In the first wave of the 2020 pandemic in several areas more sunlight less pandemic, more pigs more pandemic, and lower correlations with some other livestocks.

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Editorial note:
This text has been written in a short period of time, in the urgency of the dramatic 2020 pandemic, and then it is likely to contain some oversights, hopefully little.

Abstract

This study is essentially devoted to show statistical correlations between the intensity of the famous 2020 pandemic (variously measured) and the numerical presence of pigs (farm pigs and very cautiously wild boars) and secondarily other livestocks and even humans, following previously published results. On the whole bovine and other livestocks show lower correlations than pigs. The statistical correlation between pigs and the pandemic is studied at the levels of the provinces of Lombardia, the regions of Northern Italy, the regions of Ukraine, the countries of Southern Europe, and sketched for other areas. In Lombardia a very high correspondence is found, where farm pigs presence is overwhelming, and air is so little circulating, preserving the geographical correspondence. Pigs are not pets to contact directly: this study is essentially statistic, nevertheless it suggests that some livestocks, and especially pigs, produce aerosol to which the human virus attaches, allowing a long distance inter-human contagion, which makes questionable almost all the commonly used measures to counter the pandemic. The known protective correlations of the pandemic with the latitude and very likely sunlight are considered and integrated in the model. Clues have been found that the pig correlation fades from Spring to Winter 2020, maybe due to greater air circulation, destroying the geographical correspondence between pigs and the pandemic intensity.

Keywords: sunlight, latitude, pigs, wild boars, bovine, livestocks, covid-19, epidemic, pandemic, syndemic, aerosol

Contents

0 Prologue

In mid-April 2020 some Italian media published a statistic according to which the top 4 Italian regions for deaths per million of the pandemic were in the same order as the top 4 regions for density of farm pigs.
At this point a statistician jumps out of the chair.
The 20 Italian regions given in any order can be reordered in more than 2.4 billions of billions of ways and of these less than 1 hundred thousandth have in the first 4 positions the same order they had before the reordering.

Of course it could be a spurious correlation, with a hidden variable.

Nevertheless other similar statistical correlations will be here sought.

WHO/OMS urges[1] investigations about the routes of contagion.

PRIMVM NON NOCERE

First, do no harm

— Hippocrates, V century BC

0.1 Flash-forward

In this research patterns of the 2020 pandemic epidemic are investigated.

A statistical point of view will be kept mainly.

Almost all is based on a research which found – at country level, Italy – a *high* correlation of the deaths with the population density of farmed pigs, which here we quantify as

$$p < 10^{-5}$$

and a research which found – at world level – an *extremely high* correlation of the pandemic intensity (measured by maximum number of daily SARS-CoV-2 cases) with the sunlight at different latitudes finding

$$p < 10^{-8}$$

Almost all the present research develops the second line (that of pigs) till finding (at regional level, in Ukraine, see 13.3.2) a statistical significance

$$p < 10^{-5}$$

Due to
 so high *statistical* significances
and to
 an immediately visible *virolgical* rationale (see 18.1 and 18.4),
the new model appears

second way of contagion:
 long distance – by aerosol from pigs – human to human
 (and to a lower extent from other livestocks)
beside usual way: short distance – by droplets – human to human.

0.2 Background

The Lancet writes[2] that this epidemic it is a syndemic:

> Two categories of disease are interacting within specific population – infection (...) and an array of non-communicable diseases (NCDs). These conditions are clustering within social groups according to patterns of inequality (...) is a syndemic.

Italian *Istituto Superiore di Sanità* writes[3]

> Mean age of patients dying for SARS-CoV-2 infection was 80 (...) median 82 (...) average number of pathologies observed in women is 3.7 (...) men the average number of pathologies observed is 3.4

and similar correlations have been observed elsewhere.

Now we state this 3 patterns of the way of hitting of the epidemic:

old, ill, poor.

But the Italian most hit region of the 20 Italian regions, Lombardia, is one of the the richest in Italy which in turn is quite a rich country, and is under the median in Italy by age population, and its population may not be characterized as particularly ill.

Turning from *individuals* to *geographic communities* a link is missing.

We are going to state 2 other patterns, and a link between them:

pigs (the bad) and **sunlight** (the good).

0.3 Climate and the epidemic

0.3.1 Sunlight and the epidemic

An extremely high correlation of the epidemic with latitude found in a study[62] that explicitly consider *"the potential of Solar UVB/A photons to inactivate a virus in air (aerosol)"*.

It must be remarked the very highly significant level of the statistic

$$p < 10^{-8}$$

Another indirect confirmation is in a research[63] finding that the October 2020 COVID-19 boost date in several European countries highly correlates with the latitude and not with the temperature.

In that study the cause is identified in vitamin D, and that interpretation here will be not challenged, because of so many papers on beneficial effects[67][68] of vitamin D; at now even something with specific data[69][70] from the present epidemics.

Instead, previous study indicated an inactivating action of sunlight on the pathogen.

In fact, sunlight may really reduce the contagion in 2 ways:
inactivating the pathogen (in the air, and on objects).
boosting human resistance to the pathogen.
In the latter way, an obvious pathway – possibly not unique – is vitamin D production in human body.

0.3.2 Winds and other climatic factors and the epidemic

In this study essentially spatial correlations will be searched and found between the epidemic and pigs. Then strong air circulation is an issue in the attempt to prove the thesis because reduces the spatial correlation, carrying far the pathogen before it is inactivated by sunlight.

Some climatic factors besides sunlight have already been shown to influence the epidemic.

It has been [5]written:

> Our main findings highlight that temperature and humidity related variables are negatively correlated to the virus transmission, whereas air pollution ($PM_{2.5}$) shows a positive correlation (at lesser degree). In other words, COVID-19 pandemic transmission prefers dry and cool environmental conditions, as well as polluted air.

It has been [74]written:

> In this study we show that an unusual persistent anticyclonic situation prevailing in southwestern Europe during February 2020 (i.e. anomalously strong positive phase of the North Atlantic and Arctic Oscillations) could have resulted in favorable conditions, in terms of air temperature and humidity, in Italy and Spain for a quicker spread of the virus compared with the rest of the European countries. It seems plausible that the strong atmospheric stability and associated dry conditions that dominated in these regions may have favored the virus's propagation, by short-range droplet transmission as well as likely by long-range aerosol (airborne) transmission.

In the proposed model, wind could increase the epidemic spreading the pathogen on long distances, but may shadow the statistical spatial correlations between epidemics and pigs.

0.3.3 Air pollution

It has been[79] written in a scientific paper:

> COVID-19 death counts were collected for more than 3,000 counties in the United States (representing 98% of the population) up to April 22, 2020 from Johns Hopkins University, Center for Systems Science and Engineering Coronavirus Resource Center. (...) A small increase in long-term exposure to $PM_{2.5}$ leads to a large increase in the COVID-19 death rate.

It has been[83] written in a scientific paper:

> we estimate the relationship between long term air pollution exposure and Covid-19 in 355 municipalities in the Netherlands. Using detailed data we find compelling evidence of a positive relationship between air pollution, and particularly $PM_{2.5}$ concentrations, and Covid-19 cases, hospital admissions and deaths. This relationship persists even after controlling for a wide range of explanatory variables.

The effect of $PM_{2.5}$ on the contagion may be due to at least 3 causes:

1) inflammation of human tissues, promoting the illness;

2) transportation[65] of the pathogen;

3) sunlight shadowing, reducing UV inactivation of the pathogen.

All apply outdoor and the first 2 apply also indoor.

Several components of air pollutants are reduced by negative ions.

0.3.4 Clouds

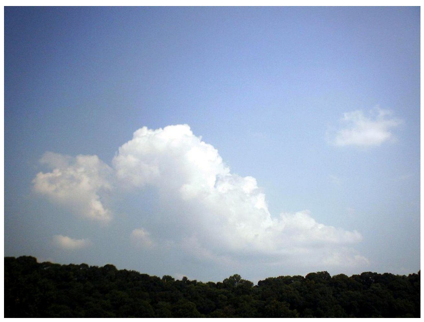
Clouds reduce sunlight – obviously.

Clouds reduce UV rays.

UV inactivate pathogens.

In the proposed model clouds increase the contagion.

This is true both for natural clouds, and anthropogenic clouds, like *cirrus homogenitus* defined[77] by the International Cloud Atlas of the World Meteorological Organization.



Natural clouds

Anthropogenic clouds

Figure (a) (left), in https://en.wikipedia.org/wiki/File:Cumulus_Cloud.jpg from Wikimedia Commons

Figure (b) (right), in https://commons.wikimedia.org/wiki/File:High_anthropoclouds_in_the_sky_of_Barcelona_(November,_2010)..JPG from Wikimedia Commons, by Mcosta1

In the trails generated by airplanes, particulate aerosols of various kinds have been[72] found. It should be investigated even the possibility that this air pollution could help spreading the virus, which could attach to the particles becoming more stable, as explained in 18.4.

0.4 Pigs and the epidemic

With reference to Europe and USA, in this study pig is *Sus scrofa*. Essentially the present research study classify them as

farm pigs, with geographic positions fixed by humans, and
wild boars, circulating in the environment.

Further details about the commonly used nomenclature are in 5.

The virus of swine flu killed 284,000 in 2009-2010 accordingly to a paper[19] published in *Lancet Infectious Diseases*.

Pigs may guest[4] a coronavirus – the kind of virus of covid-19 – suspected hazardous for humans.

With reference to another coronavirus different from that of the present epidemic, it has been[14] written:

> evidence exists that pigs can amplify MERS-CoV

0.4.1 Farm pigs and the epidemic

The idea that livestock spread infectious diseases circulate[27] from long time and now it is boosted by the November 2020 decision of Danish Government to eliminate[28] millions of minks, because of a possible infection just with a coronavirus.

The idea of a causal link between farm pigs and the epidemic is circulating[30] [32] from months, at least April 2020, when it was written[26] that in Italy the top 4 regions (out of 20) by number of cases had the same positions in the ranking by pig density per square kilometer.
An interesting coincidence to observe.

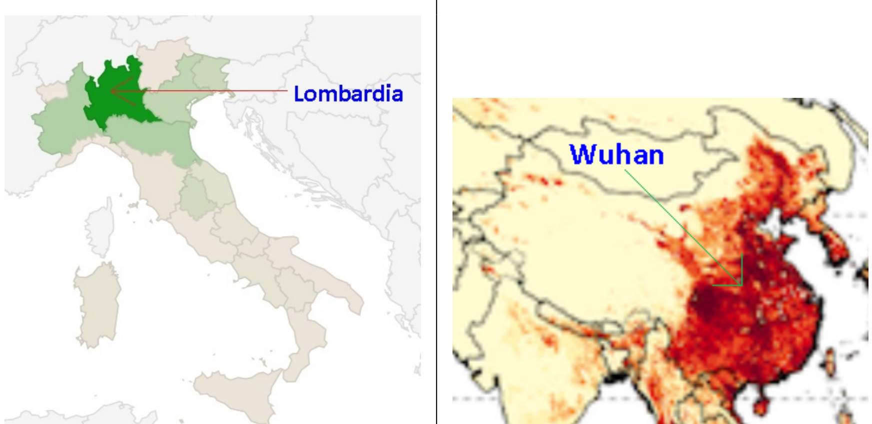


Figure 1
(a) (left) Farm pig density in Italian regions.
(b) (right) Farm pig density density in China from a FAO[33] map.

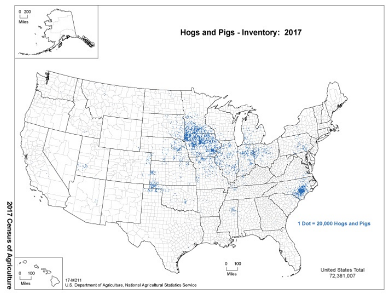
Another interesting coincidence: considering the usual subdivision of China in 22 *provinces*, Hubei, that of Wuhan, where thenon first was recognised, appears[34][35] to be one with the highest farm pig density – or, by the terms we will also use, ranks 1 for farm pig density.

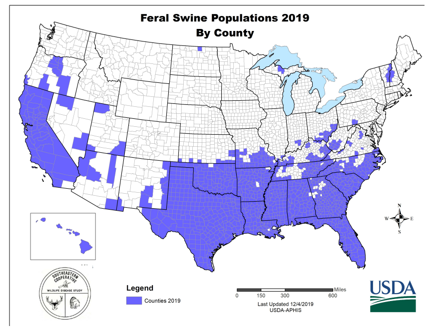
Lombardia has about half of the farm pigs of Italy and about half of the deaths of the epidemic of Italy. China had the first cases and deaths of the epidemic, and from several years and at least till[31] the beginning of 2019 had more than a half of farm pigs of the world, while in very recent times they reduced their pigs because of African Swine Fewer virus.

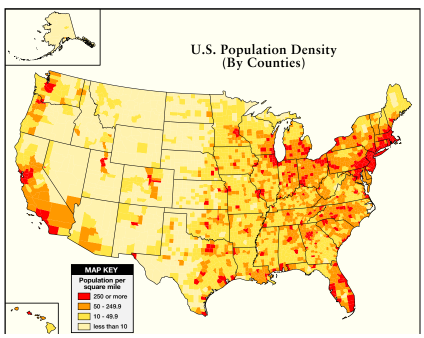
Pigs have been considered, in the pandemic, together with other livestock. We read in a scientific[83] paper:

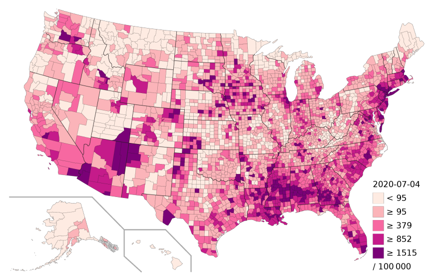
> From the outset of the epidemic within the Netherlands the south east has experienced a disproportionate number of Covid-19 cases. (...) possible explanation that has received less attention in the Netherlands revolves around the intensive livestock farming that takes place within North Brabant and Limburg. These regions house over 63% of the Netherlands' 12 million pigs and 42% of its 101 million chickens. Such intensive livestock production produces large quantities of ammonia (NH_3), which can be an important contributor to $PM_{2.5}$ concentrations.

The cases of Brazil, Germany and USA were studied[32] finding some correspondence between farm pigs and cases. In the following figures with more recent data one may see pig density and cases per 100 000 (4th July 2020) in USA.









Clusters of cases and of pigs are Southwest of Great Lakes.
Cluster of cases and of wild boars are in the South.
Others clusters of cases seem well explained by human density.

So we have pointed also to wild boars besides farm pigs.

0.4.2 Wild boars and the epidemic

As pointed out in 0.4 are exactly pigs, *Sus scrofa*, and in the present study only pigs freely circulating in the environment will be considered wild boars.

Wild boars are thought to transmit[44] pathogens to farm pigs.

Wild boars are present[45][46][47] in Lombardia, till[55] this year.

They may play a role in the contagion at least in the following 2 ways:

1) infecting humans (by air, breathing; and in other ways);
2) infecting farm pigs and this may happen at least in 2 ways:

– circulating in the environment
– as popularly said about African swine fever, the virus may reach

pig breedings on the shoes of wild boars hunters.

Differently from humans, wild boars population varies hugely year by year and during the year, roughly speaking their number explodes in spring and their total mass begins to increase already during the previous four months of pregnancy.

In the present study some clues are presented that wild boars increase the pandemic in 9.4, 12.1, 13.3, 13.4.2 and 13.5, with the important caveat in 19.3.
Those clues have to be kept very cautiously.

1 Need to compare close-latitude areas

The extremely high correlation of the latitude with the intensity of the pandemic (see 0.3.1) implies the necessity of considering groups of similar-latitude areas when looking for the possible influence of livestocks on the pandemic itself.

In this study we will consider mainly:

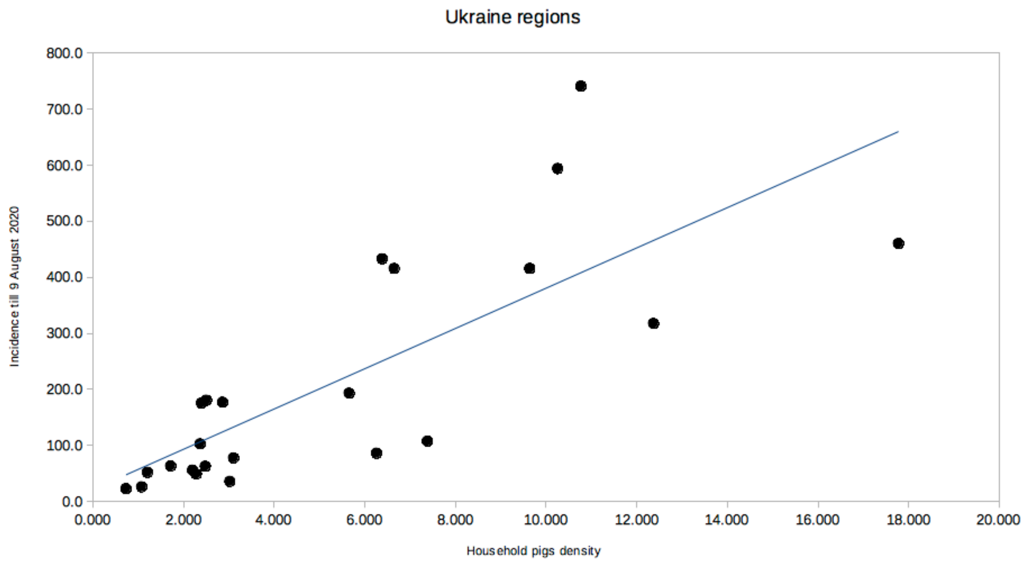
- the provinces of Lombardia
- the regions of Northern Italy
- Ukraine
- the countries of Southern Europe.

The last 3 areas extend much more on longitude than on latitude and Lombardia is a small region which extends little on latitude.

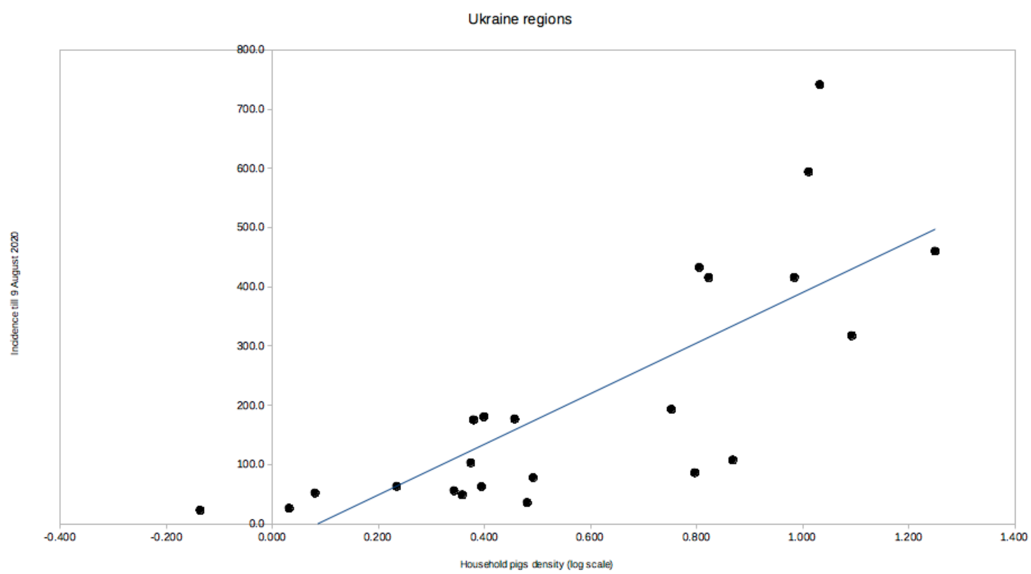
2 Statistical indexes and tests

2.1 Scatterplots and linear regression

In this study many scatterplots will represent graphically the correspondence between pigs (or other livestocks) densities in some areas and the intensities of the pandemic (somehow measured) in the same areas.
Those diagrams are easy to understand. Here it is an example.



Take in account that usually log scale is used as in this example.



The corresponding scatterplot (with the same data) made with ranks can be found in 13.4.1.

The correlation coefficient will measure the alignment of points and the regression line will be added to the scatterplot.

Surely good fittings of the lines to the points are clues for the model, but take in account that 2 dots have a perfect alignment without any meaning. The statistical tests considered in the following 2 paragraphs, instead, take in account also the numerosity of the datasets.

2.2 Testing linear increasing monotonicity

To test that to more pigs correspond more deaths, or more cases, or whatever, one may test the linear increasing monotonicity of scatterplots of pandemic vs pigs density, in particular in log scale for densities.

Being n the sample size and r the Pearson's correlation coefficient, the significance may be tested using

$$t := r\sqrt{\frac{n-2}{1-r^2}}$$

which should have[49] approximately a Student's t-distribution with $n-2$ degrees of freedom, at least[50] for $n > 20$.
Such a numerosity will be reached only in the statistics about Ukraine, see Section 13.

2.3 Testing increasing monotonicity of ranks

To test that to more pigs correspond more deaths, or more cases, or whatever, one may test the monotonicity of their respective ranks. Being n the sample size of X and Y and ρ_s the Spearman's rank correlation coefficient, which is exactly the Pearson's correlation index for ranks, the significance may be tested using

$$\rho_s := 1 - \frac{6\Sigma d_i^2}{n\left(n^2-1\right)} \tag{1}$$

(or simply ρ instead of ρ_s) where the d are the differences of the corresponding ranks.
At least if $4 \le n \le 30$ a table[7] of critical values for the 1-tail test for increasing monotonicity is available

H_0: X and Y are independent

H_A: there is a trend associating larger values of X to larger values of Y.

The null hypothesis H_0 is refused at significance level α if ρ_s (in that text ρ_s is denoted r_s) is > than the corresponding critical value of the table for α and n.

Here are some values of that table, and some of them will be used in this study.

n	.001	.005	.010	.025	.050	.100
.						
.						
.						
6	–	.9429	.8857	.8286	.7714	.6000
.						
8	.9286	.8571	.8095	.7143	.6190	.5000
9	.9000	.8167	.7667	.6833	.5833	.4667
10	.8767	.7818	.7333	.6364	.5515	.4424
.						
12	.8182	.7273	.6713	.5804	.4965	.3986
.						
.						
.						
23	.6186	.5306	.4852	.4150	.3518	.2767
24	.6070	.5200	.4748	.4061	.3435	.2704
.						
.						
.						

If data are more than 20, also the theory of the previous paragraph 2.2 may be applied.

3 Pigs livestocks correlate more: clues

3.1 Weight correlations by weighting livestocks

This study is essentially devoted to show statistical correlations between the intensity of the pandemic (variously measured) and the numerical presence of pigs (farm pigs and very cautiously wild boars) and secondarily other livestocks.
Nevertheless a further piece of information is given by the masses (instead of numerical amount) of those livestocks.

These very approximate weights (in kilogrammes) will be used.

