RAILWAYS AND ENVIRONMENT IN GREAT BRITAIN AND FRANCE: AN APPLICATION OF GIS AND DIGITAL ELEVATION MODELING

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Abstract

This paper uses GIS and digital elevation modeling to study the relationship between railways, topography, and economic development in France and Great Britain during the long nineteenth century. From the 1860s, maturing technology enabled railways in England and Wales to navigate rugged terrain and reach further into the countryside, passing over the landscape with less environmental degradation than before and bringing economic benefits to many remote communities in the short run. In France, regional disparities in rail service and its benefits—a favored north and under-developed south—were accentuated by the mountainous topography of much of the Midi until a state program of railway expansion, launched in the 1880s, made itself felt in the 1890s and after.

Keywords: rail transportation, digital elevation modeling, economic development, France, Great Britain

> The new railways "slashed like a knife though the delicate tissues of a settled rural civilization. They left their scars on park and copse; they raised high walls of earth across the meadows. . . .Your railroad mounds, vaster than the walls of Babylon, they brutally amputated every hill on their way."[1] (John Ruskin, ca 1870)

In Ruskin's day the relentless pace of railway building stoked his ire at the vandalism he saw laying waste to the treasured English countryside. The London to Birmingham railway line was one notable example. Completed in 1837-8 by Robert Stephenson, it carved its way through some 100 miles of valleys and hills, pushing aside untold tons of earth here, tunneling there, and raising huge embankments elsewhere. These were the scars on park and copse that Ruskin so bemoaned.

Not all of his contemporaries agreed. Indeed, many more hailed Stephenson's achievement as testimony to British engineering genius—truly "the cutting edge" of railway engineering. Progress, after all, advanced through human control over nature. Hence the flattening of the landscape to make way for steam-powered trains was nothing less than a grand step forward in the transportation revolution that was underway. Three cheers for the marvelous new line!

This paper attempts to make sense of both points of view in a study using GIS and digital elevation modeling to investigate the relationship between new technology and the environment, railways and topography. With geo-temporal evidence for England and Wales, it shows that the leveling "of every hill" along the London to Birmingham line, epitomizing the heroic age of railway building in the of the 1830s to the 1850s, was superseded by new methods of rail construction in the 1860s and 1870s. Instead of leveling hill and copse, new lines negotiated the landscape over which they passed with a lighter touch than before. Thanks to more powerful locomotives, steel rails, and other improvements, trains steamed over and through the valleys, climbing grades unachievable in the heroic age of rail and thus reaching further into remote and topographically challenging areas of the country. Turning to France, I use digital elevation modeling in another way to argue that the uneven distribution of rail transport there was at least partly the result of the upland topography of the French south. The scarce presence of railways the southern uplands put those regions at further economic disadvantage vis-à-vis the north and northeast where a growing rail network continued to expand.

1. England's London to Birmingham Line: A Big Dig of Heroic Proportions

One of the renowned marvels of the early railway age was the London and Birmingham line, completed by Robert Stephenson in 1838. Given the locomotives of the day, Stephenson kept the *average* grade of the line at 1 to 330, that is, a one foot rise required 330 linear feet of track to complete. To maintain such a slight grade over some 100 miles of valleys, hills, and gorges entailed major excavations at four points along the route. At Tring, there was a huge cutting, 2½ miles long and up to 40 feet deep; at Wolverhampton, an equally imposing embankment led to a second cutting at Blisworth that ran 1½ miles and up to 60 feet deep. Finally at Kilsby a long tunnel served to flatten out the roadway from Crick to Rugby.[2] (See Map 1 and Images 1 and 2.)

Another way to appreciate the topographical challenges that Stephenson faced and met is to study the graph in Figure 1 showing both the general rising of the landscape between greater London and Birmingham and the prominent peaks at four or five places along the way.

