Part I

People, Production, and Consumption

CHAPTER ONE

Eighteenth-Century History and the European Environment

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Historical Climatology: Review and Development

Recent concerns about future global warming have prompted scientists to look to the past, and there is a growing understanding of how climate has changed over the centuries and recognition that such changes have had consequences for the societies that experienced them. The eighteenth century is of particular interest, because it was from that time that temperature, rainfall, and other instrument-based data began to be gathered following the invention a century earlier of the barometer and the thermometer, by Torricelli and Galileo respectively. For earlier periods reliance is placed on contemporary documents such as tax returns, farm and estate records, chronicles, letters, and diaries from which the climate record can be inferred. It is now acknowledged that the careful analysis of such items can provide an unexpectedly detailed picture of the climate and weather of the time. It is this recognition that has given rise to the discipline of "historical climatology." Some of the early research in this field was conducted by historians, exemplary amongst which is the work of members of the French Annales school such as Fernand Braudel and Emmanuel Le Roy Ladurie (1972). On the climatological side, endeavors began earlier, though with little immediate effect. The Swiss scientist Louis Dufour (1870) and his French contemporary Alfred Angot (1885) both recognized the climatological significance of documentary sources, as did Charles Brooks (1926) some years later in the UK. But it is the contributions of Professors Hubert Lamb (1982, 1988), Christian Pfister (1984), and Rudolf Brázdil (1996) that set "historical climatology" on its present path and Brázdil et al. (2005) have provided an overview of the current state of historical climatological studies in which they stress the developing interest in past responses to weather extremes and variations.

This concept of social vulnerability is an important one that has recently been accorded increased attention in the social sciences by writers such as Oliver-Smith (2004). Not all, however, agree on the role that the environment plays in social evolution, and Fogel has argued that famines are "related to an extremely inelastic demand for food inventories, rather than to natural calamities" (1992: 280). A

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century earlier, Durkheim (1882), in his desire to provide sociology with the methodological objectivity of the sciences, was of the firm opinion that social history was only explicable in terms of social factors.

Despite such reservations, Ingold (1992) proposed that environmental and human history are inseparable and that each is implicated in the evolutionary life of the other. Post (1990) has also offered some interesting reflections on the connections between mortality, disease, and subsistence crises in which he observed that the latter "were invariably preceded by natural calamity" (1990: 241). He recognizes the more direct connections to food supply and prices, but argues that such connections are anything but predictable, nor do they conform to any recognized pattern. For him, natural disasters exercise control over poorer elements of society through the medium of such issues as problems of sanitation, unemployment, and vagrancy, all of which would hasten the onset of epidemics and facilitate their spread. Pfister and Brázdil (2006) have, from the climatological side, offered similar views. Nevertheless, occasionally quantifiable relationships have been discovered. Parry and Carter (1985) found that the pre-industrial agricultural "frontier" of southern Scotland rose or fell by 140 m for every degree of temperature change. But it is Parry who best summarizes the problem: "The task of evaluating the impact of changes of climate on the path of economic history is an extraordinarily difficult one. It embraces two disciplines which have traditionally adopted very different paths of enquiry and which require from their disciples very different realms of expertise" (1981: 319).

Such areas of uncertainty and debate notwithstanding, there is an undeniable link between climate and the success or otherwise of agricultural systems and food supply. In the long term, climate sets limits to the nature and variety of crops that can be successfully cultivated. Across northern Europe, for example, wheat production is confined to the drier and warmer districts, its place being taken by barley where growing seasons are shorter, or by oats as the climate becomes cooler and wetter in northern and more western districts. These are, however, the broadly defined circumscriptions on agriculture set by long-term average conditions and might be described as first-order climatic controls. But climate is both variable and unpredictable, and year-by-year changes can lead to good or bad harvests with inevitable consequences for political and economic systems as food prices fluctuate to reflect provision and demand. These might be described as second-order controls, and they form the focus of this chapter. They are, as noted above, complex and have responses that are more sensitive and less predictable than those of first-order effects. Subsistence agricultural practices are, for the most part, more vulnerable than commercial systems where reserves can be stored or traded to offset periods of shortage, and while some eighteenth-century systems were benefiting from investment and from the so-called "agricultural revolution" in farming practices that began in England, others lagged behind. Fagan (2000) is highly critical of the conservatism and inefficiency of French agriculture in the eighteenth century, which left it anachronisitically sensitive to inclement weather. Elsewhere in Europe, Pfister and Brázdil observed in connection with case studies from central Europe that "A group's ability to anticipate, cope with, resist and recover from crises and disaster depends on a variety of social, economic, political and environmental processes" (2006: 115). More generally it is important to note that average crop yields – a product of first-order influences – are less important in the current context than the risk and frequency of failure in meeting the minimum demands, which depend upon the second-order controls.

