Demography, Depopulation, and Devastation: Exploring the Geography of the Irish Potato Famine

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I n the latter half of the 1840s, the potato crop in Ireland failed. As a result a progression of circumstances led to a 20 percent decline in population between the censuses of 1841 and 1851. This dramatic decrease in population was a product of death through famine and disease together with heightened rates of emigration. The down-turn in the population of Ireland continued, albeit at a lesser rate, for the remainder of the nineteenth century and well into the twentieth—this at a time where Europe's population increased from around 320 million in 1880 to 420 million by the turn of the century.[1] It is not surprising, therefore, that the famine and its aftermath dominate the historiography associated with nineteenth-century Ireland.

This article discusses some of the key spatial patterns associated with the famine. Our analysis is based on a comprehensive database of Irish historical statistics, largely extracted from the printed Irish census returns for 1841, 1851, 1861, and 1871, agricultural returns from 1852 (when they first become reliably available), and a set of maps generated from the data at a range of scales.[2] The first half of this article is concerned with simple but essential visualization of spatial patterns. Using GIS methods not previously applied to the famine, these data are adjusted on to a common set of poor law union or barony administrative boundaries to facilitate examination over several census years. The latter part of this article uses more complex analytical techniques to explore multivariate patterns over space and time. Here we are able to reconcile and compare data gathered for different sets of boundaries using a technique called areal interpolation. Spatial analysis is then used to explore the changing relationships between different datasets.

Our work addresses a major lacunae in the literature. Scholars have produced exhaustive studies of the famine at local and national levels. These studies have used either qualitative or quantitative sources, and in

some instances both. But despite the remarkable scope and detail of studies of the famine, its spatial characteristics and geographical impact and implications have not been adequately addressed. Not only is the geography of this pivotal event in Irish history poorly understood, but scholars have drawn broad conclusions about regional differences without anchoring them in evidence. Where geographical substantiation has been used, it has almost invariably been limited to the county level. We will argue that county-level data give a coarse and often misleading picture of the famine's spatially variable impact; that in fact mapping famine data at the scale of the county obscures more than it reveals.

It is not our intention to be overly critical of much scholarly work on the famine period by a large number of historical geographers and historians. Nor is it an aim here to review earlier work in detail. Advanced visualization, geographical information systems (GIS), geographical information science (GISc), and spatial analysis are techniques that are new to historical scholarship, in part the result of recent technological advances and in part through increased interdisciplinary work between scholars. These approaches will increase our understanding of the famine. It still remains remarkable, however, that spatial aspects of the famine have largely been ignored by academics, with few maps created, almost all of those concerned with population, and analysis based on counties. There has been even less spatial analysis. A few short examples will serve to illustrate the point.

As we have noted, advanced quantitative analyses of the famine have been conducted. Joel Mokyr's efforts stand out in terms of their scope and authoritative nature.[3] In his most significant work there is not a single map. Of more concern is that the quantitative data Mokyr deploys are at a macro level. Thus we find information for Ireland as a whole, for Ireland divided into six regions (northeast, northwest, central, east, south, and west), for the four provinces, and occasionally for the 32 counties. We will demonstrate in this article that the impact of the famine, and its causes and consequences, varied over space. This local to regional variation controverts statistics at national or near-national level no matter what the complexity of multiple correlations used. Our results indicate that local variations are masked and extremes ignored using macro-statistics. Analysis based on county units or larger areas is virtually aspatial.

Even publications that describe themselves as historical atlases for Ireland, and contain many maps, fail to deal with the famine comprehensively. Although the number of poor law unions in distress in each county is recorded in Seán Duffy's *Macmillan Atlas of Irish History*, it fails to produce time-series demographic data and restricts its examination of the famine to the county. This in itself is interesting as, unlike baronies, poor law unions crossed county boundaries. It is unclear how this "anomaly" was handled. Where there are time-series—as for emigration between 1851 and 1911—the unit of analysis is the county. [4]

It is concerning that more statistical choropleth maps have not been created for the famine period. With the exception of Kennedy, et al.'s *Mapping the Great Irish Famine*, there has been no attempt to systematically map the progress and impact of the famine.[5] The sumptuously produced *Atlas of the Irish Rural Landscape* contains some statistical maps for the famine period, and indeed a few of these plot barony and poor law union data.[6] What is lacking, however, are maps showing change over time. The *Atlas of the Irish Rural Landscape* offers the reader tantalizing snapshots but does no more.

We suggest in this article that a significant, if not overwhelming, break on the development of time-series data is the impact of boundary change for smaller spatial units. In fact, some fifty years on, the work of T.W. Freeman still stands out as some of the most sophisticated visualization work done on the geography of the famine. In the 1940s and 1950s, he produced detailed maps of population density for a limited number of fixed points in time. His maps, based on parish boundaries with manual by-sight adjustment to identify heavily populated areas, was groundbreaking if imprecise.[7] GIS allows us to visualize population data based on a variety of algorithms that address the problems associated with choropleth maps that Freeman identified—that a variable is unlikely to be evenly distributed over a polygon. It is remarkable that, as GIS has developed, the Freeman maps remain key and have not been exposed to GIS. Further, Freeman generally avoids map series showing change over time, presumably due to the problems of intercensal boundary change. Where time series are produced, there is little indication of how boundary changes were addressed.[8] Again, GIS can help to resolve these issues. Notwithstanding methodological developments, Freeman's maps are widely reproduced, not least in the *Atlas of the Irish Rural Landscape*, published in 1997.[9] It is time to move on.

It is worth noting that scholars undertaking historical-geographical studies in Ireland do not face particularly difficult methodological or source-related problems compared to other countries. Indeed Ireland has an unrivaled range of advantages in contrast to many other states. The outer boundary of the state remained constant for centuries. Nor have there been dramatic changes in administrative geographies. Townlands have formed the building-blocks of all other administrative units since the sixteenth century. A historical geographical information system being developed in Belfast is making use of these units to construct all other administrative boundaries.[10]

Key Geographies of the Famine

During the 100 years preceding the famine, Ireland's population grew at a rate equal to or in excess of that found elsewhere in Europe. For instance, its growth was more than double that in France.[11] By the 1840s,

Cork was the fourth largest city in the United Kingdom, and Dublin the eleventh largest city in Europe. Contrary to the European trend of increasing urbanization, however, Ireland remained primarily rural, its people dependent upon agriculture. Only after the famine was this pattern reversed during a period of continuous population decline from the 1850s to the partition of the state in the 1920s. Beyond this, population growth was stunted until the last two or three decades of the twentieth century, when a more sustained and steady population increase has been observed.

While rates of population growth and decline convey part of the impact of the famine, particularly its long reach beyond the nineteenth century, the actual population head counts are even more startling. In 1821, the time of the first census, Ireland's population was 6,801,827.[12] Before the famine began in earnest in 1845, the population increased by about 1.5 million giving a pre-famine population of approximately 8.3 million. The first clear post-famine population count available to us comes from the 1851 census, which gives the island's population as 6,552,385. In other words, the population had fallen below that of 1821, with a loss of 1.75 million people. The 1901 census presents a population of just fewer than 4.5 million, a figure that remained fairly steady until 1971. Two factors make this information still more remarkable. First, over this period, every other European state was gaining in population. Second, population decline and stagnation had a clear spatial dynamic. It was far worse in some parts of Ireland than in others. It is to the spatial dynamic that we now turn.

