Chapter 2
The European Mortality Crises of 1346–52 and Advent of the Little Ice Age

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Abstract Between 1315 and 1352 populations in first northern, then southern and finally the whole of Europe succumbed to a succession of devastating mortality crises. These derived from a common episode of climatic instability generated by global processes of climate reorganisation. From the 1330s, climate forcing grew in strength until between 1342 and 1353 all parts of Eurasia were experiencing exceptional levels of environmental stress. This was the context for the poor harvest of 1346 in northern Europe and failed harvest of that same year in southern Europe, plus concurrent arrival of plague in the Crimea following is long westward migration from its reservoir region in the Tibetan-Qinghai Plateau of western China. In Europe the human impact of this conjuncture of climatic and biological extremes was amplified by escalating warfare and onset of a severe commercial recession. The notorious mortality crises of 1346–52 thus emerge as a multi-causal and multi-dimensional disaster.

Keywords Climate change · Extreme weather · Harvest failure · Famine · Plague · 1340s

The innate seasonal and annual variability of weather in temperate Europe meant that harvest shortfalls were an unavoidable feature of pre-industrial economic life. Moreover, the effect of the transition to the atmospheric circulation patterns of the Little Ice Age (LIA) was to heighten that variability. In England, for instance, during the 200 years spanning both the Wolf (c. 1282–1342) and the greater part of the Spörer (c. 1416–1534) solar minima (Stuiver and Quay 1980), between 1270 and 1480, one grain-harvest in nine delivered a net yield at least 20% below trend (Campbell and Ó Gráda 2011, 865). Especially to be dreaded were the back-to-back failures of this magnitude that occurred on average two to three times a century, for, at the least, these caused serious subsistence crises and, at the worst, major famines, when populations suffered a net loss as fertility slumped and mortality soared. In these

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crisis situations, deaths from starvation and hunger-related diseases reflected both the absolute supply-side deficiency of food and the demand-side inability of many of the poorest and most vulnerable individuals and households to gain licit access to such food stocks as were available. Social and economic factors, therefore, in the absence of effective institutional counter measures, typically compounded and sometimes greatly amplified the human consequences of bad weather.

Agricultural producers obviously did what they could to mitigate the risks of harvest failure by cultivating a mix of winter-sown and spring-sown crops and combining arable with pastoral husbandry but were effectively powerless when confronted by extreme weather events that depressed output across the board and over a geographically extensive area. High storage costs meant that carryovers of food stocks from one year to the next were always small and were soon exhausted when harvests failed in consecutive years. Prior to the development of long-distance bulk supply networks that tapped into different climatic zones, external sources of relief food supplies were limited and costly to obtain, especially for inland localities lacking cheap water transport. Major cities often succeeded in securing relief grain supplies, their rural hinterlands did not (Jordan 1996, 146–147, 161–162; Keene 2011; Jansen 2009, 22–23). Inadequate transport infrastructures, imperfect markets, ineffective governments, significant numbers of households and individuals living below the poverty line, and the want of systematic welfare provision beyond Christian charity all meant that malnutrition became rife and excess deaths difficult to prevent when harvests failed in successive years.

Late-medieval chroniclers commonly commented upon the links between bad weather, poor harvests, high food prices, hunger, and famine deaths among poor people (Schofield 2013, 74–76). Verification of these assertions is provided by independent palaeo-climatic evidence of weather conditions, the historical record of grain harvests and prices, and occasional archaeological finds of mass burials of economically, socially and demographically marginalised individuals (Connell et al. 2012), notably malnourished parentless, landless and jobless young males and females. In England the acute scarcities of 1202–1204, 1258 and 1295/96, all of them the result of back-to-back harvest failures, are well documented (Campbell 2016, 57, 61, 201–202), as are those of 1282 and 1286 in Tuscany (Herlihy 1967, 123). In each case annual prices of staple bread grains rose by between 50 and 100%. These thirteenth-century crises occurred notwithstanding the still prevailing relatively stable and benign climatic conditions of the Medieval Climate Anomaly and the momentum of economic expansion established by the medieval commercial revolution (Campbell 2016, 30–133), which demonstrates that setbacks could and did occur even at the best of times.

Significantly, none of these thirteenth-century subsistence crises constituted more than a temporary interruption to the strongly rising population trends then prevailing in England, Italy and Europe as a whole (Fig. 2.1). On the contrary, over the course of that century Europe's population grew by over a third and Italy's and England's by approximately half. In fact, on the bishop of Winchester's large multi-manorial complex of Taunton in Somerset the 1258 food crisis had no observable effect upon the rising numbers of adult males in tithing and even during the more straitened conditions of the 1290s numbers of recorded males held more-or-less steady, before rising to a temporal peak in the 1310s (Titow 1961, 224, revised by Christopher Thornton). No matter how grim these thirteenth-century famines may have been for those exposed to them, demographically and economically they were essentially transitory events. Not so the famines and harvest failures of the next century.

During the first half of the fourteenth century serious harvest failures occurred in increasingly close succession in both northern and southern Europe and, in both regions, at the point when population growth ceased and decline set in (Fig. 2.1). The greatest of these famines have consequently acquired a prominence in the historiography of the period, especially in those neo-Malthusian analyses that emphasise the imbalances that had arisen between population and available resources on the one hand and the diminishing returns to both land and labour on the other (Abel 1935, 1980; Postan 1966; Hatcher and Bailey 2001, 21–65). By any standard they were certainly unusually severe events, whether measured by the sheer scale of the precipitating food-availability decline, the magnitude of the consequent socio-economic stress, or the numbers of those who perished (Campbell 2010, 284–313). Levels of price inflation were unprecedented (Fig. 2.2a) and the real wage rates paid alike to building labourers (Fig. 2.2b) and farm labourers plunged to their lowest levels on historical record (Munro no date; Clark 2007, 2009).

During the Great Northern European Famine of 1315–1318, so great was the mismatch between supply and demand that in England, in breach of thirteenth-century precedent, oats prices doubled and those of barley and wheat trebled (Fig. 2.2a). That substantial excess mortality occurred both here and across northern Europe is beyond doubt, with the worst affected communities and regions sustaining net population losses of approximately 10% (Jordan 1996, 117–122, 146–148; Campbell 2009, 42–44). A dozen years later, in 1329/30, it was southern Europe's turn to suffer. Here, too, the scale of the harvest shortfall sent prices soaring and the purchasing power of labourers' daily wage rates tumbling (Fig. 2.2a, b). In hard-pressed Florence only determined action by the civic authorities in the form of the bulk purchase of imported southern Italian grain and subsidised sale of bread baked in the commune's own ovens prevented the situation from escalating out of hand (Jansen 2009). Few other cities, however, proved to be as resourceful (Herlihy 1967, 124) and problems were particularly acute in the countryside where most people had to fend for themselves.