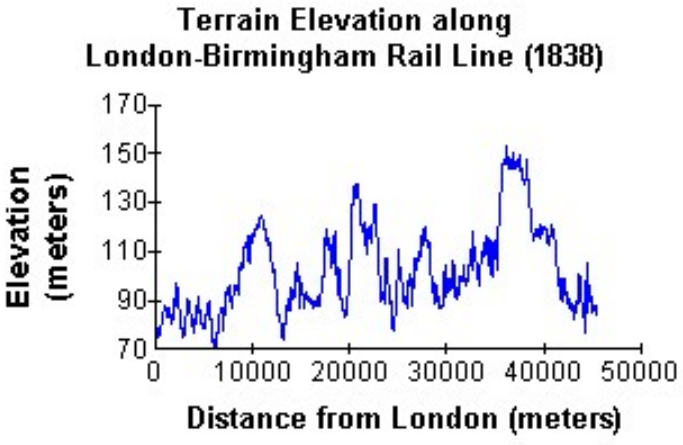
Map 1. London & Birmingham Line on a digital terrain model of the topography

2. Wales: Conquering the Hills: Rail Construction ca. 1860-1880

Image 1. Tring Cutting

Image 2. Wolverhamton Embankment

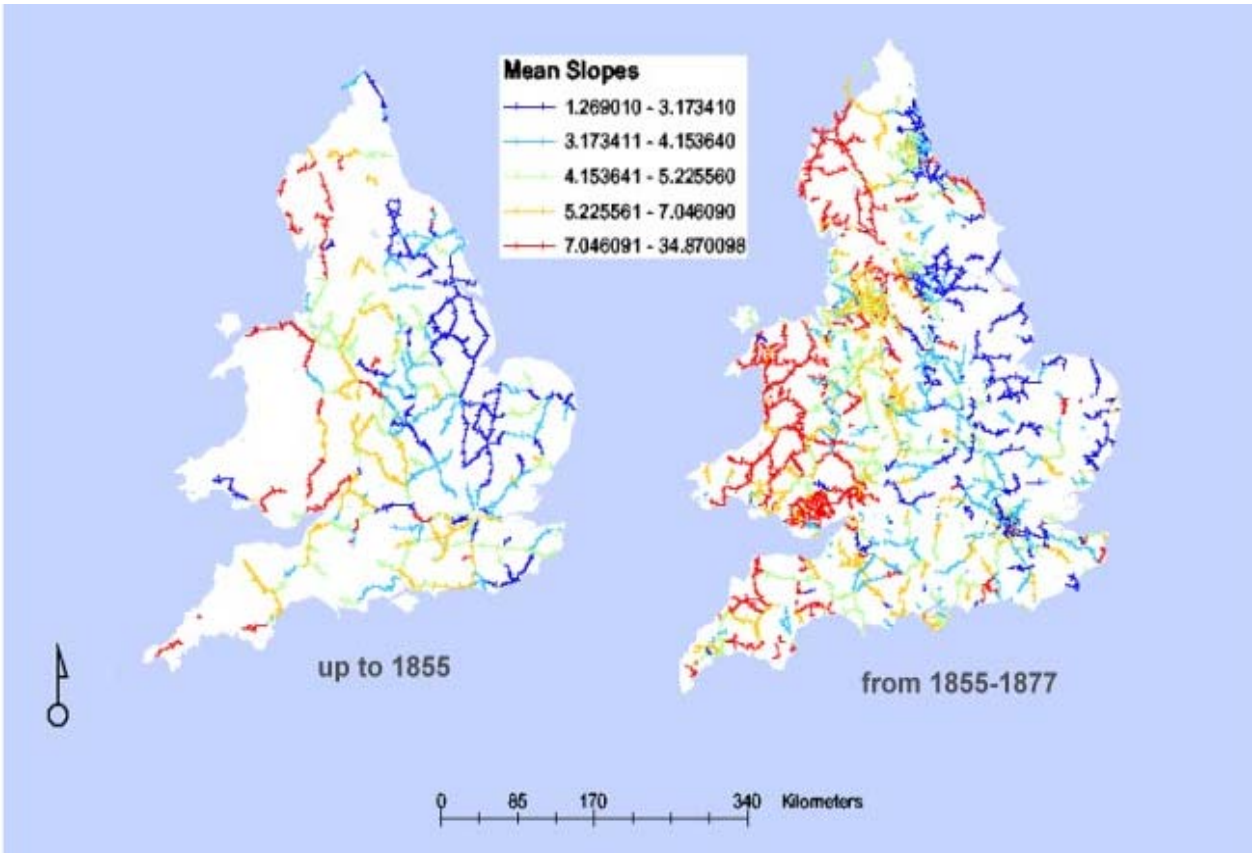
Figure 1.