We have already suggested that, until recently, the literature attached to the famine, while making some references to spatial variation in population change, did not map it. As indicated, a few county-level maps exist. The thirty-two Irish counties offer a poor spatial resolution, however, and completely mask urban-rural variations in population change. This is a serious issue because the literature suggests that in some cities, such as Dublin, Belfast, Cork, and Galway, population increased significantly. If true, this would seriously compromise a county-based geographical interpretation, for a large increase in a town's or city's population would mask a decline in the population of rural areas. We can address these concerns by examining population and associated data at poor law union and barony level.[13] Figure 1 illustrates the limitation of county-based maps. This shows population density in 1841 at the county level and the same variable for poor law unions. It is clear that much local information is masked at the county level. The county map shows that only County Dublin fell into the highest density category of seventy-five or more people per hundred acres. At the other end of the spectrum, only County Donegal fell into the lowest category of fewer than twenty-five people per acre. At poor law union level a much more complex pattern emerges. Of greatest significance perhaps is that pre-famine population density was lowest in poor law unions in the far west. In part, this low figure might reflect the
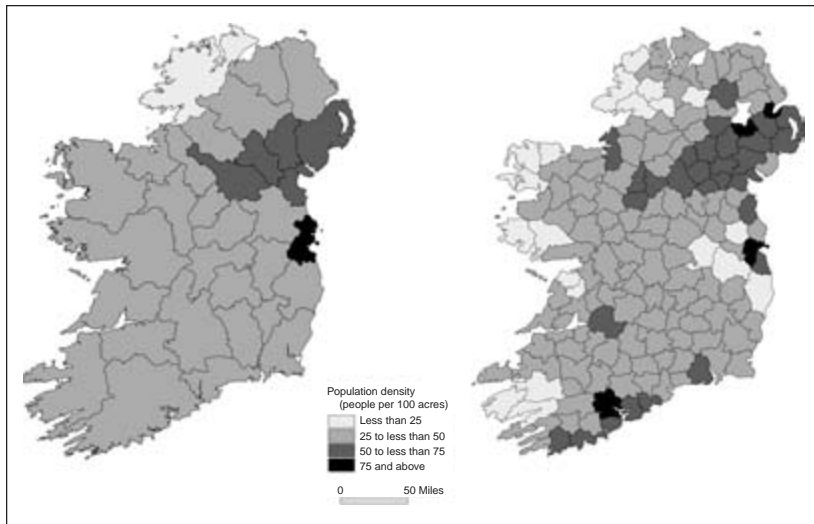
Figure 1. Population density at county level and poor law union level in 1841. Source: Database of Irish Historical Statistics.

very poor land in some areas, thus reducing the amount of terrain for agriculture and the support of the population. Inferior land was also found inland in the west but here, almost universally, population densities were higher falling between 25 and 50 people per 100 acres. Figure 2 shows for counties population change from 1841. Once again, the loss of detail is clear when compared to Figure 5 showing population change at poor law union level over the same period, with slightly differently derived variables. We discuss population change in more detail in the second part of this article where the data have been plotted onto a common geography.

The census did not measure poverty directly, but variables such as literacy and housing quality do provide indicators of its extent. Housing quality is as a proxy for wealth. Illiteracy identifies individuals who would find it harder to escape from the impoverished countryside into the towns and cities, or onto the boats sailing to Britain or North America.

A unique feature of the Irish census was the enumeration and classification of the housing stock into four categories. From 1841 a quality measure was applied to the inhabited housing, a practice that was maintained until 1911. Housing was graded on the basis of the quality of building materials, the number of rooms, and the presence of windows. A fourth or lowest grade of house was defined as made of mud with only one room. A third-class house was built of mud with between two and four rooms and windows. A second-class house had to have from five to nine rooms with windows, and a first-class dwelling was determined as being better than the preceding three classes.

Figure 3 shows the spatial distribution of fourth-class housing, "all mud cabins having only 1 room,"[14] for three censuses, those of 1841,

1841 to 1851

1841 to 1861

1841 to 1871

Pop. Loss (%)

20 and above
10 to less than 20
5 to less than 10
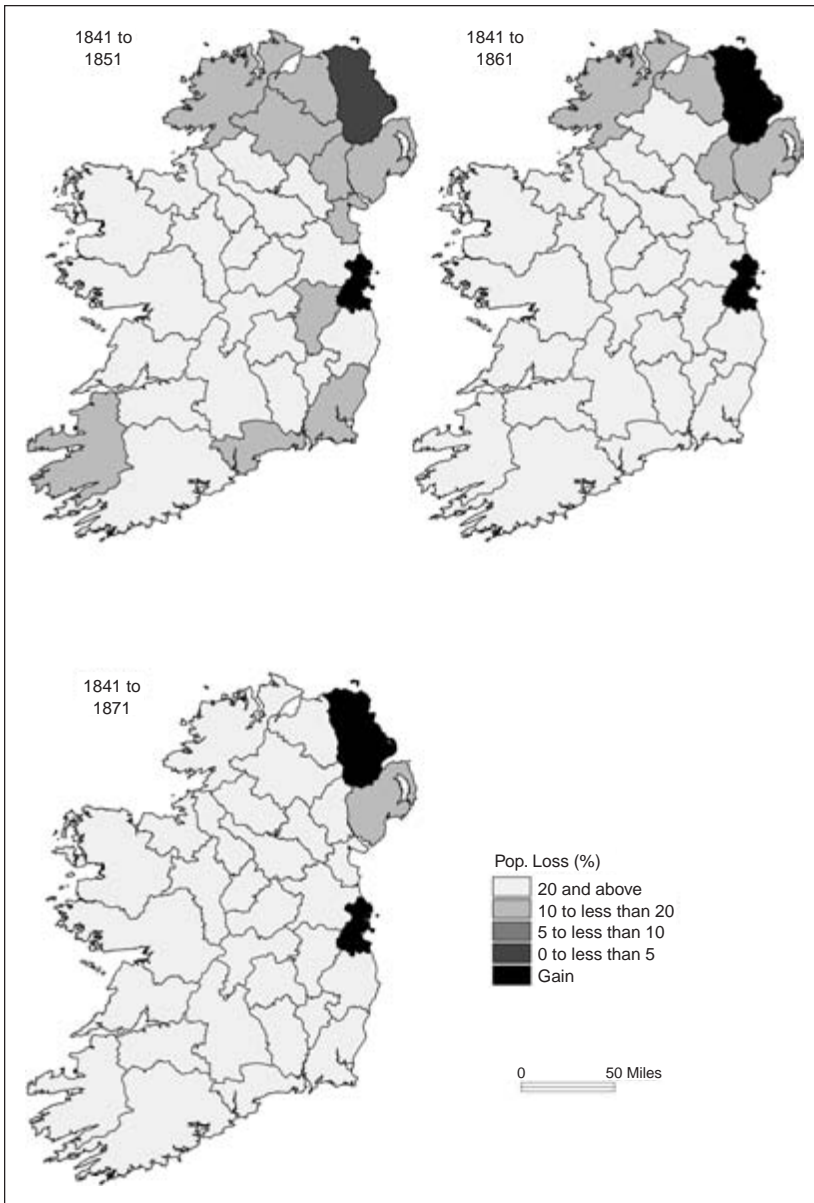0 to less than 5
Gain

0   50 Miles

Figure 2. Population change at county level, 1841-'71. Source: Database of Irish Historical Statistics.