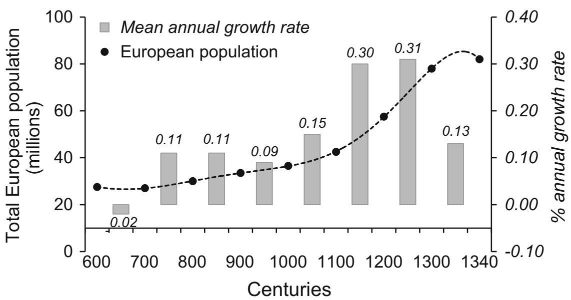


Fig. 2.1 Estimated total European population and average annual growth rates, AD 600–1340 (*Source* Biraben 1979, 16)

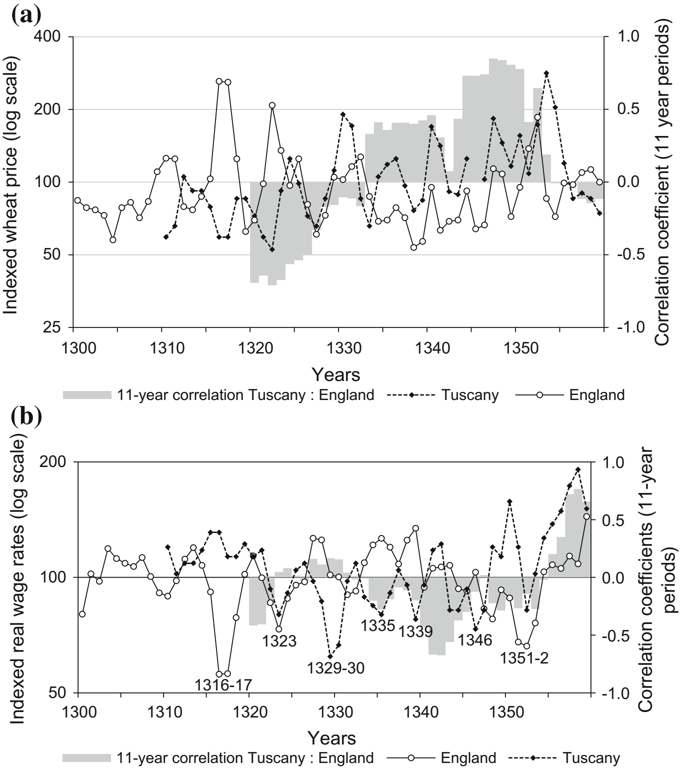


Fig. 2.2 **a** Indexed annual English and Tuscan wheat prices (100 = mean 1310–49) and the correlation between them (11-year periods, end-year plotted) (*Sources* Farmer 1988, 790–1, 1991, 502; Malanima no date). **b** Indexed annual English and Tuscan building labourers' daily real wage rates (100 = mean 1310–49) and the correlation between them (11-year periods, end-year plotted) (*Sources* Munro no date; Malanima 2012)

It is difficult to deny that these great crises arose in part because of the enlarged proportion of the population living on or below the poverty line, as defined by the ability to afford the more abundant and better quality respectability basket of consumables rather than some version of the inferior bare-bones consumption basket (Broadberry et al. 2015, 215–216, 328–330). The cumulative effect of generations of population growth (Fig. 2.1) had reduced many in the countryside to the status of semi-landless small holders, while the populations of most towns and cities had been swollen by an influx of landless rural migrants (Rutledge 1988, 28; Kowaleski 2014, 593–596). In England by the close of the thirteenth century, where average population densities were more than double the European average and maximum densities, at over 60 per km^2, were four times that average (Campbell and Barry 2014, 66–68), small holders, cottagers, agricultural labourers and rural artisans collectively accounted for over three-quarters of all rural households. Together, they occupied just a third of all the arable land and received less than half of total rural incomes (Campbell 2016, 168–170). Processes of subdivision, sub-letting and piecemeal reclamation had stoked the multiplication of these immiserated households and the morcellation of the holdings from which they struggled to eke out a living, augmented by whatever else they could earn from casual labouring and an assortment of by-employments (Campbell 2005). The situation was little different in rural Tuscany and was especially pronounced in northern France and the southern Low Countries, where population densities often exceeded 70 per km^2 (Pounds 1973, 332, 337; van Bavel 2010, 283). By the 1330s Guy Bois (1984, 287) considers that three-quarters of the population of Normandy were "wretched smallholders with 1–2 acres of land". Survival of numbers of these households was threatened whenever harvests failed, prices soared, wage-earning opportunities withered and tax demands rose.

The challenge of economic survival would have been less acute had market-generated economic growth of the sort envisaged by Adam Smith created supplementary means of earning a livelihood outside of agriculture. That, after all, had been the case for much of the twelfth and early thirteenth centuries when Europe's demographic expansion had been underpinned by an equally dynamic commercial revolution (Lopez 1971; Campbell 2016, 85–130). But from the 1290s the European economy was in the grip of a deepening commercial recession which reinforced the traditional economic reliance upon primary production and fed the hunger for land. Responsible were military and commercial setbacks in the Levant; a tightening Mamluk monopoly upon Red Sea trade with India and the Orient; punitive papal embargoes upon Christian trade with the Sultan of Egypt; interference by the French Crown in the hitherto politically neutral operation of the Champagne Fairs and discrimination against the many Flemish and Italian merchants who traded there; the increasing risks to trade and traders almost everywhere presented by armies, war bands, brigands, pirates and corsairs; and successive bankruptcy of the Sienese and Florentine banking companies (Campbell 2016, 135–142). Traffic still flowed along Europe's commercial arteries, and those that connected Europe with Asia, but it was reduced in volume and subject to higher tolls. It also increasingly fell foul of the depredations of rent-seeking lords and war-mongering monarchs.

Figure 2.3a illustrates some of the more quantifiable of these developments: a fall of at least 75% in the seigniorial revenues generated by the English international fairs of St. Giles Winchester and St. Ives (Huntingdonshire) between 1285 and the 1340s; an 80% reduction in tax receipts from the Champagne Fairs between 1295 and 1340; a halving of the rental values of Cheapside property in central London between 1305 and 1335; a 73% decline in the value of English overseas trade handled by alien merchants between 1300 and 1335; and (Fig. 2.3b) an upsurge in English net tax receipts following Edward III's declaration of war against France in 1337. Collectively, this evidence leaves little doubt that national and international trade had declined to a particularly low ebb by the 1330s and 1340s. As Munro (1991, 120–130) has highlighted, deteriorating security on the old trans-Alpine overland routes, piracy on the alternative but more circuitous and costly shipping route between the Mediterranean and North Sea, and the manifold delays,