Table: approximate weights of livestocks and humans

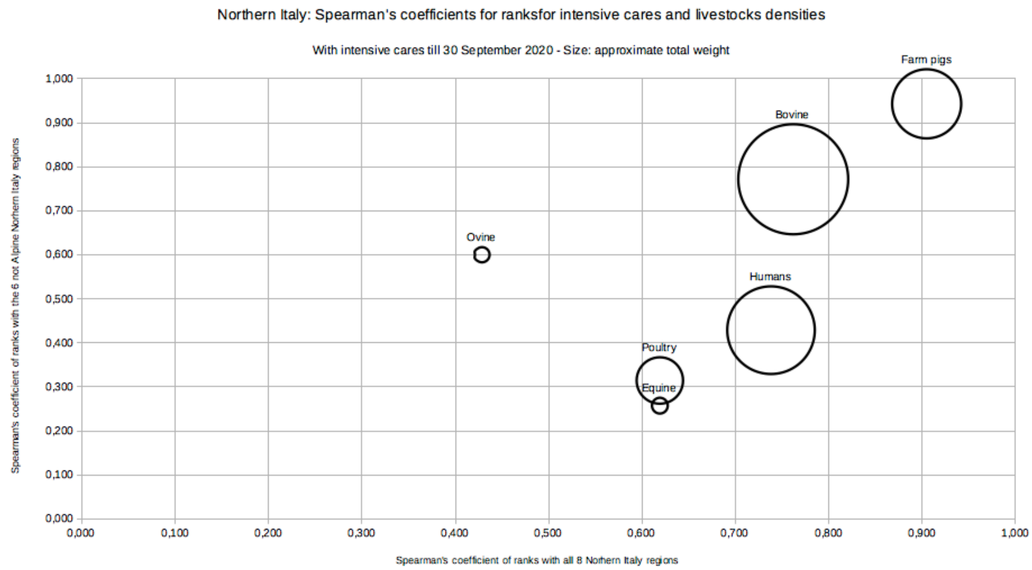
2 kg	rabbits
3 kg	poultry
45 kg	humans
50 kg	ovine (sheep & goats)
100 kg	pigs
500 kg	bovine
550 kg	equine

Those values are not completely documentable, coming from common knowledge and several sources, in particular interpolating Wikipedia data[17], after conversion in kilogrammes: "A Grossvieheinheit (GV or GVE) is a conversion key used to compare different farm animals on the basis of their live weight. A Grossvieheinheit represents 500 kilogrammes (roughly the weight of an adult bull). In the wild it excludes small animals like amphibians and insects, but is used for game in forestry and hunting."

Those values are extremely approximate (taken in account that a head of livestock grows and has in so sense a definite weight) but those data will have a small relevance in the present study, essentially almost in this Section 3.

3.2 North Italy: clues for pigs, comparing livestocks

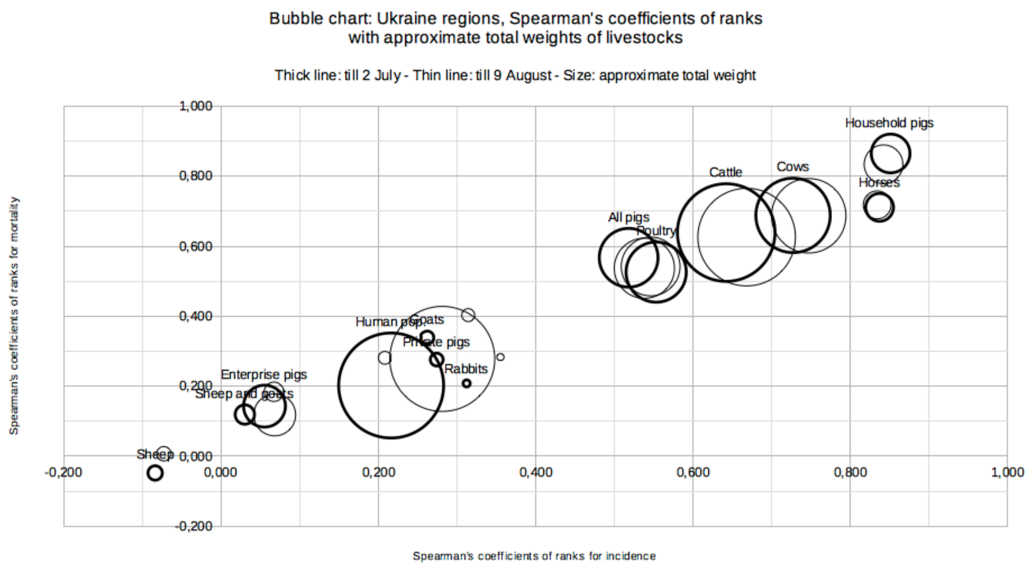
The following bubble chart is made with the approximate weights written in 3.1 and the Spearman's correlation coefficients written in 10.4 and livestocks and humans amounts in 8.6.



Remarks about the bubble chart above. Observing the above diagram, one can reasonably conclude that in North Italy (both considering the complete model with 8 regions and the reduced model with 6 regions) farm pigs density highly correlates with the intensity of the pandemic (measured by intensive cares till 30 September) and secondarily bovine density.
Poultry, ovine and equine correlate much less, but the little amount of total weight of ovine and equine weakens the result.
Also human density correlates less than pigs and bovine densities.

3.3 Ukraine: clues for pigs, comparing livestocks

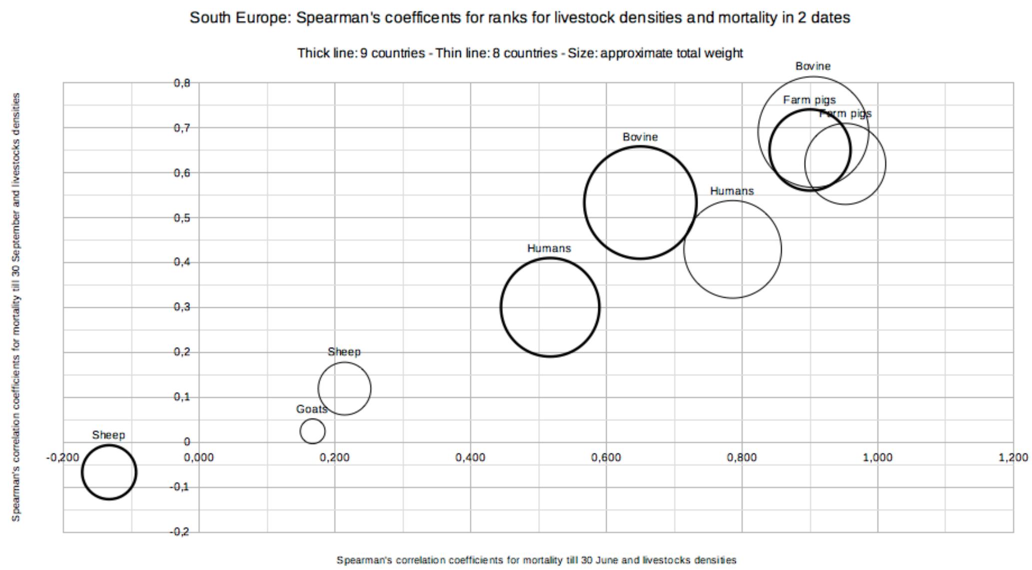
The following bubble chart is made with the approximate weights written in 3.1 and the Spearman's correlation coefficients written in 14.3 and livestocks and humans amounts in 14.1



Remarks about the bubble chart above. Observing the above diagram, one can reasonably conclude (for Ukraine regions, with the exclusion of Kyiv oblast and municipality, see 13.2, remaining 23 regions) that household pigs correlate really a lot with the intensity of the pandemic (measured both by incidence and mortality, in 2 dates) and secondarily bovine and then poultry.
Very meaningfully, human density correlates much less.
Sheep, goats and rabbits are scarcely present (as total weight, approximately represented by bubble sizes) in comparison with several other livestocks and then any statement about their correlation with pandemic should be kept cautiously, nevertheless their correlations with the pandemic intensity is low or, for sheep, absent.
A challenging open problem is represented by horses, highly correlating, not so scarcely present (weighting), for which consistent data have been collected only for Ukraine regions.
As remarked in 14.4 the high correlations between household pigs density and bovine density weakens the result of the high correlation between household pigs density and pandemic intensity, becoming difficult to distinguish the effect of pigs and bovine (where pigs, there bovine, roughly said).
Also the not so low correlation of poultry density with pigs, bovine and horses density is a problem of the same kind.

3.4 South Europe: clues for pigs and bovine

The following bubble chart is made with the approximate weights written in paragraph 3.1 and the Spearman's correlation coefficients written in paragraph 16.1 and livestocks and humans amounts in Section 16.



Remarks about the bubble chart above. Observing the above diagram, one can reasonably conclude (for South Europe countries, with the exclusion of Cyprus and Malta, see 15.1, and for goats also Albania for missing data, remaining 8-9 countries) that pigs and bovine correlate a lot with the intensity of the pandemic (measured by mortality, in 2 dates).
Ovine have low or no correlation.
Human densities exhibit an intermediate position, as a whole.

3.5 Conclusion: pigs are more involved, clues

Considering the results of previous paragraphs 3.2, 3.4 and 3.3, several clues have been found that as a whole pigs correlate with the pandemic intensity more than various other livestocks (and highly).

Further confirmation should be searched in other areas of the world.

From now on, we will focus essentially on pigs.

4 The proposed model sun-pigs

4.1 Model

We will show evidences of this model for the pandemic contagion:

0. Inter-human, short distance, by droplets and objects
1. Inter-human, long distance, by aerosol from livestocks
2. Farm pigs are the most involved livestocks
3. Sunlight decreases long distance contagion.

Point 0 is the standard model.
Points 1 and 2 are the core of this study.
Point 3 is already indicated by the 2 studies already cited.

Furthermore clues will be shown for

4. Wild boars are implicated – to be kept very cautiously
5. The pigs correlation fades from Spring to Winter 2020.

4.2 How to test the model of pigs

To test the model we need an area of the world

1) with very high reliability for statistics
2) with a very high number of humans
3) with a very high number of pigs per human
4) with statistics for the epidemic and pigs at the same, good, scale
5) with large differences among sub-areas, for pigs and epidemic
6) with very low atmospheric circulation
7) with very high homogeneity in solar irradiance.

Considering the list above, an exceptionally prominent area of the world is the Italian region Lombardia, of which its subdivision in 12 provinces will be considered, verifying if more pigs correspond to more epidemic intensity.

Point 6 is needed because strong air circulation may destroy the geographical correspondence between pigs and pandemic intensity. Point 7 is required because sunlight may weaken the pathogen.

4.2.1 Details

About point 1: of course in no statistic about the epidemic, data of Turkmenistan may be used, a country declaring (till November 2020) no deaths, no cases, and ranking 180 in the *press freedom index* in 2020, among 180 countries.
For reliability of statistics also *human development index* has to be considered because for the desired purposes freedom to refer data is useless in case of inability to collect data.
We require first quartile ranking for both those indexes.

Italian Region Lombardy will be considered for testing the model.

1) For that region, epidemic data are given from Italy, ranking in the first quartile both for *press freedom index* and *human development index*.
2) Lombardia has more than 10 millions inhabitants (2020).
3) Lombardia has more than 4 millions farm pigs (2020), which is > 0.4 pigs per human (EU-27 has ≈ 0.3 and the whole world ≈ 0.1).
4) and 5) good for Lombardia, see Section 7
6) Lombardia has an atmospheric circulation exceptionally limited, as may be seen from European Space Agency map of wind speeds in https://www.esa.int/ESA_Multimedia/Images/2018/01/Wind_speed_in_Europe and in Vaisala wind map (reported in 11.7) of mean wind speed (at 80 m): air moves slowly on that region. So in the proposed model of contagion largely due to pig breedings, the spatial correlations among pig breedings and cluster of cases should be well preserved.
7) Lombardia is a small region of the world which extends little in latitude and also the Vaisala map of solar irradiance vaguely confirms that in that region solar irradiance is quite homogenous.

4.2.2 Successive relaxation of requirements

After testing the hypothesis of pigs, a relaxation will be allowed, considering countries scoring better then median in both human development index and press freedom index, with the small exception of Ukraine, which performs slightly worse for one index.

5 Pigs of all kinds

The used nomenclature is quite intricate. In an attempt to simplify the issue, we quote[78] Wikipedia:

> A pig is any of the animals in the genus Sus, within the even-toed ungulate family Suidae. Pigs include domestic pigs and their ancestor, the common Eurasian wild boar (Sus scrofa), along with other species.

In Europe and USA the only species of the genus *Sus* is *Sus Scrofa*.
For the purposes of this study, the only distinction is between
farm pigs, with geographic positions fixed by humans, and
wild boars, circulating in the environment.
In various sources several words are used to classify pigs, even with(3) ambiguities. In the present study farmed wild boars are considered farm pigs, which they are: farmed, *Sus scrofa*.

Other words used in different contexts which will not concern our study include swine, hog, feral pig, feral domestic pig, razorback, wild hog, sow, and of course wild boar.

6 Measuring the epidemic

The intensity of the epidemic may be measured in various ways.

One may chose among at least these 3 parameters, and others exist:
1) the number of deaths caused by the epidemic;
2) the number of “cases” of the epidemic;
3) the number of intensive cares caused by the epidemic.

All those 3 may be measured till a date (cumulative) or at a date and in the present study the first way will be always chosen.
All have pros and cons.

The z-scores of mortality, will be considered too.

[3] We read in English Wikipedia:
“The feral pig is a pig (Sus scrofa) living in the wild, but which has descended from escaped domesticated swine, mostly in the Americas and Australia. Some feral pigs are hybrids with wild boars. Razorback and wild hog are American colloquialisms, loosely applied to any type of feral domestic pig, wild boar, or hybrid in North America; pure wild boar are sometimes called ”Russian boar” or ”Russian razorbacks”.”

6.1 The problem "died from" vs "died with"

Every death of this pandemic has not a single cause. As already pointed out in 0.1, in Italy comorbidity is huge, with the considered illness accompanied by several others severe pathologies, including cancer and ictus. To attribute the death to the specific illness here considered is a difficult medical matter, inevitably solved case by case in different ways. The problem cannot be solved here.
It has been written[85] in a scientific paper:

> In the UK, the official COVID-19 daily mortality update provided by Public Health England includes all patients who died having tested positive for SARS-CoV-2 by polymerase chain reaction (PCR) from sputum or nasopharyngeal swab. However, it is not currently clear if these patients died as a direct consequence of COVID-19 infection.
> (...)
> Between 23 March 2020 and 28 April 2020, a total of 162 patients with a positive SARS-CoV-2 PCR died in Leeds Teaching Hospitals NHS Trust. Of these, COVID-19 infection was documented as the direct cause of death in 150 (93%).

For Italy hints to avoid that parameter are the media relations of several cases as[84] classical "He dies from Covid aged 30 (...) he was in a coma: a colleague shot him accidentally" published by a respectable media, though probably on large numbers the situation is similar as in UK, as we read in a report[86] of Istat:

> COVID-19 is the directly responsible cause of death in 89% of deaths positive in the SARS-CoV-2 test

6.2 Problems with the number of "cases"

The number of cases is even more problematic than deaths.

In Italy 2 or 3 or even more case may refer to the same person, tested repeatedly, according to laws varying in time and places.

But there is a bigger problem: the number of tests have increased hugely during time, from Spring to Autumn, and in that increase a sub-area may have been late: with so a rapid increase, that delay may destroy completely the proportion among sub-areas – which is exactly what is searched in the present study.

6.3 Another parameter: intensive therapies count

The count of intensive therapies has not the problems exhibited by the count of cases, exposed in previous paragraph, relating to hugely increasing numbers, according to different laws and habits in different places, with possible different delays destroying proportions among sub-areas.

Just as for deaths, there could be a problem of intensive care “due to” the pathogen and “with” it. But since before the pandemic the occupation of intensive therapies was little and then it become very large, it measures quite well just the impact of the pandemic. The number of deaths “from” or “with” the pathogen remained always little in comparison with the total daily number of deaths, so leaving greater space for errors in comparison with the count of intensive therapies.

This parameter will be used for Northern Italy regions in 9.

6.4 GitHub for Italy, Worldometer for Europe

In the present study the data from GitHub will be used for Italy, reporting counts for cases and intensive cares (and many other parameters) for Italian regions, and cases for provinces, and Worldometer for Europe – but it does not gives the count of intensive therapies, so deaths counts will be used for Europe.

The database GitHub has been well[9] described:

> (...) on-line GitHub repository provided by the Coronavirus Resource Center of the John Hopkins University (CRC-JHUL https://github.com/CSSEGISandData/COVID-19). Such data are provided daily by the Italian civil-defense department. CRC-JHU global data are updated daily and cover, currently, the course of epidemics in 261 different world countries, by providing the daily cumulated numbers of Confirmed SARS-CoV-2 cases, Deaths and Healings.

The database Worldometer has been well[87] described:

> Worldometer (...) is a reference website that provides counters and real-time statistics for diverse topics.
> (...)

is managed by "an international team of developers, researchers, and volunteers"

7 Comparison: Lombardia provinces

So now an area of the world will be considered, the Italian region Lombardia, the

first and most affected of the 20 regions of Italy

which in turn is

one of the first and most affected of the almost 200 *countries*.

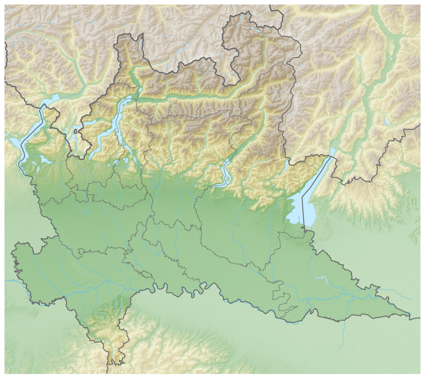
That region, among the 20 Italian regions, is first in Italy both

for number of farm pigs (more than triple than next region)

and density of farm pigs (more than triple than next region).

(Quite strikingly almost half of farmed pigs of Italy are in Lombardia and about half of the deaths of Italy are in Lombardia.)

First of all a statistical analysis will be performed considering subareas of the area Lombardia: the 12 *provinces* of that region.
There is no arbitrary statistic adjustment in all that: it is the usual subdivision of level next to region. (Though technically in Italy only 11 of the 12 provinces are officially named "provincia", not Milano).



Orographic map of Lombardia

Fig. (a)

The provinces of Lombardia

Fig. (b)

Fig. (a) from Wikipedia(4).

Fig. (b) from Wikipedia, public domain image.

7.1 Lombardia, 31 March 2020

The first death in Lombardia, and in Italy, dates[18] 21 February 2020. The fundamental database GitHub[8] starts the historic series from 24 February, with 7 deaths, clearly corresponding to several previous days.

In this section it will be considered Lombardia on 31 March 2020, not considering meaningful a statistic for the last day of February, at the very beginning of the epidemic in Italy.

In 7.2 the situation will be investigated month by month, following in particular the Pearson's correlation index between pig density (on log scale) and cumulative cases, and the Spearman's rank correlation coefficient ρ.
We may anticipate that the (geographical and then statistical) correlation is very high and that in Autumn it fades. See also 7.3.

[4] By Tschubby, licence in https://creativecommons.org/licenses/by-sa/3.0/deed.fr

7.1.1 Original data for Lombardia, 31 March 2020

Province	Area	Human population	Farm pigs	(a)Cases till 31 March
Bergamo	2755	1110457	890418	8803
Brescia	4786	1262135	1358038	8367
Como	1279	599637	2148	1101
Cremona	1770	358578	969149	3869
Lecco	806	337256	4269	1470
Lodi	783	229946	356688	2116
Mantova	2341	411959	1190459	1688
Milano	1576	3233541	77959	8911
Monza	405	871523	3504	2462
Pavia	2969	545611	233078	2133
Sondrio	3196	181249	1834	470
Varese	1198	890418	1018	893

(a) from GitHub[6]. Retrieved 5 December 2020

7.1.2 Derived data for Lombardia, 31 March 2020

Province	Rank for farm pig density	Farm pig density	Cases per million	Rank for cases per million
Bergamo	8	107.8	7927	10
Brescia	9	283.8	6629	9
Como	3	1.679	1836	2
Cremona	12	547.5	10790	12
Lecco	4	5.297	4359	8
Lodi	10	455.5	9202	11
Mantova	11	508.5	4097	7
Milano	6	49.47	2756	4
Monza	5	8.652	2825	5
Pavia	7	78.50	3909	6
Sondrio	1	0.5738	2593	3
Varese	2	0.8497	1003	1

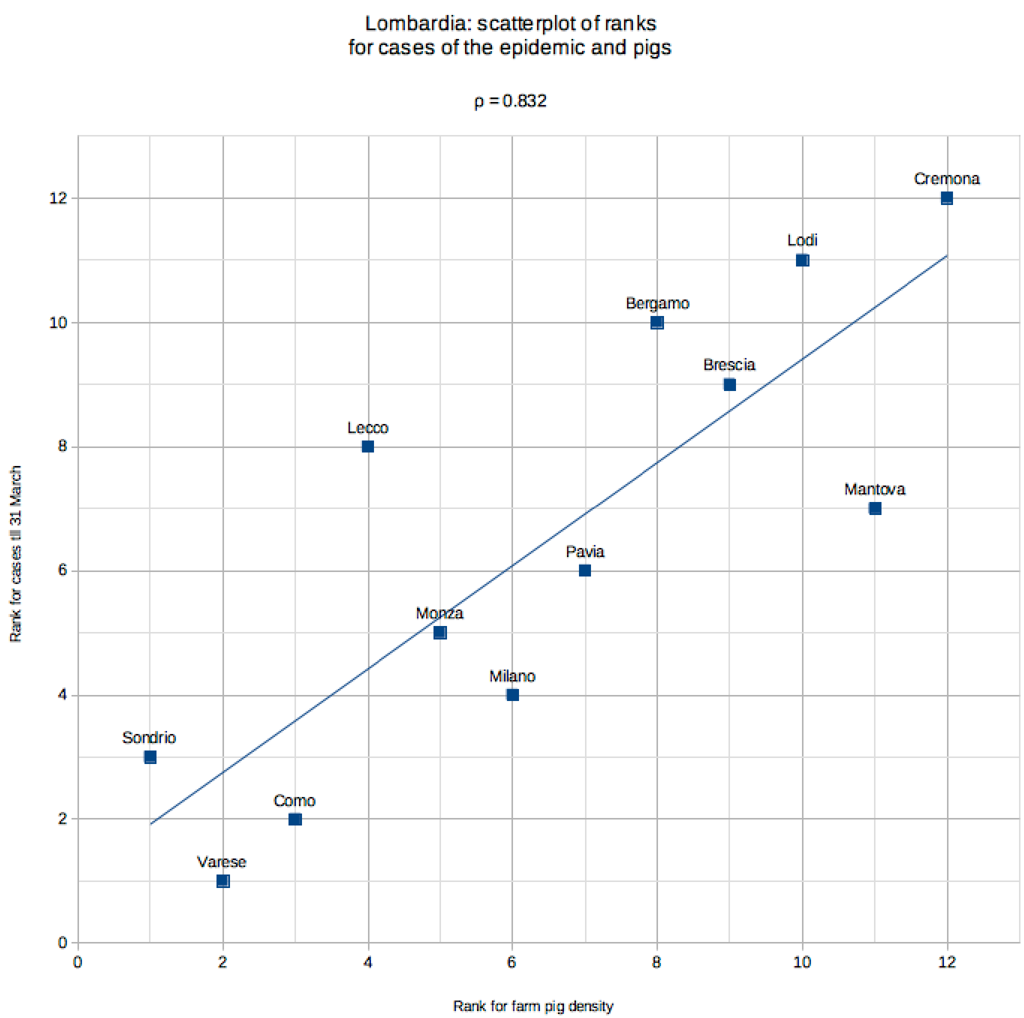
7.1.3 Ranks

The increasing order is chosen: 1 corresponds to the lowest farm pig density, and to the lowest number of deaths per million.

provinces													
rank for pigs	P_i	1	2	3	4	5	6	7	8	9	10	11	12
rank for cases	C_{P_i}	3	1	2	8	5	4	6	10	9	11	7	12
provinces													

Considering the ranks P_i and C_{P_i}, at a glance, it appears that yes, generally

more farm pigs, more cases per million.



