THE GRAPE PHYLLOXERA PLAGUE AS A NATURAL EXPERIMENT: THE UPKEEP OF VINEYARDS IN CATALONIA (SPAIN, 1858-1935)

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We present a comparative analysis of the impact and outcome in Catalonia of the wine rush and crash unleashed by the spread of the Grape Phylloxera plague in Europe (1865-1890). In order to explain why many rural districts in the provinces of Barcelona and Tarragona were able to resume winegrowing after the plague, while most in the provinces of Girona and Lleida were not, a statistical model is used to check the economic resilience of the Catalan districts to the external ecological and economic shock. The model combines the population densities as a proxy of the opportunity cost in labour allocation, the demand pull of commercial growth measured by the time-distances to the city of Barcelona, and the agro-climatic land's suitability for growing vines, as measured by the Hugling and Winkler indices or the mean slopes of land. After comparing the vineyard allocation in every district in 1860, 1889 and 1920, these variables are used to explain the differing capacities to endure the Phylloxera plague in Catalonia.

JEL categories: N53, N54, Q17, Q54, Q56, R14, R40

Keywords: Spain, Phylloxera plague, vineyard specialization, factor endowment, time-distances, ago-climatic land suitability

The Grape Phylloxera plague was an ecological external shock, and at the same time a deep economic crisis in the European wine production which led to a new start.[1] For winegrowers both the ecological and economic impacts were closely related to the first globalization process experienced before the First World War. The insect that started killing the French vines in 1863 had arrived from America as one of the bioinvasions channelled through the «Columbian biological exchange».[2] By the end of the 19th century the plague had ravaged every old European grapevine. The recovery of European wine production and exports was only possible through another «Columbian exchange» through the use of American varieties of vines, which had coevolved with the Phylloxera insect for three centuries, by grafting them onto the rootstocks of old European ones in order to replant new vineyards resistant to the plague that might keep

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[1] Garrier, *Philoxéra*; Pan-Montojo, *Bodega*; Paul, *Science*.

[2] Crosby, *Columbian*; McNeill, *Plagues*; Diamond, *Guns*.

the traditional wine tastes. This large-scale replant had to be undertaken in a newly integrated highly competitive global agrarian market.

For an economic and environmental historian the Grape Phylloxera plague can be seen as a «natural experiment», that enables us to test the economic impacts and reactions of a sudden ecological shock by using the comparative method.[3] The advance of the plague from the South of France in the 1860s to all over Europe in the 1890s ravaged many parts of the regions previously specialized in wine production (Map 1). This created a succession of wine rushes in different areas, where new vineyards were suddenly planted to substitute for French wines until the plague reached them. The waves of wine rushes and crashes created an economic environment of high price volatility, a trend of relative price cuts and rising unit costs in an atmosphere of strong social unrest that became the specific viticulture path into the global agrarian crisis at the turn of the 19th and 20th centuries (Graph 2).[4]

Eventually, only some European winegrowing regions were able to overcome the economic impacts of the Phylloxera plague. In order to recover after the ecological shock they had to adapt wine production and exports to the price volatility and rising unit costs experienced during the first agrarian world crisis. Understanding why some of them succeeded while others failed may provide some interesting answers to the question about how an economic activity can react to a sudden external ecological shock. We focus our analysis on Catalonia (Northeast Spain), contrasting the ability to endure and recover from the plague shown by the main winegrowing districts in the provinces of Barcelona and Tarragona, against the failures experienced in the districts of Lleida and Girona.

CATALAN VITICULTURE BEFORE AND AFTER THE PHYLLOXERA

What happened in Catalonia during the plague and afterwards? The four Catalan provinces reacted in different ways to the sudden wine rush from the 1860s to the mid 1880s, and then to the complete ruin of all vineyards (Graph 3; notice that in 1880-84 data is only available for the provinces of Barcelona and Tarragona). The provinces of Barcelona and Tarragona, where vineyard specialization had taken root in a long-lasting process that started as early as the 17th century, did not experience a dramatic increase in new plantations when the French vines became ravaged: rising only 16.4% and 15% from 1860 to 1885. Then, following the death of all the old grapevines, winegrowers were able to replant and upkeep nearly as many hectares of new vineyards as before the plague: in 1935 there were 6.4% more hectares planted with vines in Barcelona than in 1860, and only 1.1% less in Tarragona.

Things evolved differently in the other two provinces, which in 1860 accounted for less than one third of the Catalan acreage planted with vines (Map 5). The frontier province of Girona was obviously the first one to be hit by the plague coming from France in 1878, allowing almost no time for a sudden big rush before the death of their grapevines.[5] There, winegrowers were only able to replant one third of the acreage of vineyards that existed in 1860. The province of Lleida experienced the highest increase

[3] Diamond, *Collapse*, p. 17: «*—i.e., to compare natural situations with respect to the variable of interest*».
[4] Garrabou ed., *Crisis Agraria*; Van Zanden, First Green Revolution; Campbell and Overton ed., *Land*; Koning, *Failure of Agrarian Capitalism*; Simpson, *Long Siesta*, and Agrarian Crisis; Persson, *Grain Markets*.
[5] Piqueras, Filoxera en España.

of new plantations that tried to substitute for the vacuum of French production and exports from 1860 to 1885, and nearly doubled the area planted with pre-Phylloxera vines until the plague reached and destroyed them. But afterwards, winegrowers were only able to replant with resistant varieties less than half the hectares of vineyards that existed in Lleida in 1860 (Graph 3 and Map 5).

Thanks to technical improvements made by winegrowers mainly in the province of Barcelona, through the increase in manuring and the use of chemical fertilizers, the hectolitres of grape juice produced increased even more than the acreage of new vineyards planted after the Grape Phylloxera plague. The mean yearly wine production was 33% higher in 1930-34 than in 1890-94, while the hectares planted with grapevines had increased by 28% (Table 4). The recovery of vineyard specialization from the Phylloxera plague went beyond a simple restoration of an earlier regime, especially in the province of Barcelona. From 1890 onwards, Catalan winegrowers and wine industries succeeded in connecting their increasing wine production with the new emerging export market of Mediterranean agricultural goods to north-European and north-American consumers. These technical and commercial improvements were part of the pool of innovations that enabled farmers all over Europe to overcome the agrarian crisis at the end of the 19th century and during the first third of the 20th.[6]

However, as we have seen, other Catalan winegrowers in the provinces of Lleida and Girona were unable to endure the Phylloxera plague and restart winegrowing. The vineyard acreage peaked in 1885, with 367,445 hectares planted in Catalonia (58,961 more than in 1860, in spite of the 33,670 hectares already ravaged by the plague in Girona). From 1885 to 1935 nearly ninety thousand hectares were lost only in the province of Lleida, out of the 109,317 hectares formerly planted with vines that disappeared in Catalonia in the meantime. Here we come to our main question: why were so many winegrowers throughout counties located in the provinces of Barcelona and Tarragona able to overcome the plague and keep most of their vineyards, while the majority of them in the provinces of Lleida and Girona failed and gave up this activity?

A simple comparative analysis seems to discard the entrepreneurial innovations developed as institutional responses to the general agrarian crisis at the end of the 19th century as the answer, such as the spread of cooperatives. We know that cooperatives appeared in all four Catalan provinces, and their activities in organizing commercial channels to sell outputs or buying new inputs were developed in olive oil and cereal production as well as in winegrowing.[7] We also discard natural endowment taken as a simple encompassing answer, although we consider that agro-ecological features did play a role that has to be taken into account together with other economic factors. For example, all the rural districts in the province of Girona, and also the eastern ones in the province of Barcelona, receive a higher amount of rainfall than the rest of Catalonia. This might have allowed them to overcome the agrarian crisis at the end of the 19th century with a wider range of agrological options, instead of having to resume winegrowing.