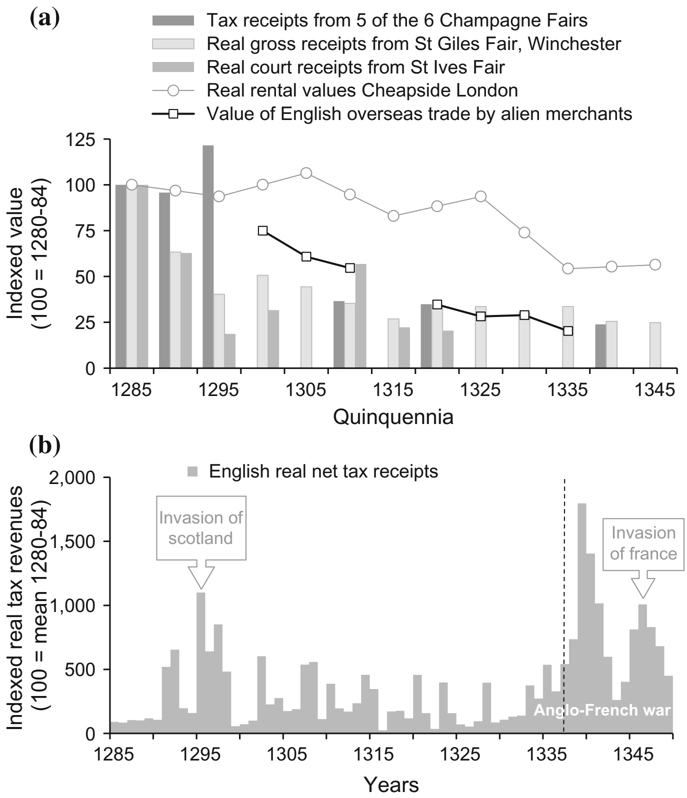


Fig. 2.3 **a** Indicators of contracting international commerce, 1285–1345 (*Sources* Edwards and Ogilvie 2012, 137; Titow 1987, 64–5; Moore 1985, 208; Keene 1984; Lloyd 1982, 210–24). **b** England: total deflated net receipts from direct and indirect taxation, 1285–1349 (*Source* Ormrod 2010)

disruptions and upsets of war were increasing risks all round and therefore greatly elevating transaction costs. This narrowed the range of commodities capable of being traded for a profit at a distance at the very time that overseas markets were themselves becoming less accessible to European merchants. The most obvious casualty was the cheap, light northern cloth once manufactured and traded in quantity to Mediterranean markets. By the second quarter of the fourteenth century English manufacture of these textiles was in advanced decline and Flemish producers were switching to high-quality luxury woollens, although this provided only partial compensation for loss of the once profitable *says* manufactory (Munro 1991, 110–116, 1999). Since textile manufacture was northern Europe's single largest industrial source of employment, legions of households found their livelihoods squeezed or jeopardised. This, of course, had negative multiplier effects for many other activities. Europe's long commercial boom was over and self-reinforcing economic decline was eroding employment opportunities, depressing earnings and

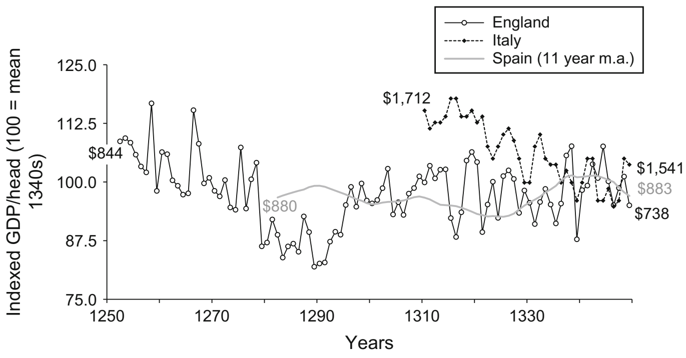


Fig. 2.4 Indexed GDP per head England (1252–1349), Spain (1282–1349) and the centre and north of Italy (1310–1349) (*Sources* Broadberry et al. 2015, 227–229 with additional estimates by Bas van Leeuwen; Álvarez-Nogal and Prados de la Escosura 2013, 14; Malanima 2011, 205)

depleting the limited welfare resources available to relieve food crises: the social and demographic consequences of harvest failure were increasingly grave.

These were not materially rich societies to begin with and even the most successful—Flanders and the centre and north of Italy—were undoubtedly becoming poorer. For the latter, Malanima (2011) has made annual estimates of national income. These indicate a 16% contraction in Gross Domestic Product (GDP) per head between 1310 and 1347, from over $1700 to barely $1400 ($1990 international), with notable, mostly harvest-driven, downturns in 1322/23, 1329/30, 1339 and 1346 superimposed upon this declining trend (Fig. 2.4). The worst year of all, 1346, when the last of the great Florentine mercantile societies finally failed (Hunt and Murray 1999, 116–117), was also a year of harvest crisis (Herlihy 1967, 105). The city's diminished finances meant that relieving that putative famine presented a far greater challenge than the earlier and more acute shortfall of 1329/30 (Jansen 2009).

England was barely half as rich as the centre and north of Italy and its service and industrial sectors were correspondingly less developed (Broadberry et al. 2015, 194–196, 374–375). It was a comparatively poor economy specialising in primary production with most value-added activities geared towards domestic consumption. Its GDP per head ranged between peaks of around $900 in the most prosperous years of the third quarter of the thirteenth century and troughs of less than $700 when murrain devastated the national wool clip and bad weather ruined harvests. National income growth failed to match population growth for most of the second half of the thirteenth century but GDP per head then recovered somewhat as population growth eased. Thereafter, during the first half of the fourteenth century, the economy bottomed out and a state of zero growth prevailed punctuated by the sharp contractions of 1315/16, 1321 and 1339 (Fig. 2.4). In such a poor society, so heavily dependent upon agriculture for food, industrial raw materials and export earnings, it is hardly surprising that agricultural output failures should have squeezed national income hard. It is perhaps more surprising that each crisis was followed by a recovery to the *status quo ante*. Recovery to the modest prosperity of the 1250s, however, required more sustained growth and under the commercial, economic and demographic circumstances then prevailing that proved unattainable.

The Spanish economy similarly appears to have been locked into a state of zero growth (Fig. 2.4). Its GDP per head of less than $900 remained much the same in the 1340s as it had been in the 1280s. Unlike England, land-abundant and labour-scarce Spain's lack of growth had little to do with resource constraints and much more with Europe's general loss of commercial dynamism at this time (Álvarez-Nogal and Prados de la Escosura 2013). For an economy at its level of development, coping with significant harvest shortfalls, as in 1301, 1331–1333 and especially 1344–1347, posed a significant challenge (Oliva Herrer 2013, 97–102, 106–109).