Final remark: p-value. To test the increasing monotonicity of ranks, with $n = 12$, Formula (1) gives 0.832 (which is in fact ρ_s)

which grants, as may be seen in the table in Section 2.3,

$$p < 0.001$$

and largely, in fact.

7.1.4 A logarithmic model

We hypothesise for 2 random variables X and Y, of which the data x_i and y_i are samples, a logarithmic relation

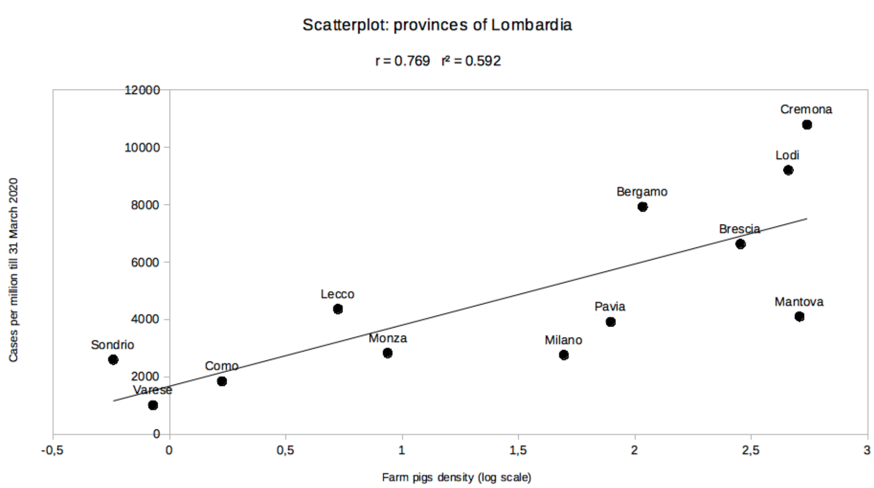
$$Y = a \cdot \ln(b \cdot X)$$

with some positive constants a and b.

The relation is characterised by

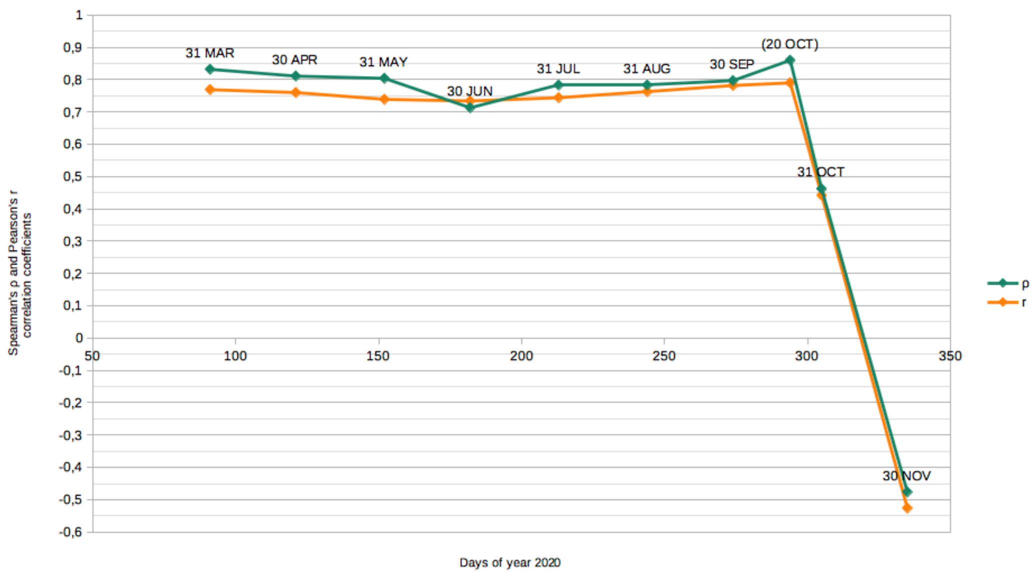
$$(1 + u\%) \cdot X \rightarrow Y + v_u$$

that is to say, an increase of $u\%$ in farm pig density is associated with an increase of v_u in cases per million.
Notice that the increase v_u depends only by u, not by X.
Simply said:
a doubling of farm pigs, (that is to say $u = 100$),
is associated with
an increase $a \ln 2$ of cases per million
a tripling, $a \ln 3$,
and so on.
And a is a fixed – at now unknown – constant.
(And b has little intrinsic meaning, it depends on the area unit of measurement used for farm pig density. Farm pig population density is in heads/km^2 and by logarithm properties, any other area unit works equally, affecting only b, not a.)



This method of the logarithms of densities, which has been chosen in this study, should be compared in further developments with the method of considering densities just the way they are.

7.2 Following Lombardia month by month



7.3 Fading of the pig correlation during time

In the last decade of October, suddenly the geographical correlation between the pandemic and pig presence disappears, as it may be seen in the previous paragraph 7.2.
This does not imply that pigs harm less: or they harm less, or they harm till on a longer distance (for meteorological reasons, such as air circulation), so weakening the geographical correspondence, searched in the statistical correlations. A clue of the latter possibility is presented in 15.3. A third possibility is that in some provinces they have started to make so many swabs, finding cases, to alter the proportions.

See also 17.

8 Italy

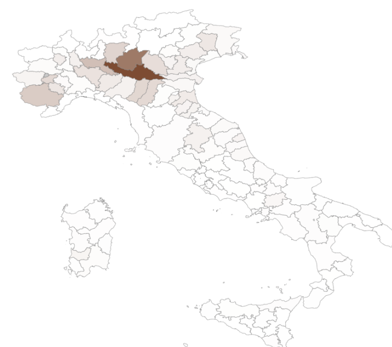
8.1 Maps of Italy

Orographic map of Italy

From Wikimedia Commons

in https://it.wikipedia.org/wiki/File:Italy_topographic_map-blank.svg

by Eric Gaba (format converted)



Farm pig density

From Anagrafe Nazionale Zootecnica

in https://www.vetinfo.it/j6_statistiche/#/report-pbi/31

(screenshot)

The areas of the map of farm pig density resemble the Italian *provinces*, but they don't always coincide. It is clear that the large majority of Italian farm pigs are in Northern Italy.

8.2 Remark on the number of Italian Regions

Italy is officially divided in 20 regions. One of them is split at several levels in 2 sub-regions, so that many Italian statistics are presented for 21 "areas".
In this text the subdivision in 20 regions will be always used.

8.3 20 regions

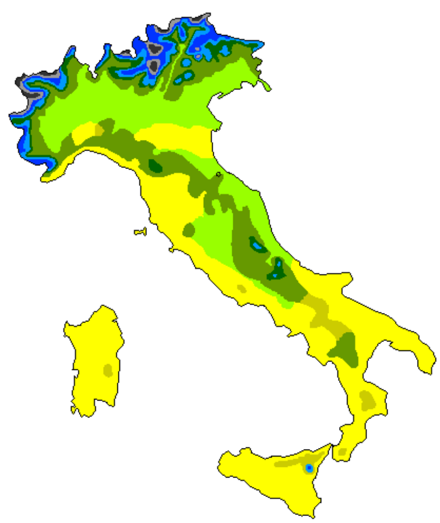
As already said in 8, Italy is officially divided in 20 regions. One of them is splitted at several levels in 2 sub-regions, so that many Italian statistics are presented for 21 "areas".
In this text the subdivision in 20 regions will be always used, and from a statistical point of view this is necessary because from the data of 21 areas we may compute the data for 20, but the converse is impossible. In this paragraph, we will use data available only for

the subdivisions in 20 regions: the mean altitude of town halls.

8.4 Climate of Italy

The Italian climate is very various, nevertheless ultra-simplifying it may said that 18 regions have a "mediterranean" climate and 2 regions have an "Alpine" climate: Trentino-Alto Adige and Valle d'Aosta and on the Alps, in Northern Italy, quite bluish in the figure below. In those regions the mean elevations of town halls are 759 m and 951 m respectively, while all other 18 regions are below 650 m, usually much less.

Because of the strong dependence of the proposed contagion model on air conditions, it is reasonable to exclude from the statistic those 2 regions, Trentino-Alto Adige and Valle d'Aosta, and to make separate observations for them. They are the 2 red dots in the Figures in 9.3 and 9.4.



Map of Kppen climate classification system for

Italy according to Mario Pinna.

by Carnby, from Wikimedia Commons

Map of the Regions of Italy

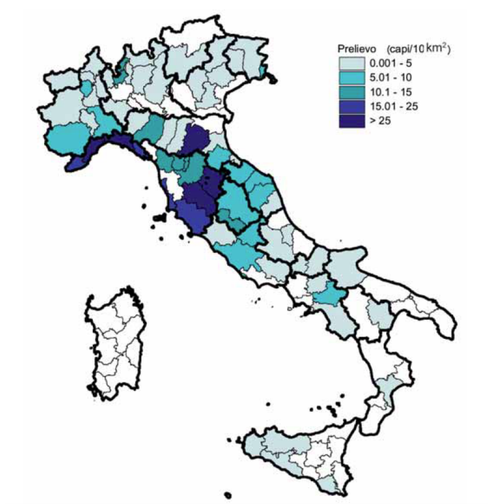
by LorenzoF06, original artwork from mac9

from Wikimedia Commons

8.5 Wild boars

In this analysis wild boars (free pigs in environment) are really a big problem because they are not exactly counted. In Lombardia

(previously discussed in 7) in 2019 only 5 802 wild boars were[54] culled, which is a clear clue that the number of wild boars is negligible in comparison with the number of farm pigs, 4.4 millions. On the contrary, Liguria has only 1 079 farm pigs (2020) and 15 275 culled wild boars (2004-05). On the basis of the map below of culled wild boars density (on province scale) and of the data of the following table, it appears that 2 regions, Liguria and Toscana, have exceptionally high wild boars density.
Since the proposed contagion model is based mainly on pigs and wild boars are pigs, it is reasonable to exclude from the statistic those 2 regions, Liguria and Toscana.



Here we consider deaths in the week 23-29 March 2020, which is the first week of Spring, beginning weeks from Monday.

8.6 Original data

Region	(a) Area km^2 2019	(b) Population 2019	(c) Farm pigs 2020	(d) Culled wild boars 2004-05	(e) Cases 23-29 March 2020	(f) Mean elevation of town halls 2004
Abruzzo	10 832	1 305 770	74 778	*1 162	771	563
Basilicata	10 073	556 934	68 140	*1 140	121	633
Calabria	15 222	1 924 701	50 286	–	341	418
Campania	13 671	5 785 861	93 762	*2 100	725	322
Emilia-R.	22 453	4 467 118	1 131 026	12 827	5 564	213
Friuli-V.G.	7 924	1 211 357	245 324	1 340	604	207
Lazio	17 232	5 865 544	42 123	4 850	1 312	416
Lombardia	23 864	10 103 969	4 401 068	2 701	13 516	279
Marche	9 401	1 518 400	117 797	5 735	1 110	339
Molise	4 461	302 265	21 998	275	60	631
Piemonte	25 387	4 341 375	1 290 317	12 662	3 737	421
Puglia	19 541	4 008 296	39 196	180	730	184
Sardegna	24 100	1 630 474	180 530	4 018	299	278
Sicilia	25 832	4 968 410	78 111	293	830	391
Umbria	8 464	880 285	205 287	6 995	489	404
Veneto	18 345	4 907 704	685 706	117	3 171	177
Liguria	5 416	1 543 127	1 079	15 275	613	250
Toscana	22 987	3 722 729	119 918	42 223	1 845	278
Trentino-A.A.	13 605	1 704 819	14 734	30	1 176	759
Valle d'Aosta	3 261	125 501	75	688	220	951

(a) from Wikipedia[42], 2019 Istat data
(b) from Wikipedia[42], 2019 Istat data
(c) from Anagrafe Zootecnica[41]
(d) from Banca Dati Ungulati[46]
(e) from GitHub database[6], not considering cases "in aggiornamento" (*updating*)
(f) from 2004 Istat[10] data
* partial (underestimated)

8.7 Derived data

Region	(l) Human population density	Farm pig density ranks	(g) Farm pig density heads/km^2	(h) Culled wild boars heads/km^2	(i) Cases per million 23-29 March	Cases per million ranks
Abruzzo	121	8	6.903	0.1073	590.46	11
Basilicata	55	6	6.765	0.1132	217.26	7
Calabria	126	4	3.304	–	177.17	3
Campania	423	7	6.858	0.1536	125.31	1
Emilia-R.	199	14	50.373	0.5713	1245.55	15
Friuli-V.G.	153	12	30.960	0.1691	498.61	9
Lazio	340	2	2.440	0.2815	223.68	8
Lombardia	423	16	184.423	0.1132	1337.69	16
Marche	162	10	12.530	0.6100	731.03	13
Molise	68	5	4.931	0.0616	198.50	6
Piemonte	171	15	50.826	0.4988	860.79	14
Puglia	205	1	2.006	0.0092	182.12	4
Sardegna	68	9	7.491	0.1667	183.38	5
Sicilia	192	3	3.024	0.0113	167.06	2
Umbria	104	11	24.254	0.8264	555.50	10
Veneto	268	13	37.378	0.0064	646.13	12
Liguria	285	–	0.199	2.8203	397.25	–
Toscana	162	–	5.217	1.8368	495.60	–
Trentino-A.A.	79	–	1.083	0.0022	1094.14	–
Valle d'Aosta	38	–	0.023	0.2210	1752.97	–

(g) derived data from (a) and (c) of the previous table

(h) derived data from (d) and (a) of the previous table

(i) derived data from (b) and (e) of the previous table

(l) derived data from (a) and (b) of the previous table

8.8 Difficulty to consider the level of regions

To find the influence of pigs on the pandemic in Italy at the level of regions is very difficult because Italy spans more for latitude than longitude and all the regions with many pigs have high latitude and all regions with low latitude have few pigs.

Region	Rank for farm pigs (1=highest)	Latitude	Partition of Italy
Lombardia	1	45.5	Northern Italy
Piemonte	2	45.1	Northern Italy
Emilia-Romagna	3	44.5	Northern Italy
Veneto	4	45.4	Northern Italy
Friuli-Venezia Giulia	5	45.6	Northern Italy

For all the 5 regions above farm pig density is >30 heads/km^2.

Region	Farm pig density	Rank for latitude (1=lowest)	Partition of Italy
Sicilia	low	1	Southern Italy
Calabria	low	2	Southern Italy
Sardegna	low	3	Southern Italy
Basilicata	low	4	Southern Italy
Campania	low	5	Southern Italy
Puglia	low	6	Southern Italy

For the 6 regions above farm pig density is low: <8 heads/km^2.

The model forecasts that the epidemic is increased both by farm pigs and latitude. In view of what just said, it is impossibile to search a correlation considering all the Italian regions, being impossible to distinguish clearly the causative effect of latitude, and of pigs.

Then we will consider only the regions of Northern Italy, so diminishing the interference with latitude.

9 Comparison: pigs, North Italy regions

9.1 Regions of Italy

The subdivision in Northern, Central and Southern Italy is standard in Italy. These are the 8 regions of Northern Italy:
Piemonte
Lombardia
Veneto
Emilia-Romagna
Friuli-Venezia Giulia
Valle d'Aosta – red dot – excluded: Alpine climate
Trentino-A.A. – red dot – excluded: Alpine climate
Liguria - orange dot – excluded: overwhelming wild boars presence.

For those 8 regions an analysis will be performed, limiting the interference with latitude.
The intensity of the epidemics will be measured by cumulative number of intensive cares, till 30 September 2020.

9.2 North Italy, data about pigs and pandemic

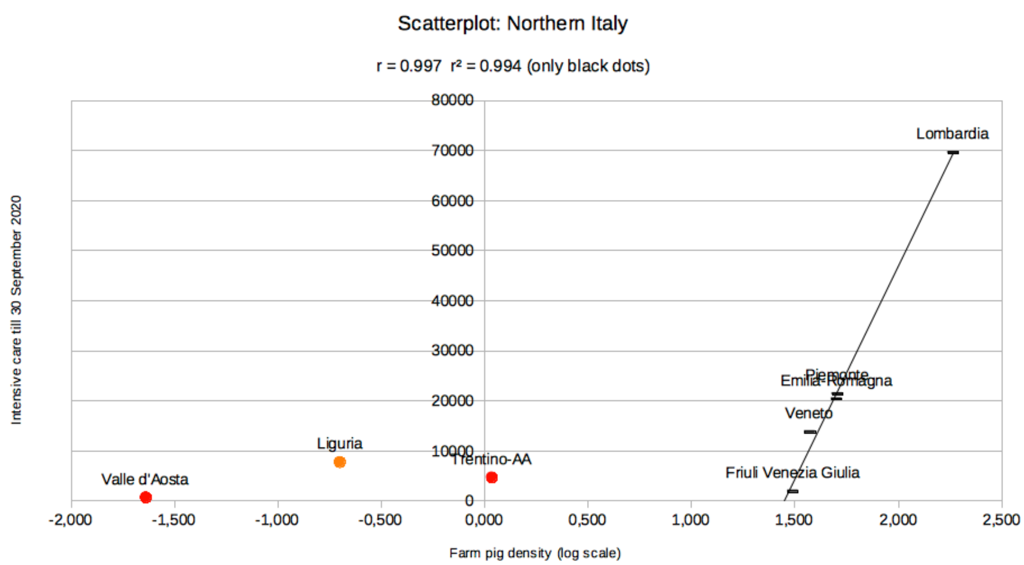
Region	ranks for farm pigs density	[a]farm pig density heads/km^2	[b]culled wild boars density heads/km^2	[c]intensive cares till 30 September	ranks for intensive cares
Emilia R.	3	50.373	0.5713	20376	3
Friuli V.G.	1	30.960	0.1691	1965	1
Lombardia	5	184.423	0.1132	69616	5
Piemonte	4	50.826	0.4988	21422	4
Veneto	2	37.378	0.0064	13824	2
Liguria	(wild boars)	0.199	2.8203	7777	
Trentino A.A.	(Alpine)	1.083	0.0022	4717	
Valle d'Aosta	(Alpine)	0.023	0.2210	729	

[a] See paragraph 8.7

[a] See paragraph 8.7

[c] From [8] GitHub, retrieved 5 December 2020.

9.3 North Italy: scatterplot and regression



Pearson's r is exceptionally high, $r = 0.997$, after the 3 exclusions, but it relates to only 5 regions.

9.4 An attempt to include wild boars

There are not precise estimates of the number of wild boars in Italian regions. The best data found in the present research is the count 2004-2005 of culled wild boars, at the scale of regions of Italy, not perfectly consistent: 1 region lacks of data completely, and 3 are given with partial underestimate. But all those 4 are not in Northern Italy. See table in 8.6.

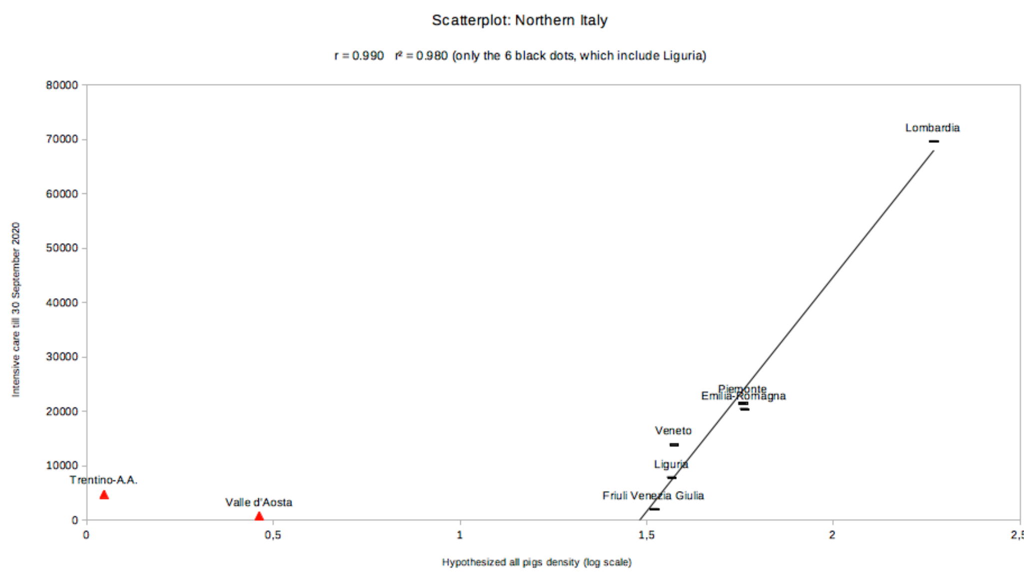
If one hypothesizes that in every region the wild boars are equally proportional to the number of culled wild boars it is possible to obtain an estimate of the amounts of wild boars in the regions.
For example supposing a 5% rate of culling in the considered season, one has to multiply by 20 the number of culled wild boars to estimate the total number of the wild boars, region by region. Precisely said n the number of culled wild boars in a region and $a\%$ the rate of culling, wild boars will be $\frac{1}{a\%} \times n$. Unluckily we do not know a and the hypothesis of its equality for all regions is quite unrealistic and data are old and the number of wild boars is greatly variable during the year; nevertheless something can be done.
Futrthermore it is conceivable that wild boars harm differently than

farm pigs. So we will use something as

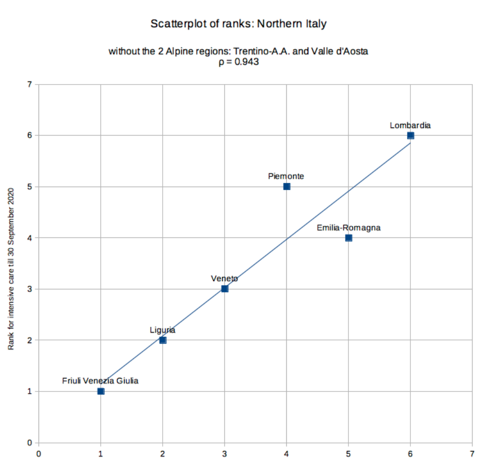
$$hypothesized\_weighted\_all\_pigs\_density =$$

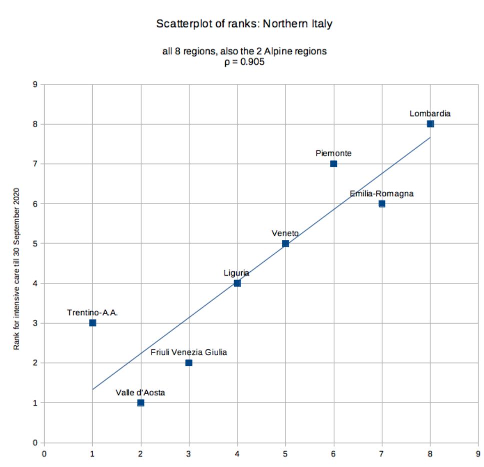
$$farm\_pigs\_density + c \times wild\_boars\_density$$

and a good result is obtained with $c := 13$, as may be seen in the scatterplot below.