1851, and 1861 based on baronies. Barony-level data were not published in the 1871 census. In 1841, more than 50 percent of the housing stock in much of the west was regarded as fourth class, reflecting the large percentage of housing falling into this category. In some baronies the per-
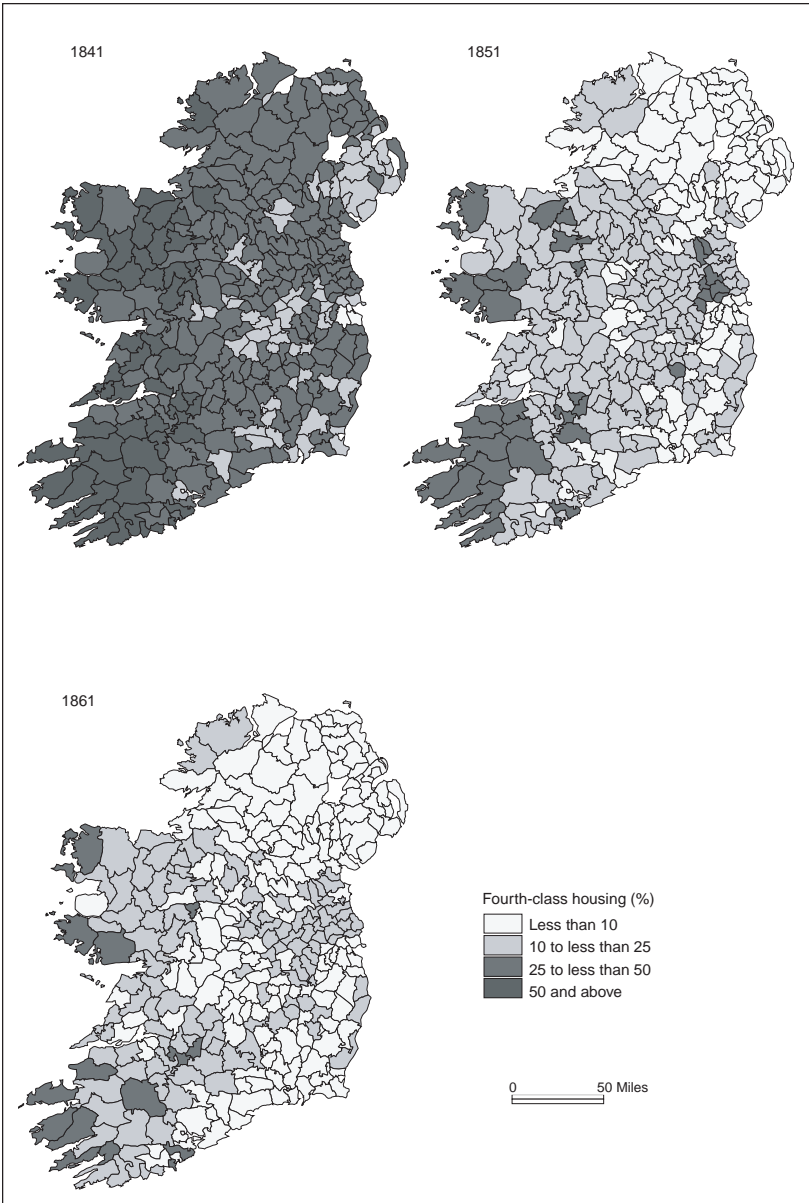
Figure 3. Fourth-class housing at barony level, 1841-61. Source: Database of Irish Historical Statistics.

centage was remarkably high. In all but one of the baronies in County Kerry more than 50 percent of the housing was fourth class, as were all baronies in west Cork. Many baronies in Counties Mayo and Galway also had more than 50 percent of housing in the poorest category. Through-

out Ireland as a whole, the vast majority of baronies in 1841 contained more than 25 percent fourth-class housing. The cities were the exceptions. In much of County Down, and parts of County Dublin and the baronies of Newcastle, Upper Cross, and Rathdown, less than 10 percent of housing was fourth class. It should be noted that in the cities the lack of fourth-class housing did not necessarily indicate a higher standard of accommodation. In Dublin in particular, where a high percentage of first-class houses were found, many families occupied tenements that the census defined as the best quality housing in terms of the size of the building. Multiple occupancy was not reflected in the housing quality categorizations.

In 1851, the census shows the distribution of fourth-class housing to be much the same. The major change was a significant decline in the percentage of the poorest housing. Unlike 1841, no baronies reported more than 50 percent fourth-class housing, although in the west, baronies with 25 to 49 percent of housing in this category were fairly common, frequently corresponding with the areas which in 1841 had more than 50 percent poor housing. In the east, more dramatic changes are evident. Throughout much of the Province of Ulster, and almost all of the counties which today comprise Northern Ireland, less than 10 percent of the housing was classified as fourth class. The same was true in baronies around and to the south of Dublin. In 1861, mapping of the census returns demonstrates that the decline in poor housing continued. For much of Ireland less than 10 percent of housing was then classified as fourth class. There continued to be a remarkable continuity in the spatial pattern of fourth-class accommodation. It remained most common in the west but, in percentage terms, at a far lower level than was the case in either 1851 or 1841.

In summary, immediately before the famine the majority of the Irish housing stock was fourth class or "all mud cabins." Post-famine, there was a marked decline by 1851. As is the case for many socioeconomic statistics in Ireland, the trends established during and immediately after the famine continued for decades. Thus we see a further fall in fourth-class housing in 1861, a decline that continued to the end of the century.