Our hypothesis tries to search for the answer in economic and socio-environmental history. We consider that the most apparent difference between the Barcelona and Tarragona provinces that succeeded in enduring the plague, and the ones of Lleida and Girona that failed, was this: vineyard specialization had taken root step by step,

[6] Carmona, Colomé, Pan-Montojo and Simpson eds., *Viñas*; Pinilla and Ayuda, Internacional Wine Market.
[7] Planas, Cooperativismo.

throughout a historical process that had started in the 17th century or even earlier. Thanks to such a long-lasting development, winegrowing became a true *culture* in these specialized rural areas tightly rooted in agrarian societies and cultural landscapes.[8] The factorial endowment, know-how and skills that had been accumulated enhanced their economic resilience, allowing them to continue winegrowing after the plague.

Things were not the same in the provinces of Lleida and Girona. Until the 1860s the province of Lleida not only had much less acreage of grapevines, but many of them used to be planted in sparse rows between strips of land alternatively sown with cereals or let lie fallow, surrounded by olive or almond trees growing on the margins. This traditional pattern of associated crops in the same pieces of land fitted very well with an age-old agricultural feature of the Mediterranean landscapes, that maintained a small proportion of vineyards as part of an agrarian system devoted to growing the traditional Mediterranean trilogy: always a little oil and wine produced for local consumption, together with as much wheat and barley as possible. What happened in the provinces of Tarragona and Barcelona from the 17th century onwards was something very different: a specialization process linked with increasing commercial exports towards the emerging Atlantic economy.

HOW A COMPARATIVE ADVANTAGE HAD ARISEN

There is a strong consensus among economic historians that this commercial vineyard specialization, developed in the littoral and pre-littoral districts of Barcelona and Tarragona provinces, played a key role in the relatively early beginning of industrialization and modern economic growth in Catalonia. Since the publication of Pierre Vilar's masterpiece *La Catalogne dans l'Espagne moderne* (1962), historians and economists have stressed the role played by the spread of vineyards that took place during the 17th, 18th and 19th centuries. Brandy and wine exports linked the Catalan economy to a large foreign market from which it could import cotton. The possibility of exports deepened regional specialization and offered an increasing number of working people a way to earn their living, thus avoiding the Malthusian fate typically associated with fast population growth. It also increased the rural population's purchasing power and their consumption of industrial textiles, and enabled landowners or their inheritors to accumulate rural savings which were increasingly invested in new trading or industrial enterprises and railways.[9] This strong historical link between vines and the cotton industry which developed in Catalonia stands in sharp contrast to the trend of «*vigne contre draperie*» which characterized other contemporary regions such as the French Languedoc.[10]

Many economic and environmental historians also regard commercial specialization in woody crops such as vines, olive or almond trees as a key feature in the available capabilities for the agrarian development in the western Mediterranean basin during the 18th and 19th centuries, where agrarian specialization became a characteristic vehicle for Smithian-type growth.[11] However, in recent times it has been stressed that the Dutch-

[8] Agnoletti ed., *Cultural Landscapes*; Tello, Garrabou and Cussó, Energy and Land Use; Garrabou, Tello and Cussó, Social Metabolism.
[9] Sánchez and Nadal, Éxito Algodonero; Sudrià and Pascual, Financing a Railway; Valls, *Catalunya atlàntica*, and Viticulture et Industrialisation.
[10] Fohlen, En Languedoc; Dugrand, *Villes et champagnes*; Berger and Maurel, *Viticulture*; Johnson, *Industrial Languedoc*.
[11] Vries, A modest proposal.

English mode of «agrarian revolution» in the European Atlantic area was impracticable in the Mediterranean bioregion due mainly to its low rainfall.[12] Therefore, environmental constraints also played an important role in the vineyard specialization developed in southern Europe during the last stage of pre-industrial «organic» agriculture.

The idea of an «organic economy», put forward by Anthony Wrigley and Rolf Peter Sieferle among other scholars, may help to highlight this relationship between the environmental constraints and the economic forces behind the viticultural focus of agrarian development in the western Mediterranean basin.[13] From a historical standpoint we consider «organic» any agrarian system in which nearly all of the energy and material flows come, directly or indirectly, from the photosynthetic capture of solar radiation. In this «area-based» energy system the entire economy is highly dependent on the biological net primary production that can be attained from the land.[14] A key feature of this organic agriculture was the bioregional diversity of limiting factors that became bottlenecks for economic development. Consequently, technological and socioeconomic responses to these environmental constraints necessarily had to be different. The bioregional diversity of past organic agrarian developments stands in very sharp contrast to the uniform global tendencies that characterize the great transformation undertaken after the «green revolution» of the 20th century.

One of the main goals of our research project is to conduct a historical analysis of the links between energy efficiency, land-use efficiency and a healthy landscape ecology from the perspective of ecological economics.[15] Specifically, we intend to assess and explain the role played by market specialization in driving the diverse agrarian systems in the western Mediterranean basin towards a more advanced organic economy prior to the second industrial revolution and the coming of the cheap oil era. From the point of view of ecological economics, trade is usually seen as a two-edged sword: while it has often been a powerful factor in environmental degradation, it can also foster a better allocation of resources which might also be useful for reducing human impact on natural systems. The first outcome may arise from the ecological-scale effect over a set of biophysical flows that become increasingly unlocked, together with the socio-environmental consequences of a possible unfairness of trade when it entails an unequal ecological exchange.[16] The second outcome may actually arise through a backward shift of the limiting factors known in ecology or agronomy as «Liebig's minimum», either indirectly, with a product specialization for which each bioregion has a relative «ecological optimum», or directly, by transferring limiting goods from one bioregion to another.[17] Economic and environmental historians can contribute to a clearer assessment of this complex and often ambiguous relationship between trade, economy and ecology, through the comparative analysis of different historical paths of commercial specialization and globalization.

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[12] González de Molina, Environmental constraints; Garrabou, Conflict and environmental tension.
[13] Wrigley, *Poverty*; Sieferle, *Subterranean Forest*; McNeill, *Something New*; Krausmann, Schandl and Sieferle, Socio-Ecological Regime Transitions.
[14] Fischer-Kowalski and Haberl eds., *Socioecological Transitions.*
[15] Marull, Pino, Tello and Mallarach, Loss of Landscape Efficiency.
[16] Hornborg, McNeill and Martínez Alier eds., *Rethinking Environmental History*.
[17] Grigg, *Dynamics of Agricultural Change*, p. 47-67. Ecologists have dismissed the simple theory that every ecosystem tends towards a single «climax», and that every external disturbance would only move it back from its own «equilibrium» end. For each territory there is not a single natural «vocation» but rather a set of possible outcomes. Therefore, any «ecological optimum» must be understood only as a relative bias within an open range of possibilities.

We intend to contribute to this area of research by analysing the scope of trade in Catalonia in the production and consumption of staple agrarian products during the second half of the 19th century. Having reconstructed the energy balances of the agrarian system prior to 1860 in a series of local case studies so as to compare them with current values, and having assessed the changes in land-use and its impact on landscape ecology, we now aim to identify the turning points that transformed a specialized Catalan agriculture into a globalized one before and after the agrarian crisis at the turn of the 20th century.[18] Three main features distinguished the agrarian specialization in brandies, wines and sparkling «*cava*» developed in the Catalan provinces of Barcelona and Tarragona. After having started very early in the 17th century, it advanced slowly but steadily during the 18th and 19th centuries until the sudden Phylloxera rush and crash which was eventually overcome. Secondly, winegrowing was always combined with cereals and other crops in several types of complex agrarian landscapes, which were hardly ever devoted to monoculture. Third, the intensity of vineyard specialization remained diverse locally, and sometimes changed municipal location throughout its long history.