9.5 Scatterplot of ranks





9.6 Final remark: p-value.

Weighting for wild boars, without the 2 Alpine regions.
To test the increasing monotonicity of ranks, with $n = 6$, Formula (1) gives 0.94286 (which is in fact ρ_s) which grants, as may be seen in the table in Section 2.3, $p < 0.005$ but if as it is probable the critical value there reported .9429 is an approximation just of our value 0.94286 then for a bit it is not completely true the <, but only the =, while the test is defined exactly by <. Then we could conclude only $p < 0.10$ but very largely, and in any case a good statistical significance. With all likeliness

$$p < 0.006$$

Weighting for wild boars, with the 2 Alpine regions.
To test the increasing monotonicity of ranks, with $n = 8$, Formula (1) gives 0.905 (which is in fact ρ_s) which grants, as may be seen in the table in Section 2.3,

$$p < 0.005$$

10 Comparison: livestocks in North Italy

Here we address the reader to Section 8.2 and 8.4 for several details and maps of the regions of Italy.

Regions of northern Italy from https://commons.wikimedia.org/wiki/File:Italia_settentrionale.svg

by es:Usuario:Mnemoc + User:noieraieri

10.1 Table: North Italy, livestocks, original data

Region	Bovine	Poultry	Sheep	Goats	Equine
Emilia-R.	572 270	23 061 432	52 418	15 698	10 749
Friuli V.G.	75 429	6 837 858	20 901	7 681	2 859
Lombardia	1 505 113	26 641 770	117 311	94 111	19 819
Piemonte	817 830	9 348 939	125 106	79 524	14 354
Veneto	755 573	50 445 381	69 687	26 339	12 987
Liguria	12 580	64 182	8 297	9 097	5 078
Trentino-A.A.	169 613	722 836	74 465	39 709	7 172
Valle d'Aosta	32 384	5 998	2 174	4 756	810

10.2 Table: North Italy, livestocks, derived data

Region	Bovine density	Poultry density	Sheep density	Goats density	Equine density
Emilia-R.	25.497	1027.485	2.335	0.699	0.479
Friuli V.G.	9.509	862.007	2.635	0.968	0.360
Lombardia	63.073	1116.442	4.916	3.944	0.831
Piemonte	32.215	368.261	4.928	3.133	0.565
Veneto	41.186	2749.761	3.799	1.436	0.708
Liguria	2.323	11.850	1.532	1.680	0.938
Trentino-A.A.	12.467	53.131	5.473	2.919	0.527
Valle d'Aosta	9.931	1.839	0.667	1.459	0.248

10.3 Comparing the correlations of various livestocks

As explained in 8.4, it seems reasonable to consider Northern Italy in 2 ways, with all its 8 regions, and excluding 2 of them with "Alpine climate".
The subdivision in Northern, Central and Southern regions is standard in Italy. These are the 8 regions of Northern Italy:
Piemonte
Liguria
Lombardia
Veneto
Emilia-Romagna
Friuli-Venezia Giulia
Valle d'Aosta – Alpine climate
Trentino-A.A. – Alpine climate

For those 8, and 6, regions an analysis will be performed, limiting the interference with latitude, because Northern Italy extends more along longitude than latitude, see Section 1.
The intensity of the epidemics will be measured by cumulative number of intensive cares, till 30 September 2020. About the significance of considering intensive cares data, see 6.3.

10.4 Spearman's coefficients of ranks

The following table shows the Spearman's correlation coefficients of ranks for livestocks and the cumulative number of intensive cares till 30 September, and it is made with the data in 8.7, in 9.2 and in 10.2.

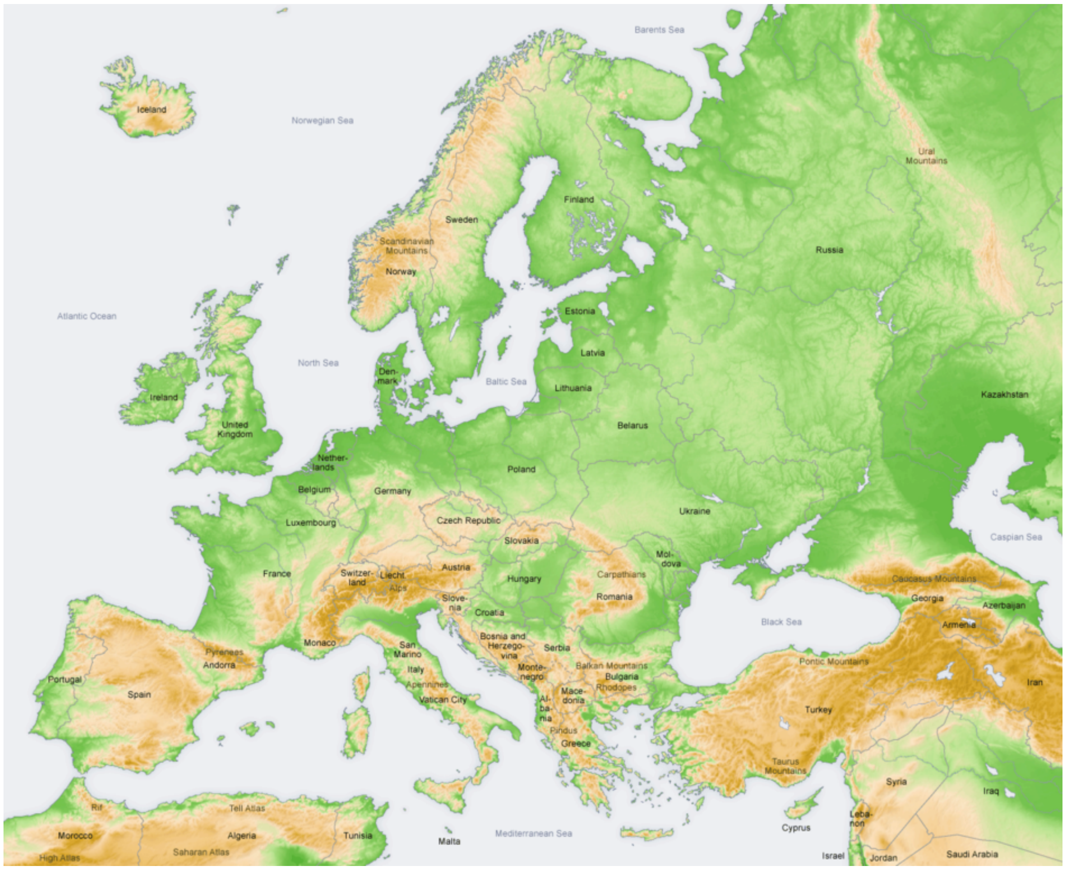
TABLE: SPEARMAN'S COEFFICIENTS FOR PANDEMIC, LIVESTOCKS & HUMANS

Type of livestock and humans	Correlation with 6 regions	Correlation with 8 regions
Pigs	**0.943**	**0.905**
Bovine	0.771	0.762
Poultry	0.314	0.619
Sheep and goats	0.600	0.429
Sheep	0.657	0.452
Goats	0.600	0.429
Equine	0.257	0.619
Human pop.	0.429	0.738

11 Europe: data and maps

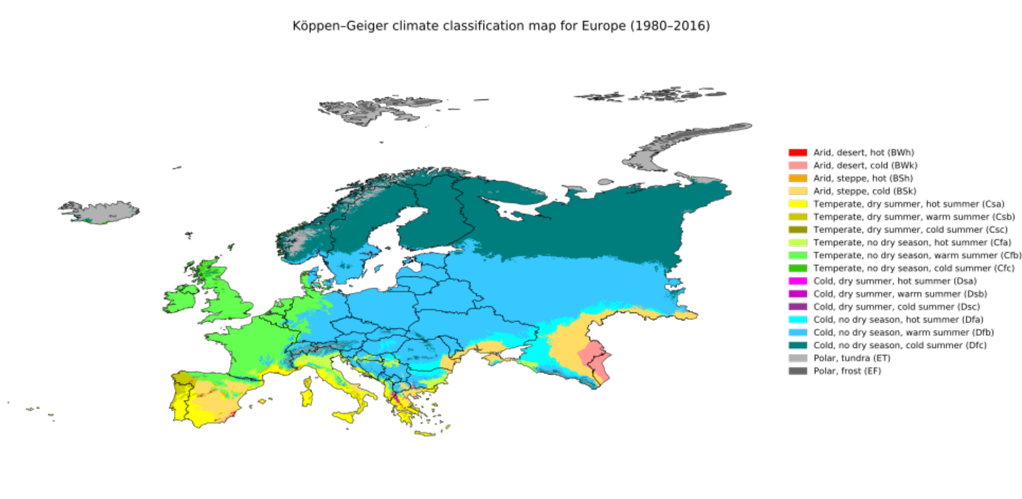
11.1 Europe: map of countries

11.2 Orographic map of Europe



by San Jose, based on the Generic Mapping Tools and ETOPO2

11.3 Europe: map of climate



by Beck, H.E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., & Wood, E. F.

11.4 Europe: data

[a]Country	[b]Popul. weight. lat.	[c]Area	[d]Hum. pop. dens.	[e]Pig dens.	[f]Deaths per million	[g]Max z-score of mortality
Albania	41.2	28748	99	6.40	210	
Austria	47.8	83858	107	33.11	184	4.21
Belgium	50.8	30510	378	203.51	1197	24.71
Bosnia and H.	44.2	51129	65	[1]10.60	552	
Bulgaria	42.8	110994	63	5.90	284	
Croatia	45.3	56594	72	18.54	236	
Cyprus	35.0	9251	95	39.14	28	4.05
Czechia	49.8	78866	136	19.12	549	
Denmark	55.9	[5]44493	131	284.13	130	2.38
Estonia	59.0	45339	29	6.41	60	2.85
Finland	61.7	338145	16	3.08	67	2.77
France	47.1	[4]551695	122	24.86	672	24.36
Germany	50.8	357386	233	74.00	148	[2]
Greece	38.7	131940	81	5.46	96	3.53
Hungary	47.3	93030	105	30.87	299	3.15
Iceland	64.3	102775	3.6	0.35	73	
Ireland	53.1	70273	71	22.37	398	11.79
Italy	42.9	301338	199	28.18	730	16.94
Kosovo	42.7	10887	164	3.69	–	
Latvia	56.8	64589	29	4.72	62	
Lithuania	55.2	65300	43	8.76	93	
Luxembourg	49.6	2586	242	31.94	348	2.97
Malta	35.9	316	1628	114.84	208	3.98
Montenegro	42.4	13812	45	[3]1.71	600	
Netherlands	52.1	[4]41198	426	289.67	487	20.72
N. Macedonia	41.7	25713	81	7.62	606	
Norway	61.1	[6]385178	15	[8]0.21	54	2.48
Poland	51.7	312685	123	35.27	251	
Portugal	39.8	[7]91568	112	24.08	319	8.4
Romania	45.7	238397	81	16.47	453	
Serbia	44.8	77453	89	35.92	111	
Slovakia	48.7	49036	111	12.79	90	
Slovenia	46.2	20273	104	12.78	348	9.51
Spain	39.7	[4]498511	95	[3]61.79	872	41.97
Sweden	58.9	450295	23	3.15	609	12.93
Switzerland	47.0	41290	209	33.74	380	11.78
UK	52.7	[4]242495	275	19.17	754	36.17

Remark.
Data come from different sources and inconsistencies are possible.

a. Here we list the countries considered by EuroStat livestocks statistics in https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural_production_-_livestock_and_meat, from which Turkey has been excluded lacking of data for pigs.

b. The country population weighted center (PWC) latitudes were obtained from the Baylor University population resource http://cs.ecs.baylor.edu/~hamerly/software/europe_population_weighted_centers.txt and refer to year 2000. They are intended to resume any whole country in a single latitude keeping in consideration the effective geographic distribution of people.

c. https://en.wikipedia.org/wiki/List_of_European_countries_by_area Retrieved 18 December.

d. Derived data from area data in https://en.wikipedia.org/wiki/List_of_European_countries_by_area and population data in https://en.wikipedia.org/wiki/List_of_countries_and_dependencies_by_population

e. Derived data from pig data (2018) of EuroStat in https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural_production_-_livestock_and_meat and area data in https://en.wikipedia.org/wiki/List_of_European_countries_by_area

f. Data from https://www.worldometers.info/coronavirus/ Retrieved 13th November 2020.

g. Data from EuroMOMO in https://www.euromomo.eu/graphs-and-maps/ Retrieved 13th November 2020.

1. This figure derives from the amount of pigs qualified as “estimate” by EuroStat.

2. EuroMOMO gives z-score of mortality only for two sub-areas of Germany: Berlin and Hesse; their maximum are 2.89 and 3.58.

3. This figure derives from the amount of pigs qualified as “provisional” by EuroStat.

4. This is the area of the portion of the country in the European continent.

5. This is the area of Denmark, including Faroe Islands.

6. This includes Svalbard and Jan Mayen.

7. This includes the Azores Islands and the Madeira Archipelago.

8. From 2019 data[23] 81 792 farm pigs; 2018 was 86 961; 2020 estimate is 75 840, retrieved 13th Nov. 2020

Turkey has been removed both because its territory is almost all outside Europe, and because EuroStat table lacks just the data of pigs.

11.5 Farm pigs in Europe: a map

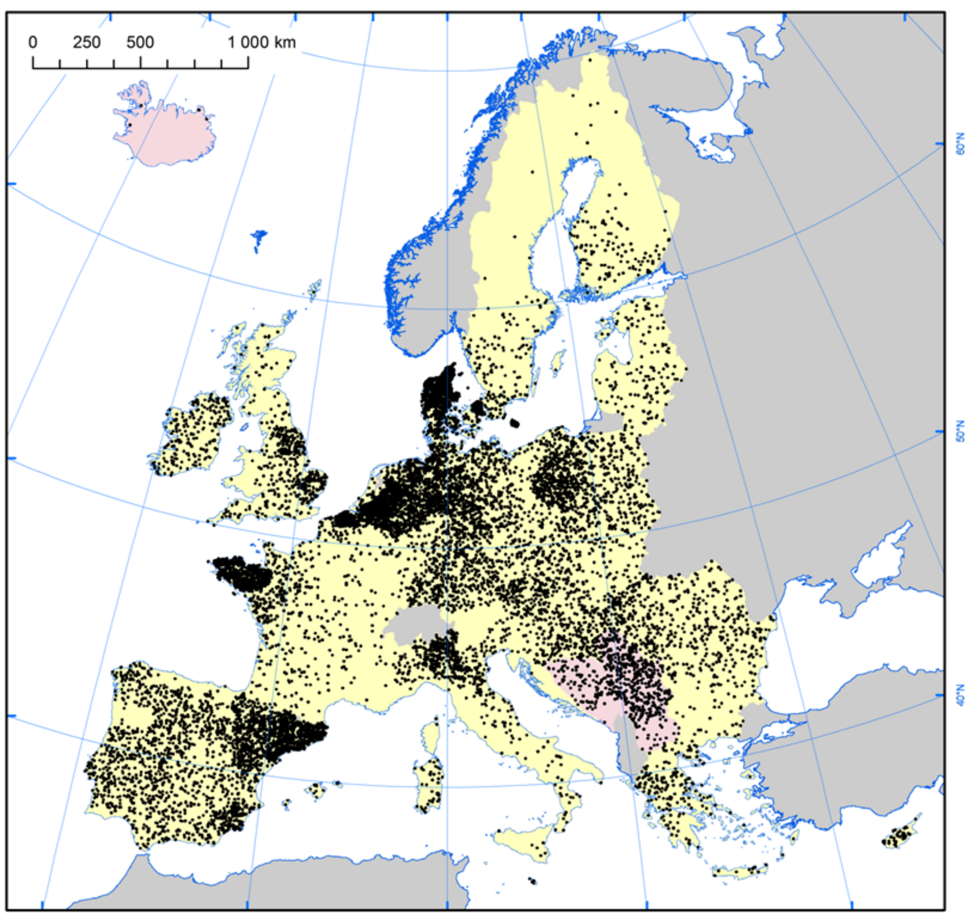


Figure above: map (2013) of sows[57] in Europe.

11.6 Wild boars in Europe

11.6.1 2018 PLoS One wild boar map

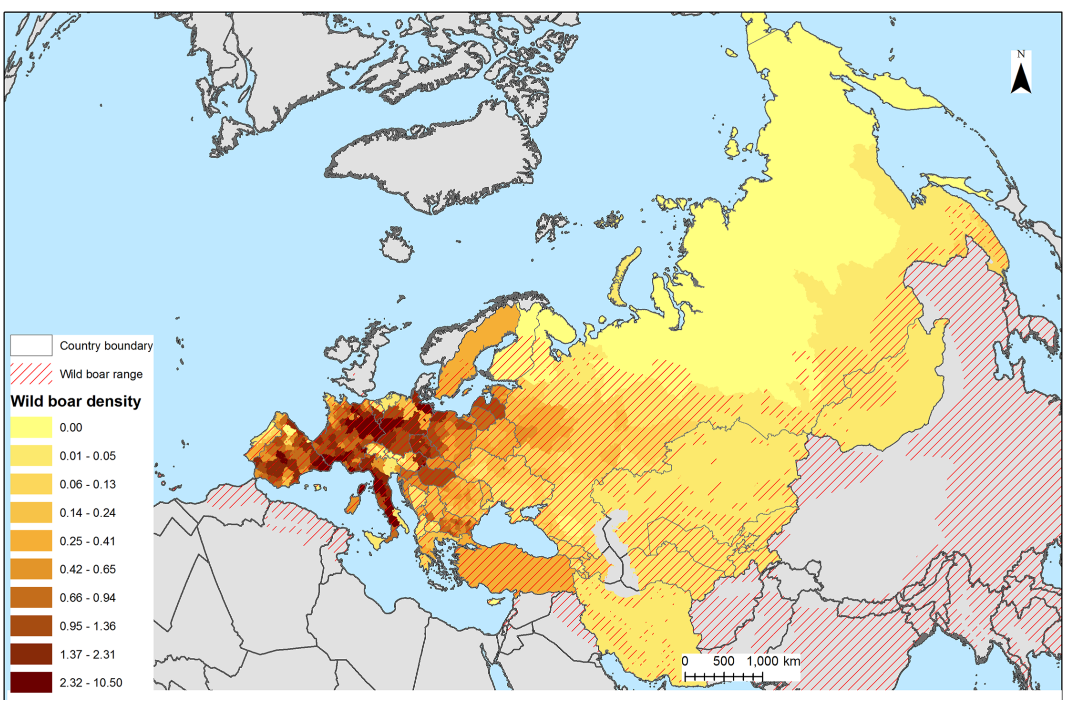


Figure above: Wild boar mapping using population-density statistics[52]

11.6.2 2019 FAO wild boar map

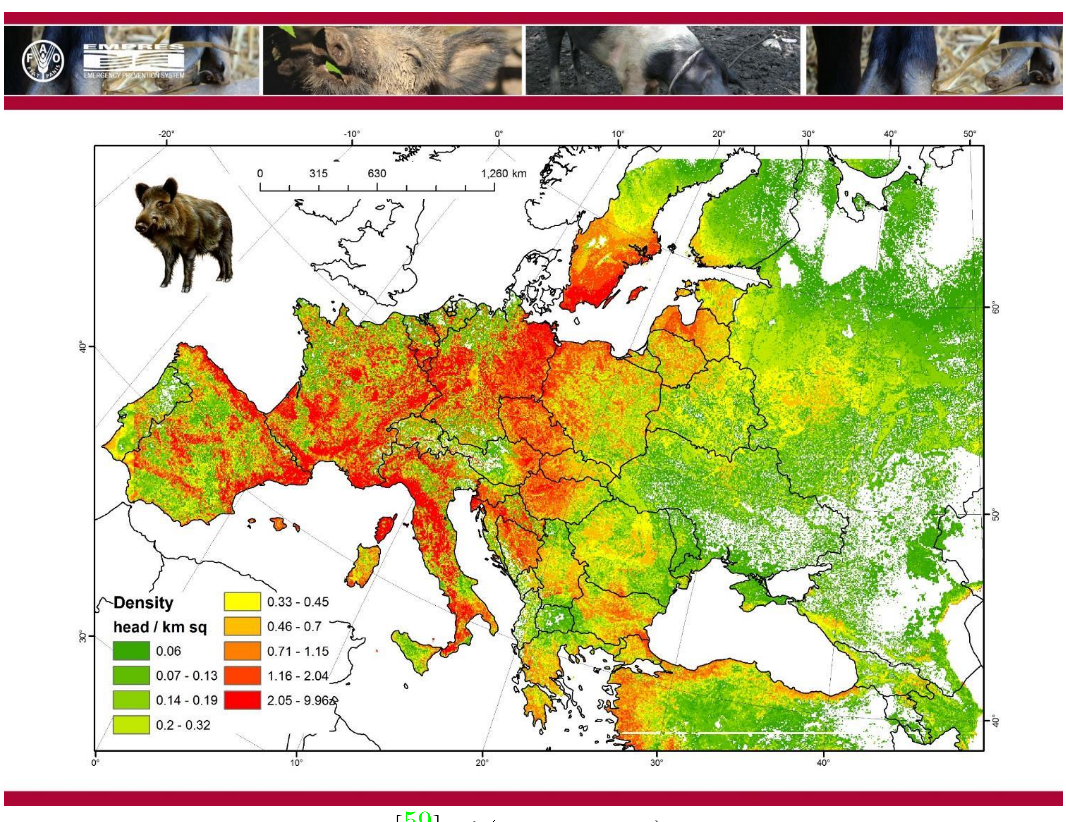


Figure above: map[59] of (hypothetical) wild boars density.