The Climate of Eighteenth-Century Europe

There is general agreement concerning the climate of Europe during the eighteenth century. Not only were the thermometer and barometer much-improved instruments at this time, providing more reliable measures than those of their predecessors, but the age of Enlightenment had created an intellectual atmosphere in which data and observations were gathered, recorded and compared often within the context of organized networks, or through the agency of learned societies. Such endeavors began as early as the seventeenth century when the grand duke of Tuscany, Ferdinand II, established the Accademia del Cimento (Academy of Experiments) in his native Florence. In 1654 Ferdinand and Leopold de Medici established the first international network of observatories, the so-called Rete Medicea, that included not only Florence but also Bologna, Parma, Rome, Milan, Paris, and Warsaw (Camuffo, 2002). It ceased operating in 1667, but just 10 years later the Royal Society's first curator, Robert Hooke, devised a scheme for making standardized weather observations. Early in the eighteenth century Johann Kanold set up a network of corresponding observers (Brázdil et al, 2002) with quarterly reports being published from 1718 to 1726. In 1770 Karl Theodor, then Prince-Elector of the Palatinate, established an observational network through the Societas Meteorologica Palatina, the correspondents of which could be found as far afield as Stockholm and Rome, while in 1778 the Société Royale de Médecine was founded in Paris and organized its own network of observers (Kington, 1988a). The political uncertainties of the closing years of the century were to bring these enterprises to a regrettable conclusion. None of these notable endeavors should, however, diminish the contribution of those many observers across Europe who engaged in weather studies in a spirit of individual inquiry. Most notable in Britain, if only because his observations and writings have been made so accessible by the efforts of Kington (1988b), is Thomas Barker of Lyndon Hall, Rutland, whose daily record extends, remarkably, from 1733 to 1800. These instrumental observations provide a platform on which our knowledge of the climate of the century is based, but the even greater wealth of documentary records of floods, droughts, crop return, estate papers, and other documents provide yet further evidence. Deriving absolute temperatures and rainfalls from non-instrumental sources remains an area of debate, but climatologists have enjoyed much success in producing carefully scaled indices of these two important phenomena.

Drawing on such sources, objective and statistical substance is given to the study of past climates by the central England temperature series. This dataset of monthly temperatures starts in 1659 and continues to the present day, being brought up to date each month by the UK Met Office (<www.metoffice.gov.uk/research/hadley centre/CR_data/Daily/HadCET_act.txt>). It was developed by the late Professor Gordon Manley (1974), and while it represents conditions in England, it is also broadly representative of trends across most of western and central Europe. Figure 1 is based on this series and reveals only too clearly the problem of generalized statements made on such an inherently variable phenomenon as climate. The year-to-year changes are so marked that "running means" are used to smooth out

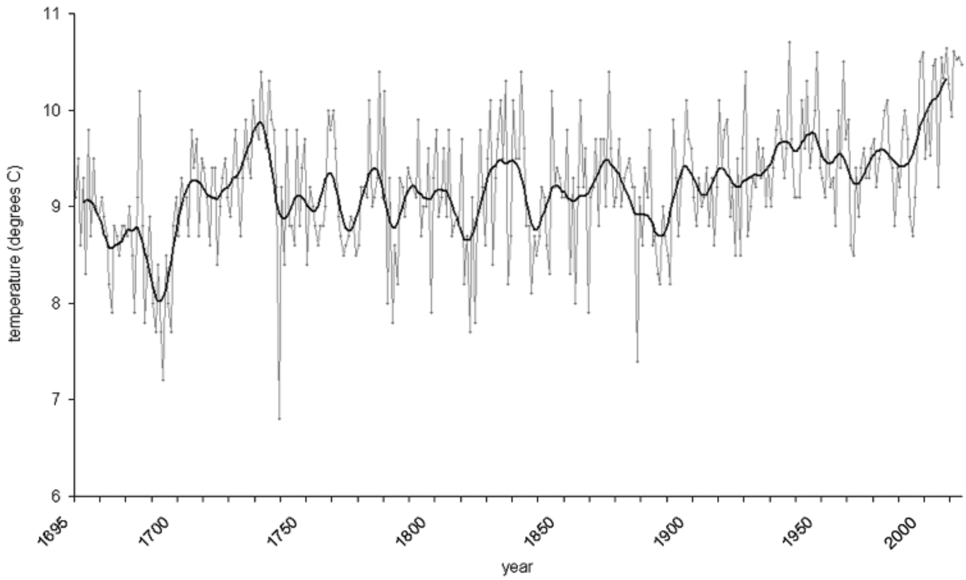

Figure 1 The central England temperature annual series, 1659–2005. The 12-year running mean (to identify the longer-term trends) is superimposed in bold

such variations and to reveal the underlying trends. Useful though such a summary is, it fails to convey any sense of the variations within the year. Temperatures are, however, one part of a wider climatological picture. Regionally based rainfall records begin only in 1766 with England and Wales series prepared by the Climatic Research Unit of the University of East Anglia (<www.cru.uea.ac.uk/cru/data/>). In contrast to temperatures, rainfall can vary greatly over short distances and it would be wrong to extend the climatological picture presented by the England and Wales data beyond that region. Snowfall, because of its often more dramatic consequences and episodic character, was often recorded and allows for long series to be constructed, and that of Manley (1969) takes the British record back over 300 years.