In the 1860s, the increasing power of locomotives and other technological improvements enabled rail companies to break entirely new ground, pushing farther into the countryside and upward over the hills and mountains into remote areas, bringing new resources and populations into the expanding rail network and national markets. To capture these significant changes the digital elevation model again proves very useful. In the GIS I built for this purpose, two sets of lines were draped over the digital terrain and compared: one set comprised the lines in existence up to 1855; the second set, the new lines built from 1855 to 1876. Because the draped lines conform to the elevation of the underlying topography, we can then measure the

slope of individual line segments and then calculate the average slope for a given section of railway. Map 2 displays the mean slopes for the two periods.

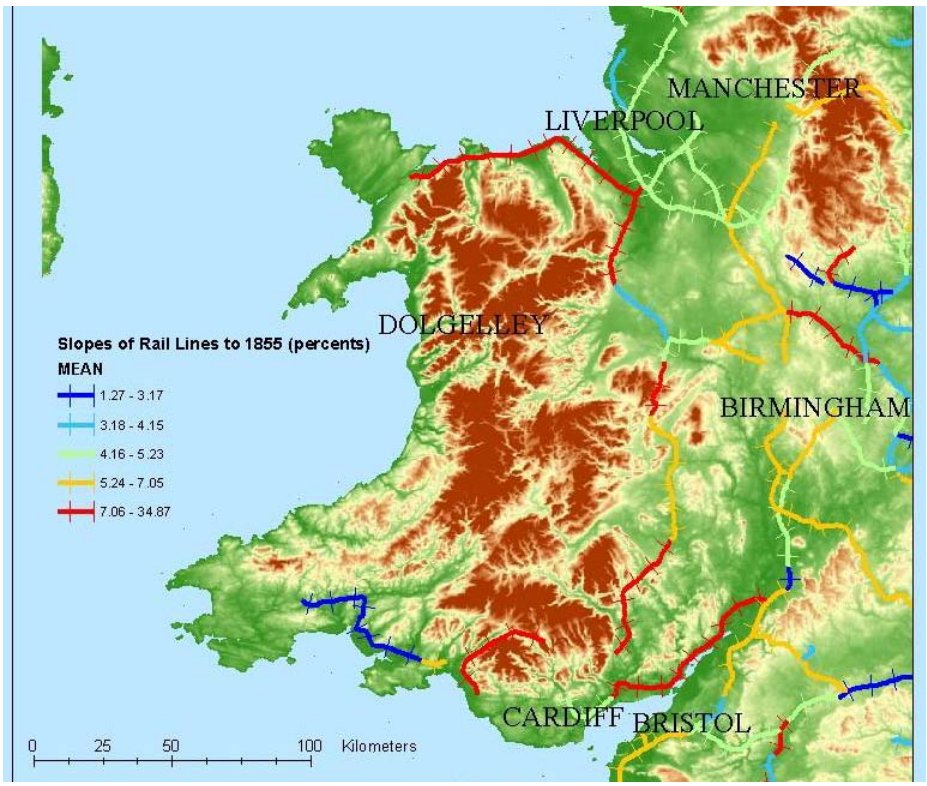
Map 2. Mean Slopes of Rail Lines, 1830-1855 and 1856-1877 (expressed in average percentage change over a rail segment)