From 1841, the Irish census contains information on literacy. The census enumerated the population by both age and sex into three categories—those who could read and write, those who could read but not write, and those who were illiterate. It is important to realize that these literacy assessments were based on abilities in English. It is conceivable that those who were literate in Irish were recorded as being illiterate in English. Since Irish speakers were far more prevalent in the west, illiteracy levels here may be overstated. The data are further complicated as literacy was not tested in any way by the census; it relied on a statement by the head of household, although if the householder was illiterate, the form would have been completed by the enumerator to a degree acting as a control for erroneous claims of being literate. Whereas the prevalence of Irish speak-
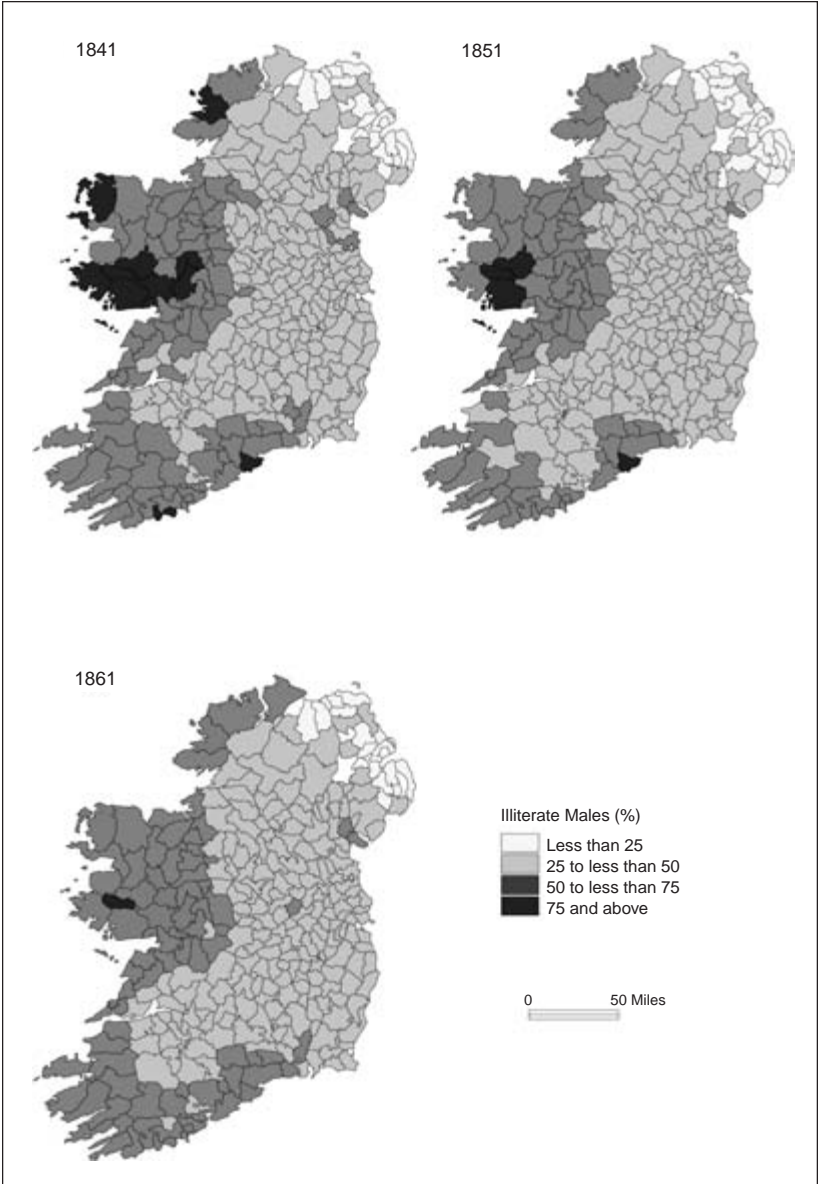
Figure 4. Male illiteracy at barony level, 1841-61. Source: Database of Irish Historical Statistics.

ers may be reflected in a reduction in English literacy levels, self-certification probably resulted in an overstatement of the percentage of the population who were literate. All statistics are, of course, problematic but in any analysis we should bear in mind that literacy levels may be generally overstated except where Irish speaking was strong.

Levels of illiteracy varied significantly between males and females. Typically, literacy levels amongst females were significantly below the level for males but the geographical patterns were much the same. Hence we restrict discussion here to the data for males. Figure 4 shows the percentage of illiterate males at barony level for 1841, 1851, and 1861. In 1841, only twelve baronies recorded male illiteracy above 75 percent, with a decline to four baronies in 1851 and just one, Ross in County Galway, in 1861. During this thirty-year period levels of literacy amongst enumerated males increased steadily with high illiterate levels increasingly found only in the west and subsequently the far west. Interesting very high levels of illiteracy were also found in County Waterford on the southern coast and along the isolated Carlingford peninsula in the barony of Dundalk Lower and the nearby barony of Farney.

It is clear from data relating to population, housing, and literacy that the period of 1841 to 1871 was one of significant changes in Irish society, and that these changes had a profound spatial dynamic. Change was greatest during the famine years of the late 1840s but continued well beyond the immediate crisis. The same is true for a range of other maps that can be derived from Irish census data. We are well served by the census in this period because it acted as a social survey rather than a simple count of population. We could therefore have included maps on the Irish language, on occupations, on changes in agriculture, or on diet. While the ranges of maps that can be generated are extensive, and more complex multivariate maps might be created, there is considerable scope to move beyond the simple creation of visualizations to a spatial analysis of the famine. These matters are considered in the next section of the article.

Spatio-temporal Analysis

A significant difficulty with using the census and other longitudinal sources to analyze change over time in quantitative terms is that data were published for incompatible spatial units and the boundaries of these units vary temporally. Even straightforward examinations of geographies by sight are made more complex by boundary change. To deal with this, we plotted the visualizations in the first part of this article onto a common set of administrative units, something not previously attempted at sub-county level in a systematic way.[15] Quantitative analysis of change over time is seriously compromised by the changing boundaries of the administrative units used to publish the data. The result of this in Ireland is the lack of any substantive spatial analysis for units smaller than counties. As county boundaries did not change significantly, work at this level is possible but, as discussed above, findings at this coarse granularity are inherently limited and flawed.

In mid-nineteenth-century Ireland most demographic data were published at barony level, of which there were around 320 depending on

date, while agricultural data, also available from the census were pub-
lished for around 160 poor law unions whose boundaries rarely coincided
with barony boundaries. This has been a major limitation on our ability
to perform quantitative statistical analyses with these data. Using GIS
and a spatial statistical technique known as "areal interpolation" we can
work around this problem. With areal interpolation it is possible to take
data published using one set of units and estimate its values for another
set. This allows us to interpolate all of our data onto a single set of admin-
istrative units, such as 1851 poor law unions, to allow direct comparisons.
At the core of this is a GIS "overlay" operation that calculates the degree
of overlap between every source unit and every target. Once we have this,
the easiest way of estimating the values for the target district is to assume
that the original data are evenly distributed across the source units and
allocate data accordingly.[16] Obviously this assumption of even population
distribution is unrealistic but strategies can be developed to overcome the
problem.[17] In this article we use a technique based on the EM-algorithm[18]
to interpolate a range of data from the censuses between 1841 and 1871
onto 1851 poor law unions to allow us to examine change over time
through spatial analysis.

Our concern in this work is what factors influenced population loss
in Ireland in the period from 1841 to 1871 and how this varied over space
and time. To answer this, we measure population change as a normalized
percentage but, as almost all population change was population loss we
subtract the change from zero to give a measure of loss rather than the
more conventional population gain. This gives a value between 100.0,
complete depopulation of a previously populated area, and –100.0, popu-
lation moving into a previously unpopulated area.[19] This differs from a
conventional rate in that it is a symmetrical measure, thus a loss of 20
percent is the direct opposite of increase of 20 percent. With a conven-
tional rate, where population change is only divided by the start popula-
tion, this is not the case.[20] We find broadly similar population distribu-
tions to those noted earlier in the article although here we concentrate on
change between each census rather than over several decades.