There is, however, no suggestion that the climate of the eighteenth century was in any way unique. It wasn't, and it should be seen within the longer-term changes taking place in the past millennium. The so-called "Little Ice Age," which prevailed from the fourteenth to the nineteenth centuries, is generally regarded as the coldest period of European history since the retreat of the great ice sheets some 10,000 years ago. Moreover, the closing decades of the seventeenth century had been the very coldest of the period, with well-documented reflections on the horrors that accompanied crop failure: famine, disease, and rising food prices. By comparison, the opening years of the eighteenth century, must have been seen as almost benign, as temperatures underwent a slow, if at times faltering, recovery.

The combination and timing of extremes of precipitation and of temperatures of the type experienced during the Little Ice Age were often critical. For many forms of production, cool and wet summers can be more damaging than cold winters. Dry springs can be harmful for germination of crops, while wet summers can create havoc

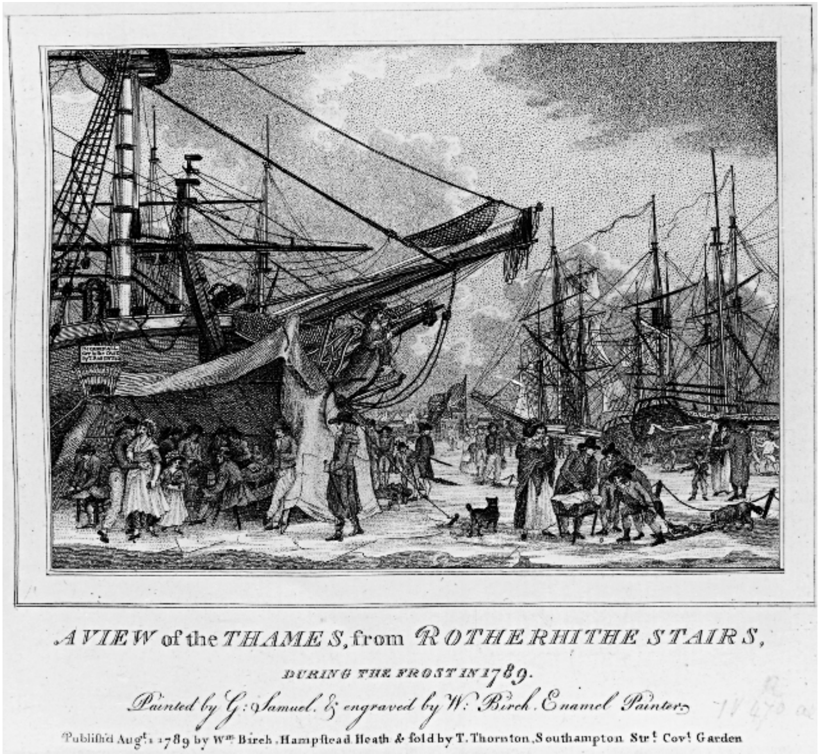

Figure 2 Merchant shipping frozen in the ice at Rotherhithe Stairs during the great frost of 1789. *City of London Libraries and Guildhall Art Gallery*

with the harvest. Such disruptions to the agricultural system have been described by Pfister and Brázdil (2006) as "Little Ice Age-Type Impacts" (LIATIMP) They single out long wet spells as being particularly detrimental, leading to a reduced flour content in grain and also leaving crops vulnerable to molds and attacks by the grain weevil (*Sitophilus granaries*). Such prolonged spells of wet weather can also be harmful outside the growing season, and when they occur in autumn they can deplete soils of nutrients, particularly soluble nitrogen. Cold springs can also create problems by delaying germination or destroying emergent crops with late frosts.

The data to hand provides a useful point of departure in any attempt to grasp the climatic character of the eighteenth century. The closing years of the seventeenth century were remarkable by any standards, and the conditions of the eighteenth represent a general improvement. But cold spells continued to occur, with occasionally alarming consequences partly as a result of their wholly unexpected nature bringing in their wake disruptions to life, the economy, and agriculture (figure 2). The 1730s were, for example, amongst the warmest until the recent years of "global warming," but the decade concluded with the coldest year in the central England series (1740). Other cold years followed, and major crises of mortality, food supply, and food prices occurred in the 1740s and 1770s. Both coincided with periods of poor weather. The mortality crisis of the 1740s saw death rates rise by 21 percent across Europe (Post, 1990), while the corresponding figure for the 1790s was 17 percent. The rates varied from region to region, but Post has presented a detailed analysis of these two critical periods and claims the 1740s mortality wave to have been "an outstanding fact of European population history" (1990: 245). In both cases the immediate cause of much of the mortality was disease. At a time when the average expenditure on food accounted for over 65 percent of the income of the laboring populations, such groups were always vulnerable to price increases and a consequent diminution of their dietary intake. The degree to which malnutrition gives rise to vulnerability to disease is another complicating factor but one for which there exists a prima facie case to answer.