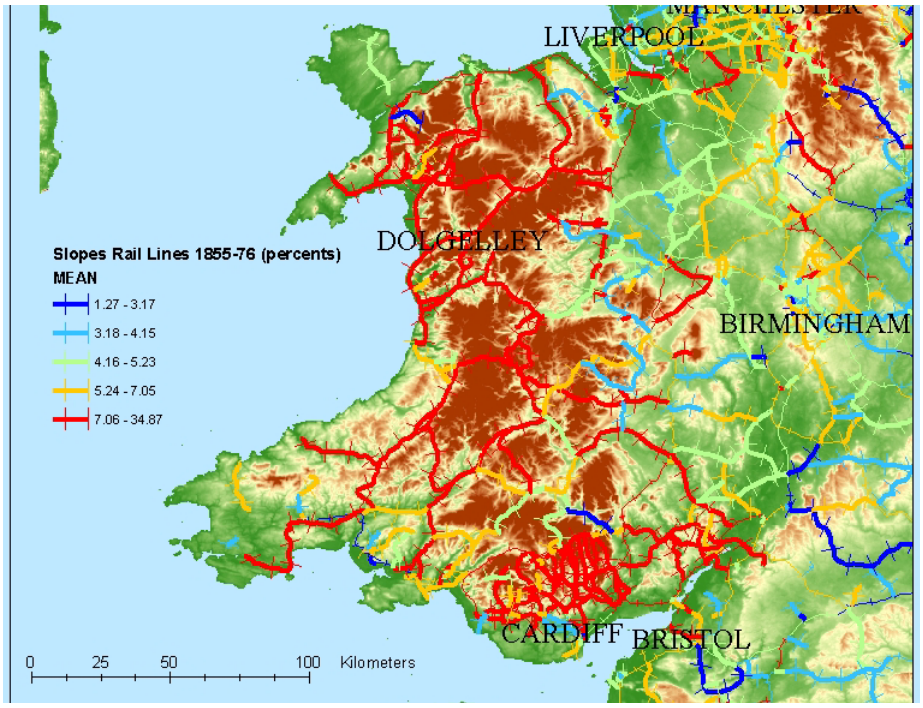
Several striking changes stand out in Map 2. The extensive expansion of the rail system from 1855 to 1877 is evident in the right-hand figure, showing how the network was reaching more and more of rural England and Wales. Furthermore, as shown by the red lines indicating the highest average slopes, the expansion of the 1860s and 1870s carried rail service into new areas of remote and difficult terrain. Prominent in this respect were the upland regions in the Northwest comprising the Lake District and mining areas near the border with Scotland. In the Southwest, new lines reached steeper terrain in Devon and Cornwall. Even more striking developments were underway in Wales. Whereas the rugged, interior terrain of Wales was all but untouched by rail up to the 1850s, thereafter a major program of railway construction, financed largely by the Welch themselves, was devoted to conquering the hills and mountains of the region. Not surprisingly, the slate mines in the north and iron and coal mines in the south were the first areas to be well served by rail transport. But the agrarian regions of Central Wales were drawn into the expanding rail network as well.

Turning up the magnification on Wales reveals further details. Map 3 **Error! Reference source not found.**shows how railways constructed up to 1855 skirted the hilly and mountainous core of the region, while Map 4 for the years 1855 to 1876 displays how the new lines built navigated the hilly and mountainous terrain of the interior where none had existed before. New lines in the south knit together the expanding iron and coal mines near Swansea and Cardiff, while those in the central highlands assured the connection of the agrarian areas to coastal ports, with the new routes serving the northern slate mines, and, to the east, with whole the network in England. Compared to Stephenson's London-Birmingham railway, which had virtually flattened the hills in order to connect the two cities, the new Welsh lines adapted themselves to the hills, mountains, and valleys mainly by running over rugged terrain.