Following the qualitative interpretations proposed by many Catalan historians, using the traditional tools of comparative analysis based on case-studies and descriptive statistics, we began by figuring out a number of variables in order to build a model to explain agrarian vineyard specialization in the province of Barcelona and the rest of Catalonia in the mid-19th century. We have assembled all available data on vineyard acreage in the 35 districts of the four Catalan provinces in 1858-60, 1885-89 and 1922. We have also incorporated other available statistics on population densities, and estimations at a district level of the heliothermal indices of Huglin and Winkler that assess the agro-climatic local suitability for winegrowing, together with the weighted average in the slope of lands. Building this historical model to explain the upkeep of vineyard specialization has required the complementary skills and efforts of a team of researchers made up of historians, economists, agronomists and ecologists that are now working together in our research project.

We started building and applying this econometric approach to explain the local differences in vineyard or cereal specialization around 1860 in the nearly three hundred municipalities of the province of Barcelona. A first statistical set of tests is already in print in a book on *The impact of markets in the management of the rural land* edited by Gérard Béaur and Vicente Pinilla, where we use a model that combines the «Boserupian» push of population increase (measured with the previous population growth from 1718 to 1860), the demand pull of a «Smithian-type» of growth (measured using the terrestrial distances to the nearest seaport), and the agrological land's suitability for sowing grain or growing vines (as measured by mean rainfall, slopes and frost risk). This historical model does not aim at explaining all types of vineyard specialization in every period of time or geographic location, but the role played by this specific set of factors throughout the long-lasting spread of vines in the municipalities of the province of Barcelona that led to a particular organic-based agrarian economy during the second half of the 19th century.[19]

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[18] Pomeranz, *Great Divergence*; Williamson, *Globalization*.

[19] For an epistemological and methodological approach to this kind of modelled historical explanation see Daniel Little's idea of «*meso-history*» [Accessed 27 May 2009] Available on-line URL: http://www.changingsociety.org/ChangingSociety/Research_page.html).

POPULATION GROWTH AND AGRARIAN CHANGE IN AN «ADVANCED ORGANIC» ECONOMY

However, as Ester Boserup pointed out, the relationship between population growth and agricultural innovation is complex and changeable: while in some range the increase of population density becomes an important driving force for the development of more intensive land-uses, such as the Mediterranean viticulture, beyond a certain threshold further increases in population density become related to the development of industrialization and urbanization that may limit or even question the winegrowing specialization by increasing the opportunity cost of labour. There is also a lower threshold of densities below which the «Boserupian» population pressure stops leading to agricultural intensification, and favours other more extensive land-uses such as cereal crops.[20] We know that between 1860 and 1920, Catalonia, and especially the province of Barcelona, saw the consolidation of its early industrialization. Thus we need to establish with some accuracy the margin of variation in population density from which we can still expect a positive relationship between population growth and winegrowing specialization, in order to differentiate them from an upper threshold of population densities beyond which the link between the two variables may become insignificant or even negative.

We take the amount of labour required to cultivate a hectare of vines, compared with the labour needed to crop a hectare of cereals, as the crucial data to estimate the range of land-labour ratios that could determine a factor endowment favourable to viticulture. We know through a detailed study we made on the Land-Time Budget Analysis (LTBA) of a rural municipality in the province of Barcelona that around 1860 one hectare planted with vines required 73 man-equivalent working days a year, whereas in a rather intensive cropping of cereals and legumes without fallow practised in the same area only 42 working days were needed at the time.[21] Another very detailed study on the economic accounting of a vineyard farm in the same province between the 1920s and 1930s tells us that technological innovations adopted after the Phylloxera plague had increased by 30% the labour required by the new viticulture, up to 94 annual man-equivalent working days a year per hectare.[22] However, other contemporary sources also tell us that the extensive cultivation of cereals with fallow practiced in inland Spain only required 25 working days per hectare a year.[23] This was also the case in the Catalan province of Lleida, were population densities matched the Castillan ones from 1860 to 1920.

Assuming that the agricultural active population worked on average 8 hours a day during 240 days a year, and that there was the same 0.37 ratio of agricultural active people over the total population that we get in the abovementioned local case study on LTBA towards 1860, we can calculate from the labour required for a unit of land devoted to grow vines, an optimal population density that ranged between 0.8 and 1 hectare of cropland per inhabitant. This would have meant between 82 and 105 inhabitants/km^2 if all the land had been covered with vineyards, which of course is not plausible except in very specific local cases. In order to calculate the mean optimal population density for growing vines a proportion of vineyards over the total extension of land must be applied, which varied greatly from one village to another. Taking as a reference the averages of cropland acreage that in Catalonia ranged between 30 and

[20] Boserup, *Population.*
[21] Garrabou, Tello and Cussó, Ecological and Socio-economic functioning.
[22] Anonymous, *La revisió dels contractes de parceria*, p. 12.
[23] Carrión, *Latifundios*, p. 324.

40% of the total provincial size from the years 1860s to the 1880s, an optimal population density for viticulture would have hovered between 25 and nearly 40 people per km^2.

This fits very well with the data we have from the available census (Map 6). While population densities remained around 25 inhabitants/km^2 in the province of Lleida, mainly devoted to cereal crops except during the short-lived wine rush during the Phylloxera infestation of French vines, all the other Catalan provinces already had population densities above 40 inhabitants/km^2 from 1860 to 1920. However, only in the province of Barcelona they had climbed from 94 to 175 inhabitants/km^2, or from 1,978 to 5,662 in the Barcelona district, due to the advance of industrialization and urbanization. It is interesting to note that according to Ester Boserup 65 inhabitants/km^2, or one and a half hectares per person in most of rain-fed agricultural areas of the world is the maximum level of population density that can be sustained by a highly intensive agrarian system. Only an urban-industrial economy can maintain population densities higher than that.[24]

Let us imagine for a moment what it would have meant to rely on only 1.5 hectares per person to feed the local population and provide them with fuelwood and pasture with an organically based intensive agricultural system, and in a Mediterranean bioregion subject to low rainfall and where keeping livestock and obtaining fertilizers became severely limiting factors. As in any type of organic agriculture, an innovative response had to deal with two difficult side-effects: the scarcity of fertilizers and firewood. The Mediterranean solution of planting vineyards helped to prevent firewood and manure becoming bottlenecks that might have halted the progression towards a more intensive land-use pattern. Vines were planted mainly by poorer peasants in poor, sloping land, and no manure was put on them after planting. However, the specialization in vine cultivation was only partially maintained, which enabled the poly-cultural landowners of the typical scattered Catalan farms to use most of what little manure was available on the better soils used primarily for cereals and legumes, together with some fruit trees, vegetables and hemp. After vintage time, even the green shoots of the vines were used as fodder for sheep, which in turn produced the much-needed manure to fertilize other crops. Vines were also pruned to provide a valuable substitute for increasingly scarce firewood.[25]

The high transportation costs before the railway reinforced the role played by local and regional endowment of land and labour, both in ecological and economic terms.[26] In that sense, the location of every district must have had a deep impact on the economic accessibility to foreign markets. For the same reason, the extension of railways should have led to a dramatic reduction in transport costs taken as a measure of access to markets.[27] The dataset on time-distances we have assembled clearly show this drastic reduction of the journey time to Barcelona experienced in Catalonia between 1856 and 1920 (Map 8). According to our data, in several districts of Lleida and Girona the arrival of the train divided by four or five the existing time-distances to the city of Barcelona. On average the spread of the railway network divided by almost three the time needed to travel from any Catalan district to Barcelona. While in 1856 only 10 districts were less than 6 hours away form the harbour of Barcelona, in 1920 already 24

[24] Boserup, *Population*.
[25] Tello, Garrabou and Cussó, Energy and Land Use.
[26] Fischer-Kowalski, Krausmann and Smetschka, Modelling scenarios.
[27] See for Catalonia Pascual, *Caminos de la Era Industrial*; and for Spain, Herranz-Loncán, Spatial Distribution.

out of 35 were. After a change of this magnitude we might expect that the distance to Barcelona ceased to be a critical factor for the location of vineyards. However, a comparison between Maps 5 and 8 reveals that vineyard location did not change so much in spite of the dramatic cuts in transport costs experienced from 1880 to 1920. This could mean that a path dependency kept alive the comparative advantage previously accumulated by those regions that already enjoyed a vineyard specialization before 1860.