This is not the arena in which to debate the possible causes of the Little Ice Age, other than to note that in this "pre-industrial" age control was exercised by factors in addition to the greenhouse gases that dominate public thinking in the early twenty-first century. Solar variation is an important element, and the quiescence of the sun during the Maunder Minimum between approximately 1645 and 1715, a time when sunspot activity seems to have all but ceased, is held to be a significant factor in the abiding and extreme coolness of that same period (Beckman and Mahony, 1998; Eddy, 1976). Also of importance were the volcanic eruptions of the period. The atmospheric dust veils created by such events could lead to global and regional cooling of the order of up to a degree, and cause serious local disruption, although the effects rarely extend beyond 24 months of the eruption. The 1780s were years of notable volcanic activity (Lamb, 1970) and of anomalous weather patterns. Significant eruptions occurred in Iceland in 1783 (Eldeyjar, Lakigígar, and Skapta Jökull), Hekla erupted in 1784, Vesuvius in 1785, 1787, and 1790, and Etna in 1787, to which can be added a number of equally large eruptions elsewhere in the world whose dust veils embraced the planet. The economy of Iceland suffered immediate consequences, but other areas were not spared, and ash falls in northern Scotland were sufficient to destroy crops, while further afield in Holland the sulfurous atmosphere also reduced crop yields. Stothers (1996) describes the spread of the dust cloud, citing evidence from such distant locations as Budapest, Rome, and the Middle East. The results were no less dramatic in central Europe and the winter of 1783/4 was the sixth coldest in the Prague record, followed in 1785 by the coldest spring on record in Europe. Dust was noted in Prague within weeks of the eruption on June 6, 1783. Such falls of acid aerosols, dust, and the concentrations of associated gases were widespread and were known as "dry fogs." These events may have had results other than those of reducing crop yields, and Witham and Oppenheimer (2005) have suggested that were two peaks of mortality, one in August and September of 1783, and the other in January and February of 1784, that might have accounted for over 19,000 deaths in Britain. Gratton et al. (2005) make similar claims for mortality peaks in France and the Low Countries.

The longer-term, climatic, results of such large volumes of dust being discharged into the atmosphere were also significant. Písek and Brázdil (2006) have presented evidence for summer cooling and winter warming in the two to three years following such eruptions, but the picture is by no means consistent. There is evidence also (Kington, 1988a) that the normal westerly circulation of the European mid-latitudes began to break down in this decade. The current average is over 90 westerly days per year, but in 1785 it fell to just 45. July 1783 was the warmest in the central England temperature series until the recent years of global warming, but there were also some very cold winters in 1784 and 1785. The spring of 1785 was exceptionally cold, prolonging an already severe winter. This was followed by drought, causing a forage crisis in French farms in particular. Rye and oat bread replaced wheat bread, which could be afforded only by the wealthiest in French society. At this time over half the income of a French peasant was spent on bread, and the economic strains imposed by the costs of the American War of Independence, which had concluded in September 1783, found the country ill prepared for such a series of agricultural failings.

Not long afterwards, the year 1788 was one of the driest on record with only 63 percent of normal rainfall. This picture of extreme weather was widespread across Europe and the winter of 1788/9 was again severe (figure 2), at a time when over 80 percent of the income of the poorest classes in France was spent on bread. As has been observed, "this is not to attribute the revolution which changed French society to the weather, but it can hardly be gainsaid that the weather intensified the pressures that released the explosion" (Lamb, 1982: 238). This is, however, an extreme case and the diversity of climate and of political and social consequences across Europe is so wide as to forbid helpful generalizations. For this reason, the following sections treat Europe in distinctive parts, each displaying different responses to similar, but by no means identical, climatological stimuli.

The British Isles: Adaptation and Evolution in a Maritime Setting

The term maritime will have one connotation amongst historians, another for climatologists. For the latter, it signifies a climate at once temperate yet often humid; one in which droughts occur but are neither regular nor frequent. Yet even within that definition lie shades of meteorological character that create the differences between the demands of Highland Scotland and the agricultural advantages offered by lowland England (Wheeler and Mayes, 1997). In all areas, however, the first three decades of the eighteenth century were a time of increasing warmth and recovery from the rigors of the closing decades of the previous century, particularly in Scotland, where the marginal character of much agrarian enterprise left it always vulnerable to even small shifts of climate. In the 1690s the harvest failed for seven years in a row, and at one stage it was reported that 20 percent of the population had been reduced to begging. Others removed to Ulster to escape the agricultural disaster of their homeland. Not without good reason these times were known in Scotland as "the ill years of King William's reign." How far such impositions weakened the Scottish economy and reduced its political will, perhaps paving the way for the Act of Union in 1707, can only speculated upon. As a measure of the abiding coolness of this period, travelers to Scotland often noted permanent snow on the Cairngorm summits. In 1771 Thomas Pennant recorded on a visit to the highlands that "many of them [were] topped with perpetual snow" (2000: 82). This intrepid traveler also noted that a local laird not far from Dingwall "holds the forest from the crown by a very whimsical tenure, that of delivering a snowball on any day of the year that is demanded . . . for snow lies in the chasms of Ben Wyvis in the form of a glaciere through the year" (2000: 108). This remarkable persistence of snow, perhaps ice also, suggests temperatures some 2 degrees Celsius lower than those that prevail today.