Map 3. Rail Lines in Wales up to 1855

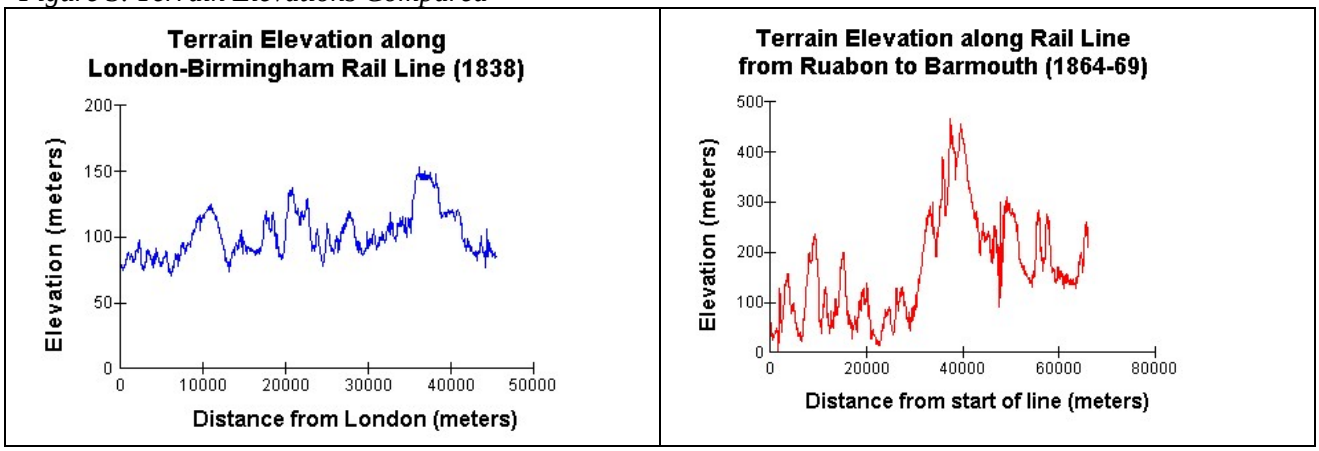


Map 4. New Rail Lines in Wales, 1855-1876



That the Welsh landscape was more daunting than that faced by Stephenson is borne out by the two graphs in Figure 3 depicting two topographical profiles. Whereas the topography crossed by the L&B line tends to hover between 70 to 150 meters in elevation, the terrain on the Welch Ruabon to Barmouth line rises from sea level to highland peaks of over 400 meters.

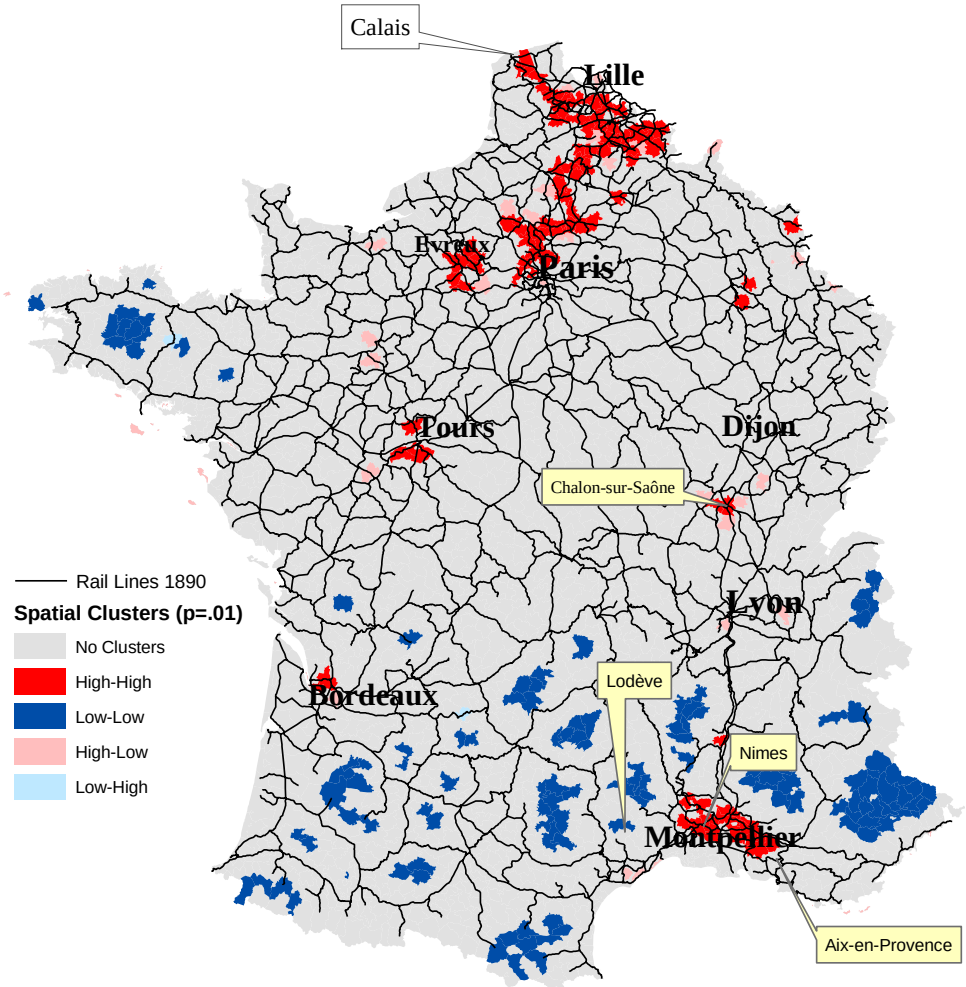
Figure 3. Terrain Elevations Compared



3. France: Disparities in Rail Transport and the Role of Topography

In France, as in Britain, rail transport that reached into remote areas opened a variety of new economic opportunities.[3] Wood, coal, and other natural resources in previously inaccessible areas could now be brought into production. In agrarian regions, railways revitalized local agriculture in certain regions by opening up distant markets and stimulating local production. From the 1860s, the growth of stock-raising and the meat trade marked the successful adaptation to new market conditions by some farmers, while others moved from cereal production into dairy farming to meet the rising urban demand for butter and especially fresh milk. Before modern refrigeration came into general use, fresh milk shipped to London and Paris came more and more from regions at increasing distances from these cities.