Figure 5 shows population loss in each of the decades from 1841 to
1871 while Table 1 shows summary statistics for these figures. In both
cases, the fact that we are using standardized areas means that we can
make direct comparisons over time. Clearly there was a pattern of spec-
tacular but declining population loss. In the 1840s the median popula-
tion loss was 12.9 percent. Only five unions gained population, three
around Dublin, and Belfast and Cork. Population loss was most limited
in the north and east of the country with high rates being found in the
south, especially in the vicinity of Skibbereen, and in the midlands and
the west. In the 1850s, although decline had slowed, it was still high with
a median rate of 7.45 percent. There was a clear split to the pattern with
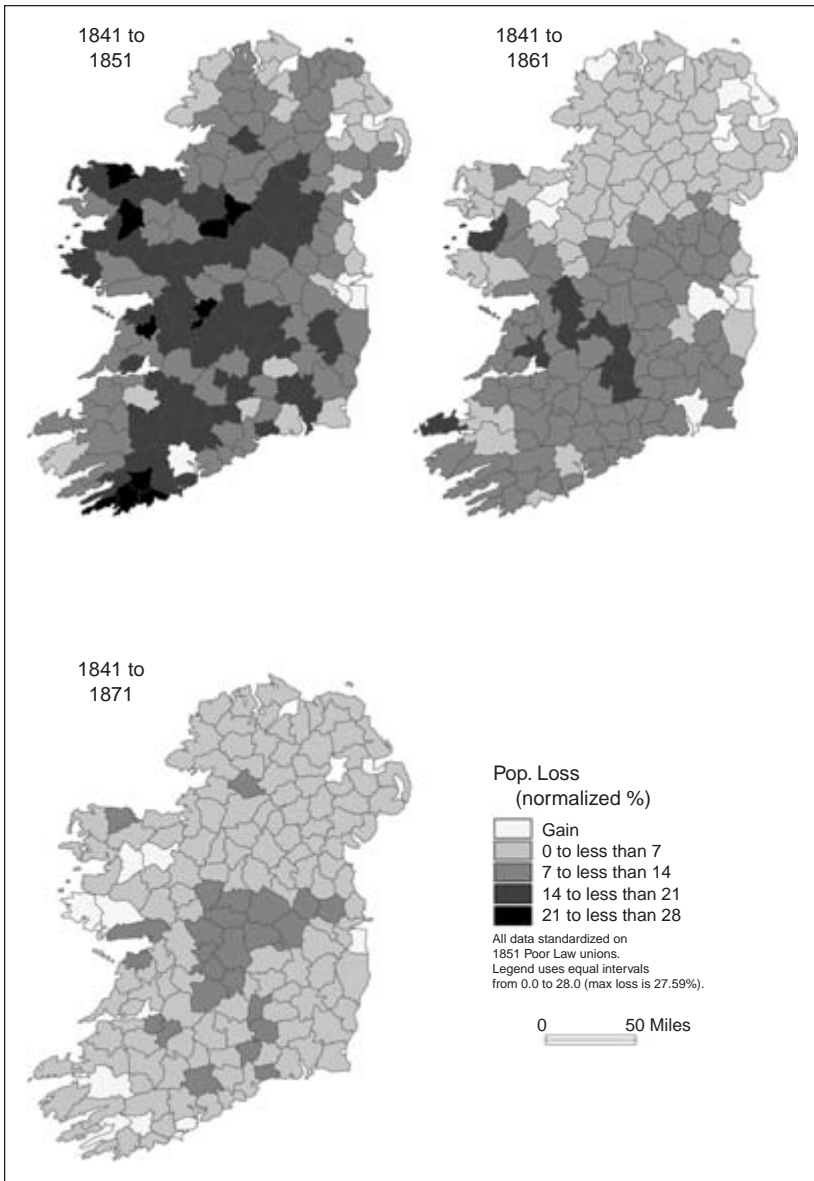areas in and around Ulster having the lower rates. The highest rates were

Figure 5. Population change in Ireland at poor law union level, 1841-71.

not found in the far south or the west but were concentrated in a line that ran northwest from County Waterford to County Galway. Although population loss had slowed it was still pervasive with only 11 of the 163 unions actually gaining population. In the 1860s population loss again slowed but remained persistent. The median rate had dropped to 4.8 percent but

Table 1. Five figure summaries of population loss and number of unions gaining population for poor law unions in Ireland, 1841-71.

Five figure summaries are the minimum, lower quartile, median, upper quartile, and maximum. The "Gaining pop." row refers to the number of unions that gained population in the decade (out of a total of 163).

	1841-51	1851-61	1861-71
Min.	-11.00	-6.95	-16.77
L.Q.	9.10	3.55	2.72
Median	12.88	7.45	4.82
U.Q.	17.43	11.24	6.41
Max.	27.59	17.00	10.75
Gaining pop.	5	11	10

the highest rates were now located consistently in the midlands, particularly Counties Offaly and Tipperary. Ten unions gained population in the 1860s but their pattern was very different from the previous decade but interestingly while Belfast and Rathdown, just south of Dublin, were two of them. Of the remaining eight, four were in the south and another four in the west. If we look at the ten unions that lost the most population in each of these three decades only two, Borrisokane and Roscrea, both in the north County Tipperary area, appear twice—in the 1840s and then the 1860s. The pattern of gain (or very limited loss) was a little more consistent with Belfast and Rathdown appearing in the top ten in all three decades while Ballymena, Dublin South, and Swineford appeared twice, Ballymena and Dublin South in the 1840s and '50s and Swineford in the 1850s and '60s. Belfast, Ballymena, Rathdown, and Dublin South are all predictably in or near major cities, however, Swineford is in County Mayo, a county commonly perceived to have been among the worst affected by depopulation.

Having established the geographical pattern of population decline, the next stage is to explore how this relates to variables such as fourth class housing and illiteracy, indicators of poverty discussed earlier. Figure 6 shows the changing patterns of literacy and of housing type over the thirty-year period through histograms. The graphs show clearly that over the period the majority of population loss was concentrated amongst the illiterate and that the proportion of housing that was fourth class declined massively in the 1840s and continued to decline in the 1850s. Unfortunately, housing classes were not published at barony level in the 1871 census so geographical analysis of these data into the 1860s is not possible. Data on literacy was still available in 1871 and this shows that in the 1860s the number of people who were illiterate remained constant while
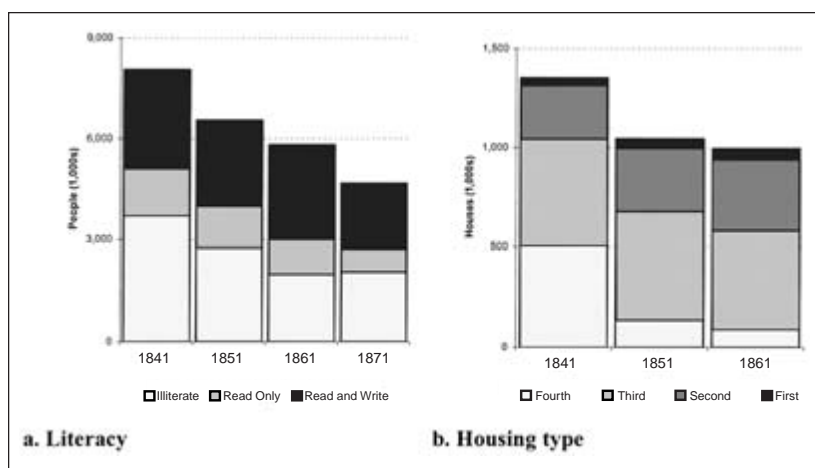
Figure 6. Population decline by: a. literacy, and b. housing type. Source: Database of Irish Historical Statistics.

the number of literates and those who could only read declined. If we assume that, in general, lower standards of literacy were found amongst the poorly housed then these data imply that during and after the famine the poor, who lived in fourth-class houses and were illiterate, were the hardest hit, while the rich, living in first-class housing and who were fully literate, were barely affected. By the 1860s, however, it seems as if population loss may have moved through the social scale into the more affluent sectors of society.