For these and other countries, war was a key ingredient of the deteriorating economic situation and greatly aggravated the plight of populations during some of the most testing of these years. For example, in 1296 the heavy taxes that underwrote Edward I's invasion of Scotland compounded the hardship arising from the run of seven consecutive poor harvests from 1289 to 1295 (Figs. 2.3b and 2.6a) (Schofield 1997). Thirty years later, during the washout harvests of the Great Northern European Famine, fortunes were reversed and England became the target of hit-and-run Scottish raids following Edward II's crushing defeat at the Battle of Bannockburn in June 1314 (McNamee 1997, 72–122, 169–186; Campbell 2010, 290–291). Distracted by the Scots pouring south over the border, there was little the royal government could do to alleviate the disaster of famine unfolding at home beyond enforcing traditional regulatory measures on baking and brewing, encouraging grain imports and prohibiting exports (Sharp 2013). This did, however, provide a precedent for future government responses to dearth and famine. Those in the north of England who bore the brunt of both the Scottish attacks and the relentlessly wet weather naturally suffered the worst, especially as local civic and ecclesiastical infrastructures of relief and stocks of grain fell victim to the raiders (Kershaw 1973, 14–16, 25–26; Sharp 2013, 631). The situation in the Lordship of Ireland was even graver, for in 1315 it had been invaded by a Scottish army ruthlessly intent upon living off the land and destroying the Lordship's capability to support English military activity in Scotland. Financially and demographically, the Lordship of Ireland never fully recovered from this double disaster (Lydon 1987).

Ireland's experience was not unique. Across Europe, wars fought for a mixture of dynastic, feudal, political, religious, territorial and commercial reasons were on the increase (Munro 1991, 121–127). Everywhere they disrupted trade and commerce, drove up transaction costs, diverted scarce resources to military ends, bankrupted creditors, destroyed capital stock, undermined such limited welfare resources as were available, spread diseases and generally added to the misery of many. Militarily, probably no decade was more punitive in these respects than the 1340s, as bitter and ruinous conflicts erupted between rival Christian dynasties and states, between Christians and Muslims, and between competing Mongol and Muslim khanates (Campbell 2016, 267–276). In the west, England invaded France and Scotland invaded England. In the south, the old rivalries and conflicts continued between the Guelphs and Ghibellines and the Genoese and the Venetians, Florence fought Pisa for control of Lucca, and in southern Italy and Sicily the Angevins fought the Aragonese. To the east, the Byzantine Empire succumbed to a debilitating civil war, to the advantage of the encircling power of the Ottomans. On the Black Sea, the Venetians at Tana and Genoese at Kaffa fell foul of the Kipchak Khanate. In Persia and Syria the Kipchak Khanate fought the Il-Khanate and the Il-Khanate fought the Egyptian Mamluk Sultanate. And in the eastern Mediterranean the papacy enforced its embargo on Christian trade with Muslims and especially the Egyptians. These conflicts, and the crime, piracy and brigandage which they spawned, drove the international commercial economy deeper into recession (Figs. 2.3a and 2.4) and, for those directly or indirectly ensnared in them, heightened the susceptibility to major harvest failures.

The situation would have been serious enough if the risk of harvest failure had remained constant but, instead, that risk was increasing as climatic instability, and the concomitant incidence of extreme weather events, rose. By the 1270s the era of high solar irradiance responsible for the Medieval Climate Anomaly had ended and as the Wolf Solar Minimum started to bite (Fig. 2.5) the transition began to the cooler global temperatures and altered and less stable atmospheric circulation patterns that characterised the LIA (Campbell 2016, 2–6, 198–208). As Fig. 2.5 illustrates, the year-on-year variability of temperatures, rainfall and growing conditions increased, as expressed by the rising variance of annual northern hemisphere and North Atlantic sea-surface temperatures, the band widths of a Scottish speleothem (a proxy for annual precipitation), and the ring widths of British Isles oaks

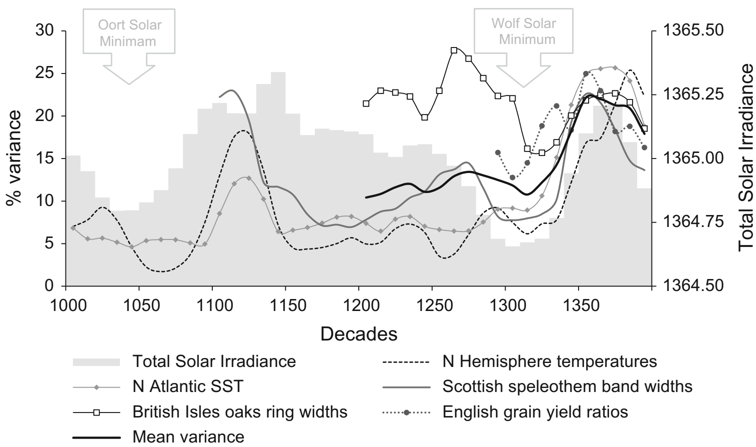
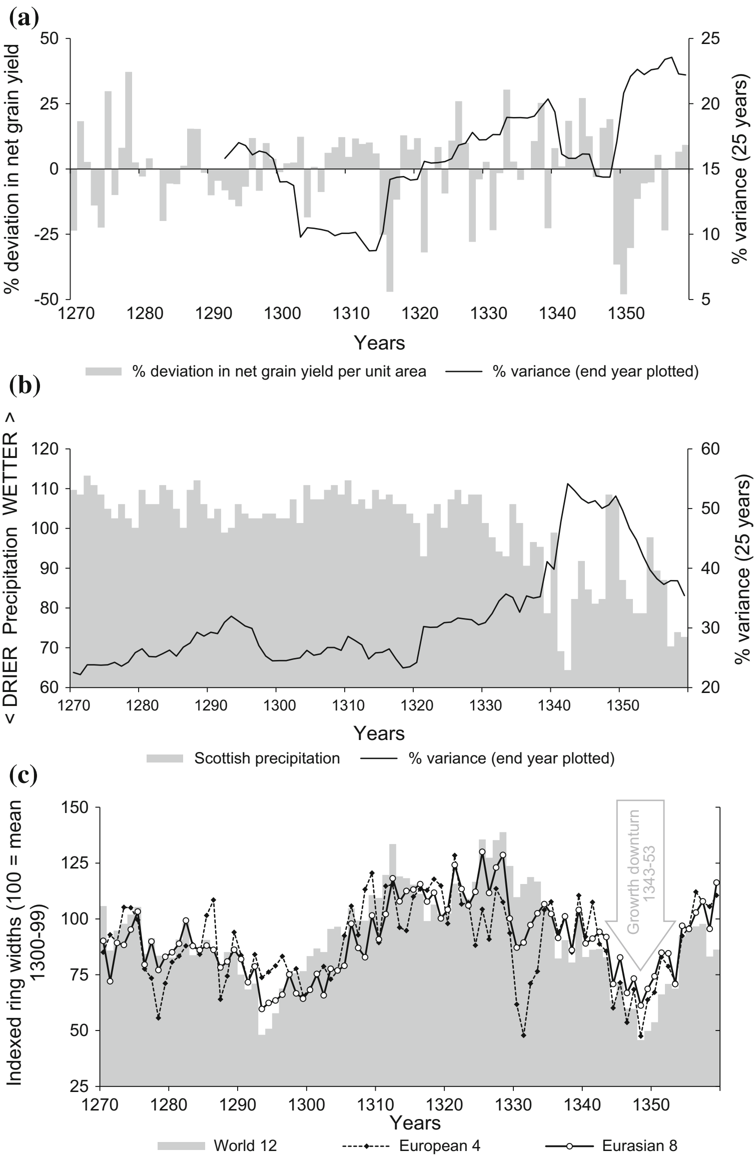