From this low point the agricultural sector began to grow during the first half of the eighteenth century. It has been suggested (Michaelowa, 2000) that the average rate of growth was 0.6 per cent between 1700 and 1760, slowing to 0.1 percent over the following 20 years. At the same time the numbers of livestock increased, as did their average weight (Deane and Cole, 1962), and the weight of livestock sold at Smithfield doubled during the century. Such developments must not be attributed exclusively the general climatic improvement of the times. In the same century agricultural practices were improved by the efforts of, amongst others, Lord Townshend and Thomas Coke. But these were not years of unremitting growth. There were setbacks when climate failed to provide the necessary warmth or moisture and Hoskins (1968) identified 1709, 1740, and 1759 as being particularly troublesome. The cold conditions of 1740 had immediate consequences. Livestock prices rose in response to the failure to provide fodder, while riots occurred as grain was being moved for export (Charlesworth, 1983). Yet even this catastrophe was partly offset by the diversification that had taken place in English agriculture. Had wheat been the overwhelmingly dominant cereal crop its loss in the ground over the winter of 1739/40 would have disastrous. Fortunately, barley and oats were also popular and were sown in the spring, thereby offsetting the loss of the winter wheat. It is interesting to note that France, with less ability to diversify, suffered more under an almost identical climatic regime.

The second half of the century revealed little tendency to marked or continued warmth, and it was rainfall that lent character to these 50 years. The decade 1751 to 1760 provided 10 wet summers with an overall average rainfall some 25 percent greater than that for the present day. The periods 1763–72 and 1775–84 also provided summers some 15 percent wetter than might today be anticipated. But it was only in marginal areas of Scotland and Ireland that crop failures were severe. That of 1783 was notable, and in Stirlingshire the unripened corn was buried beneath the winter's first snow on October 31, but this was a coolness aggravated by the great volcanic eruptions in Iceland noted above that cast their gloomy veil of dust over much of northwest Europe.

The problems of Scotland's climate were intensified by oceanic as well as atmospheric changes. The seventeenth and eighteenth centuries saw the southward extension of cold Arctic water to replace the warmer waters of tropical origin – the so-called North Atlantic Drift – more commonly associated with the seas around the north of the British Isles. The purely climatic consequence of this shift was to rob the region of much of the warmth otherwise derived from the Atlantic waters, with the result that the temperature contrast between southern England and Scotland was increased. This had the further consequence of creating a situation in which Atlantic depressions became stormier and more active. The "Great Storm" of December 1703, described by Defoe (1704) and more recently by Brayne (2002) and Wheeler (2003), was but one of a number of severe events; Lamb (1991) provides a detailed list of these occurrences. The storm of Christmas 1717 claimed 11,000 lives around the margins of the North Sea. Further severe storms punctuated the following decades, but the 1790s were remarkable for the number of extreme events: 1791 (with two), 1792 (with four), and 1795. Although they were episodic in character, the loss of life that they caused (an estimated 8,000 killed in the 1703 storm) and coastal flooding with damage to housing, farmland, and stock, had notable short-term consequences for those unlucky enough to experience them. The Great Storm of 1703 is estimated top have caused £2 million of damage in London alone. But they mark events and conditions that were short-lived and episodic in character; after this conditions returned to the climatic norms that had prevailed previously. It is, therefore, difficult to gauge their more enduring influence on the economy, although the lack of evidence suggests them to have been transitory in this respect. It should not be forgotten that these storms differ in degree, but not kind, from the hundred or more cyclonic systems that cross northwest Europe each year in what is one of the world's stormiest and most unsettled climatic regions.