11.6.3 2020 ENETwild wild boar map

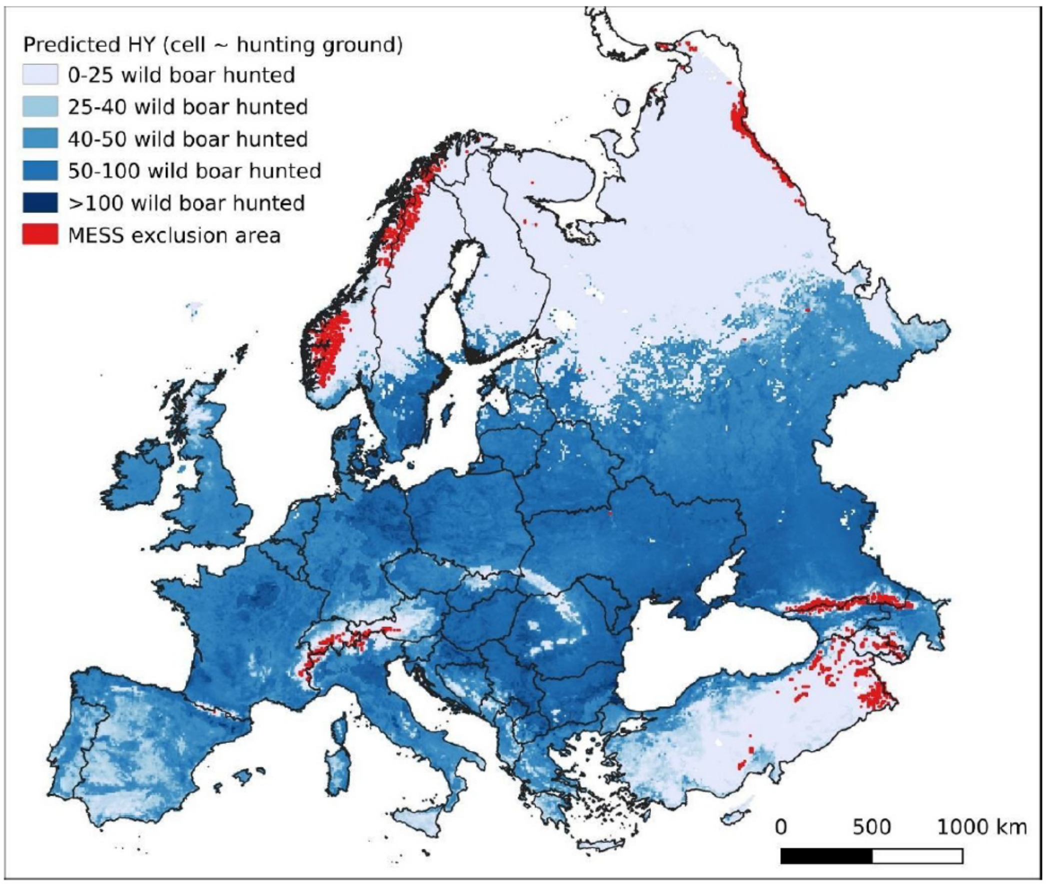
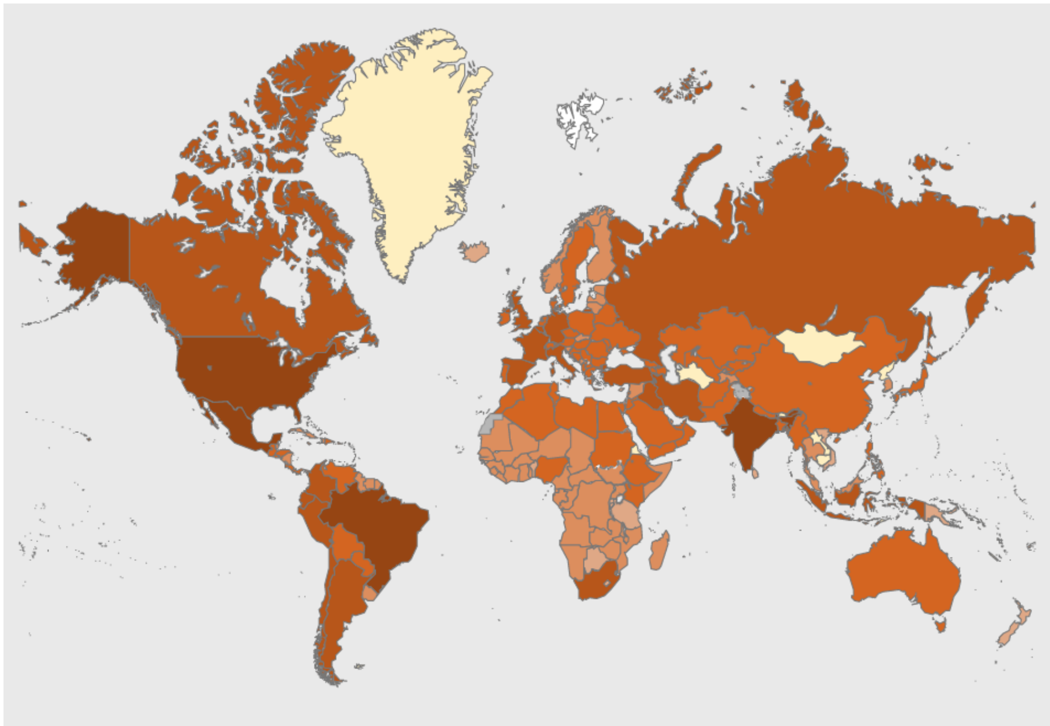


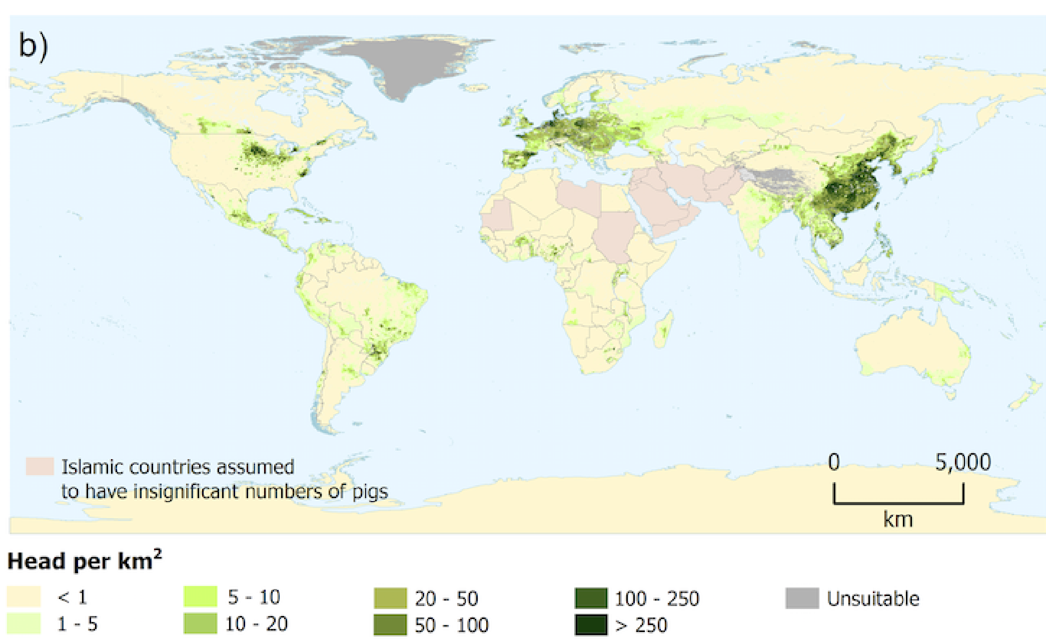
Figure above: map[58] of (hypothetical) wild boars density.

11.7 World maps

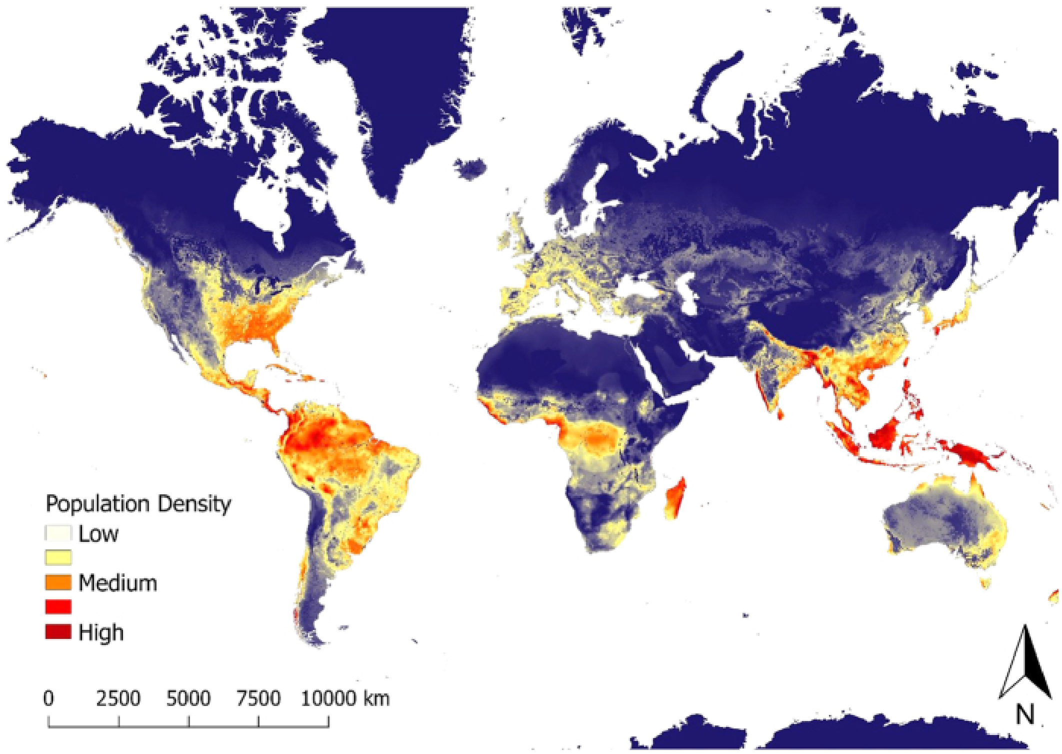
First of all let's see[20] a WHO/OMS world map (at 11th November 2020) of deaths of the pandemic.



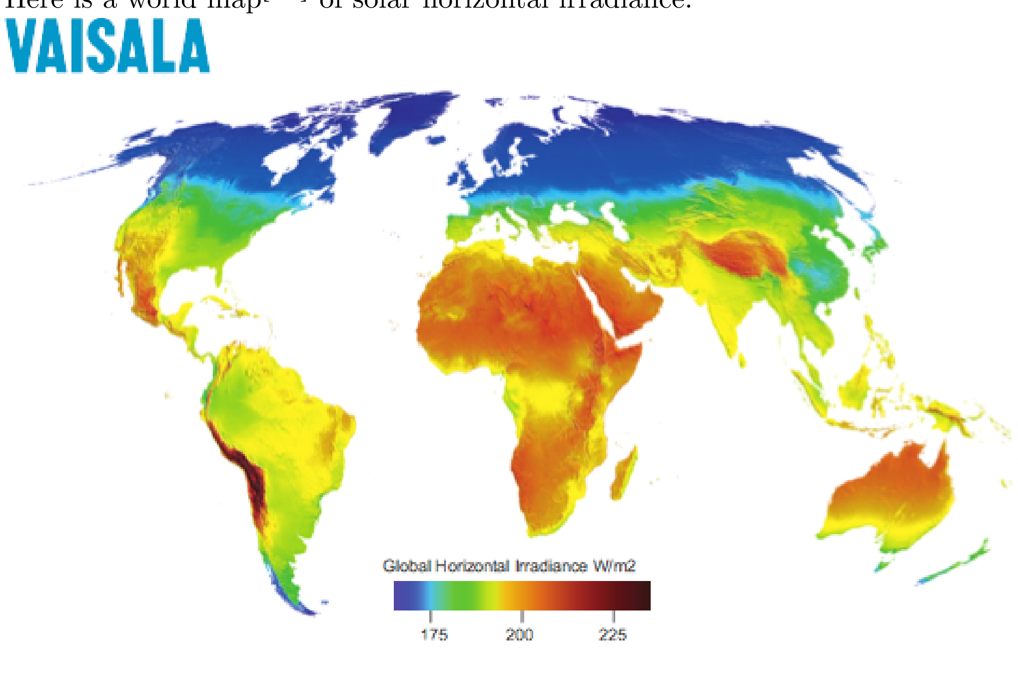
Then let's see[24] a world map (2014) of farmed pigs.



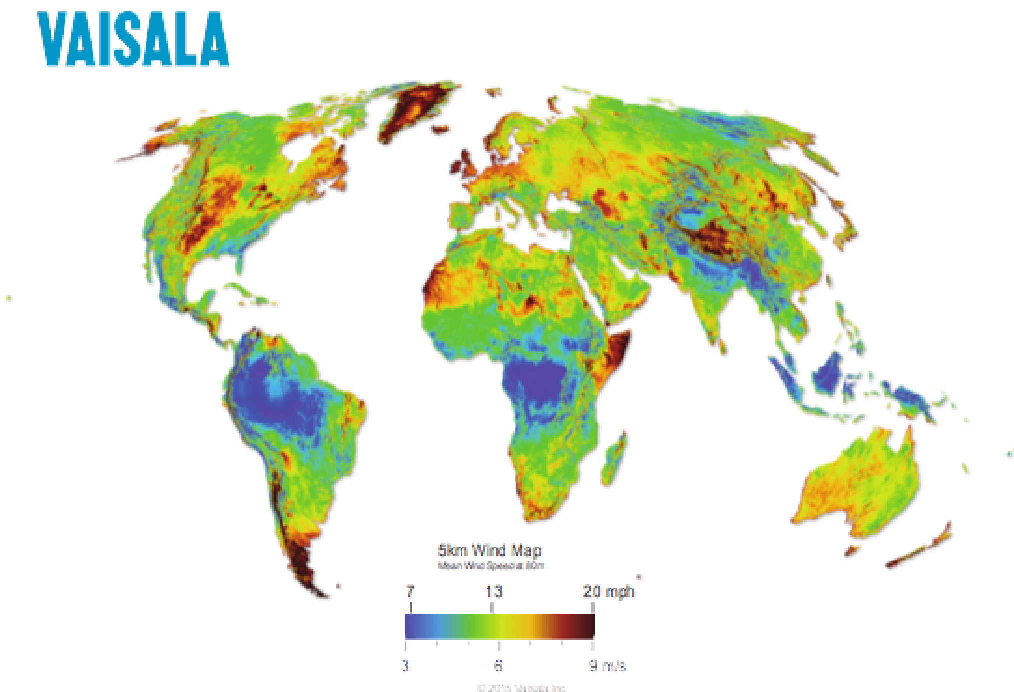
Then let's see[25] a world map (2017) of wild boars - hypothetic.



Here is a world map[64] of solar horizontal irradiance.



Here is a map[64] of wind intensity of the world.



See also World Wind Atlas in https://globalwindatlas.info/.

12 European comparisons

In the following 5 paragraphs it will be shown that the abundance of pigs (farm pigs and wild boars), together with latitude and solar irradiance, is sufficient to explain some differences in the death toll of the epidemic among European countries.

A deeper analysis should include the other livestocks, see Section 3.

Solar irradiances have ben roughly estimated from Vaisala map reported in 11.7.
Hypothetical wild boars population densities have been roughly estimated from the maps in 11.6, 12.1 and 12.2.
Deaths per million are from Worldometer in https://www.worldometers.info/coronavirus/ and refer to different dates during the extension of this study.
In the table in 11.4 one may find this other data and their sources:
- country population weighted center (PWC) latitudes
- farm pig density
- human population density

- max z-score of mortality
except for farm pig density of Norway, see 12.1.

12.1 Comparison: Scandinavian peninsula

The entity of the epidemic, measured both by deaths per million (attributed to covid-19) and by maximal z-score of mortality (all-causes mortality), was the lowest in Norway and the highest in Sweden.
This is exactly the same ranking of farm pigs number, farm pig density and (estimated) wild boars density. (Further research is needed to assess the matter of the extreme inhomogeneity in the distribution of humans, pigs and wild boars in those countries.)

So the new model well accounts for the widely-discussed issue of the different epidemic intensities in those 3 countries, and especially the much more favourable outcome of the epidemic in Norway compared to Sweden.

Country	Farm pigs density head/km^2	Wild boars density	Deaths per million	max z-score of mortality 2020
Norway	•	∘	+	†
Finland	•••••••••••••••	∘∘	+	†
Sweden	••••••••••••••••	∘∘∘∘∘	+++++++++	††††††

More precisely, we have the data of the following table.

Country	Farm pigs	Farm pig density head/km^2	Wild boars density$^\diamond$	Deaths† per million	max z-score of mortality 2020$^\bullet$
Norway	81 792*	0.212	∘	54	2.48
Finland	1 041 200**	3.076	∘∘	67	2.77
Sweden	1 417 200**	3.147	∘∘∘∘∘	609	12.93

* data[23] 2019; 2018 was 86 961; 2020 estimate is 75 840, retrieved 13th Nov. 2020

** data[61] 2018

$^\diamond$ roughly estimated from the map below and maps in 11.6

† data[22] 13th Nov. 2020 from Worldometer, retrieved 13th Nov. 2020

- data[21] till 45th week 2020, retrieved 13th Nov. 2020

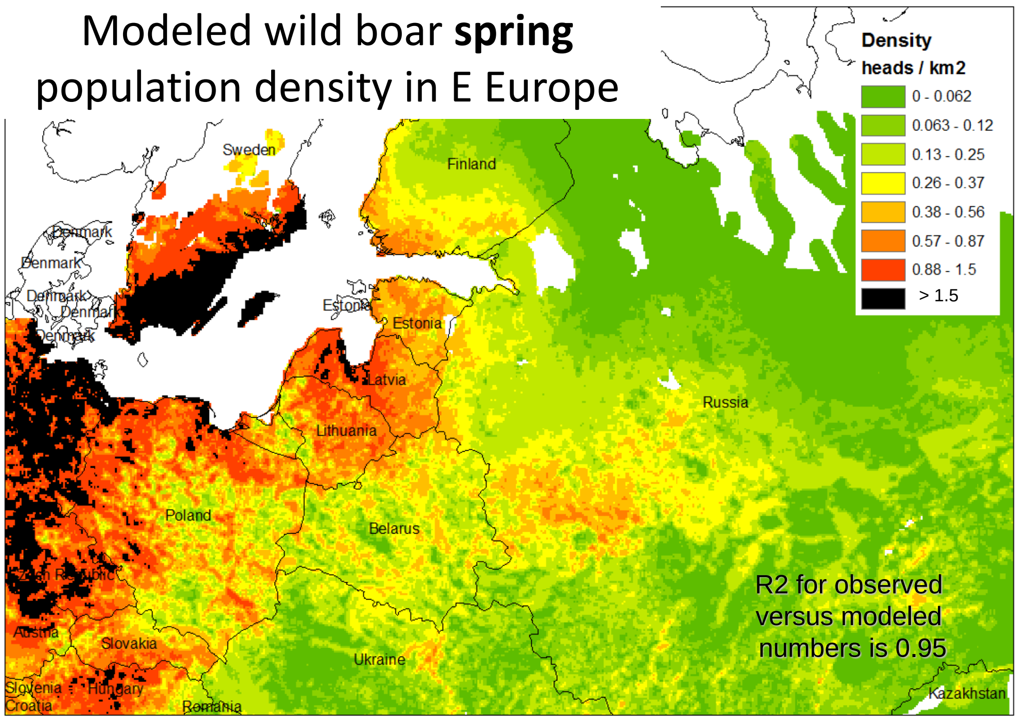


Figure above: spring wild boar density (hypotethical) in[53] Southern Sweden and Finland

12.2 Comparison: Iberian peninsula

Portugal and Spain are quite similar adjacent countries, almost[5] completely occupying a well-defined geographic region, the Iberian peninsula.

But in Spain the epidemic hits much more than in Portugal.

The differences of the populations of farm pigs and wild boars in the 2 countries may explain that largely-discussed issue, as may be seen in this table and in the following.

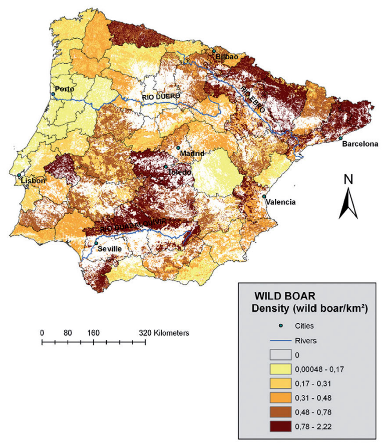
Country	Popul. weight. lat.	Solar irrad.	Wild boar density	Farm pig density	Human popul. density	Deaths per million	max z-score of mortality
Portugal	very similar	similar	∘	••	∧∧∧∧∧∧∧∧∧∧∧∧	†††	+
Spain	very similar	similar	∘∘∘	•••••	∧∧∧∧∧∧∧∧∧∧	††††††††	+++++

More precisely, we have the data of the following table.

[5] From Wikipedia, the free encyclopaedia, for Iberian Peninsula writes "It is principally divided between Spain and Portugal, comprising most of their territory, as well as a small area of Southern France, Andorra and the British overseas territory of Gibraltar". Retrieved 17th Nov. 2020

Country	Popul. weight. lat.	*Solar irrad.	◇Wild boar density	Farm pig density	Human popul. density	Deaths per million	max z-score of mortality
Portugal	39.8	similar	∘	24	112	319	8.4
Spain	39.7	similar	∘∘∘	62	95	872	41.97

* roughly estimated from Vaisala map in 11.7
◇ roughly estimated from maps in 11.6 and that here below in this paragraph.
All other data are in the table given in 11.4.



Wild boar density[51] map of the Iberian peninsula

12.3 Comparison: Slovakia vs Austria and Hungary

These 3 countries have:
– similar weighted latitudes: 48.7, 47.8 and 47.3, to which similar solar irradiances correspond (see 11.7);
– similar human population densities: 111, 106 and 105.
But Slovakia has low pig density 12.8, and few deaths per million 90, while Austria and Hungary have high pig densities 33.1 and 30.9, and many deaths per million 184 and 299.
(For that triplet of countries, the comparison with z-scores of mortality –which will be used in the following remark– is impossible because EuroMOMO does not provide data for Slovakia).

Country	Weighted Latitude	Solar irradiance	Farm pig density	Human pop. density	Deaths per million
Austria	similar	similar	•••	similar	++
Hungary	similar	similar	•••	similar	+++
Slovakia	similar	similar	•	similar	+

More precisely, we have the data of the following table.

Country	Weighted Latitude	Solar irradiance	Farm pig density	Human pop. density	Deaths per million
Austria	47.8	similar	33.1	106	184
Hungary	47.3	similar	30.9	105	299
Slovakia	48.7	similar	12.8	111	90

12.4 Comparison: Belgium

Belgium is the country with the highest number of deaths per million (1259 in Worldometer at 17th Nov. 2020) in Europe and even in the world.
Its position is quite prominent, followed by San Marino which is a microstate and Peru which is in Americas and has 15% deaths per million less than Belgium. (Than Andorra follows which is another microstate.)
Notice that it ranks 3rd both for pig density and population density in Europe data in 11.4 with 37 countries.

13 Comparison: pigs, Ukraine regions

The position of Ukraine, its quite flat orography and its quite uniform climate may be appreciated in 11.1, in 11.2 and in 11.3.

13.1 With pigs of 4 kinds

Ukraine is a very special case because it is the only region for which in this research it has been possible to find at the same geographical scale of several subareas data about the pandemic, and data about both farm pigs and wild boars. Furthermore the source[13] about farm pigs distinguishes 3 kinds of them, counted at 1 January 2020:

enterprise farm pigs
private farm pigs
household farm pigs.

Wild boars densities data come from another[60] source (2010).

That quadruple distinction among pigs will allow a further interesting study, about wild boars.

Notice that in recent years large fluctuations of the number of farm pigs[11] have occurred. It has been written[12]:

> Numbers are continually fluctuating but (...) a drop of 8.4% (3.334 million head against 3.639 million) in pig

> livestock populations is observed, according to UNIAN (24th October 2017).
> "The largest reduction was reported by agri-businesses (...) There are many factors that affected the situation: African swine fever (ASF) outbreaks (...) The tendency of reducing the number of pigs in the households is continuing and it almost does not react to the temporary market factors, that is, it is evolutionary, (...) and the total number of pigs at the beginning of next year is expected to be the lowest in Ukraine's current history, at the level of 6.1 million head (...)"

Data about wild boars are old (2010), nevertheless some statistics may be attempted in this study because some conclusions do not rely on absolute numbers and it conceivable that some proportionality among wild boars in the regions has been at least partially preserved.

13.2 Ukraine: data

In this research a consistent series of reports for incidence and mortality for each Ukraine region (oblast) have been found and we will use the first, dated 2 July, and the last, dated 9 August.

Nevertheless a problem arises when comparing those data with farm pigs data and wild boars data: because of this the most reasonable solution found was simply to exclude the region (oblast) of Kyiv and the municipality (City) of Kyiv.