If this were the case, it would be expected that areas with high levels of illiteracy and fourth-class housing at the start of each decade would be the ones that suffered the highest levels of population loss over the ensuing decade. Comparing map patterns would be one way to investigate this along the lines of some of the maps in Section 1. However, we suggest there are better approaches that are not susceptible to variations in perception of the individual reader. One option is to use a statistical technique such as regression. A major problem with this is that most statistical methods, including standard regression, are "whole map," in other words, crucially they assume that a relationship remains constant across the whole study area. This is unhelpful and effectively denies that relationships may vary over space. While using regression in this article we also make use of "local" analysis techniques where the results are able to vary over space thus stressing diversity rather than similarity.[21] Specifically, we use geographically weighted regression (GWR) that allows us to explore the relationships between multiple variables both globally and locally.[22] Conventional (or global) regression tests whether there is a relationship between one variable, termed the dependent variable, and one or more other variables thought to influence it, termed the independent variables. It is able

to state whether or not a statistically significant relationship exists using *t*-values, and to quantify the steepness of the relationship using the regression coefficients. GWR enhances this by permitting the relationships to vary through the use of a distance decay model that allows the parameters to fluctuate over space. In this way, different coefficients and *t*-values can be calculated for every location on the study area.

A regression analysis was carried out for each of the three decades from the 1840s to the 1860s. In each case, population change over the decade was the dependent variable being predicted by the percentage of the population who were illiterate and the percentage of the population who lived in fourth-class housing at the start of the decade. As urban centers also seem to influence population loss, two measures of these are also included as dummy variables: "large towns" flags whether a union contained a town that was enumerated in the 1841 census as having a population of over 50,000.[23] This gives us six unions: Belfast, Dublin North, Dublin South, Cork, Limerick, and Waterford. Small towns include all unions that contained a town with over 5,000 but less that 50,000 in 1841. There were thirty-two of these.

Full results from the global regression are presented in statistical Appendix A. The analysis shows that in the 1840s, a union with an average amount of fourth-class housing and illiteracy lost 13.53 percent of its population but that this was reduced by 2.29 percentage points and 12.99 percentage points if the union contained a small or a large town respectively. The coefficient for illiteracy shows its population loss would increase by 0.17 percentage points for every percentage point above average illiteracy or decrease by the same below average illiteracy. It also shows that once towns and illiteracy are taken into account, fourth-class housing does not have a statistically significant impact on population loss. The r^2 value of 38.0 percent shows the amount of the total variation in population loss that can be predicted from the model. This is a very high value with data that are this crude. This therefore suggests that population loss in the famine decade was strongly related to rural poverty. The negative values for urban areas suggest either that towns were less affected by the famine, or that out-migration and death from towns was more than compensated for by in-migration from rural areas.

The patterns for the 1850s and 1860s are less convincing but remain interesting. In the 1850s, illiteracy remained statistically significant but at a lower level than in the 1840s while towns were no longer significant suggesting that population loss was unaffected by whether an area was rural or urban, although the coefficient for large towns remained high. By the 1860s, large towns were having a significant impact on reducing decline but none of the other variables were statistically significant.

Using GWR demonstrates that the relationship described above derived from straightforward regression, is highly simplistic. Figure 7 shows the GWR results for the same analysis although the coefficients for small

Figure 7. GWR results for population change with demographic variables, 1840s to 1860s.
The independent variables are small and large towns, fourth-class housing, and illiteracy. The intercept term and the coefficients for fourth-class housing and illiteracy for the 1840s, '50s, and '60s are shown. Class intervals on the intercept maps use equal intervals of four percentage points from 0.0 to 24.0 as the maximum value is 22.02. Class intervals on the other maps use equal intervals of 0.2 spreading out from a class of –0.09 to 0.09 which shows little relationship.

and large towns are not shown as these did not show major spatial variations. The pattern that we might expect, of a positive relationship between population loss and fourth-class housing and illiteracy, was only found to the east of the country although here fairly consistently for both variables (other than illiteracy in the 1840s). The opposite seems to have happened in the west. Population loss rose in areas of relatively low fourth-class housing and illiteracy. Again, this pattern appears fairly consistently over the three decades although its emphasis moves further south over time. Illiteracy in the 1840s, the only exception to this pattern, found to be strongly positive in the global regression, was only positive in the north and to a lesser degree the extreme south. For much of the rest of the country it showed no clear relationship.

Figure 8. GWR results for three variables from the population change with demographic and agricultural variables, 1850s and 1860s. For reasons of space only, the most interesting variables—large farms, pigs per capita, and potatoes per capita—are shown. The full list of independent variables is small and large towns, percentage of landholdings that are over 200 acres (large farms), cattle per capita, sheep per capita, pigs per capita, acres under potatoes per capita, fourth-class housing, and illiteracy. Class intervals use equal intervals of 0.2, spreading out from a class of –0.09 to 0.09, which shows little relationship.

The intercept terms also show interesting variations. These map the average rates of population loss predicted in an area with average amounts of fourth-class housing and illiteracy and no towns. In 1841 there was a clear band of high rates stretching from Counties Waterford to Mayo, an area that almost mirrored the area of highest population loss in the following decade. In the 1850s and 1860s the pattern changed to have high values concentrated around Limerick although in the 1860s this was not apparent from Figure 4 due to the low values compared to earlier years. In all three decades the lowest intercepts were found in the north of the country.

Clearly we need to develop a more sophisticated model based on additional variables. Unfortunately, for the 1840s there is a lack of other

possible explanatory values to add to the model but for 1851 and 1861 a large amount of agricultural information exists at poor law union level. We have interpolated this onto 1851 poor law unions to allow it to be compared with the demographic information. Specifically the following variables were used: the percentage of landholdings that were over 200 acres representing large farms; the numbers of cattle, sheep, and pigs, respectively, per head of population in the union; and the acreage of each union under cultivation with potatoes also per head of population.

The global regression results for this analysis are presented in full in statistical Appendix B. In summary, the coefficients for both large towns and illiteracy became statistically significant for both decades; in the 1850s, farm size and head of cattle per capita do not appear to have been significant but sheep and pigs were both positively related to population loss and potatoes were negatively significant. In the 1860s, the only changes were that both pigs and potatoes ceased to be significant. This suggests that in the 1850s, particularly, livestock farming was pushing people off the land or taking advantage of the availability of land to expand, while potato farming was encouraging them to stay.

Figure 8 shows the GWR results for some of these variables, for reasons of space the full set cannot be shown. We present the most interesting variables here which were large farms, pigs per capita, and potatoes per capita. The patterns found complement the results revealed in Figure 7 that showed illiteracy and, to a lesser extent, fourth-class housing being positively related to population loss (as might be expected) but only in the east. In the west and south there was often a negative relationship that seemed counter-intuitive. The inclusion of agricultural variables suggests that in the 1850s large-scale agriculture was actually a prime driving force behind much of Ireland's population loss particularly north of Munster. This was particularly true of pig farming and sheep farming that were both strongly positively related to population loss. If an additional set of data values are added to the model that combine the values each of these variables with the percentage of large farms, the two seem to be acting together to increase population loss. The presence of potatoes and, to a lesser extent, cattle is negatively related to population loss.

A tentative explanation for this might be that in this period the expansion of large agricultural estates over much of Ireland drove many people from these parts. In the east the poor in particular were affected while in other areas all of the population were involved with the slightly better off being perhaps more able to move in response to this expansion. This explanation is, however, currently speculative as it is based on limited models of crude data and is guilty of ecological fallacy where conclusions about the behavior of individuals is derived from patterns in aggregate data.[24]

The pattern changed again in the 1860s when the role of agriculture in explaining population loss seems to become far less important. Pigs in

particular fell from a global coefficient of 0.283 with a *t*-value of 7.18 and GWR significance over most of the country to a global coefficient of 0.008 and a (not statistically significant) *t*-value of 0.38 with not a single GWR result that is either significant or has a coefficient of over 0.1. Potatoes showed a similar if slightly less dramatic pattern. Large farms still were related to population loss in much of the center of the country but now seemed to be reducing loss in the north and south. Speculatively, using the information on literacy in Figure 6, this may be because population loss in the 1860s for much of the country had moved up the social scale and was no longer concentrated in the poor.