Fig. 2.5 Total Solar Irradiance and percentage variance as an indicator of the level of environmental instability, 1000–1399. Total Solar Irradiance is the mean of the chronologies derived from ice cores and tree rings. Variance is calculated for 51-year (grain yields 25-year) moving periods and end-year plotted, then 5-year smoothed. The variance of grain yields is for a combined index of wheat, barley and oats yields gross of tithes and net of seed (*Sources* Delaygue and Bard 2010; Vieira et al. 2011; Mann et al. 2008; Proctor et al. 2002; British Isles oaks ring widths (25-series master chronology), data supplied by M.G.L. Baillie; Campbell 2007)



and yields per seed of southern English grain crops (proxies for growing conditions). In all five of these independently estimated paleo-climatic proxy series the amplitude of annual variations was becoming magnified, resulting in a doubling, on average, of the level of variance between the 1320s and 1350s. In northwestern Europe this meant that the weather was becoming more unsettled, bringing heightened ecological stress and an increased risk of harvest failure and crop and

◀**Fig. 2.6** **a** Percentage variance of, and percentage deviations from trend in, English net grain yields per unit area, 1270–1359. **b** Scottish precipitation index (100 = mean 1270–1359) based on the band widths of a speleothem from Cnoc nan Uamh Cave, 1270–1399, and percentage variance of those band widths. **c** Ring widths of temperate trees as a proxies for global, Eurasian and European growing conditions, 1270–1359. *Notes* **a** Net grain yields are gross of tithes and net of seed; yields of wheat, barley, and oats are combined using the ratio 2:1:1. **a** and **b** Percentage variance of grain yields and speleothem band widths is calculated for 25-year moving periods and end-year plotted. **c** The 4 European chronologies are European oaks, Fenoscandian pines, Polar Urals pines and Alpine conifers; the 4 Asian chronologies are Tien Shan junipers, Qinghai junipers, Mongolian Siberian larch and Siberian Siberian larch; the 4 non-Eurasian chronologies are North American bristlecone pine, Chilean and Argentinan fitzroya, New Zealand cedars and Tasmanian huon pine. All chronologies are indexed on 1300–99 and standardised to have the same coefficient of variation. (*Sources* Campbell 2007; Campbell and Ó Gráda 2011, 866; Proctor et al. 2002; European oak and pine, Siberian larch, North American bristlecone pine, Chilean and Argentinan fitzroya, New Zealand cedars and Tasmanian huon pine chronologies supplied by M. G.L. Baillie; Tien Shan juniper chronology supplied by Jan Esper; other chronologies from Büntgen et al. 2011; Yang et al. 2014; Jacoby et al. no date)

livestock diseases in its train. For the growing numbers living close to the margin of subsistence, life was becoming increasingly precarious. In effect, climate change was elevating the risks of serious supply-side food shortages at precisely the time that population pressure, commercial and economic contraction and escalating warfare were rendering society less able to cope with them (Campbell 2016, 253–261).

English harvests of wheat, barley and oats are exceptionally well documented across this pivotal period by annual manorial accounts and a small but significant corpus of tithe accounts (Fig. 2.7a). Figure 2.6a plots the combined net yield per unit area of the winter and spring grains (wheat, barley and oats, weighted using the ratio 2:1:1) as percentage deviations from trend, together with the variance calculated on the raw data for moving 25-year periods and end-year plotted. The consecutive sub-standard yields of 1289–1295, culminating in the back-to-back failures of 1294/95, when harvests were respectively 12% and 14% below trend, show up clearly. A lull of 20 years then followed, when variance declined, there were no back-to-back shortfalls, and the 1304 harvest alone was seriously deficient, with an 18.5% shortfall. The washout harvests of 1315–1317, respectively 25, 47 and 12% below trend, were therefore effectively bolts from the blue (Fig. 2.6a). These are the shortfalls responsible for the Great Northern European Famine of these years, when inflation of grain prices reached unprecedented levels (Fig. 2.2a), environmentally induced sheep murrains devastated flocks and depressed wool output, and the Great European Cattle Panzootic began is inexorable westward spread through the mixed-farming regions of northern Europe from Bohemia in 1316, to England in 1319 and eventually Ireland in 1321 (Newfield 2009, 159–163). The 32% harvest shortfall of 1321 (Fig. 2.6a) represents the sting-in-the-tail of this extended seven-year crisis, which stands out as the first and geographically most widespread famine of the LIA in northern Europe. Northern Europe's loss was, however, southern Europe's gain, for the latter was spared the inclement weather and, instead, experienced bumper harvests, as manifest in the low Tuscan wheat prices of 1316,

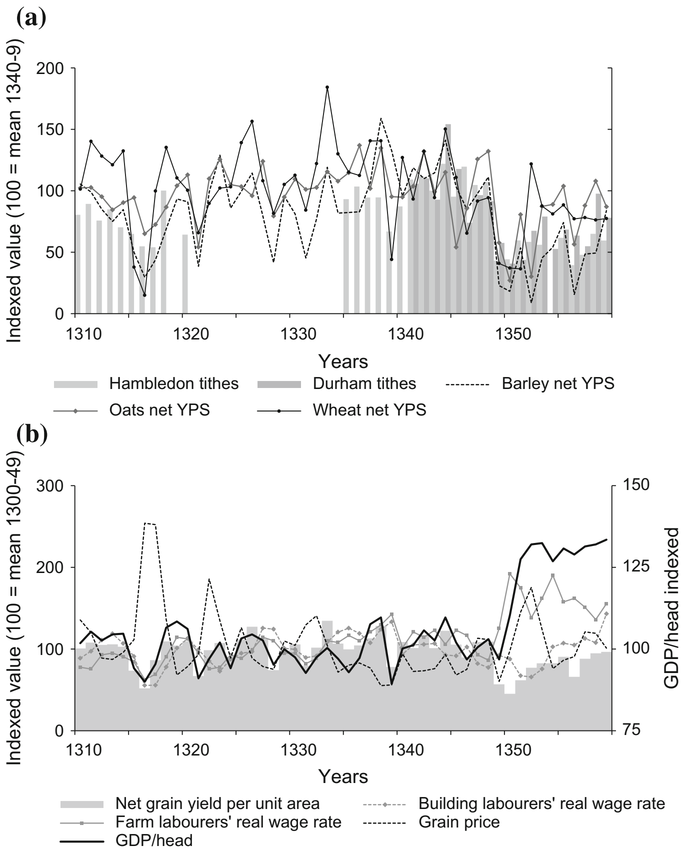


Fig. 2.7 **a** English grain harvests (100 = mean 1340–49), 1310–59. **b** English grain yields, grain prices, the daily real wage rates of farm labourers and building labourers, and GDP per head, 1310–59. *Notes* **a** Wheat, barley and oats yields per seed are gross of tithes and net of seed. **b** Grain yields per unit area are gross of tithes and net of seed; yields of wheat, barley, and oats are combined using the ratio 2:1:1 (*Sources* Campbell 2007; tithe data for Hambledon, Hants., and Co. Durham parishes supplied by Ben Dodds; Farmer 1988, 790–1, 1991, 502; Munro no date; Clark 2009; Broadberry et al. 2015, 227–229)

1317 and 1322 and shipments of grain from the Mediterranean to northern Europe (Fig. 2.2a). The contrast between weather and harvest conditions in England and Tuscany at this time is evident in the strong negative correlation of at least −0.5 that prevailed between wheat prices in the two countries until 1325 (Fig. 2.2a).