OUR HYPOTHESIS: HISTORY, MARKET ACCESS AND AGRO-ECOLOGY MATTER TOGETHER

As we have said, the vineyard specialization of the Catalan districts could be explained by three main sets of variables: agro-climatic endowment for winegrowing, population densities, and time distances to the seaport of Barcelona as an indicator of market access. We are going to test the statistical significance of these factors in order to explain the degree in winegrowing specialization of every district during the whole period from 1858 to 1922. To do this we propose the estimation of panel data from equation (1):

$$Y_{i,t} = \alpha_i + \beta \cdot X_{i,t} + \varepsilon_{i,t} = \alpha_i + \beta_1 \cdot AGRECOL_i + \beta_1 \cdot MKAC_{i,t} + \beta_1 \cdot POPDEN_{i,t} + \varepsilon_{i,t} \quad (1)$$

The model is aimed at explaining the percentage of cropland devoted to vineyards ($Y_{i,t}$) in each district in the whole period, taking into account: the agro-ecological variables ($AGRECOL_i$) such as the indices of Huglin (HUG_i) and Winckler (ETI_i) of climatic suitability for vines, or alternatively, the weighted mean slope of land expressed as a percentage ($SLOP_i$) seen as a proxy for land suitability to cereal crops and vineyards; the market access ($MKAC_{i,t}$) assessed by the time-distances in hours to the Barcelona market and harbour ($BCNTIMDIS_{i,t}$) following the existing roads and railroads; and the population density ($POPDEN_{i,t}$) taken as a proxy for factor endowment in land-labour ratios.

First of all, in order to measure the impact of agro-ecological factors on vineyard specialization in the Catalan districts we estimate equation (1) by OLS, incorporating as variables the Huglin (*HUG*) and Winkler (*ETI*) indices together with market access and population densities, or alternatively the weighted average of land slopes (Table 9). The results in columns (a) and (b) show that only the latter are significant, while the agro-climatic indices are not. The heliothermal indices of Huglin and Winkler are used world-wide to assess the climatic suitability for growing vines in any region on Earth, and even to predict the effects of climate change on vineyard location.[28] However, a very important first result of our research has been to check that these indices do not appear significant in the tests, in order to explain the historical vineyard locations in Catalonia from 1858 to 1922 at district level. After having tried them several times in several ways, we have found the solution to the apparent paradox by looking carefully at the Maps 5 and 7. The higher Huglin and Winkler scores are reached on the coastline, especially in the delta of the Ebro river, or in the inland plane of Lleida. However, most of the Catalan districts with a long-lasting vineyard specialization were located in the pre-littoral corridor that lies in between these littoral and inland places. That means two

[28] Tonnietto and Carbonneau, Multicriteria.

very important things: 1) the climate zone well endowed for growing vines was and still is broader than the area actually exploited; and 2) although vineyard specialization developed in districts agro-climatically suitable for viticulture, they were not always the most suitable.

The first areas where vineyards were grown to make and export brandies during the 17th and 18th centuries were located in some points of the coastline, near the towns of Mataró and Tarragona-Reus. But later on most of these early specialized locations abandoned viticulture in favour of other more profitable crops or economic activities, except when they had developed a high quality brand. Catalan vineyards moved location towards the pre-littoral corridor while table wines replaced brandy as the main export product during the 19th century.[29] Ironically, vines became more widespread again in the coastline, as well as in the inland plains of Lleida, only during the short-lived wine rush when the Phylloxera first infested the French vines. After the plague, the centre of gravity of vineyard specialization returned again to the pre-littoral corridor in Southwest Barcelona and Northeast Tarragona provinces.

However, if we replace the climatic indices in the test shown in Table 9 with the weighted average of land slopes in each district, the result in column (b) tells us that this variable becomes significant but has a negative sign, meaning that vines were not planted in the most sloping districts like the ones in the Pyrenees. In a previous model we tested to explain the vineyard specialization achieved towards 1860 in all the municipalities of the Barcelona province, we found that vines used to be planted mainly in poor sloping soils not suitable enough to crop wheat.[30] According to that, vineyard location can be better explained at a municipal scale by the most unsuitable land for cereals rather than by the most suitable land for vines. Nevertheless, looking at the available data at district level the result found here is the opposite: vines could not be planted in soils with slopes so pronounced as those prevailing in the Pyrenees and other parts of Catalonia. We are faced again with a question of ranges and thresholds. A different result could have probably be found if the weighted average of the slope had been calculated only for cropland, rather than for the total area. Unfortunately, the available cadastral maps do not cover all the municipalities and districts before the 1950s in Spain. Therefore the most relevant statistical result obtained here is to remind us that in assessing agrological and ecological features scale matters.

Anyhow, we come to the conclusion that natural endowment alone can explain neither the spatial pattern nor the historical trends of vineyard specialization in Catalonia during the last three centuries, at least watching it at district level. Socioeconomic factor endowment and travel costs for market access are needed to do that. So after having arrived at this very important conclusion from the first (a) and (b) columns in Table 9, we need to look at the changing socioeconomic variables. In column (c) we conducted a second estimate of the equation (1) by fixed effects for all districts. By construction, in this fixed effects estimation the constant varies for each district, thus capturing the characteristics of every spatial unit. The result shows that the variable of time-distances for access to markets appears significant and with expected negative sign, meaning that commercial specialization in winegrowing continued to be correlated with a better access to the city of Barcelona, in spite of the big improvements in transport facilities. However, population density is not a significant variable in this case (c). As we explained in the preceding discussion on the meaning of different ranges and thresholds

[29] Valls, *Catalunya atlàntica*.
[30] Garrabou, Tello and Cussó, Explaining agrarian specialization.

of population density taken as a proxy for land-labour ratios, we know that the very high densities in the district of Barcelona were clearly related to other types of urban-industrial economic dynamics since 1860. Therefore, we repeated the exercise taking that district out. The new estimate (d) shows again significant results and the expected negative sign in the variable of access to markets, and this time the population density also becomes significant and with the appropriate positive sign, meaning that up to a point vineyard specialization was positively related to a greater population per unit of cropland.

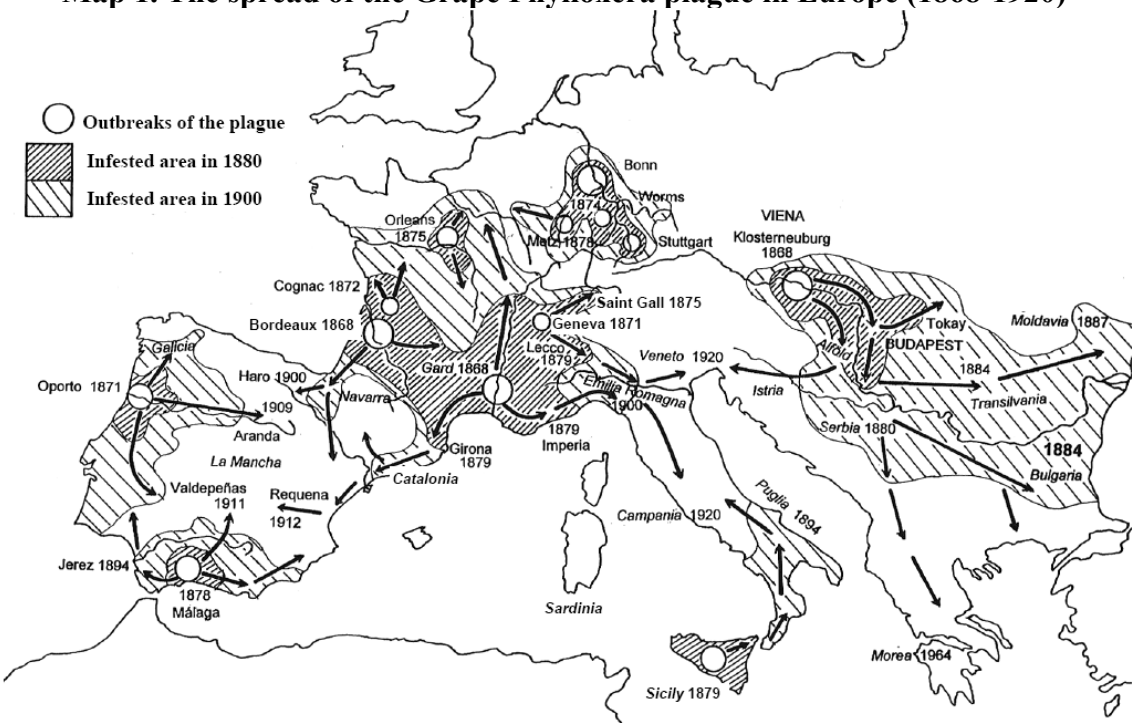
ON THE ECONOMIC AND ECOLOGICAL RESILIENCE OF A CULTURAL LANDSCAPE: ANY LESSONS?