It cannot be overstated that studies of this sort are fundamentally driven by the data available and that this will inevitably affect the results. This is why we are able to make comments on the impact of agriculture after but not during the famine as accurate data are not available for that period. Interpretation of some variables can be complex. For example, the presence of livestock may be positive as it provides alternative foodstuffs and income for the poor, or may be negative as it is being farmed for the export market and is thus removing fertile land from the local population. It is tempting to stress areas where the models work well and ignore areas where models do not work well. One interesting feature of GWR is that it is able to quantify the degree to which the model works either through local r^2 values, that give the amount of variation in the dependent variable predicted by the independent variables and the coefficients, or through the use of local *t*-values that measure whether the result in one place can be considered statistically significant.[25]

Figure 9 explores the degree to which the data available "explained" the pattern of population loss in the 1850s and '60s where both the agricultural data and the demographic data are used. On the left, local r^2 values are mapped, while on the right, the number of statistically significant *t*-values is shown out of a possible nine if there was a significant result for all variables. A clear spatial pattern emerges in the 1850s, specifically that the available data do a poor job of "explaining" population loss in the south of the country where frequently no variables or only the urban variables were statistically significant. This suggests that some additional factor or factors were important in explaining population loss through the 1850s and that the crude agricultural variables available do little to help our understanding of population loss in this region. This is particularly important as many case studies of Ireland around the famine period have focused on southern areas such as Skibbereen. Our work suggests that assuming that these studies have relevance to the whole of Ireland is flawed as different processes seem to be occurring in the south than elsewhere. The pattern is less clear cut in the 1860s, but it appears that the south is better explained in this decade and that weaknesses are more prevalent in the centre of the country.
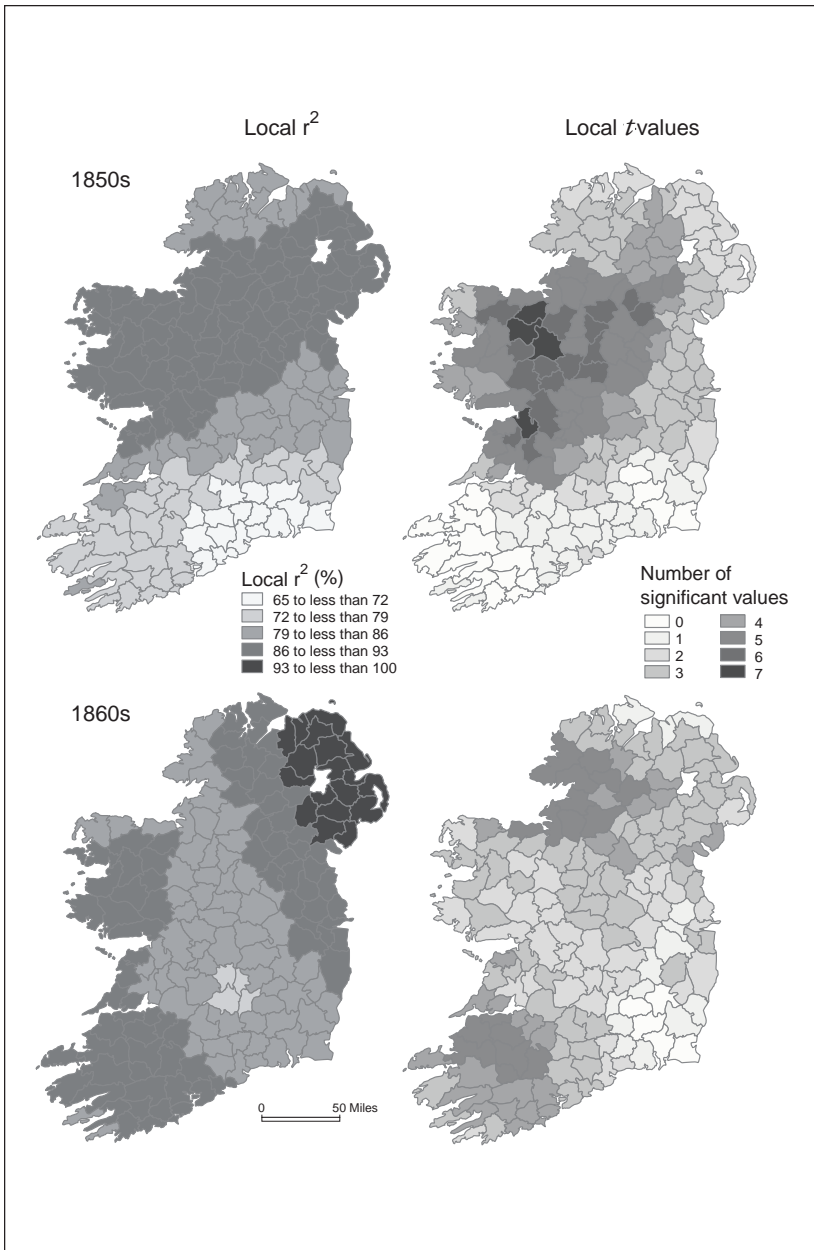
Figure 9. Explanatory power of GWR models for 1850s and 1860s. The maps on the left show local r² values as calculated in GWR using equal interval-class intervals of 7 percentage points starting at 65.0 percent (the minimum value is 66.7 percent). The maps on the right show the number of independent variables that are statistically significant at the 5 percent level out of a possible nine: small towns, large towns, percentage of landholdings over 200 acres, cattle per capita, pigs per capita, sheep per capita, potatoes per capita, percentage of housing that is fourth class, and percentage of population that is illiterate.

Conclusions

This article reflects work in progress, but work that has already pushed our understanding of the famine beyond its current boundaries. We have shown that at a local level the famine and its aftermath had a significant and dramatic geography. Using straightforward visualization over time with common boundaries, we find geographies that challenge the existing literature, which has been limited by problems of comparing time-series information for differing boundaries. In poor law unions containing larger towns population, decline was limited and population densities tended to be lower in the far west. The impact of the famine in terms of population loss was not focused only in the west. In fact, many baronies in that region suffered less than those in the midlands. We find a radical change in the quality of housing in which the population were living. In 1841, many areas in the west had more than 50 percent of housing was fourth class. By 1861, such housing was rare. In our analysis, most notably using GWR, we show that the interplay of social and economic conditions led to variations in the severity of population loss at sub-county level. In the east we find a strong relationship between illiteracy, poor housing, and population decline. In the west the situation is reversed, with areas with higher levels of literacy and better housing losing population more rapidly. This is an important new finding, and there are others that will lead to a reinterpretation of elements of the development and impact of the famine. As we move to create a full historical GIS for Ireland, linking and relating disparate qualitative and quantitative sources in space and time, the research opportunities will multiply.[26]

Acknowledgements

Notes

1.   See M.M. Postan and H.J. Habakkuk, *The Cambridge Economic History of Europe*, Vol.6:1, *The Industrial Revolutions and After: Incomes, Population and Technological Change* (Cambridge: Cambridge University Press, 1966): 61.