Iceland and Scandinavia: The Challenge of Ice and Cold

It is perhaps not surprising that in a cool period, the northern latitudes should suffer to a marked degree. Yet the problems that beset communities in these outermost reaches of Europe were even greater than might be expected. It is fortunate that both Norway and Iceland are well documented in respect of agricultural activities in the eighteenth century. In Norway the *landskyld* (land rent) could not be charged without official assessment and the value was fixed as a proportion of the farm's yield. The documents relating to these assessments have survived and provide a vivid picture of decline and crisis in eighteenth-century Norway in the face of climatic and environmental change. Grove and Battagal (1980) have provided a study of the records from the Sunnfjord Figderi region of western Norway, the results of which apply equally to other areas. *matrikkel* (general tax) commissions of inquiry were held in 1667 and again in 1724, the results of which reveal that environmental decline has already set in across the region, but the 1740s seem to have been years of unprecedented catastrophe here as elsewhere in Europe, with 1743 being notably inclement and producing heavy rains and consequent landslides. Cattle and fodder crops were the key agrarian elements. Regrettably the hay production was not itemized, but the cattle population in this period fell by about 20 percent, although this decline varied from sub-region to sub-region. Remission of taxes (*avtak*) could be applied for on the basis of damage by floods, rockfalls, and advancing glaciers to farmland and buildings, although not on the basis of poor weather alone, and here the evidence of widespread problems is unambiguous and assessments of tax reductions of up to 50 percent were not unknown. The difficulties tended to be worse in the upland, more marginal, areas and less marked on the coast, but nowhere was immune to environmental threats. Whereas the loss of livestock might be attributed directly to climatic change and cooling, which reduced the growing season, lower fodder production led to reductions in the capacity for winter stall feeding. The cooling climate not only lowered the altitudinal limits on agriculture, it also, in a picture to be re-created in the mountainous areas of central Europe, encouraged glacier advance, landslides, rockfall and floods (over frozen ground). Matters were most serious in the period 1740–60, with floods being a common cause for seeking *avtak*. The crop failures of 1741, 1742, 1748, and 1773 seem to have been associated with mortality peaks, and while some deaths may have been the direct consequence of starvation many were the result of disease, such as typhus and dysentery, that found a vulnerable population at these times. Thereafter conditions seem to have stabilized, although at a lower level of agricultural activity than had prevailed a century before.

The corresponding situation in Iceland (Ogilvie, 1980) was similar, but exacerbated by the yet more marginal and vulnerable setting of this society. Not only is the island sensitive to modest changes of climate but the latter is cold enough to support the island's ice cap with the associated risks of flooding and of glacier advance that were familiar in Norway. The volcanic eruptions noted earlier add a final, equally unwelcome, aspect to the gamut of environmental risk in the form of lava, ash, and earth tremors. Moreover, Iceland's northern coast in particular lies beyond the immediate reach of the warm waters of the North Atlantic Drift, leaving the area subject to lower sea and coastal temperatures and to occasional freezing that rendered the all-important coastal trade and fishing all but impossible.

In common with Norway, the 1750s were among the worst years of the century. The combination of cool conditions with high precipitation encouraged ice cap accumulation and glacier advance. Farms were abandoned and sea ice persisted late into each year, reaching a climax in 1756 when the sheriff of Húnavatnssýsla, whose jurisdiction extended to northwest Iceland, observed: "The sea was covered by ice the whole summer and this has prevented all fishing and all delivery of foodstuffs from Copenhagen and also affected grass crops and it has not been possible to harvest the little which has been grown because of the continual fog, sleet and rainy weather" (B.S., 1756). Starvation was not uncommon and crime rates increased as families found themselves unable to meet their needs from the meager products of their agricultural activities. The economy was based on livestock and winter stall feeding, and the succession of poor and wet summers that marked the period led to the loss of livestock either by enforced slaughter or starvation as fodder supplies failed to meet the winter needs calculated (in modern day needs) as 3 cubic feet of fodder per sheep, 10 to 15 cubic meters per horse, and 35 to 40 cubic meters per cow.

Milder conditions in the 1770s were not, however, sustained and the 1780s were arguably (Ogilvie, 1992) the coldest of the century, a decade made worse by the eruption of the volcano Lakagígar (Laki) in 1783, which cast a dust and ash veil over the island that poisoned plant life and led to loss of animal and human life on a huge scale. It is estimated that 9,000 died of starvation in its aftermath. It was this same dust that destroyed the crops in northern Scotland that same year, while the temperature of the northern hemisphere was is estimated to have fallen by 1 degree Celsius.

Fishing was an important and traditional component of the economic system of Iceland, providing food not only for domestic consumption but also for export. The incursion of sea ice, most common along the north coast, but much less frequent to the south, limited the possibility of fishing. Such obvious difficulties obscure a more profound consequence of environmental changes at the time. While acknowledging the problem of manning the fishing boats after the smallpox outbreak of 1708–9, climatic conditions also played a significant role, with the southwards encroachment of cold Arctic waters lowering sea surface temperatures everywhere. The incursion of cold Arctic waters had a direct cooling effect on the climate, adversely affecting the cod (*Gadus spp.* – the principal catch for Iceland fisherman). Cod require sea temperatures in the order of 4 to 7 degrees Celsius in order to reproduce (Woodhead and Woodhead, 1959). As sea temperatures fell below this critical range, stocks moved southwards and out of easy reach of Iceland, thereby inflicting an additional blow to an already beleaguered agrarian system. Such evidence suggests that the northern seas as far south as the Faroes were dominated by Arctic water and were inhospitable to cod for much of the century and well into the following one. One official record from western Iceland in 1744 reports that "everywhere the cod catch was the worst that people could remember for many years . . . in most places most boats did not catch more than about 10 fish and in many places less" (cited in Grove, 1988).