Map 5. Disparities in Rail Transport, 1890



In France, however, the economic benefits associated with rail transport fell primarily to the north as compared to the south. Indeed, by 1890, when eighty to ninety percent of the French rail system was in place, recognized disparities in rail service and associated economic benefits were far from being eliminated, as is clear in Map 4 highlighting areas with little or no proximate access to rail service against those with uncommonly high levels of service.[4] The under-served areas (in blue) were prominent in central Brittany and more generally through regions south of a line running from Bordeaux to Lyon.[5]

Favored regions (in red) were prominent also. As a port and entrepôt for the wine trade, Bordeaux joined the Montpellier-Marseilles area as places in the Midi that were exceptionally well served by rail. A hub for the trade in mass-market wines with large port facilities within easy reach, the Montpellier-Marseilles area connected world and regional markets to Lyon and the North via a regional junction of lines at Chalon-sur-Saône. In additional to the Paris region, Tours and the textile center of Evreux were well-endowed with rail service, as was the agglomeration of industry and highly productive agriculture running from Paris to Lille and Calais.

If some regions were "left behind" because they lost out in the fierce competition for rail transport, other regions in the disadvantaged south were victims of challenging topography and an associated history of poor communications and sparse capital investment. This becomes apparent in Map 5 where the rail lines existing in 1890 are overlaid on a digital terrain model. Before the 1860s, when technological improvements such as steel rails, more powerful locomotives, and effective coupling systems took hold, the hilly and mountainous regions of the Massif Central, Pyrenees, and Alps were deemed all but inaccessible to steam-powered locomotion. In the southern Alps, things began to change in 1875 with the opening of a line from Marseille to Gap. In the northwest, Brittany saw its first rail service Rennes and Nantes in the late 1850s, with lines along the perimeters of the peninsula opening in the 1860s and connections to some parts of the interior in the 1870s and 1880s.[6]