Considering the evidence at hand, we believe we have accounted successfully for a great deal of the variability in the specialization in vine cultivation between the districts in Catalonia before and after the Phylloxera plague, in a way that stresses the path dependency experienced by a comparative advantage that had been previously created through a long-lasting historical process. Viticulture became a rooted cultural landscape in these specialized Catalan districts, and this character reinforced their economic resilience to a sudden external shock like the grape Phylloxera plague. If there is any lesson to get here, perhaps it would be to stress the importance of betting for comparative advantages deeply rooted in the differentiated natural, social and cultural fabric of every landscape. Although no commercial specialization will last for ever, this kind of socio-environmental base can enhance the resilience of the economic system against exogenous shocks.

The significant statistical results we have obtained can also be seen as an indirect confirmation of the Heckscher-Ohlin theoretical explanation of commercial specialization, by means of the relative factor endowment of land and labour. However, our main aim as historians is to understand how these different land-labour ratios arose, and why they were kept in the Western Mediterranean bioregion over a long historical period. While the agro-ecological endowments can be seen as almost immobile, the available labour supply was created instead by the relative presence or absence of landless peasants. These poor peasants sought to earn their living working as tenants of a *rabassa morta* lease on the thin and sloping soils offered to them by landowners.[31] This peculiar Catalan tenancy contract called *rabassa morta* lasted until the death of the vines planted by the tenant. The fact that this leasing system became so widespread might be understood as a collective achievement of a very difficult agreement between wealthy landowners and landless peasants. The social conflict over land entitlement between these *rabassa* tenants and landowners lasted from the 18th century, and until the Spanish Civil War in 1936-39. Nevertheless, the contractual agreements reached between them in the meantime helped to reduce the prevailing agrarian inequality, and channelled the social unrest triggered by this conflict towards creating a more productive rural society.[32] This may also help to explain why the «Boserupian» push of population growth, combined with the growing inequality in land ownership, seems to have played such an important role that deserves to be better analysed in future improvements of the model. A further discussion is also needed on how to deal with the endogeneity problem that working with these socio-demographic variables may entail.

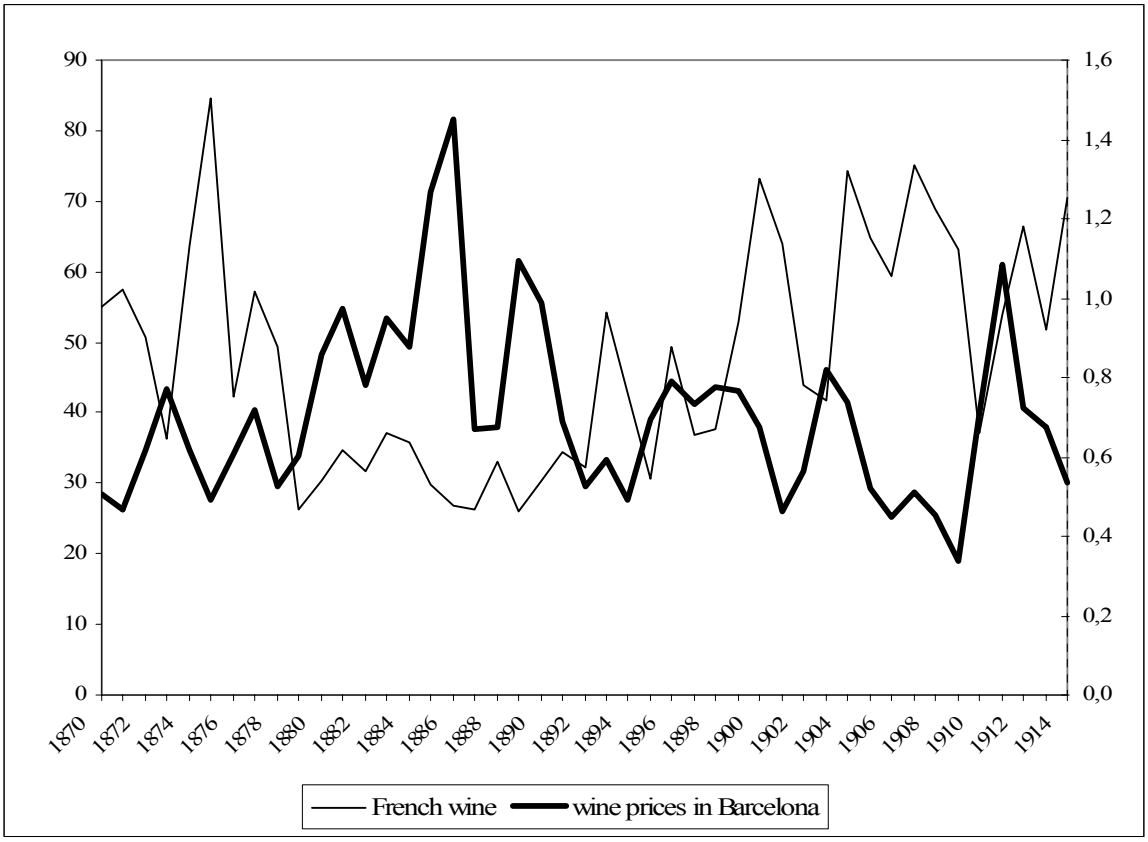
[31] Olarieta, Rodríguez-Valle and Tello, Preserving and destroying soils,
[32] Garrabou, Planas, and Saguer, Sharecropping; Garrabou, Cussó and Tello, Cambio de usos del suelo.

Map 1. The spread of the Grape Phylloxera plague in Europe (1868-1920)