Given this background, it is scarcely surprising that the population of Iceland should have fallen dramatically during the century. The 1703 census estimated the population to be 50,358. The smallpox epidemic that followed is thought to have reduced it by one-third, although the 1734 census gives a total of 43,377, suggesting a recovery from the earlier decline. This demographic trend continued through the more temperate years of the 1730s and 1740s, rising to 48,000 in 1755. The climatic deterioration of this decade was soon registered in mortality, however, and the 1759 estimate was 42,822. A recovery then took place, but the devastation of the 1780s saw the population plummet to 38,363 in 1786.

Western and Central Europe: Changing Climate in a Continental Setting

The general trend of climate in central Europe followed that for other parts of the continent. A steady recovery until 1740 from the devastation of the 1690s was followed by cold years of the early 1740s, the 1750s, and the 1780s. Yet the years of recovery were by no means without incident. In central Europe the 1720s and 1730s were marked by wet summers, while brief periods of recovery were observed in Switzerland in 1759–63 and again in 1778–84. Cold and wet conditions dominated between these spells, and the cool summers were of critical importance because the winter snows did not melt, thus allowing the alpine glaciers to advance into farm and grazing land. The period 1769–71 was particularly difficult, with the staples of wheat, milk, and potatoes being in short supply and famine setting in where the problem was most acute. Weather diaries from Bern and Zurich add some statistical substance to these observations. Between 1705 and 1714 snow covered the ground on only 42 days on average, but this rose to 111 days in the cold winters of 1730–1, 1769–70, and 1788–9. Such data suggest a mean temperature some 1.5 degrees Celsius lower than those that prevailed for much of the twentieth century. Springs tended to be cool, with winter extending well into March. The protracted snow cover allowed the parasite *Fusarium nivale* to flourish and attack cereal crops to devastating effect.

Meanwhile, for western Europe, and for France in particular, the work of Le Roy Ladurie (1972), using the dates of grape harvest, has offered a detailed picture of temperature fluctuations over the centuries from the mid-1300s onwards. This series is of particular value as grape harvest dates – at least until modern times, with new technologies – provided unusually high statistical correlations with summer temperatures. The grape harvest dates have also been shown to corroborate the instrumental record of Manley's central England temperature series. In common with other regions of Europe, the temperature fluctuations take the character of groups of warm or cool years and not, predominantly, of individual years. Ladurie identified 1711–13, 1739–52, and 1765–77 as times when springs and summers were cool. On the other hand, 1718–37, 1757–63 and 1778–83 were periods of relative warmth. Nevertheless, grape harvest dates reflect only the spring and summer (growing season conditions) and Ladurie fails to note, for example, the catastrophic winter of 1708–9, when it is estimated that 100,000 died in France alone. Nonetheless, even here the picture varied from region to region and was less severe in those areas with more diversified agricultural economies such as Brittany.

The early 1770s witnessed severe subsistence crises in central Europe as a series of cold and wet autumns and springs, beginning as early as the late 1760s, with late snows and cool summers, caused grain prices to rise dramatically. In the German states and Austria the price of cereals rose by 111 percent, raising the specter of famine, disease, and mortality. In Bohemia the cost of rye rose by a factor of 3 between 1769 and 1771, and of oats and barley by a factor of 4. This led to severe social dislocation as unemployment, begging, and crime all increased. Pfister and Brázdil (2006) estimate that Bohemia's population fell by 250,000 (10 percent of the total) and that it took 13 years for a full demographic recovery, forming a bleak a backdrop to the serf uprising of 1775. But, importantly, the same authors also draw attention to the less dramatic responses in the nearby districts of Bern, where social vulnerability was mitigated by measures such as poor relief and by a better system of market integration that allowed the export of grain in times of plenty, but its import when required by internal demand. The mercantilist policies of the Habsburg domains, that included the Czech lands, prevented such freedom of trade.

These data can be supplemented by the growing volume of instrumental observations gathered in France from the 1780s under the auspices of the Société Royale de Médecine that established one of the world's first organized networks of meteorological observatories (Kington, 1988a). With some justification, both from the point of view of data availability and of its historical timing, Ladurie could claim that the 15 years that preceded the French Revolution are amongst the most interesting periods for the historian of the vine and of climate. The years from 1778 to 1781 witnessed hot summers and excellent grape harvests, not only in France but also in the nearby Rhineland and German vineyards. The following year saw a marked decline when a cold and wet summer took its toll. The following year was no better, and in Champagne, for example, the yield was 60 percent below normal. A pattern was then set for poor summers with diminished productivity not only in grapes but across the full spectrum of agricultural activities. The year 1788 offered only a temporary respite for wine production but, and as a reminder of the complexity of connections between climate and agriculture, this was a poor year for wheat, the warmth coming too early for this crop. Then came the tragedy of 1789 when the winter and spring proved to be exceptionally cold, with matters scarcely improved by an indifferent and wet summer. How far the climatic events and consequent agricultural failures of these years contributed to the French Revolution is a question that may never be satisfactorily answered.