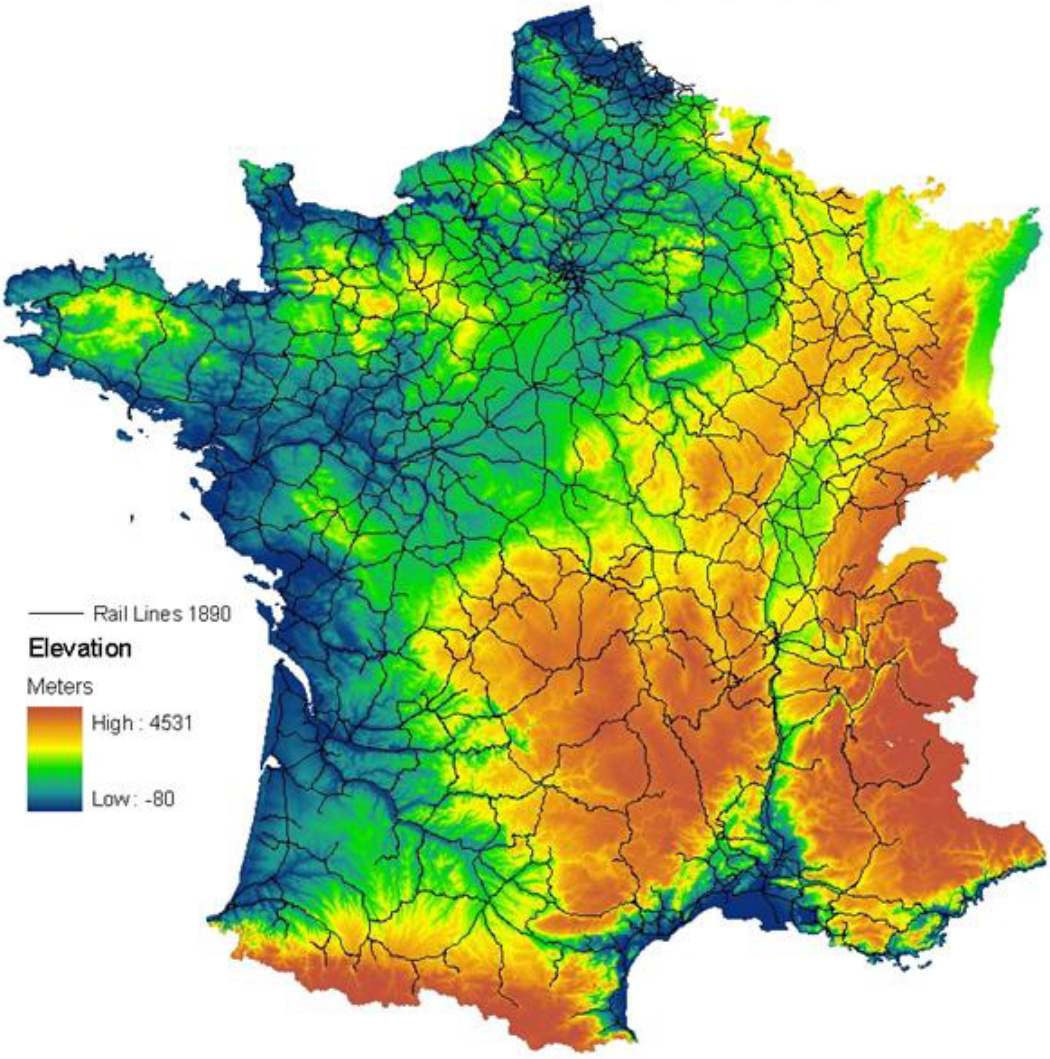
But even as the technology matured, rail companies were reluctant to undertake the extraordinary costs of bringing rail service to upland regions that were considered poor investments. In the Hérault, for example, the once flourishing textile center of Lodève, facing decline in the 1850s, placed its hopes for revival on the Company of the Midi's plan to establish a new route linking Montpellier to Paris and making Lodève a hub for traffic going north and south. When the Ministry of Public Works rejected the plan in 1862, the city's industrial future was foreclosed.[7]

Hence in 1890, and in contrast to the mountainous areas in the Meurthe et Moselle and the Vosges, where railways served the mining and wood industries and strategic military functions on the frontier with Germany, clusters of upland cantons in the South and in the Alps still lagged well behind the developing north and northeast in the transport revolution. This was the geography of uneven capital development at the time. Increasingly concerned about the economic disparities in this geography, the French government in the 1880s launched a vast program of state-subsidized railway expansion directed both at the growth of the national rail network and at the building of secondary network of narrow-gauge lines that would attach remote rural areas to the cities and the national system.[8]

4. Conclusion

Writing in the 1870s, Ruskin's demonization of railway vandalism in the countryside was a throwback to a time past. The domination of the physical landscape that so marked the heroic age of railway expansion had given way in the 1860s to an engineering practice that tended to pass over the landscape rather than through it. The ruling gradients of 1/330 used by Stephenson in the 1830s were superseded by steeper gradients ranging from 1/150 to 1/100 on average, thereby approaching the average capacities of trains today. As steel rails, more powerful locomotives, and other innovations lessened the need for vast excavations and earthworks, the extension of rail transport into rugged areas such as Wales fostered new economic development in mining, agriculture, and commerce as well as tourism. To various and shifting degrees, such development gave rural communities a second chance at growth or stability, a second chance for rural people to stay put by adopting to changing economic circumstances.

Map 2. Railways and Topography, 1890



More slowly than in England and Wales, similar economic opportunities developed in parts of France that acquired access to rail transport. Geographically four times the size of England and Wales, France had not only more ground but higher ground for its rail network to cover if service was to be extended to uplands and mountainous regions of the Massif Central, the Pyrennes, the Alps, and the Vosges. The French state recognized the challenges and acted to meet them more aggressively than did the British government across the Channel, directing a rail system based on a mixture of private and state financing and geared to favoring the public good over profits alone. Ministers and legislators realized that modernizing rural France required new lines that would likely operate at a loss—a cost they deemed urgent and justifiable. Hence, after the defeat by Prussia in 1870 and in the face of an agrarian crisis in the 1880s and 1890s, the state intensified efforts at rural modernization through the so-called Freycenet program of railway expansion. One of its objectives was to reduce the transport disparities between north and south that were noted above. The program eventually bore fruit. By the 1920s, for example, the agricultural rate of growth in the hitherto under-developed south equaled and surpassed that in the north, closing an economic gap centuries old.[9] Very likely, that economic growth owed much to the realization of Freycenet program and continuing state intervention.