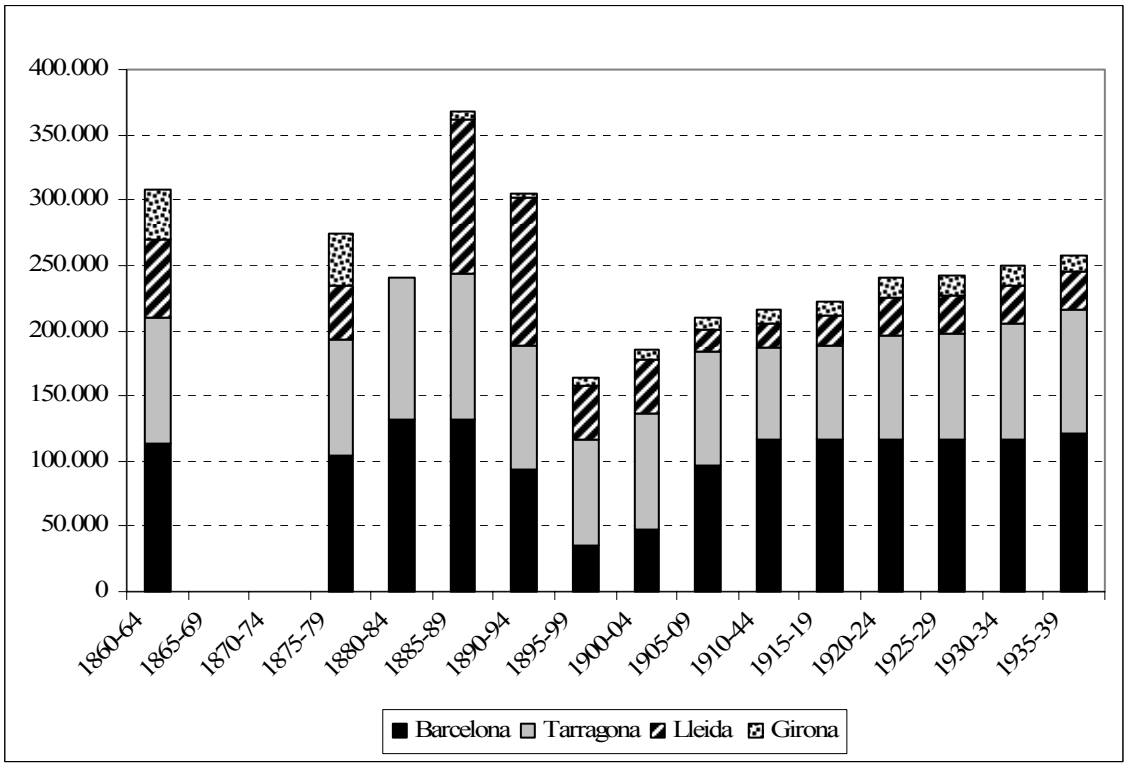
Source: our own, adapted from Piqueras, Filoxera en España, p. 106.

Graph 2. Wine produced in France and Algeria (in millions of hectolitres, left axis) and wine prices in Barcelona (in pesetas per hectolitre, right axis), 1870-1914



Source: Garrabou, Tello and Cusso, Explaining agrarian specialization; Garrier, *Philoxéra*, p. 175.

Graph 3. Land devoted to vineyards in the four provinces of Catalonia in hectares (1860-1935)



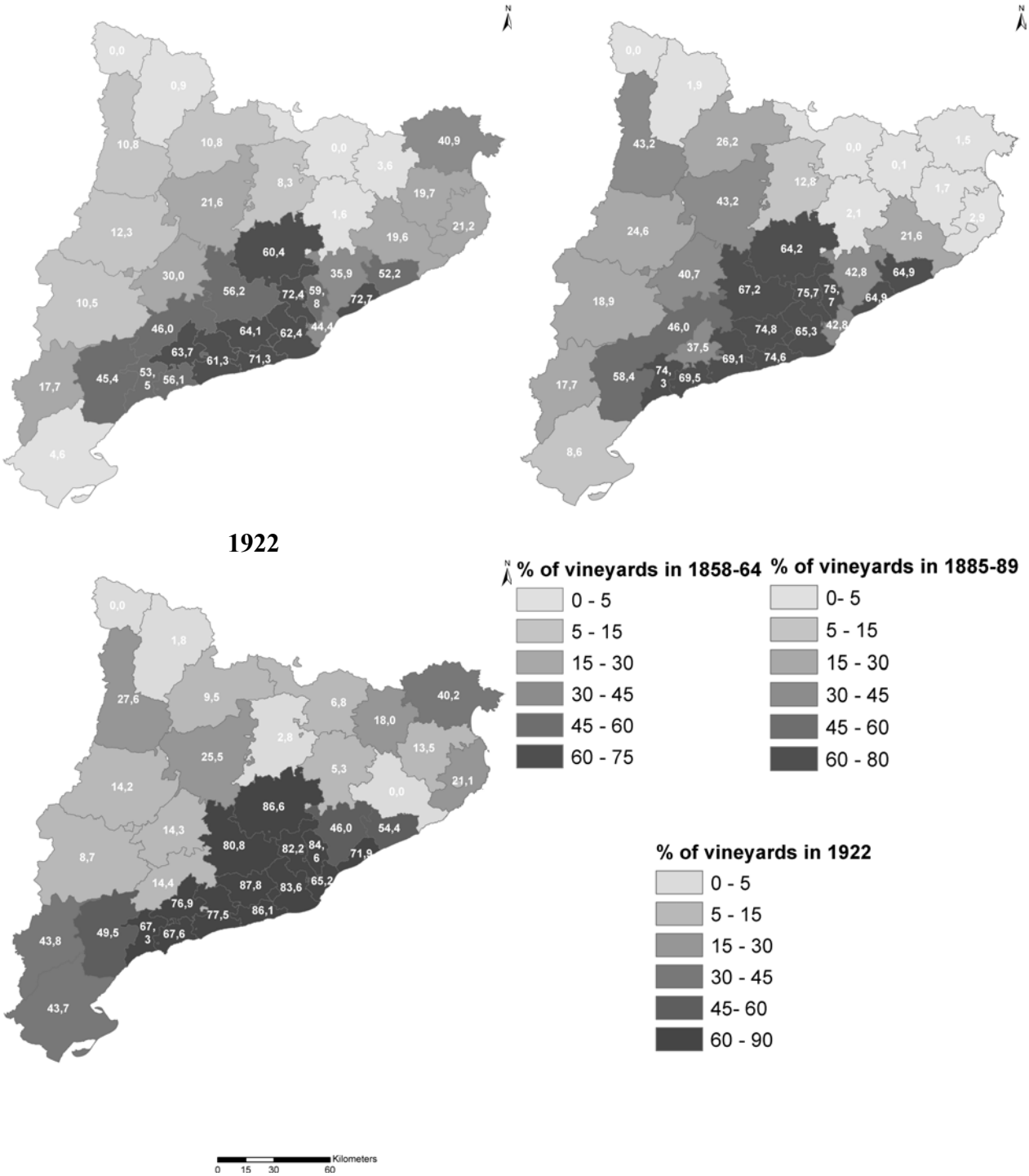
Source: our own, from Moreno, *Estadística Territorial*; Martínez Quintanilla, *Provincia de Gerona*, p. 295-297; Llovet Mont-ros, *Contribución*; Roig Armengol, *Memòria*; García de los Salmones, *Invasión Filoxérica*, p. 193; Junta Consultiva Agronómica, *Estadística*, p. 265-300; Garrabou and Pujol, Canvi Agrari, p. 80-81; GEHR, *Estadísticas históricas*; Heras and Mas, *Viticultura i Fil·loxera*; Piqueras, Filoxera en España, p. 135; and Valls, *Dinàmica*. Notice that in 1880-84 data is only available for the provinces of Barcelona and Tarragona.

Table 4. Five-year mean wine production in the four Catalan provinces (in hectolitres of grape juice, 1890-1934)

	Barcelona	**Girona**	**Lleida**	**Tarragona**	**CATALONIA**
1890-1894	10,330,557	321,856	8,499,954	8,623,763	27,776,129
1895-1899	4,451,321	460,822	3,924,483	6,082,960	14,919,586
1900-1904	9,407,277	811,231	3,127,252	6,574,141	19,919,901
1905-1909	9,128,789	831,906	1,140,292	7,080,729	18,181,716
1910-1914	12,150,214	850,807	1,373,239	8,175,214	22,549,474
1915-1919	18,067,230	1,957,778	1,365,749	9,320,052	30,710,809
1920-1924	21,474,627	2,268,922	1,712,615	12,122,787	37,578,951
1925-1929	18,468,333	1,647,409	1,048,112	9,369,795	30,533,649
1930-1934	13,773,209	1.207.384	1,120,856	7,768,326	23,869,775
*Δ **1890-94** to **1930-34***	*3,442,652*	*885,529*	*-7,379,098*	*-855,437*	*-3,906,354*
*%Δ **1890-94** to **1930-34***	*33.3*	*275.1*	*-86.8*	*-9.9*	*-14.1*
*Δ **1890-94** to **1920-24***	*11,144,070*	*1,947,067*	*-6,787,339*	*3.499.025*	*9.802.823*
*%Δ **1890-94** to **1920-24***	*107.9*	*605.0*	*-79.9*	*40.6*	*35.3*

Source: our own, from GEHR (1991). Regular yearly statistics of agricultural production in every Spanish province only began in 1890.