The Mediterranean World: Water-Limited Agrarian Systems

Climatic conditions in most of northern and western Europe are broadly similar in being mid-latitude and humid in character. The driving seasonal force is temperature variation. These considerations no longer prevail when the Alps or Pyrenees have been crossed and the Mediterranean region beckons. Here the rainfall, usually so plentiful to the north, is a commodity to be cherished and water supply a matter of greatest social and political importance.

With the exception of the mountainous areas of Italy and Spain and of the high Meseta of the latter, temperatures remain above the growing limits for most plants (5°C) throughout the year, and it is rainfall that marks the progress of the seasons. Summer is the dry season, while spring, winter, or autumn are the times of year when rain might be anticipated. The impression provided by the mean annual figures, many of which are comparable with those of northern European sites, are deceptive because they disguise the seasonal pattern and the huge losses to evaporation and transpiration that often leave less than 25 percent of the rainfall to meet local water demands, of which agriculture is commonly the most important. Many agrarian activities tend to be circumscribed by water availability, and from Roman, and more certainly Moorish, times, irrigation schemes of a complexity and sophistication not found elsewhere in western Europe have created some unique landscapes and administrative structures, including long-standing institutions such as famous Tribunal de las Aguas de la Vega de Valencia. This venerable foundation dates from at least the medieval period and governs water supply to the many irrigated holdings in the *huerta* that still exist around the city (Glick, 1970). Historical climatic studies have yet to exploit fully the documentary sources available in Spain and Italy, and elsewhere they have scarcely been examined in any detail; the study by Font Tullot (1988) of Spain's climatic history is uniquely comprehensive for the region. He points to some themes that Iberia shares with its northern neighbors: the cold winters of 1708–9 and 1716–17, with warming then characterizing the next three decades as Spain also began to recover from the most intense phase of the Little Ice Age. Cold conditions returned, as they did elsewhere, in the great winter of 1739–40, and in a description reminiscent of those who portrayed in words the famous frost fairs on the Thames, Rico Sinobas observed of the effect of great frost on the river Pisuerga in Valladolid: "throughout the river remained frozen to a great depth, people crossed it as if it were a field. They danced, took teas and played games" (1854: 25). Such cold conditions, which continued to plague the country for much of the century, brought heavy snows, exacerbated by Spain's mountainous character and generally elevated nature. The century overall was characterized by storms and frequent heavy rainfall. Barriendos Vallve and Martín-Vide (1998) found that the Mediterranean littoral was particularly subject to severe rainfall events between 1760 and 1800. In Andalusia, Rodrigo et al. (1999) have demonstrated again that it is rainfall, either through an abundance or through deficiency, that exercises the principal control over agriculture. They suggest that the poor harvests of 1750, 1751, and 1752 were the result of drought, while those of 1764, 1765, 1768, and 1770 were a consequence of floods and excessive rainfall. Summers were, as always, dry, but widespread droughts were less frequent than has been the case since, although that of the temporary warm phase of 1749–53 stands out. Local droughts occurred, and that of 1718–25 in Aragon was severe enough to all but destroy local agriculture. There were similar local problems in the Mediterranean coastal areas and Balearics in 1772–4, but the Kingdom of Naples escaped the worst consequences of the subsistence crisis that marked at that time the lands to the north of the Alps.

Severe weather doubtless caused problems, but the general availability of water did much to promote agriculture in the years following the uncertainties of the War of the Spanish Succession. It might also have provided an important basis for the developments brought about by the reforming Charles III (r. 1759–88). It was, however, generally recognized that Spain's agricultural system was backward in terms of capital, land tenure, and technology. This left it always vulnerable to the natural vicissitudes of climate to a degree unknown in other more developed agrarian economies. Charles III's reform moved some way to improving the situation (Vicens Vives, 1969), but Spain, and indeed other Mediterranean nations, continued to labor under this handicap of environmental vulnerability.

Conclusion

The political and cultural diversity that characterized Europe is matched by its environmental, geographic, and climatic divisions, and the foregoing case studies and examples warn against offering generalizations concerning the interactions between these physical factors and social systems. This is not, however, to deny that such connections exist. Then, as now, societies at all stages of social and economic development can find themselves vulnerable to the seemingly capricious, sometimes devastating, consequences of extreme weather and climate. As a measure of the continuity of the vulnerability of societies to natural disasters, the victims of famine, flood, and drought in eighteenth-century Europe would have identified with the residents of the more exposed districts of New Orleans in the aftermath of hurricane Katrina in 2005.

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