The twenty years that followed the Great Northern European Famine were entirely different from those that had preceded it. The variance of English grain yields rose significantly, as harvests swung between bad and good, but with abundant harvests, including the back-to-back bumper harvests of 1325–1327 and 1337/38, outnumbering deficient (Fig. 2.6a). At the same time notable Tuscan wheat-price spikes in 1329–1331, 1335/36, 1340/41 and 1347 indicate that southern Europe was now being penalised by repeatedly bad and unseasonable weather (Fig. 2.2a). More intriguingly, the correlation between wheat prices in Tuscany and England swung from negative to positive (Fig. 2.2a). Given the worsening commercial and economic environment, especially the rising transaction costs in international trade, it seems improbable that this price correlation is to be explained by closer integration of southern and northern European grain markets. Instead, stronger climate forcing and onset of autocorrelation between northern and southern European weather patterns are the more likely over-arching causes. Thus, from 1328 to 1333, while wet weather was ruining harvests in southern Europe (and boosting growth of Atlantic cedars in northern Morocco (Esper et al. 2009), English grain producers were experiencing a mixture of cold, hard winters and unusually dry summers: hence the poor English harvests of 1328 and 1331 but bumper harvest of 1333 (Fig. 2.6a, b). Again, in 1339 bitter winter cold in northern Europe proved to be the counterpart of excessive rain in southern Europe and triggered a sharp rise in wheat prices in both regions, albeit with southern producers getting the worst of the deal (Fig. 2.2a). 1346 was another bad harvest year in both regions. But whereas Florentine chronicler Giovanni Villani lamented, “not in a hundred years had there been such a bad harvest of grain and fodder and wine and oil and everything else in this country as there was in this year […] all because of too much rain” (Jansen 2009, 22), on the Winchester estates in southern England it was a wet winter followed by an extended summer drought that depressed grain yields (Titow 1961, 399–400). Crucially, therefore, and in direct contrast to the situation in 1315–17, by the 1330s and 1340s when the weather turned bad the whole of Europe seems to have been adversely affected to some degree and in one way or another. If wheat prices are taken as a crude proxy of harvests, the consistently strong positive correlation between Tuscan and English wheat prices from 1334 to 1349 implies that climate forcing of growing conditions across the continent had become exceptionally marked (Fig. 2.2a).

The annual band widths of a speleothem from the Cnoc nan Uamh cave system in northwestern Scotland capture the marked changes in atmospheric circulation and associated precipitation that were taking place (Fig. 2.6b), as the North Atlantic Oscillation weakened, polar high pressure became more dominant and the North Atlantic winter westerlies shifted south (Proctor et al. 2002; Trouet et al. 2009). Scottish rainfall in 1321 was the lowest in 100 years, 1329–1333 (when Morocco experienced the wettest weather in at least three centuries) were drier still, and 1339, when deep winter cold enveloped the whole of Britain (Britton 1937, 139; Titow 1961, 396–397), the driest year in over 250 years. This trend towards colder and drier winters was, however, fitful, with the result that the variance of speleothem band widths rose dramatically throughout the 1320s and 1330s, to a peak in the early 1340s (Figs. 2.5 and 2.6b). Instability was exceptionally pronounced during that environmentally most stressful of decades: 1342 delivered the lowest rainfall since the 1070s but then in 1348 and 1349 the winter westerlies rebounded to their previous strength (Fig. 2.6b) and mild, wet, cyclonic winter weather briefly returned once again.

Contemporaries were well aware that the weather was behaving in unusual ways. As the Paris Medical Faculty reported in October 1348 (Horrox 1994, 161):

> For some time the seasons have not succeeded each other in the proper way. Last winter was not as cold as it should have been, with a great deal of rain; the spring windy and latterly wet. Summer was late, not as hot as it should have been, and extremely wet – the weather very changeable from day to day, and hour to hour; the air often troubled, and then still again, looking as if it was going to rain but then not doing so. Autumn too was very rainy and misty.

What they could not have known was that they were living through an episode of global climate reorganisation as the cumulative effects of the Wolf Solar Minimum reached their climax (Fig. 2.5). The climate changes then afoot had a depressing effect upon tree growth in temperate zones around the world. Twelve master dendrochronologies—four from Europe, four from northern Asia, one from North America and three from the southern hemisphere—collectively identify the years from 1343 to 1353 as a time of significantly reduced growth (Baillie 2000, 62–65; Baillie 2006, 33–38), with 1348 the nadir of that downturn (Fig. 2.6c). It is therefore unsurprising that in England the worst grain harvests on medieval record occurred at precisely this time (Fig. 2.6b) (Campbell 2009, 43–6).

Measured against trend, net grain yields per unit area were 10% below average in 1346 and then consistently deficient for the six consecutive years from 1349 to 1354, before failing again in 1356 (Fig. 2.6a). In a double back-to-back (i.e. three-in-a-row) failure of unprecedented proportions, the harvests of 1349–51 fell short by, respectively, 37, 48 and 30%. In 1350 the absolute grain yield per acre averaged a dismal 3.76 bushels per acre, the lowest of any year on record until the bitterly cold 1460s and 10% below the previous minimum of 4.16 bushels in the famine year of 1316. In fact, in their scale and duration the 1349–1354 harvest shortfalls eclipsed those responsible for the Great Northern European Famine of 1315–1317 (Figs. 2.6a and 2.7a). The same was true of tithe receipts recorded on the Hampshire manor of Hambledon, while those obtained on a group of County Durham manors confirm the magnitude of the drop in output in 1349–1351 and 1356/57 (Fig. 2.7a).

Yet, as massive as the supply-side failure was with winter-sown and spring-sown grains both equally affected, the price response was neither as immediate nor as dramatic as it had been in 1316 to 1318 (Fig. 2.7b). In part, this was because prices were initially restrained by monetary deflation, whereas those in 1316 to 1318 had been boosted by inflation, but it also reflected the fact that harvest failure had been accompanied by plague, so that demand contracted concurrently with supply. Indeed, the massive mortality of demesne managers and workers (in the south and southwest of England in 1348 and the rest of the country in 1349) undermined efforts to bring in the harvest and reinforced the negative effects of the adverse growing conditions upon grain production. Nevertheless, given the compelling independent evidence now available of the unstable and abnormal weather conditions prevailing at this time (Figs. 2.5 and 2.6b, c), there can be little doubt that had plague not intervened society would have become the victim of another "great famine" (Campbell 2011, 144–147), rendered all the harsher by the prevailing toxic mix of war, financial meltdown, commercial recession, economic contraction, shrinking employment and burgeoning poverty.