GIS Sources and Acknowledgements

This paper is based on the Victorian Railway GIS that I am developing at Mount Holyoke College. Some components come from The Great Britain Historical GIS and include the boundary files for the census registration districts and the demographic information on population, population density, and net migration from 1851 to 1911. I wish to thank Humphrey Southall of the University of Portsmouth and Ian Gregory of the University of Lancaster for allowing me to use data from GBHGIS (http://www.geog.port.ac.uk/gbhgis/). Data for the railways were constructed from maps, notably from the 24 sheets of the *Railway and Station Map of England and Wales* (London: Edward Stanford, 1876.).

The GIS data for France include rail lines digitized from a 1890 map by the French Army (*Cartes des Etapes de France, gravée et publiée par le service géographique de l'Armée. Edition 1890*), and the digital terrain tiles from the Shuttle Radar Mission, distributed by the USGS in tiles.

Notes

[1] Cited in W.G. Hoskins, *The Making of the English Landscape* (London: Hodder and Stoughton, 1977), p 25.

[2] Jack Simmons and Gordon. Biddle, *The Oxford Companion to British Railway History From 1603 to the 1990s*. (Oxford ; New York: Oxford University Press, 1997), pp. 135, 426.

[3] For a further discussion, see my article, "Railways and Rural Development in England and Wales, 1850-1914", *Frontères, contacts, échanges: Hommages à André Palluel*, edited by Christian Sorrel, Chambéry, 2002: 241-259.

[4] The map displays clusters of spatially-autocorrelated levels of rail density across some 1,950 cantons of France in 1890. Mapping a localized version of the spatial statistic called Moran's I (LISA) highlights regional disparities between contiguous areas where rail service was uncommonly dense (shaded red) and those where it was virtually non-existent (regions in dark blue).

[5] This geography of disadvantage corresponds somewhat with the geography of share-cropping that was so prevalent in parts of the West and Southwest. See Jonathan Liebowitz, "Tenants, Sharecroppers, and the French Agricultural Depression of the Late Nineteenth Century," *Journal of Interdisciplinary History*, 19 (1989): 432-34.

[6] Bernard Cima, *Histoire Chonologique des Chemins de Fer Français*. (Menton: Auto-édition CIMA, n.d.), in his atlas on CD-ROM, provides an extremely useful year-by-year chronology of the openings (and closings) of main lines and stations, the length of lines so affected, and accompanying maps from 1827 to 2000. Despite the opening of lines in Brittany in the 1860s and 1870s, François Caron suggests that reliable service in many parts of the peninsula was well established only in the 1880s. See his François Caron, *Histoire des chemins de fer en France, Tome premier (1740-1883)*, (Paris : Fayard, 1997), pp. 554-5.

[7] Christopher H. Johnson, *The Life and Death of Industrial Languedoc, 1700-1920* (New York: Oxford University Press, 1995), chapter. 7, "The Railroad That Never Was."

[8] The interesting debate over the extent to which disparities were accentuated or reduced is a problem that I am working to clarify. The sharpest differences are between Roger Price and François Caron. Price in *The Modernization of Rural France. Communications Networks and Agricultural Market Structures in Nineteenth-Century France* (New York. 1983): 6, concludes that railways, even after the Freycinet plan took effect, diminished rural isolation but aggravated pre-existing economic inequalities among rural regions. Caron argues that the old disparities between the rich Northeast and the poor South were attenuated, and that some of the poorest regions caught up: François Caron, *Histoire des chemins de fer en France (1740-1883)*, p. 572.

[9] Toutain, Jean-Claude. *La Production Agricole de La France de 1810 à 1990: Départements et régions. Croissance, productivité, structures*. 3 vols, Histoire Quantitative de l'économie française. Grenoble: Cahiers de l'ISMÉA [Économies et sociétés], 1992-3, vol. 3, Appendix D, Table D20, p 811.