13.2.1 Table: Ukraine, pandemic, original data

Region	(a)Incidence 2 Jul	(a)Mortality 2 Jul	(b)Incidence 9 Aug	(b)Mortality 9 Aug
Cherkasy	54.2	2.2	86.1	3.1
Chernihiv	55.2	1.1	102.8	1.8
Chernivtsi	543.0	20.3	741.2	25.0
Dnipropetrovsk	34.5	0.7	48.9	1.0
Donetsk	13.6	0.2	51.9	0.7
Ivano-Frankivsk	182.0	7.5	415.7	11.4
Kharkiv	83.1	3.2	180.6	5.
Kherson	18.9	0.3	26.1	0.4
Khmelnytsky	64.4	1.4	107.6	2.1
Kirovograd	69.7	3.3	77.7	4.2
Luhansk	3.9	0.0	22.8	0.1
Lviv	228.2	5.8	432.9	12.0
Mykolaiv	39.9	0.9	63.2	1.4
Odesa	73.0	1.0	175.5	2.8
Poltava	23.1	0.9	35.8	1.1
Rivne	336.3	6.1	594.1	8.9
Sumy	28.3	0.5	62.8	0.8
Ternopil	188.6	2.8	317.5	4.0
Vinnytsya	122.7	1.9	193.2	4.0
Volyn	243.2	6.0	415.7	8.8
Zakarpattya	243.0	7.7	460.2	17.6
Zaporizhia	34.2	1.0	55.8	1.3
Zhytomyr	117.7	2.5	177.0	3.4
Kyiv oblast	149.0	2.9	234.4	3.8
Kyiv (City of)	176.7	3.7	320.3	5.0

(a) https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/eng_ukr_cov-19_sitrep_july_2_2020.pdf, Retrieved 23 December 2020
(b) https://www.humanitarianresponse.info/sites/www.humanitarianresponse.info/files/documents/files/eng_ukr_cov-19_sitrep_august_09_2020.pdf, Retrieved 23 December 2020

13.2.2 Table: Ukraine, 4 types of pigs, original data

Region	(a) Area km^2	(b) Private farm pigs 1 Jan 2020	(b) Enterprise farm pigs 1 Jan 2020	(b) Household farm pigs 1 Jan 2020	(c) Wild boars density 2010
Cherkasy	20,900	19,800	204,000	130,800	0.165
Chernihiv	31,865	6,400	60,100	75,400	0.125
Chernivtsi	8,097	2,500	119,600	87,200	0.165
Dnipropetrovsk	31,914	28,800	269,700	72,800	0.04
Donetsk	26,517	9,600	422,700	31,900	0.065
Ivano-Frankivsk	13,900	3,000	212,200	92,400	0.125
Kharkiv	31,415	1,400	12,200	78,700	0.09
Kherson	28,461	6,100	67,000	30,600	0.01
Khmelnytsky	20,645	16,800	159,800	152,400	0.065
Kirovograd	24,588	19,700	137,200	76,300	0.04
Luhansk	26,684	13,700	26,000	19,500	0.04
Lviv	21,833	20,400	193,100	139,300	0.125
Mykolaiv	24,598	5,000	35,400	42,200	0.01
Odesa	33,310	9,500	70,600	79,800	0.065
Poltava	28,748	15,900	186,800	86,900	0.09
Rivne	20,047	4,900	29,900	205,600	0.125
Sumy	23,834	2,000	52,600	59,100	0.09
Ternopil	13,823	8,100	127,900	171,000	0.04
Vinnytsya	26,513	14,200	95,700	149,900	0.065
Volyn	20,144	25,400	76,200	194,200	0.125
Zakarpattya	12,777	12,600	21,700	227,100	0.165
Zaporizhia	27,180	4,100	128,000	59,800	0.04
Zhytomyr	29,832	8,500	41,200	85,400	0.165
Kyiv oblast	28,131	25,600	440,700	79,000	0.165
Kyiv (City of)	839				

(a) https://en.wikipedia.org/wiki/List_of_Ukrainian_oblasts_and_territories_by_area

(b) [13]

(c) http://www.fao.org/3/a-ak755e.pdf

Remark. The original data about wild boars densities are given as intervals and here they have been reduced to the arithmetical mean of the extremes. For example 0.165 is from the intervals 0.15–0.18.

13.2.3 Table: Ukraine, 4 types of pigs, derived data

Region	(a) Private farm pigs density	(a) Enterprise farm pigs density	(a) Household farm pigs density	(a) All farm pigs density	(b) All pigs density (with wild boars)
Cherkasy	0.947	9.761	6.258	16.967	17.132
Chernihiv	0.201	1.886	2.366	4.453	4.578
Chernivtsi	0.309	14.771	10.769	25.849	26.014
Dnipropetrovsk	0.902	8.451	2.281	11.634	11.674
Donetsk	0.362	15.941	1.203	17.506	17.571
Ivano-Frankivsk	0.216	15.266	6.647	22.129	22.254
Kharkiv	0.045	0.388	2.505	2.938	3.028
Kherson	0.214	2.354	1.075	3.644	3.654
Khmelnytsky	0.814	7.740	7.382	15.936	16.001
Kirovograd	0.801	5.580	3.103	9.484	9.524
Luhansk	0.513	0.974	0.731	2.219	2.259
Lviv	0.934	8.844	6.380	16.159	16.284
Mykolaiv	0.203	1.439	1.716	3.358	3.368
Odesa	0.285	2.119	2.396	4.800	4.865
Poltava	0.553	6.498	3.023	10.074	10.164
Rivne	0.244	1.491	10.256	11.992	12.117
Sumy	0.084	2.207	2.480	4.770	4.860
Ternopil	0.586	9.253	12.371	22.209	22.249
Vinnytsya	0.536	3.610	5.654	9.799	9.864
Volyn	1.261	3.783	9.641	14.684	14.809
Zakarpattya	0.986	1.698	17.774	20.459	20.624
Zaporizhia	0.151	4.709	2.200	7.060	7.100
Zhytomyr	0.285	1.381	2.863	4.529	4.694
Kyiv oblast	0.910	15.666	2.808	19.384	19.549
Kyiv (City of)					

(a) derived data from (b) and (a) of the previous table

(b) derived data from (c), (b) and (a) of the previous table

13.3 Comparison: Ukraine, pigs, coefficients

13.3.1 Table: Ukraine, pigs, Pearson's coefficients

Type of pigs densities	Incidence till 2 Jul	Mortality till 2 Jul	Incidence till 9 Aug	Mortality till 9 Aug
Private farm pigs density	0.147	0.091	0.131	0.162
Enterprise farm pigs density	0.209	0.286	0.173	0.220
Household farm pigs density	**0.743**	**0.630**	**0.775**	**0.704**
Wild boars density	0.498	0.482	0.542	0.534
All farm pigs density	0.568	0.545	0.580	0.575
All pigs density (with wild boars)	0.570	0.547	0.583	0.578
Weighted all pigs density 0×private + 0.075×enterprise + 1×household + 10×wild boars	0.739	0.638	0.775	0.710

Pandemic data are considered and the logarithms of pigs densities.

The coefficients of the weighted all pigs densities have been searched trying to optimise the correlation with the mortality till 2 July and in no way it may be granted that those coefficients are the best possible.
In any case the obtained result is scarcely meaningful.

Notice the high correlation of the household farm pigs density with the pandemic intensity, and secondarily that of wild boars density.

13.3.2 Remark. p-values

With $n = 23$ and the theory exposed in 2.2, we are able to give the (approximate) p-values for the test of the linear increasing monotonicity. Computations[29] have been performed online.

TABLE OF p-VALUES

	Incidence 2 Jul	Mortality 2 Jul	Incidence 9 Aug	Mortality 9 Aug
Private farm pigs density	(0.25)	(0.34)	(0.28)	(0.23)
Enterprise farm pigs density	(0.17)	(0.093)	(0.21)	(0.16)
Household farm pigs density	**0.000024**	**0.00064**	**<0.00001**	**0.000089**
Wild boars density	0.0078	0.0099	0.0038	0.0043
All farm pigs density	0.0056	0.0027	0.0036	0.0042
All pigs density (with wild boars)	0.0023	0.0035	0.0018	0.0019
Weighted all pigs density 0×private + 0.075×enterprise + 1×household + 10×wild boars	0.000028	0.00053	< 0.00001	0.000074

Again notice the high likelyhood for the statement “More pigs, more epidemics”, especially for household farm pigs, and secondarily wild boars.

13.3.3 Table: Ukraine, pigs, Spearman's coefficients

Type of pigs densities	Incidence 2 Jul	Mortality 2 Jul	Incidence 9 Aug	Mortality 9 Aug
Private farm pigs density	0.274	0.276	0.208	0.281
Enterprise farm pigs density	0.055	0.143	0.068	0.118
Household farm pigs density	**0.851**	**0.865**	**0.842**	**0.834**
Wild boars density	(ties)	(ties)	(ties)	(ties)
All farm pigs density	0.519	0.561	0.545	0.536
All pigs density (with wild boars)	0.518	0.567	0.546	0.542
Weighted all pigs density 0×private + 0.075×enterprise + 1×household + 10×wild boars	0.829	0.850	0.829	0.807

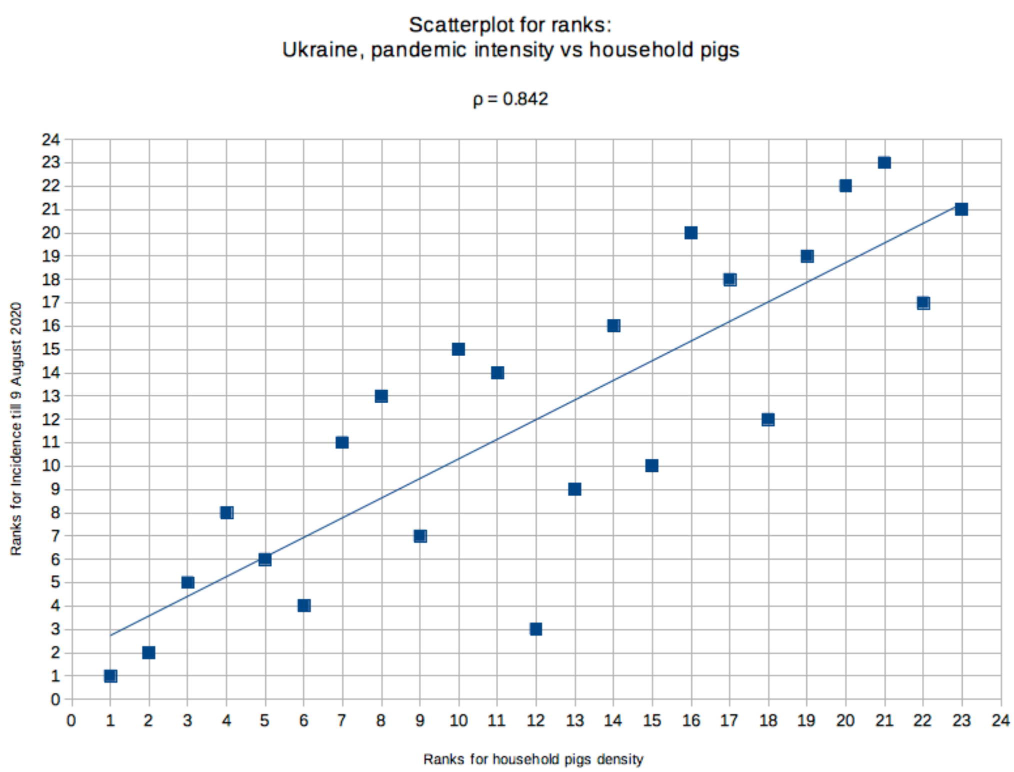
The analysis for wild boars densities have not been performed because data have several ties, that is to say several data are equal, having the same ranks. (Remember that the data about wild boars densities are largely approximate, see Remark in 13.2.2.)

Also from the point of view of the ranks, notice the high likelyhood for the statement “More pigs, more epidemics”, especially for household farm pigs.

13.4 Scatterplots: Ukraine, pigs and pandemic

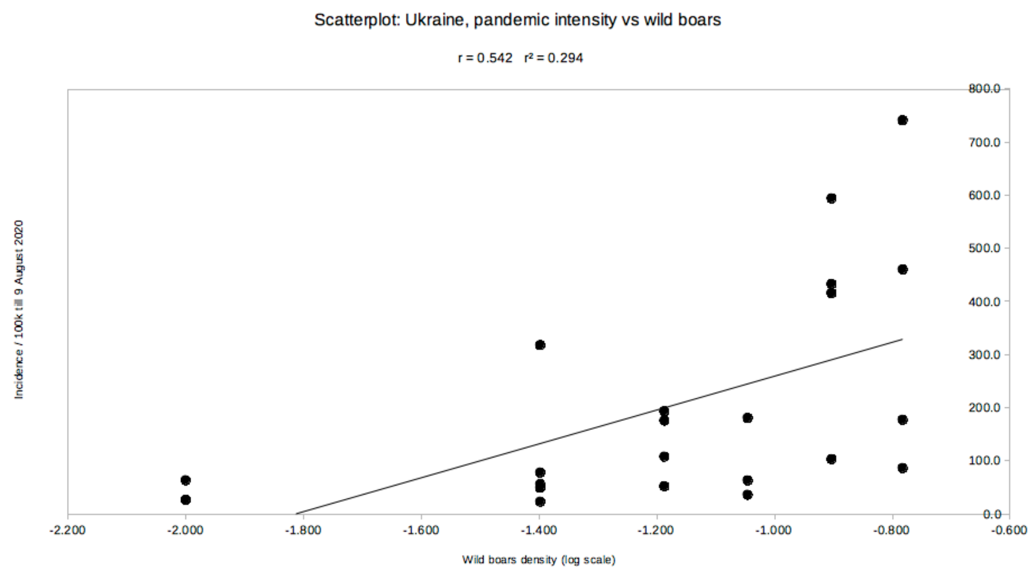
In this paragraph some scatterplots are given, particularly meaningful among all those corresponding to the data of the previous paragraphs.

13.4.1 Scatterplot: Ukraine, household pigs and pandemic



Other 2 scatterplots representing the same data are in 2.1

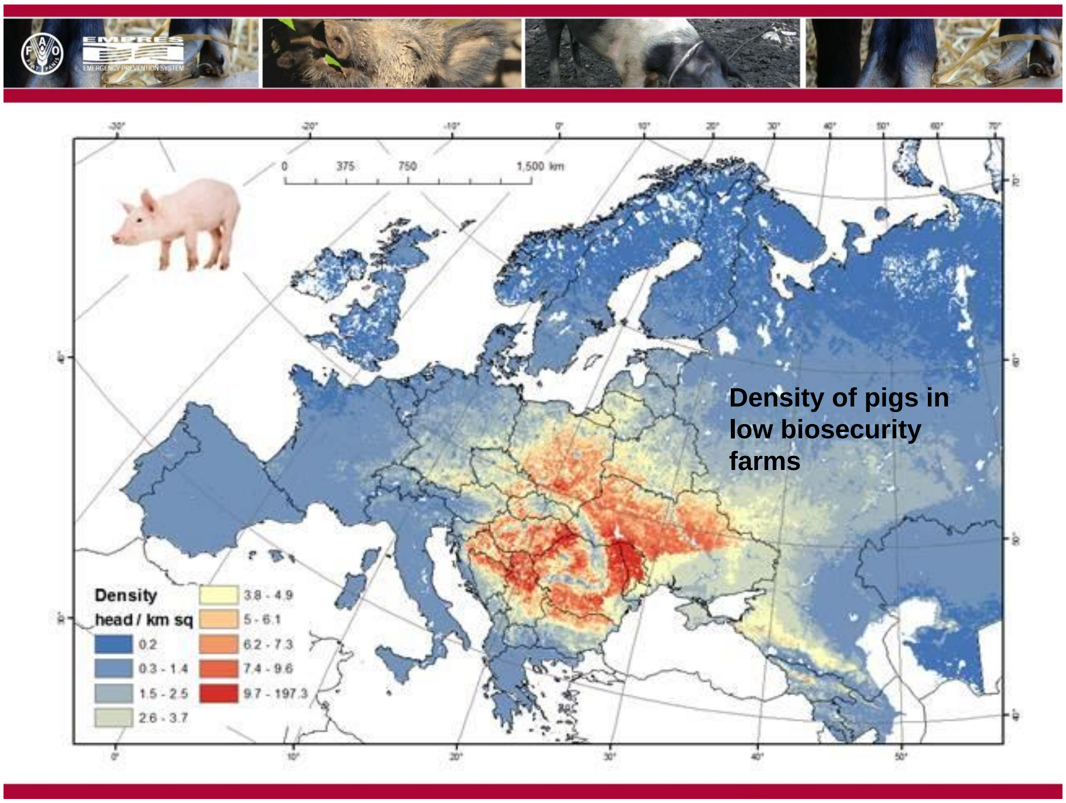
13.4.2 Scatterplot: Ukraine, wild boars and pandemic



Remember that the data about wild boars densities are largely approximate, see Remark in 13.2.2.

13.5 Ukraine: pigs, conclusions

In this model the mayor harm is given by household pigs and secondarily wild boars. All that is kind of reasonable: household pigs have closer contact with people than enterprise and private farm pigs, and wild boars (even though they don't usually have close contact with humans, with the notable exception of hunting) may contribute greatly to the contagion circulating and infecting household pigs. The contact between backyard pigs and wild boars is widely [59] [60]investigated because of African swine fever virus and just in Ukraine that contact is quite common.



Contact between farm pigs and wild boars[59]

14 Comparison: livestocks in Ukraine

14.1 Original data, livestocks and humans

TABLE: UKRAINE, ORIGINAL DATA, LIVESTOCKS AND HUMANS

Region	(a) Cattle	(a) Cows	(a) Sheep and goats	(a) Sheep	(b) Goats	(a) Horses	(a) Rabbits	(a) Poultry	(c) Humans
Cherkasy	152 900	69 300	26 100	6 700	19 400	2 600	171 400	25 261 600	1 246 166
Chernihiv	157 200	89 500	26 500	7 000	19 500	6 600	292 800	3 548 200	1 047 023
Chernivtsi	76 900	49 100	43 300	32 400	10 900	5 500	83 800	3 726 100	910 001
Dnipropetrovsk	114 800	65 400	55 400	22 100	33 300	1 000	140 100	17 763 000	3 258 705
Donetsk	53 300	29 300	35 500	16 400	19 100	700	189 300	6 104 900	4 387 702
Ivano-Frankivsk	128 200	79 000	27 600	9 000	18 600	8 400	62 500	4 908 400	1 382 721
Kharkiv	164 600	79 300	70 200	31 700	38 500	1 800	242 800	8 151 800	2 720 342
Kherson	80 700	52 400	29 800	19 200	10 600	700	61 000	5 703 400	1 063 803
Khmelnytsky	221 300	126 600	26 500	4 400	22 100	16 500	210 400	8 157 300	1 296 103
Kirovograd	82 000	46 800	34 000	8 600	25 400	2 700	102 100	5 481 000	974 724
Luhansk	45 000	20 800	22 700	10 300	12 400	1 000	39 400	931 400	2 263 676
Lviv	157 300	94 300	31 500	7 900	23 600	29 900	285 800	9 914 900	2 535 476
Mykolaiv	86 900	54 000	46 500	30 000	16 500	2 000	100 700	2 453 200	1 159 634
Odesa	145 700	90 000	293 200	224 800	68 400	9 900	308 700	2 624 500	2 387 282
Poltava	209 800	114 900	46 900	15 800	31 100	2 900	259 400	5 388 200	1 440 684
Rivne	105 500	74 200	15 400	4 600	10 800	28 200	16 900	7 266 600	1 162 049
Sumy	137 200	71 500	38 000	11 100	26 900	6 400	185 200	5 310 000	1 115 051
Ternopil	138 900	86 500	15 100	3 500	11 600	17 200	121 300	5 197 200	1 066 523
Vinnytsya	220 700	125 800	30 700	7 800	22 900	7 600	361 800	37 505 400	1 604 270
Volyn	121 800	80 400	16 500	8 600	7 900	33 400	129 500	7 759 500	1 042 855
Zakarpattya	123 400	87 700	151 400	111 900	39 500	7 900	59 600	3 572 800	1 259 497
Zaporizhia	78 400	43 500	67 500	47 800	19 700	700	63 500	4 952 200	1 755 663
Zhytomyr	179 100	101 800	22 700	5 800	16 900	27 000	470 400	7 416 500	1 249 225
Kyiv oblast	108 400	56 400	31 500	11 400	20 100	3 800	564 500	31 387 700	1 731 673
Kyiv (City of)	–	–	–	–	–	–	–	–	2 900 920

(a) [13]
(b) Remark: goats are not given exactly given as original, but it is immediately obtainable from the two data “sheep and goats” and “sheep”.
(c) https://en.wikipedia.org/wiki/List_of_Ukrainian_oblasts_and_territories_by_population

14.2 Derived data, livestocks and humans

TABLE: UKRAINE, DERIVED DATA, LIVESTOCKS AND HUMANS

Region	Cattle density	Cows density	Sheep and goats density	Sheep density	Goats density	Horses density	Rabbits density	Poultry density	Humans population density
Cherkasy	7.316	3.316	1.249	0.321	0.928	0.124	8.201	1 208.689	59.625
Chernihiv	4.933	2.809	0.832	0.220	0.612	0.207	9.189	111.351	32.858
Chernivtsi	9.497	6.064	5.348	4.001	1.346	0.679	10.350	460.183	112.387
Dnipropetrovsk	3.597	2.049	1.736	0.692	1.043	0.031	4.390	556.590	102.109
Donetsk	2.010	1.105	1.339	0.618	0.720	0.026	7.139	230.226	165.468
Ivano-Frankivsk	9.223	5.683	1.986	0.647	1.338	0.604	4.496	353.122	99.476
Kharkiv	5.240	2.524	2.235	1.009	1.226	0.057	7.729	259.488	86.594
Kherson	2.835	1.841	1.047	0.675	0.372	0.025	2.143	200.394	37.378
Khmelnytsky	10.719	6.132	1.284	0.213	1.070	0.799	10.191	395.122	62.780
Kirovograd	3.335	1.903	1.383	0.350	1.033	0.110	4.152	222.914	39.642
Luhansk	1.686	0.779	0.851	0.386	0.465	0.037	1.477	34.905	84.833
Lviv	7.205	4.319	1.443	0.362	1.081	1.369	13.090	454.124	116.130
Mykolaiv	3.533	2.195	1.890	1.220	0.671	0.081	4.094	99.732	47.143
Odesa	4.374	2.702	8.802	6.749	2.053	0.297	9.267	78.790	71.669
Poltava	7.298	3.997	1.631	0.550	1.082	0.101	9.023	187.429	50.114
Rivne	5.263	3.701	0.768	0.229	0.539	1.407	0.843	362.478	57.966
Sumy	5.756	3.000	1.594	0.466	1.129	0.269	7.770	222.791	46.784
Ternopil	10.048	6.258	1.092	0.253	0.839	1.244	8.775	375.982	77.156
Vinnytsya	8.324	4.745	1.158	0.294	0.864	0.287	13.646	1 414.604	60.509
Volyn	6.046	3.991	0.819	0.427	0.392	1.658	6.429	385.202	51.770
Zakarpattya	9.658	6.864	11.849	8.758	3.091	0.618	4.665	279.627	98.575
Zaporizhia	2.884	1.600	2.483	1.759	0.725	0.026	2.336	182.200	64.594
Zhytomyr	6.004	3.412	0.761	0.194	0.567	0.905	15.768	248.609	41.875
Kyiv oblast	3.853	2.005	1.120	0.405	0.715	0.135	20.067	1 115.769	61.557
Kyiv (City of)	–	–	–	–	–	–	–	–	3 457.592

(a) data derived from the previous table and area data from 13.2

14.3 Ukraine, livestocks, Spearman's coefficients

Table: Ukraine, livestocks, Spearman's coefficients

Type of livestocks (and humans)	Incidence till 2 Jul	Mortality till 2 Jul	Incidence till 9 Aug	Mortality till 9 Aug
Cattle	0.642	0.639	0.668	0.626
Cows	0.727	0.688	0.747	0.687
Sheep and goats	0.030	0.119	0.067	0.184
Sheep	-0.084	-0.048	-0.073	0.007
Goats	0.262	0.339	0.314	0.403
Horses	0.837	0.711	0.834	0.718
Rabbits	0.312	0.208	0.355	0.283
Poultry	0.553	0.526	0.538	0.537
Household pigs	0.851	0.865	0.842	0.834
Enterprise pigs	0.055	0.143	0.068	0.118
Private pigs	0.274	0.276	0.208	0.281
All pigs	0.518	0.567	0.546	0.542
Humans	0.216	0.202	0.281	0.278

An interpretation of the above data is in paragraph 3.3.