In southern Europe the major back-to-back harvest failure of 1346/47 marks the onset of this extended multi-dimensional crisis (Fig. 2.2). It was the latest of a succession of serious harvest shortfalls precipitated by the southerly shift in westerly rain-bearing winds and for Italy its timing could not have been worse, for the economic fortunes of this once thriving commercial economy were in advanced decline. GDP per head and the real wage rates of building labourers had been trending down for at least 30 years (Fig. 2.4), as rising transaction costs squeezed profits on its overseas trade, vital Levantine markets were lost, and a series of international credit crises reduced numbers of its leading merchant banks to bankruptcy. Italy may have remained the richest economy in Europe but, as its service and manufacturing sectors contracted, more and more households found their livelihoods compromised. Urban artisans were particularly vulnerable to shrinking employment, falling wages and rising food prices, to the concern of the more responsible civic authorities. Florence, its financial resources depleted by a futile war with Pisa, was not alone in finding that the demand for relief was in excess of its ability to match it (Jansen 2009, 22–23). Nor was there any imminent prospect of any easing of the straitened economic situation. The Flemish economy (Italy's leading northern European trading partner) was in even worse shape, Edward III was manipulating the English wool export trade to his own political ends, tough papal embargoes were squeezing the vital Venetian spice trade with Egypt, the Ottomans were continuing to encroach upon the shrinking rump of the Byzantine Empire, war was disrupting traffic along the Silk Road from China, and the Italian Black Sea colonies of Tana and Kaffa were under attack by Khan Jani Beg. Most ominously of all, in 1346 plague (*Yersinia pestis*) finally reached the Crimea from its core reservoir region of the Tibetan-Qinghai Plateau in Western China (Cui and others 2013) and over the course of the next 18 months was transmitted to Constantinople, the ports of the Aegean, Alexandria in Egypt, and, by autumn 1347, Sicily (Benedictow 2004, 61; Benedictow 2010, 585–587). Infection of Italy and Croatia followed and eventually, by November 1347, plague reached Marseille, striking at communities still recovering from the effects of the poor weather and harvest shortfalls of 1346/47. Punitively heavy mortality ensued.

The situation was scarcely better in northern Europe. Here, the poor harvest of 1346 accompanied a significant escalation in the dynastic and feudal conflict between England and France, necessitating renewed heavy tax demands in both countries (Fig. 2.3b). Normandy bore the brunt of a full-scale English military invasion, crowned with the successful siege of Harfleur and, in August of that year, crushing defeat of the French at the Battle of Crécy. Bois (1984, 277) believes that it was from this point that the once prosperous Norman economy began its long-term implosion. Scotland, Flanders, Spain and Italy all became directly or indirectly embroiled in this conflict in one way or another and in October defeat of a Scottish counter invasion of northern England and capture of Scots king David II similarly placed Scotland at the mercy of the English. Two years later plague struck all the combatants and in 1349 and 1350, as cold and wet weather ruined crops (Figs. 2.6b and 2.7a), spread far and wide throughout northern Europe, everywhere with the same devastating demographic consequences. Among this conjuncture of adverse human and environmental circumstances, none was more unfortunate than the advent of plague. Where earlier harvest shortfalls and famines had for the most part been transitory events, plague's intrusion into the human-environment equation transformed the agricultural output failure of the late 1340s and early 1350s into a watershed event (Figs. 2.7b and 2.8).

This double environmental disaster was no mere coincidence. The serial harvest shortfalls and eruption of the Second Plague Pandemic sprang from a common episode of acute environmental stress generated by processes of global climate re-organisation felt right the way across Eurasia (Campbell 2016, 277–289): witness the synchronous downturn in temperate tree growth across the Old World (Fig. 2.6c). Biological evidence incriminates the Tibetan-Qinghai Plateau in Western China as the most likely reservoir region from which the strain of *Yersinia pestis* responsible for the Black Death emerged around the time that the Medieval Climate Anomaly ended and the Wolf Solar Minimum began (Cui et al. 2013). Within this semi-arid continental region, ground-burrowing sylvatic rodents (susliks and marmots) had for centuries served as plague's maintenance hosts (Kausrud et al. 2010; Schmid et al. 2015). Possibly it was onset of a minor pluvial episode from 1310 that set in train a trophic cascade of greater vegetation growth, increased sylvatic rodent densities, higher burdens of flea vectors and wider dissemination of the *Y. pestis* pathogen, thereby advancing plague from a dormant enzootic to an active epizootic state (Stenseth et al. 2006). By 1338/39 it appears that plague may have spread westwards as far as Issyk-Kul, on a northern branch of the so-called Silk Road and at the easternmost extremity of the steppe grasslands that extended west to the Caspian Basin and beyond (Norris 1977, 10–11). Abrupt renewal of drought conditions in 1340 may then have triggered a mass die-off of plague's sylvatic-rodent maintenance hosts and adoption by the disease's flea vectors of

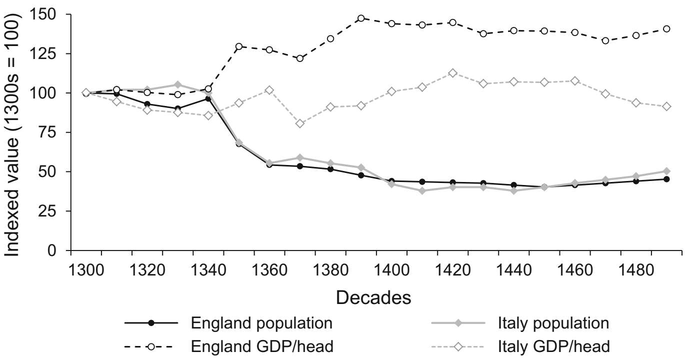


Fig. 2.8 The demographic and economic watershed of the 1340s in Tuscany and England (*Sources* Malanima 2011, 205; Broadberry et al. 2015, 227–229)

commensal rodents as substitute hosts. Since rats are far more susceptible to plague than marmots and susliks, this amplified plague from an epizootic to a more deadly and fast-spreading panzootic state. It will also have brought plague into more direct contact with humans and initiated rising numbers of zoonotic cases among them (Drancourt et al. 2006, 234).