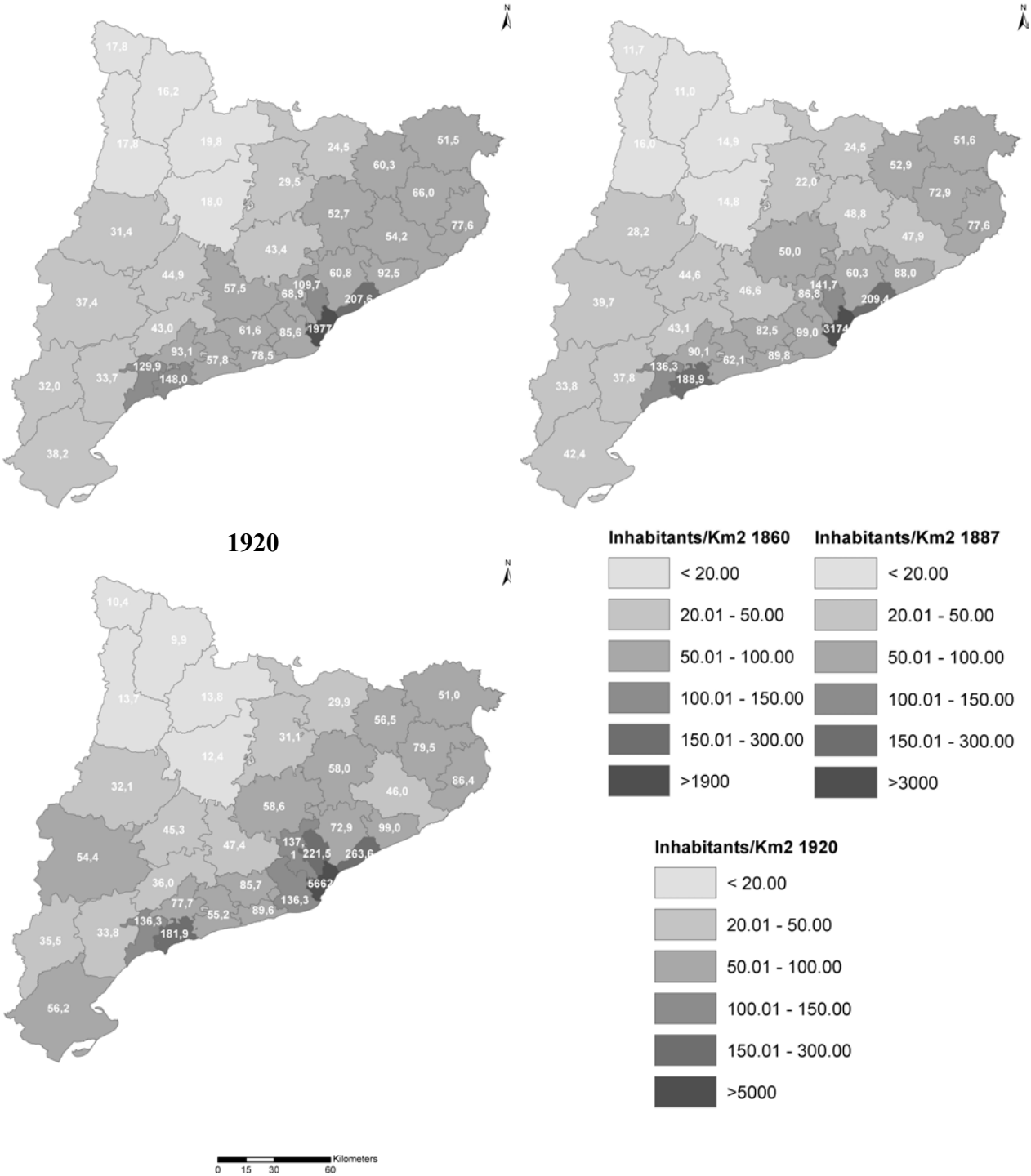
Map 5. Percentage of cropland devoted to vineyards in the districts of Catalonia



Source: our own, from the data and historical sources referred in Graph 3.

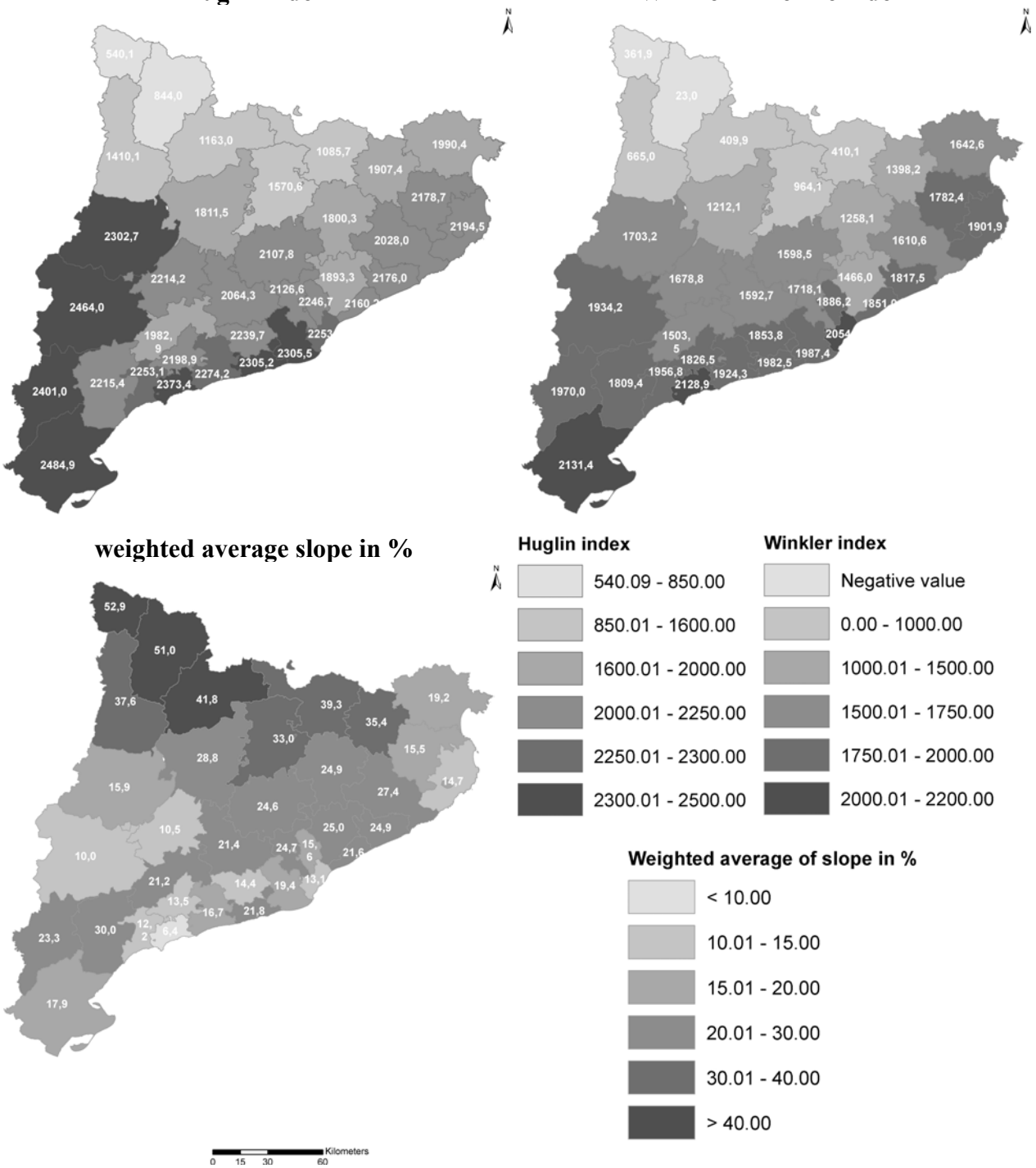
Map 6. Population densities in the districts of Catalonia

1860 **1887**



Source: our own, from the data available at the Centre d'Estudis Demogràfics, [Accessed 27 May 2009] on-line URL: http://www.ced.uab.es/index.php?newlang=eng.