14.4 Correlations among livestocks and humans

	EFP	PFP	HHP	Cattle	Cows	Sheep +goats	Sheep	Goats	Horses	Rabbits	Poultry
EFP	–	0.403	0.287	0.332	0.264	0.170	0.004	0.261	0.062	0.212	0.507
PFP	0.403	–	0.488	0.405	0.394	-0.107	-0.170	0.087	0.371	0.183	0.550
HHP	0.287	0.488	–	0.869	0.895	0.031	-0.199	0.375	0.824	0.329	0.646
Cattle	0.332	0.405	**0.869**	–	0.971	0.094	-0.218	0.480	0.705	0.575	0.640
Cows	0.264	0.394	**0.895**	0.971	–	0.071	-0.196	0.440	0.784	0.536	0.579
Sheep+g.	0.170	-0.107	0.031	0.094	0.071	–	0.835	0.815	-0.246	-0.004	-0.085
Sheep	0.004	-0.170	-0.199	-0.218	-0.196	0.835	–	0.463	-0.406	-0.301	-0.249
Goats	0.261	0.087	0.375	0.480	0.440	0.815	0.463	–	0.129	0.367	0.194
Horses	0.062	0.371	**0.824**	0.705	0.784	-0.246	-0.406	0.129	–	0.451	0.458
Rabbits	0.212	0.183	0.329	0.575	0.536	-0.004	-0.301	0.367	0.451	–	0.363
Poultry	0.507	0.550	0.646	0.640	0.579	-0.085	-0.249	0.194	0.458	0.363	–
Humans	0.439	0.269	0.197	0.186	0.178	0.487	0.404	0.470	0.047	0.080	0.374

EFP: Enterprise farm pigs

PFP: Private farm pigs

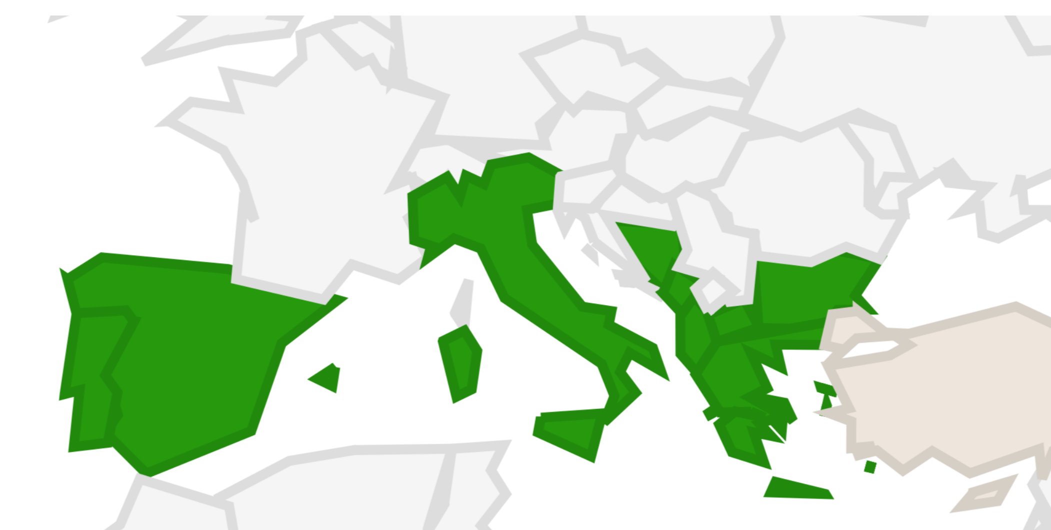
HHP: Household farm pigs

As remarked in 3.3 the high correlations between household pigs density and bovine density weakens the result of the high correlation between household pigs density and pandemic intensity, becoming difficult to distinguish the effect of pigs and bovine (where pigs, there bovine, roughly said).
Also the not so low correlation of poultry density with pigs, bovine and horses density is a problem of the same kind.

15 Comparison: pigs, South Europe

15.1 The countries of South Europe

In the 4 following paragraphs, 9 countries of Southern Europe will be considered at various times, the countries of the following map.



They are the countries in table 11.4, based on livestock Eurostat table, with (population weighted) latitude $< 44.5°$, excluding:
Kosovo: lacking deaths in Worldometer;
Turkey: lacking pig data and almost entirely outside of Europe;
Cyprus: essentially outside of Europe (geographically),
extremely Southern, island, not so large;
Malta: essentially outside of Europe (geographically),
extremely Southern, island, not so large.

The Summer solstice and the Autumn equinox are intrinsically determined breakpoints in the timeline, due to astronomical facts. If one prefers to make statistics based on human determined breakpoints, the corresponding usual standards are quarters of the year.

2020 Summer solstice[48] happened: 20th June 21:44 UTC
2020 Autumn equinox[48] happened: 22 September 13:31 UTC

In the 4 following paragraphs these times will be considered:

19th June	last day of Spring	day 171
30th June	end of second quarter	day 182
21st September	last day of Summer	day 265
30th September	end of third quarter	day 274

High correlation exists between farm pigs and deaths.

More precisely:

high Pearson's correlation between logarithm of pig density and deaths per million measured by r and r^2;

high correspondence between ranks of pig density and of deaths per million measured by Spearman's rank correlation coefficients ρ_s and the corresponding p-values which take in account the size (9) of the dataset.

15.2 Final remark: p-value.

Day 171, 19th June.
To test the increasing monotonicity of ranks, with $n = 9$, Formula

(1) gives 0.933 (which is in fact ρ_s) which grants, as may be seen in the table in Section 2.3,

$$p < 0.001$$

Day 182, 30th June.
To test the increasing monotonicity of ranks, with $n = 9$, Formula (1) gives 0.950 (which is in fact ρ_s) which grants, as may be seen in the table in Section 2.3,

$$p < 0.001$$

Day 265, 21st September.
To test the increasing monotonicity of ranks, with $n = 9$, Formula (1) gives 0.733 (which is in fact ρ_s) which grants, as may be seen in the table in Section 2.3,

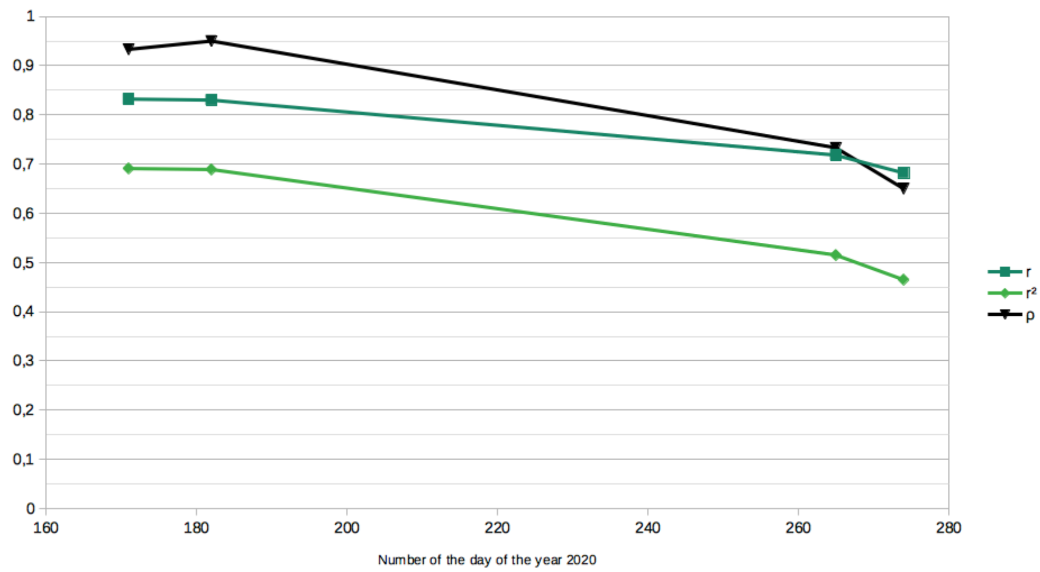
$$p < 0.025$$

Day 274, 30th September.
To test the increasing monotonicity of ranks, with $n = 9$, Formula (1) gives 0.650 (which is in fact ρ_s) which grants, as may be seen in the table in Section 2.3,

$$p < 0.050$$

day of the year	r	r^2	ρ_s	p-value for increasing monotonicity of ranks
171	0.832	0.691	0.933	< 0.001
182	0.830	0.689	0.950	< 0.001
265	0.718	0.515	0.733	< 0.025
274	0.682	0.465	0.650	< 0.050

All the 4 p-values are statistically significant.



All p-values are statistically significant and some very significant.

It should be noted that in September the correlation is less strong than in June. This could be due to atmospheric conditions, like air circulation and eliophany, reducing geographical correspondence between pigs and epidemics.

15.3 Remark on the fading of pig correlation

In progression of time from Spring to Autumn, the geographical correlation between the pandemic and pig presence tends to fade, as it can be seen in the previous paragraph.
This does not imply that pigs harm less: or they harm less, or they harm on a longer distance, so weakening the geographical correspondence, searched in the statistical correlations. A clue of the latter possibility is that the fading is greater at the finer scale of provinces of Lombardia (see 7.2 and 7.3) than at the higher scale of European countries of the previous paragraph.

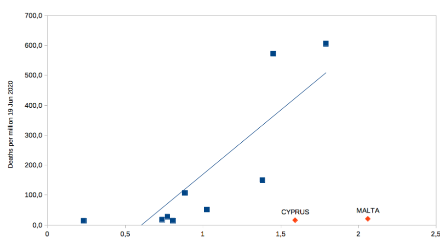
15.4 Southern Europe, last day of Spring

Let's consider deaths till 19th June 2020 in Southern Europe.
The increasing order is chosen: 1 corresponds to the lowest farm pig density, and to the lowest number of deaths per million.

Country	Ranks for pig density (1=lowest)	*Pig density heads/km^2 (increasing)	**Deaths per million 19th Jun. 2020	Ranks for deaths (1=lowest)
Montenegro	1	1.71	14.3	1
Greece	2	5.46	18.1	3
Bulgaria	3	5.90	27.8	4
Albania	4	6.40	14.6	2
North Macedonia	5	7.62	107	6
Bosnia and Herzegovina	6	10.60	51.6	5
Portugal	7	24.08	150	7
Italy	8	28.18	572	8
Spain	9	61.79	606	9

* from EuroStat livestock table, data reported in 11.4

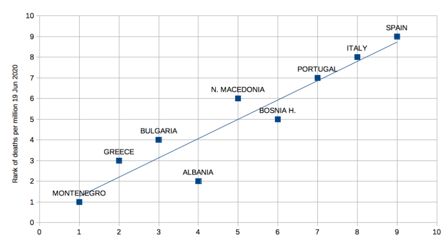
** from Worldometer, archived in https://web.archive.org/, 23:36:30 GMT capture, retrieved 21st Nov. 2020. Worldometer gives integer roundings and here data there given with 2 digits have been re-computed more accurately with 3 significant figures, based on data of Worldometer itself: total deaths and populations.



(For blue points) Pearson's

r=0.832

r^2=0.691



Spearman's rank

correlation coefficient

ρ_S = 0.933

Remark. The 2 red dots represent Cyprus and Malta, before excluded for 4+4 reasons. Nevertheless, we may notice that they have many pigs and few deaths. This is not against the theory presented in this study when considering sunlight: their eliophany is particularly high (see eliophany map in 11.7). Furthermore they are islands, not so large, which could give the advantage of continuously renewed air coming from the sea.

Final remark: p-value. To test the increasing monotonicity of ranks, with $n = 9$, Formula (1) gives 0.933 which grants, as may be seen in the table in Section 2.3,

$$p < 0.001$$

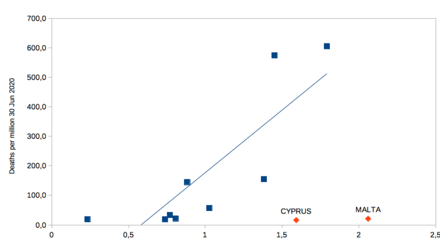
15.5 Southern Europe, 30 June

Let's consider deaths till 30th June in Southern Europe (15.4). The increasing order is chosen: 1 corresponds to the lowest farm pig density, and to the lowest number of deaths per million.

Country	Ranks for pig density	*Pig density heads/km^2 (increasing)	**Deaths per million 30th Jun. 2020	Ranks for deaths
Montenegro	1	1.71	19.1	2
Greece	2	5.46	18.4	1
Bulgaria	3	5.90	110	2
Albania	4	6.40	33.1	4
North Macedonia	5	7.62	145	6
Bosnia and Herzegovina	6	10.60	56.7	5
Portugal	7	24.08	155	7
Italy	8	28.18	575	8
Spain	9	61.79	606	9
Malta				
Cyprus				

* from EuroStat livestock table, data reported in 11.4

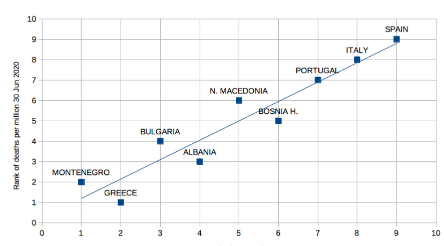
** from Worldometer, archived in `https://web.archive.org/`, 23:58:38 GMT capture, retrieved 21st Nov. 2020. Worldometer gives integer roundings and here the only data there given with 2 digits has been re-computed more accurately with 3 significant figures, based on data of Worldometer itself: total deaths and population.



(For blue points) Pearson's

r=0.830

r^2=0.689



Spearman's rank

correlation coefficient

ρ_s = 0.950

Remark. About the 2 red dots, again remark in 15.4 holds.

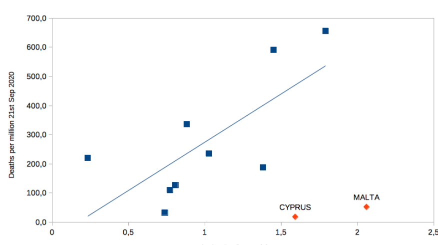
15.6 Southern Europe, last day of Summer

Let's consider deaths till 21st September in Southern Europe (15.4). The increasing order is chosen: 1 corresponds to the lowest farm pig density, and to the lowest number of deaths per million.

Country	Ranks for pig density	*Pig density heads/km^2 (increasing)	**Deaths per million 21st Sep. 2020	Ranks for deaths
Montenegro	1	1.71	220	5
Greece	2	5.46	33.0	1
Bulgaria	3	5.90	110	2
Albania	4	6.40	127	3
North Macedonia	5	7.62	336	7
Bosnia and Herzegovina	6	10.60	235	6
Portugal	7	24.08	188	4
Italy	8	28.18	591	8
Spain	9	61.79	656	9

* from EuroStat livestock table, data reported in 11.4

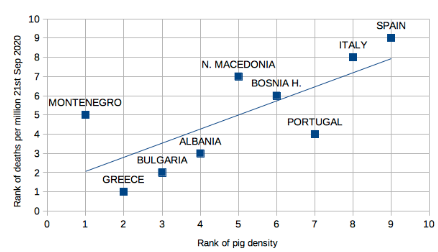
** from Worldometer, archived in https://web.archive.org/, 23:59:44 GMT capture, retrieved 21st Nov. 2020. Worldometer gives integer roundings and here the only data there given with 2 digits has been re-computed more accurately with 3 significant figures, based on data of Worldometer itself: total deaths and population.



(For blue points) Pearson's

r=0.718

r^2=0.515



Spearman's rank

correlation coefficient

$\rho_s = 0.733$

Remark. About the 2 red dots, again remark in 15.4 holds.

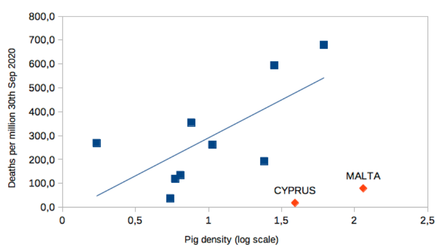
15.7 Southern Europe, 30 September

Let's consider deaths till 30th September in Southern Europe (15.4). The increasing order is chosen: 1 corresponds to the lowest farm pig density, and to the lowest number of deaths per million.

Country	Ranks for pig density	*Pig density heads/km^2 (increasing)	**Deaths per million 30th Sep. 2020	Ranks for deaths
Montenegro	1	1.71	269	6
Greece	2	5.46	37.6	1
Bulgaria	3	5.90	119	2
Albania	4	6.40	135	3
North Macedonia	5	7.62	355	7
Bosnia and Herzegovina	6	10.60	261	5
Portugal	7	24.08	193	4
Italy	8	28.18	594	8
Spain	9	61.79	680	9

* from EuroStat livestock table, data reported in 11.4

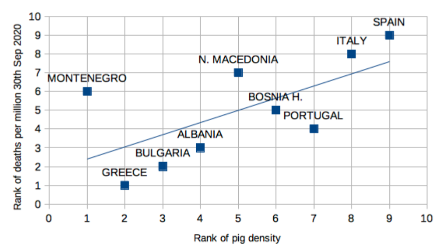
** from Worldometer, archived in https://web.archive.org/, 23:54:31 GMT capture, retrieved 21st Nov. 2020. Worldometer gives integer roundings and here the only data there given with 2 digits has been re-computed more accurately with 3 significant figures, based on data of Worldometer itself: total deaths and population.



(For blue points) Pearson's

r=0.682

r^2=0.465



Spearman's rank

correlation coefficient

ρ_s = 0.650

Remark. About the 2 red dots, again remark in 15.4 holds.

16 Comparison: livestocks, South Europe countries

Exactly with the same procedures, the Spearman's correlation coefficients ρ shown in the table in Section 16 have been obtained, considering various livestocks. Notice the multiplicity of values due to lack of some data for particular countries and to the proposed exclusion of Cyprus and Malta, see Section 15.

Table: Humans and livestocks, South Europe, original data

Country	[a] Area	[b] Pigs heads	[b] Sheep heads	[b] Goats heads	[b] Bovine heads	[c] Humans persons
Bosnia H.	51 129	542 000	1 012 000	73 000	438 000	3 280 757
Bulgaria	110 994	654 550	1 350 030	271 740	542 120	6 948 254
Greece	131 940	721 000	8 430 000	3 625 000	542 000	10 422 933
Italy	301 338	8 492 230	7 179 150	986 260	6 311 160	60 461 762
Montenegro	13 812	23 600	187 000	29 000	83 300	628 066
N. Macedonia	25 713	196 000	727 000	117 000	256 000	2 083 374
Portugal	91 568	2 205 050	2 207 790	332 590	1 632 420	10 196 667
Spain	498 511	30 804 100	15 852 530	2 764 790	6 510 590	46 754 775
Albania	28 748	184 130	1 863 840	–	467 320	2 877 795
Malta	316	36 290	13 170	5 730	14 120	441 541
Cyprus	9 251	362 100	–	–	70 820	1 207 327

(a) https://en.wikipedia.org/wiki/List_of_European_countries_by_area
Retrieved 18 December 2020
(b) EuroStat data (2018) in https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Agricultural_production_-_livestock_and_meat
(c) Worldometer population data, retrieved 24 December 2020

Table: Humans and livestocks, South Europe, derived data

Country	[a] Sheep density heads/km^2	[a] Goats density heads/km^2	[a] Bovine density heads/km^2	[a] Pigs density heads/km^2	[a] Human density persons/km^2
Bosnia H.	19.8	1.4	8.6	10.6	64.17
Bulgaria	12.2	2.4	4.9	5.9	62.60
Greece	63.9	27.5	4.1	5.5	79.00
Italy	23.8	3.3	20.9	28.2	200.64
Montenegro	13.5	2.1	6.0	1.7	45.47
N. Macedonia	28.3	4.6	10.0	7.6	81.02
Portugal	24.1	3.6	17.8	24.1	111.36
Spain	31.8	5.5	13.1	61.8	93.79
Albania	64.8	–	16.3	6.4	100.10
Malta	41.7	18.1	66.00	114.84	1 397.28
Cyprus	–	–	7.66	39.14	130.51

(a) derived data from previous table

Table: South Europe, deaths till 30 June and 30 September

Country	[a]Population	[b]Deaths till 30 June	[c]Deaths per million till 30 June	[d]Deaths till 30 Sep.	[e]Deaths per million till 30 Sep.
Bosnia H.	3 280 757	186	56.7	856	260.9
Bulgaria	6 948 254	230	33.1	825	118.7
Greece	10 422 933	192	18.4	391	37.5
Italy	60 461 762	34 767	575.0	35 894	593.7
Montenegro	628 066	19	30.3	169	269.1
N. Macedonia	2 083 374	302	145.0	739	354.7
Portugal	10 196 667	1 576	154.6	1 971	193.3
Spain	46 754 775	28 355	606.5	31 791	680.0
Albania	2 877 795	62	21.5	387	134.5
Malta	441 541	9	20.4	35	79.3
Cyprus	1 207 327	19	15.7	22	18.2

(a) (b) from Worldometer, archived in https://web.archive.org/, 23:55:28 GMT capture, retrieved 24 December 2020

(c) derived data from (a) and (b)

(d) from Worldometer, archived in https://web.archive.org/, 23:50:25 GMT capture, retrieved 24 December 2020

(e) derived data from (a) and (d)

As explained in 16, the tables in the following paragraphs summarise the Spearman's coefficients ρ for various groups of Southern European countries and various livestocks.

16.1 South Europe, Spearman's coefficients, livestocks

With the data in 15.5 and 16 the following table about Spearman's correlation coefficients of ranks can be obtained.

Table: South Europe, Spearman's coefficients, mortality, 30 June

Countries	Farm pigs	Bovine	Sheep	Goats	Humans
Bosnia H. Bulgaria Greece Italy Montenegro N. Macedonia Portugal Spain	**0.952**	**0.905**	0.214	0.167	**0.786**
The 8 above + Albania	**0.900**	**0.650**	-0.133	–	0.517
The 9 above + Malta	0.479	0.309	-0.345	–	0.176
The 10 above + Cyprus	0.218	0.391	–	–	-0.018

With the data in 15.7 and in 16 and the following table about Spearman's correlation coefficients of ranks can be obtained.