The effects of climate change upon ecological conditions in the extensive semi-arid steppe grassland region extending east and west of the Caspian Basin, still crossed in the early 1340s by a steady flow of traffic along the various branches of the Silk Road, thus appear to have been material to the Black Death's first recorded historical appearance in the lands of the Kipchak Khanate between the Caspian and the Black Seas (Benedictow 2004, 44–54; Aberth 2005, 15–16), whence, in 1346, it spread to the Mongol army besieging the Genoese port of Kaffa on the Crimean coast (Schamiloglu 1993; Horrox 1994, 14–26; Wheelis 2002). Fleas, and possibly other ectoparasites, were the essential vectors of the disease's transmission; temperatures and humidity the environmental conditions that influenced levels of flea activity; dense populations of susceptible rodents and humans the preconditions for plague's spread; marching armies and commercial traffic the instruments of that spread; the ecologies of ships, cargoes, households and settlements the enabling circumstances that impelled the pathogen on its destructive path; and the prevalence of poverty, malnutrition and proto-famine conditions the economic factors that magnified exposure and diminished resistance to *Y. pestis* and ensured that overall death rates were exceptionally heavy.

Everywhere the soaring disease mortality confounded the normal relationships between bad harvests, high prices and low real wage rates. As the well-documented example of England demonstrates (Fig. 2.8), food availability declined dramatically but so, too, did the number of mouths to be fed. Buildings were suddenly in excess supply, so that demand for building labour slumped, but the Black Death's survivors still had to be fed with the result that agricultural labour now commanded a premium, hence the daily real wage rates of building and agricultural workers diverged. Since plague killed people but not coins, money supply per head rose and price inflation, reinforced by the prevailing poor harvests, followed. Finally, plague's brutal solution to the hitherto intractable problems of under- and un-employment and land-hunger and landlessness, allowed GDP per head to rise, doing so despite the continuing weather-induced depression of grain output per unit area (Fig. 2.7a). Whereas earlier harvest shortfalls and famines, no matter how great, had made little lasting difference to prevailing prices, wages and levels of GDP per head, the plague-accompanied shortfalls of the 1340s and 1350s altered their respective trajectories in fundamental ways (Fig. 2.8). Moreover, plague proved to be an enduring biological shock whose recurrence ensured that full recovery to pre Black Death levels of population and volumes of economic activity were long delayed (Fig. 2.9). The unique conjuncture of climate change, ecological stress, fast-spreading plague, harvest failure, war and widespread poverty thus ensured that this complex crisis became a watershed demographic and economic event.

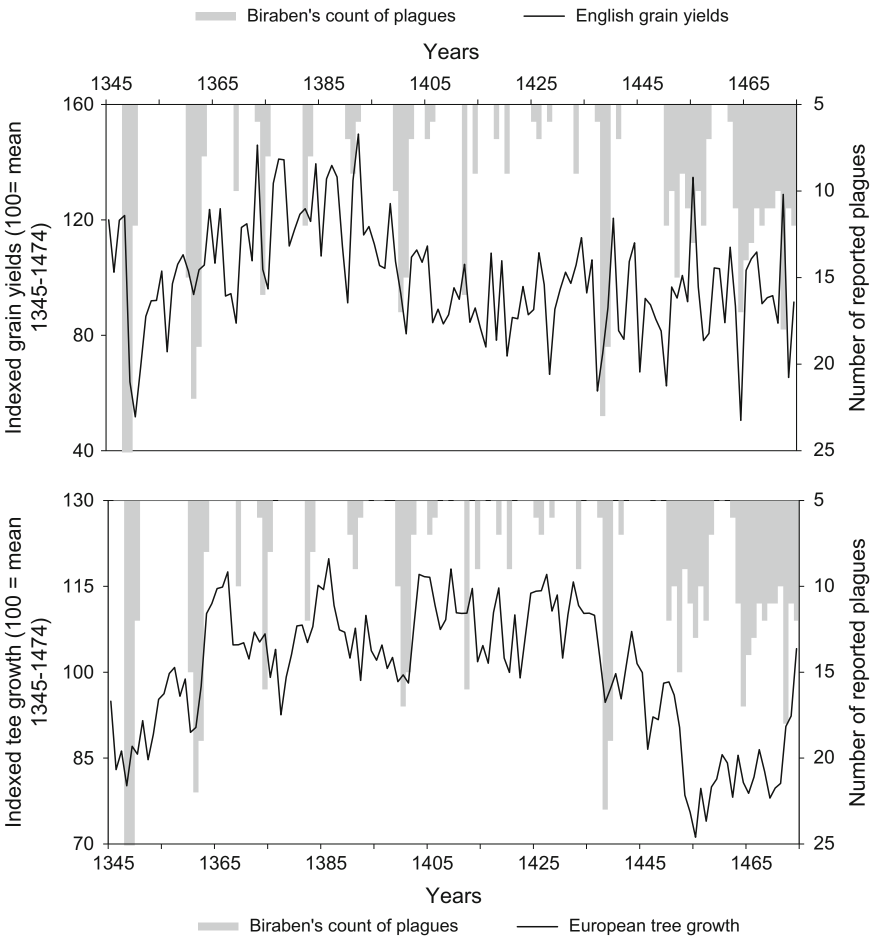


Fig. 2.9 English grain harvests, European tree growth and reported numbers of plague outbreaks in France, the Low Countries, Britain and Ireland, 1345–1475 (*Sources* Recorded references to plague outbreaks (minimum of 5 outbreaks) from Biraben 1975, 363–374; English grain yields per unit area gross of tithes and net of seed (yields of wheat, barley, and oats combined using the ratio 2:1:1) from Campbell 2007; European 5-series master dendrochronology supplied by M.G.L. Baillie)

Intervention of plague, among the most ecological of diseases and involving interactions between environmental conditions, rodent hosts, insect vectors and human carriers and victims, was the new ingredient that set the catastrophic harvest shortfalls of the 1340s apart from virtually all that had gone before. In this vital respect the 'famines' of the 1340s represented an ominous new departure. Henceforth, until almost the end of the seventeenth century, plague in Europe tended to act in concert with the extreme weather and ecological stress that were similarly responsible for harvest failure (Fig. 2.9) and, when it did so, wrought far greater prodigies of destruction than could be achieved by hunger alone (Wrigley and Schofield 1989, 332–336, 416). Of course, disease had long been responsible for most famine deaths, but following disappearance of the Justinianic Plague in the late eighth century, none had been as lethal. Whether the classic famine disease of typhus was yet present in pre Black Death Europe is unknown, smallpox had yet to acquire its later virulence, and neither diarrhoea nor dysentery was capable of killing on the same scale as plague. Consequently, where during the thirteenth century famine had proved powerless to prevent the relentless growth of population, from the mid-fourteenth century the alliance of physical and biological hazards helped thwart demographic growth for four to five consecutive generations (Fig. 2.9). Although poverty decreased and the living standards of many improved in the post Black Death world of labour scarcity and relative resource abundance, the heightened instability of LIA climates ensured that serious harvest shortfalls, as in England in 1361, 1367–69, 1375, 1390, 1400/01, 1428, 1437/38, 1441/42, 1449/50, 1457/58 and repeatedly from 1464, were still hazards to be feared and the more so because not unusually they brought plague and in due course other deadly diseases in their train. In these respects the harvest crises of the 1340s were the harbingers of things to come and exemplify the complexity and multi-dimensional character of the greatest human mortality crises.

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