2.   The Database of Irish Historical Statistics was developed at the Queen's University of Belfast with funding from the Economic and Social Research Council and Queen's University. The datasets are deposited with AHDS History at the University of Essex.

3.   Joel Mokyr, *Why Ireland Starved: A Quantitative and Analytical History of the Irish Economy, 1800-1850* (London: Allen & Unwin, 1983).

4. Seán Duffy, ed., *The Macmillan Atlas of Irish History* (New York: Macmillan, 1997): 90-93.

5. Líam Kennedy, Paul S. Ell, E.M. Crawford, and L.A. Clarkson, *Mapping the Great Irish Famine: A Survey of the Famine Decades* (Dublin: Four Courts Press, 1999). Our article builds on adjusted datasets, new map coverages, and comments from scholars in response to *Mapping the Great Irish Famine* to define far more clearly key geographies and base analysis on a firmer footing.

6. F.H.A. Aalan, Kevin Whelan, and Matthew Stout, eds., *Atlas of the Irish Rural Landscape* (Toronto: University of Toronto Press, 1997): 85-9.

7. T.W. Freeman, *Pre-Famine Ireland: A Study in Historical Geography* (Manchester: Manchester University Press, 1957): 316-17.

8. T.W. Freeman, *Ireland: A General and Regional Geography*, 2nd ed., rev. (London: Methuen, 1960): 118-34.

9. Aalan, et al., *Irish Rural Landscape*, 86.

10. For a more detailed discussion of the advantages and development of an Irish historical GIS, see "A Historical GIS for Ireland" elsewhere in this volume.

11. Joel Mokyr and Cormac Ó Gráda, "New Developments in Irish Population History, 1700-1850," *Economic History Review* 24, 2nd ser. (1984): 475.

12. The 1821 Census of Ireland, although the first fully completed Irish census, was remarkably comprehensive and accurate. Hence this figure can be relied upon. See David A. Gatley and Paul S. Ell, *Counting Heads: An Introduction to the Census, Poor Law Data and Vital Registration* (Bishop's Stortford: Statistics for Education, 2000) for more information.

13. Baronies are ancient units. Their precise boundaries were determined through the Ordnance Survey's mapping of Ireland during the first half of the nineteenth century, and through the collection of statistics at barony level in the 1821 census. Baronies nest within county boundaries. Their number changes over time. Immediately pre-famine there were 313. They became obsolete after the 1891 census. Poor law unions were more recent units concerned, as the name suggests, with the administration and distribution of relief for the poor. They were created just prior to the famine, and over the famine itself there were 131 unions. Poor law unions do not nest within other administrative boundaries—they cross both county and parish boundaries. The agricultural censuses used poor law unions rather than baronies meaning that traditionally it was very difficult to compare to the population censuses.

14. *Report of the Commissioners Appointed to Take the Census of Ireland for the Year 1841*, British Parliamentary Papers 24 (1843): xiv.

15. Using manual techniques, it is possible to plot data onto a common geography for a small number of census years. This approach was adopted in our early work. In Figures 3 and 4, post-famine data is plotted to a set of barony boundaries for 1841. We were able to do this because boundary changes in 1851 and 1861 were limited, usually involving the simple division of one barony into two. These data can be summed and plotted onto 1841 boundaries. While this approach is suitable for simple visualization over a short period of time, it cannot take account of boundary changes that do not result in the creation of a new spatial unit, and it cannot be applied over several censuses where division and subdivision of spatial units is much more complex. The more complex and precise redistricting techniques referred to later in this article are essential for more complex longitudinal analysis.

16. Thus, if 80 percent of a source unit intersects with target unit A and the remaining 20 percent with target unit B then 80 percent of its population should be allocated to A and 20 percent to B.

17. Ian N. Gregory and Paul S. Ell, "Breaking the Boundaries: Integrating 200 Years of the Census using GIS," *Journal of the Royal Statistical Society*, Series A (in press).

18. Ian N. Gregory, "The Accuracy of Areal Interpolation Techniques: Standardising 19th and 20th Century Census Data to Allow Long-Term Comparisons," *Computers Environment and Urban Systems* 26 (2002): 293-314.

19. More formally, population loss is calculated as:

Loss = (0 – [(end_pop – start_pop) / (end_pop + start_pop)]) _ 100.

20. Iain Bracken and David Martin, "Linkage of 1981 and 1991 UK Censuses using Surface Modelling Concepts," *Environment and Planning A* 27 (1995): 379-90.

21. A. Stewart Fotheringham, "Trends in Quantitative Methods I: Stressing the Local," *Progress in Human Geography* 21 (1997): 88-96.

22. A. Stewart Fotheringham, Chris Brunsdon, and Martin Charlton, *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships* (Chichester: Wiley, 2002).

23. Dummy variables have a value of either one, to indicate that a feature is present, or zero to indicate that it is absent.
24. Neil Wrigley, "Revisiting the Modifiable Areal Unit Problem and the Ecological Fallacy," in Andrew D. Cliff, Peter R. Gould, Anthony G. Hoare, and Nigel J. Thrift, eds., *Diffusing Geography, Essays for Peter Haggett* (Oxford: Blackwell, 1995): 49-71.
25. Note that local *t*-values must be used with caution due to problems with multiple significance testing.
26. Work with the Great Britain Historical GIS has taken place recently to make it more accessible and link qualitative information to the statistical data that are more generally associated with GIS. Descriptions of places at various points in time, historical and modern maps and travellers' tales are all linked to the underlying geo-statistical resource (see www.visionofbritain.org.uk). At present this work has been aimed at making information available to the public. We are developing the GIS to make it a resource for scholars.

Statistical Appendix

A. Global regression coefficients for population loss in Ireland.

	1840s	1850s	1860s
r^2	38.0 %	10.1 %	15.0 %
Intercept	**13.53**	**7.00**	**4.66**
Small towns	**-2.29**	1.51	-0.33
Large towns	**-12.99**	-3.06	**-6.31**
Fourth-class housing	-0.01	-0.04	-0.02
Illiteracy	**0.17**	**0.10**	-0.04

In each case, the dependent variable is population loss as a normalized percentage while the independent variables are small towns, large towns (both as dummy variables), percentage of housing stock that is fourth class, and percentage of the population that is illiterate. All values have been offset so that the intercept measures the expected amount of population loss in a union with no small or large towns and with an average proportion of fourth-class housing and illiteracy. Numbers in bold are statistically significant at the 5 percent level.

B. Global regression coefficients for population loss in Ireland in the 1850s and '60s.

	1850s	1860s
r^2	40.7	24.0
Intercept	**7.36**	**4.50**
Small towns	- .054	.182
Large towns	**- 4.59**	**- 5.02**
Landholdings 200+	.167	- .061
Cattle	- .033	.012
Sheep	**.033**	**.018**
Pigs	**.283**	.008
Potatoes	- .321	- .011
Fourth-class housing	- .014	- .017
Illiteracy	**.0719**	**- .060**

The following independent variables are used: small towns (dummy), large town (dummy), percentage of landholdings that are over 200 acres, head of cattle, sheep and pigs (respectively) per capita, area of land cultivated by potatoes per capita, percentage of housing stock that is fourth class, and percentage of the population that is illiterate. Coefficients shown in bold are statistically significant at the 5 percent level.