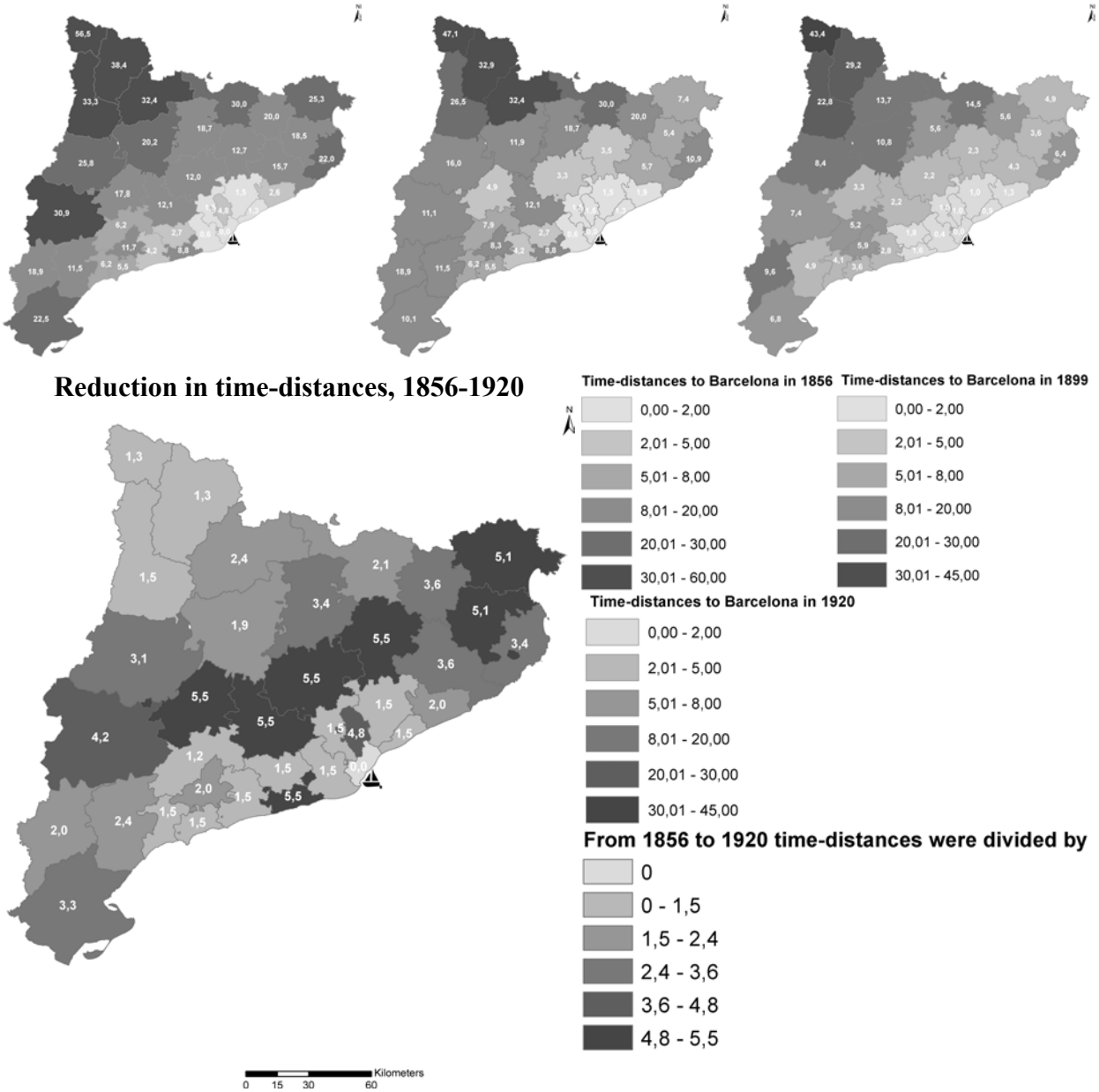
Map 7. Agro-climatic aptitude for growing vines in Catalonia



Note: Growing vines requires a Huglin index of at least 1,500 and a Winkler-Amerine index of at least 2,000. The Huglin index of helio-thermal aptitude is obtained by the expression: $IH = \Sigma\ [(T_a - 10º) + (T_m - 10º)]\ K / 2$, where T_a is the daily average temperature, T_m is the maximum daily temperature during the active period of vegetation, and K is the length ratio of days varying from 1.02 to 1.06 between 40 and 50 degrees of latitude. The Active Thermal Integral (*ATI*), is calculated by adding the daily mean temperatures above or equal to 10º C during the active period of vegetation between March and October: $ATI = \Sigma\ T_a$, where T_a is the active temperature. The Effective Thermal Integral (*ETI*) of Winkler & Amerine is the sum of effective daily mean temperatures, calculated from the monthly average temperatures multiplied by days of each month during the growing season from April to October: $ETI = \Sigma\ T_e$, where the effective temperature (T_e) is the active temperature (T_a) minus 10º C.

Source: our own, calculated with GIS by J. Marull, M. J. Cordobilla and F, Rodrígez-Valle for the research project SEJ2006-15108-C02-01/GEOG. A GIS spatial interpolation of a resolution of 180 meters has been done based on the data of air temperature taken from 160 weather stations (one station per 200 km^2) for the period 1961-1990.

Map 8. Changes in time-distances to Barcelona from the Catalan districts



Source: our own. Time-distances before the railway and until 1856 have been taken from these four references: Anonymous, *Itinerario*; Bertrán Soler, *Itinerario*; Frígola, *Relación*; and Estasen, *Cataluña*. For 1880 and 1889 terrestrial distances have been calculated with GIS by Marc Badia-Miró based on the existing railroads and roads at the time. They have been turned into time-distances by applying the average speed of 4 km/hour on horseback, 5 km/hour by cart and 20 km/hour by a «cheap» railway, according to Sociedad Económica de Amigos del País de Barcelona, *Crisis Agrícola y Pecuaria*, p. 87. For 1920 the average railway speed has been increased to 30 km/hour.

Table 9. Regressions to explain the upkeep of vineyard specialization in Catalonia before and after the Grape Phylloxera Plague

Percentage of cropland devoted to grow vines in the districts of Catalonia in 1858-64, 1885-89 and 1922				
	(a) Combined OLS estimates (Barcelona included)	(b) Combined OLS estimates (Barcelona included)	(c) Combined panel data by fixed effects (Barcelona included)	(d) combined panel data by fixed effects (Barcelona excluded)
Constant (*CT*)	-0.043 (-0.12)	0.40*** (5.00)		
Population density, inhab./km^2 (*POPDENS*)	0.002921*** (5.13)	0.002495*** (4.95)	0.0000663 (1.62)	0.001399** (2.07)
time-distance to Barcelona, hours (*BCNTIMDIS*)	-0.00568*** (-2.75)	-0.00586*** (-2.99)	-0.00485** (-2.24)	-0.00418* (-1.94)
Huglin Index (*HUG*)	0.00029 (-0.71)			
Winkler Index (*ETI*)	-0.00017 (-0.56)			
Mean slope of land in % (*SLOP*)		-0.0049** (-2.18)		
Adj R^2	0.396	0.415	0.902	0.907
Durbin – Watson	--	--	2.10	2.18
Number of observations	105	105	102	105

Note: t-ratios are in brackets; ***1%, **5% or *10% statistical confidence interval. Source: our own estimates, using the database taken from the historical statistical sources referred in the text, Graph 3 and Table 4.

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