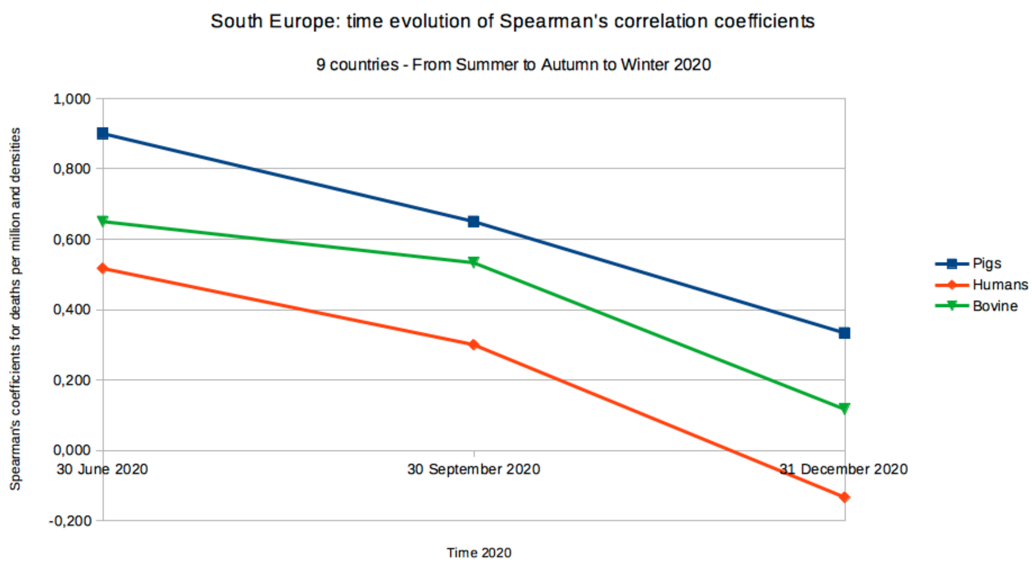
TABLE: SPEARMAN'S COEFFICIENTS, MORTALITY, 30 SEPTEMBER

Countries	Farm pigs	Bovine	Sheep	Goats	Humans
Bosnia H. Bulgaria Greece Italy Montenegro N. Macedonia Portugal Spain	**0.619**	**0.690**	0.119	0.024	0.429
The 8 above + Albania	**0.650**	**0.533**	-0.067	–	0.300
The 9 above + Malta	0.297	0.224	-0.285	–	0.018
The 10 above + Cyprus	0.082	0.318	–	–	-0.136

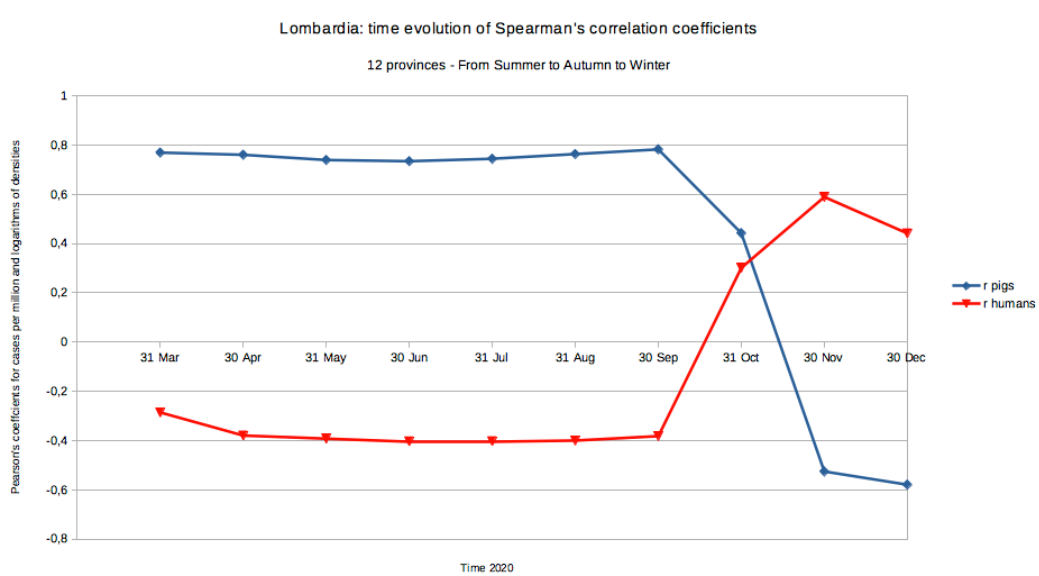
An interpretation of the above data is in paragraph 3.4.

17 Fading of the correlation during time

Clues have been found that the pig correlation fades during time, from Summer to Winter 2020. Maybe due to greater air circulation destroying the geographical correspondence between pigs and pandemic, as may be seen in the following 2 graphs.



At the level of the provinces of Lombardia, beside of the fading of the pig correlation, it may be observed also a every interesting overall increase of the correlation (from Spring to Winter) of the intensity of the pandemic (measured by cases per million) with the (logarithm of) human density, as may be seen in the following graph.



See also 7.2 and 7.3.

18 Aerosol

18.1 Pigs are not pets: long distance contagion

Though this study is essentially devoted to statistical correspondences, nevertheless, based on previous results, 2 possibilities appear clearly:

1) a pig to human contagion (and from other livestocks)

2) a inter-human contagion mediated by aerosol produced by pigs (and other livestocks).

This is a statistical and not a virological study, nevertheless the second possibility appears more likely because so different livestocks are involved, besides pigs, till even poultry (with Spearman's correlation coefficients till 0.553 with 23 regions of Ukraine, see 14.3, with p-value < 0.005).

Pigs are not pets and (even though household pigs considered for Ukraine are quite close to humans) usually they are not in very close contact with humans. In the emerging model, pigs (and other livestocks) produce aerosol, it goes through a long distance, reaches infected humans, there the pathogen attaches to the aerosol, which then reaches other humans to infect. Since the pathogen has *survived* the first long path (from pigs to humans), it is very likely to *survive* a second long path (from human to human).

All that supports a long distance contagion model.

This is quite different from the short distance transmission more often considered from humans to humans, by "big" droplets.

18.2 Contagion via respiratory droplets vs aerosol

It has been written[80] in JAMA:

> The coronavirus disease 2019 (COVID-19) pandemic has reawakened the long-standing debate about the extent to which common respiratory viruses, including the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), are transmitted via respiratory droplets vs aerosols. Droplets are classically described as larger entities (>5 μm) that rapidly drop to the ground by force of gravity, typically within 3 to 6 feet of the source person.

> Aerosols are smaller particles (≤5 μm) that rapidly evaporate in the air, leaving behind droplet nuclei that are small enough and light enough to remain suspended in the air for hours (analogous to pollen).

18.3 The utility of face masks

In this scenario the utility of usual face masks is questionable.

We read in *Annals of Internal Medicine*[81] (18 November 2020):

> How SARS-CoV-2 is transmitted – via respiratory droplets, aerosols, or (to a lesser extent) fomites – is not firmly established. Transmission of SARS-CoV-2 may take place through multiple routes. It has been argued that for the primary route of SARS-CoV-2 spread – that is, via droplets – face masks would be considered effective, whereas masks would not be effective against spread via aerosols, which might penetrate or circumnavigate a face mask.

It is possible that the pathogen flies attached to nanoparticles floating in the air, as already[65] found. Particles previously originated in pigs (and other livestocks and even humans).

In the long *distance* transmission the pathogen for long *time* risks inactivation by sun light, before reaching humans. A confirmation of this is the correlation[63], even extremely high correlation[62]; see 0.3.1.

Studies have been carried out to assess the utility of face masks: a systematic review and meta-analysis[82], published in March 2020 on the *Journal of Evidence-Based Medicine*, concluded:

> The use of N95 respirators compared with surgical masks is not associated with a lower risk of laboratory-confirmed influenza. It suggests that N95 respirators should not be recommended for general public and non high-risk medical staff those are not in close contact with influenza patients or suspected patients.

(N95 for American standard corresponds to FFP2 for European standards.)

In the same paper previously considered[81] it has been written:

> We designed the study to detect a reduction in infection rate from 2% to 1%. Although no statistically significant difference in SARS-CoV-2 incidence was observed, the 95% CIs are compatible with a possible 46% reduction to 23% increase in infection among mask wearers.
> (...)
> The face masks provided to participants were high-quality surgical masks with a filtration rate of 98%.
> (...)
> Yet, the findings were inconclusive

Nevertheless it should be noted that face masks also in the new model, preventing at least droplets from infected persons reach the aerosol particulate.

18.4 How pigs could cause the contagion

As already explained in 18.1, though this is not the main goal of this study, essentially statistical and not virological, some ways immediately appears, in which pigs may increase the contagion.

1) Pigs replicate the virus and then input it into the air.

2) Pigs spread in the air particles to which a human virus cling. About route 2, it is commonly known that virus survive much better when attached to solid matter than when floating isolate in the air. Surely much further research is needed, but the base particles could be mycobacteria, amplified by pigs, and spread.

3) A third possibility seems interesting but unlikely to be real: the illness is not always caused by the virus but at least sometimes by a mycobacterium amplified and spread in the air by pigs; the virus found by tests only accompanies the mycobacterium. This sounds strange but relations between the pandemic and anti-tuberculosis BCG vaccine, and between the pandemic and mycobateria, have been widely considered, with uncertain conclusions. It has been[89] written:

> Seventeen clinical trials are currently registered to inform on the benefits of BCG vaccinations upon exposure to CoV-2. Numerous epidemiological analyses showed a correlation between incidence of COVID-19 and BCG vaccination policies. These studies were not systematically corrected for confounding variables. We observed that after correction for confounding variables, most notably testing rates, there was no association between

> BCG vaccination policy and COVD-19 spread rate or percent mortality.

but also[90]

> In countries like India despite vast population density and other adversities, and growing numbers of COVID19 infections, the mortality rate and severity of COVID has been low in comparison to some TB non-endemic countries (...) In the TB endemic countries like India, with high population density, similar to BCG vaccination, the environmental Mycobacteria might be imparting some immune-protection from severity and deaths of COVID-19.

It has been[14] written

> Pigs are susceptible to several CoVs (...) From the obtained data available today, it would appear pigs can carry SARS-CoV and develop antibodies. Furthermore, evidence exists that pigs can amplify MERS-CoV. So far there is no evidence that pigs can become infected with SARS-CoV-2 or are capable to amplify the virus. (...) Theoretically, if pigs can be infected with SARC-CoV-2 and also amplify it, the virus would likely be present in the respiratory tract of pigs so lungs (....) Interspecies transmission from humans to other species including pigs likely requires a close contact with infected people (...) Evidence from SARS-CoV would suggest that it is likely to detect SARS-CoV-2 RNA in pigs but perhaps unlikely that the virus would be amplified in pigs.

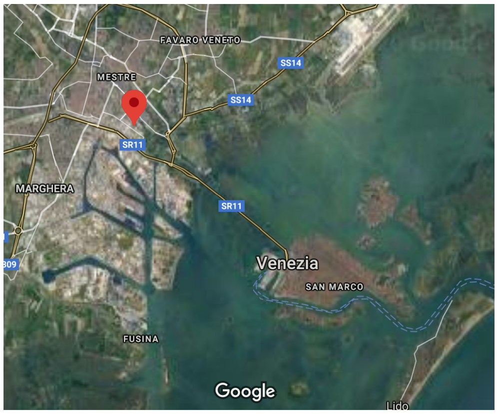
18.5 Issue against airborne transmission

A paper[73] has searched the virus in the air finding an extremely little amount, but this is not against theory exposed in the present text because of the 2 locations where the air samples were kept: 40.3°N 18.1°E in the province of Lecce (region Puglia, Southern Italy), and 45°28'47" N, 12°15'12"E in the province of Venice (region Veneto, Northern Italy).
The first place is well inside one the Italian areas with lowest farm pig density, ASL LE in the table below, 0.30 farm pigs per km^2.
The areas considered in this statistics do not coincide exactly with provinces, but that of Lecce is the same or more or less the same.

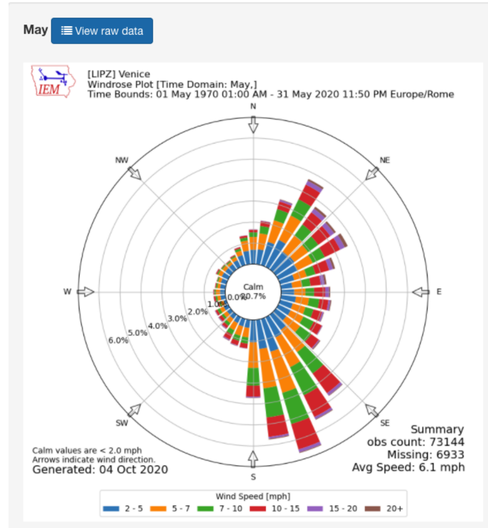
Zootechnical area	[a] Farm pig density heads/km^2 2020
ATS della Val Padana	507.03
ATS di Brescia	377.06
.	
.	
.	
A.S.L. Ferrara	20.04
Azienda ULSS n. 3 Serenissima (Venice)	17.92
ASU FC	16.76
.	
.	
.	
ASP Agrigento	0.35
ASL LE (Lecce)	0.30
ASL La Spezie	0.26
.	
.	
.	
ASL Aosta	0.02
ASL TO1	0.00

(a) from Anagrafe Zootecnica [41]

The second location in the province of Venezia is well inside the Azienda ULSS n. 3 Serenissima of the table above and there are many more pigs than in Lecce, 17.92 per km^2, which is not so much. But it is quite unlikely that in the analysed samples the pathogens from the farm pigs have arrived to the sampling apparate (the red pointer), as it appears clear from the satellite map below and from the diagram of winds in May, the time of the sampling. Essentially, it appears that in the samples there was the air from Mestre, from Marghera, from Venice, from the lagoon, and from the Adriatic Sea – the bluish zone down right in the satellite map.



(a)Satellite view from Google Maps



(b)Windrose plot, Venice, May

(a) Google. (n.d). 45°28'47.0"N 12°15'12.0"E. Retrieved from https://goo.gl/maps/HcM9DcLAqTa14s51A

(b) https://mesonet.agron.iastate.edu/sites/windrose.phtml?station=LIPZ&network=IT__ASOS

19 Issues with statistics

19.1 Issues with data about cases and deaths

It has been[91] written:

> bias is exemplified by no reported cases in North Korea (...) the worldwide epidemiologic data is highly unreliable, which specifically pertains to COVID-19 deaths per million death rate

This is unlikely to have affected very much the present study, which just to avoid those uncertainties has been limited to Europe.

All the considered countries had in 2019 *very high* or *high* (≥ 0.700) Human Development Index[15], and are in 2020 over the median for Press Freedom Index[16], apart from Ukraine a bit below the median, ranking 96 of 180.

Data of cases and of deaths of the epidemic of course are flawed by delays in reporting. But this is unlikely to have influenced significantly the present study, especially when cumulative data were considered.

Data of deaths are extremely problematic. Different countries

may follow different criteria to attribute a death to the epidemic. WHO/OMS has produced guidelines[66], but it cannot be granted that every country follows them.
From a practical point of view, this issue cannot be fixed when comparing the deaths of many countries.

Standards in cases evaluation have been modified during the pandemic. It has been written [39] (in Italian):

> Update 2/12/2020 [2 *December* 2020] (...) The positive/swab ratio includes repeat controls, so we have always preferred to consider the positive / tested persons ratio. Both, however, are on the rise due to the use of rapid antigen tests, usually not counted as swabs, but confirmed by molecular examination when positive. Conversely, a few days ago some Regions began to include rapid antigen tests in the swabs count, or at least some of them, so the data appears unreliable at the moment.

Similarly for France, with the sudden drop[88] from 10,7 to 6,3 of positivity rate in December.

The model discussed in this study considers population groups as ideal isolated systems. Of course this is an approximation. Some persons may have lived in different provinces, especially during lockdown, blocked in friends' houses.

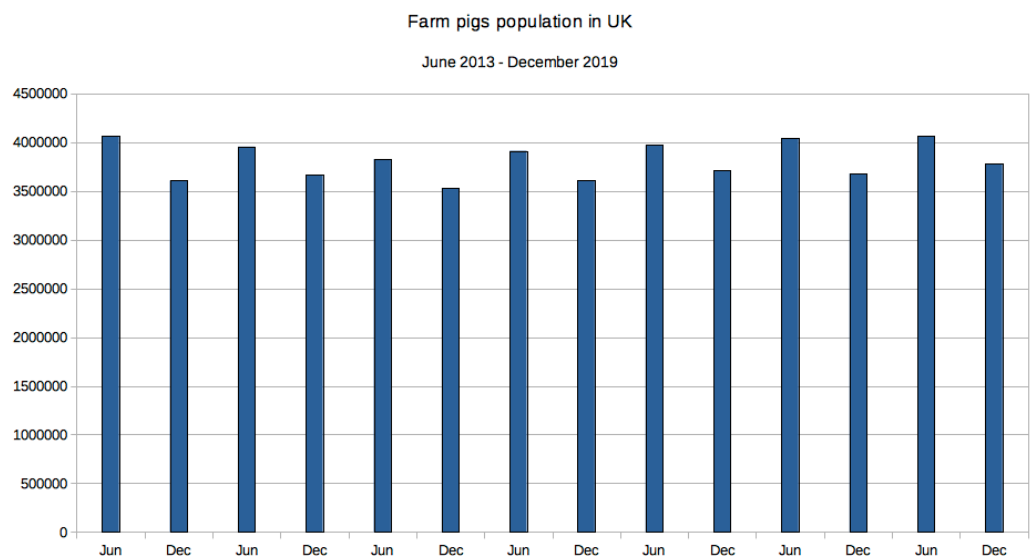
19.2 Issues with data about pigs

For any sufficiently large region of the world the exact wild boars number and the density are not exactly known. For the region Lombardia, which is the core of the present statistical analysis, the uncertainties about wild boars are very unlikely to have significantly impacted on the global analysis because in that area the amount of farm pigs is overwhelming. Take in account that in the whole year 2019 less than 6 000 wild boars result culled in the whole regione [54] Lombardia, to be compared with 4.4 millions of farm pigs. But wild boars may be partially responsible for the imperfect alignment of dots in the figures of 7.1.3 and 7.1.4.

Furthermore, there does not exist something as the number of wild boars in an area, because differently from humans, wild boar number vary hugely during the year. In Europe it reach a minimum about in March, followed by a rapid growth.

Wild boars are an annoying noise in the present statistical analysis.

Farm pigs number too is subject to cyclic fluctuations during the year.
(Very likely a small fluctuation for big holding pigs and great fluctuation for backyard pigs).



19.3 Issue with confounding factors

The most severe issue in this research is that when an area of the world is subdivided in subareas and for each of them one (overcoming all issues with data) measures (somehow) the intensity of the pandemic and the density of pigs, and then computes the statistical indexes (Pearson's correlation coefficient, Spearman's correlation coefficient, p-value), the problem remains that in the same areas other livestocks are present, with their densities, becoming confounding factors.

This has been shown clearly in 3.3 for bovine in Ukrainian regions, where it has been roughly said: where pigs, there bovine. It is difficult to distinguish the effect of pigs and bovine.

As another important example here we show that the Pearson's correlation coefficient for the densities of wild boars and household pigs in Ukraine regions is 0.5410, quite high giving a p-value < 0.004. That is to say, where wild boars there household pigs; typically countryside. For such reasons and because of the very approximate data about wild boars densities, the link between the pandemic and wild boars has to kept very cautiously.

20 Conclusions

20.1 Pigs

In this study strong statistical correlations have been found between the pandemic and the presence of farm pigs nearby. Some clues have been found also for other livestocks and – to be kept very cautiously – wild boars, which are pigs.

As far as pigs are concerned, there are 3 immediate consequences:

1) The issue of farm pigs has to be assessed in real world
2) The possible issue of wild boars has to be assessed in real world
3) The aerosol long distance contagion has to be taken in account.

20.2 Aerosol transmission and its implications

It has been written[80] in JAMA:

> Determining whether droplets or aerosols predominate in the transmission of SARS-CoV-2 has critical implications. If SARS-CoV-2 is primarily spread by respiratory droplets, wearing a medical mask, face shield, or keeping 6 feet apart from other individuals should be adequate to prevent transmission. If, however, SARS-CoV-2 is carried by aerosols that can remain suspended in the air for prolonged periods, medical masks would be inadequate (because aerosols can both penetrate and circumnavigate masks), face shields would provide only partial protection (because there are open gaps between the shield and the wearer's face), and 6 feet of separation would not provide protection from aerosols that remain suspended in the air or are carried by currents.

Till November 2020[1] WHO/OMS site reports, dating 7 July:

> To the best of our understanding, the virus is primarily spread through contact and respiratory droplets. Un-

> der some circumstances airborne transmission may occur (such as when aerosol generating procedures are conducted in health care settings or potentially, in indoor crowded poorly ventilated settings elsewhere). More studies are urgently needed to investigate such instances and assess their actual significance for transmission of COVID-19.

20.3 New model, different problems

The present research instead – without completely excluding the possibility of pig to human contagion – supports a model

contagion mainly:
long distance – by aerosol particulate from pigs – human to human

(and to a lower extent from other livestocks).

This is quite different from the mainstream model

contagion mainly:
short distance – by droplets – human to human

afforded mainly with
curfew
lockdown and stay-home
masks
social distancing
washing hands
sanitizing objects.

Almost all those measures become questionable in this model.

20.4 Bottom line

The pandemic deserves high understanding.
It may be a breakpoint in history.

Deep categories have to be used to take decisions, which will determine the future of mankind largely beyond the virus issue, touching intimately the lives of essentially all human beings, as already has begun to happen.

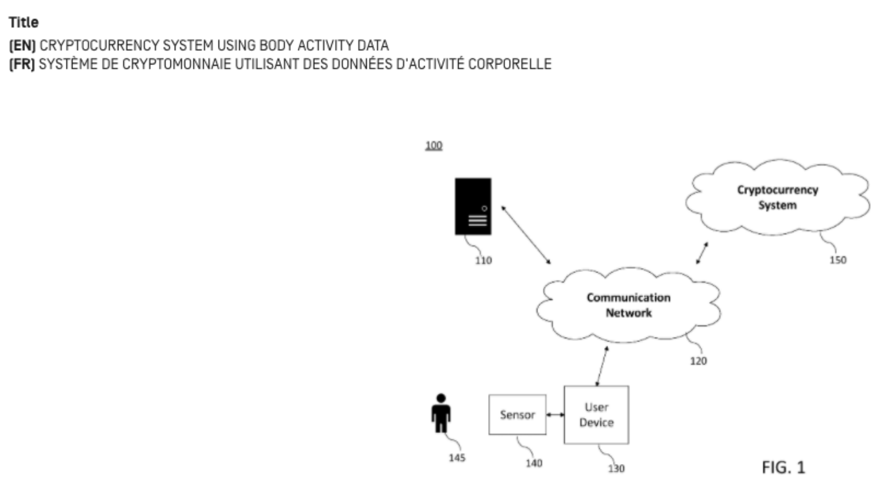
One of the core issues which are emerging is which kind of life is worth to be lived: that of caged poultry without risks of foxes, or the old normality with its risks?
But in fact the argument developed in this research shows that this may be a false dilemma: in the new model, solutions which really lower risks are clearly visible without denaturing human life.

The new proposed model gives 4 immediately visible counter-measures.

They may be framed at pairs in 2 classical *Weltanschauungen*, here below very partially sketched.

Humanism:
"Man is almost a God, free under sky; live in a beautiful garden!"

Transhumanism:
"Man needs chemicals and artificial devices; live under glass!"



https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2020060606&tab=PCTBIBLIO

A transhumanistic solution: "Heavier masks and more curfew".

A humanistic solution: "Less pigs and more sunlight".

21

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