies aimed at returning people back to rural areas, to the extent that they reduce contagion and inject confidence, have a fiscal expansionary element which should be taken into account when performing a cost-benefit analysis. This holds true not only in the current circumstances but especially in the light of future pandemics, suggesting different policies for the different parts of the territory.

People have moved out of rural areas for a variety of reasons. They will not go back unless proper incentives are provided. We highlight three main avenues. First, the next EU Common Agricultural Policy 2021–2028 should promote a sustainable development of less energy-intensive areas, aimed at reducing or reverting the depopulation of these territories. The main objective should be to identify opportunities based on the specific unique resources of these areas rather than trying to make them function in the same way as “mainstream industrialized regions” (ESPON, 2018). Second, larger investments in information and communication technology (ICT) are fundamental for these regions. The percentage of agricultural firms using ICT stands at only 3.8% and is concentrated (54% of the total) in northern Italy (ISTAT, 2014). Third, access to healthcare, welfare and education services can be drastically improved by more general digitalisation. Faster internet connections should be considered as a basic public service.

5. Conclusions

Italians living in less energy-intensive landscapes are less exposed to covid-19. Less energy-intensive landscapes have an average of 49 infected per square kilometre and 28 per 10.000 inhabitants, compared to 134 per square kilometre and 37 per 10.000 inhabitants in more energy-intensive zones. These results are confirmed by a more formal regression analysis and are robust to a variety of controls.

The payoffs for the country to revitalize rural areas can be large, paving the way to a more sustainable development model, valorizing landscape and local economic resources (ISTAT, 2016). The findings of this paper add another payoff, potentially the largest of all: making the population more resilient to the current and future pandemics. Not everybody will be inspired as Boccaccio to produce a timeless masterpiece, but a more harmonious and balanced relationship with our environment will surely help our society to better cope with the unknown ahead of us, including socio-economic and environmental challenges.

CRedit authorship contribution statement

Mauro Agnoletti: Conceptualization, Investigation, Data curation. **Simone Manganelli:** Formal analysis, Methodology. **Francesco Piras:** Data curation, Investigation.

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