Physical shocks, biological hazards, and human impacts: the crisis of the fourteenth century revisited


Published in:
Le interazioni fra economia e ambiente biologico nell'Europe preindustriale. Secc. XIII-XVIII (Economic and biological interactions in pre-industrial Europe from the 13th to the 18th centuries)

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Publisher's PDF, also known as Version of record

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Physical Shocks, Biological Hazards, and Human Impacts:
The Crisis of the Fourteenth Century Revisited

Abstract

The thesis of this paper is that biological hazards, be they brief and disastrous or prolonged and corrosive, acted within a physical environmental context, which was itself subject to considerable variation in the short, medium, and long terms. Not unusually, periods of heightened environmental instability coincided with periods of increased disease activity and some specific years were thus doubly disastrous for humans and/or crops and livestock. At the very least, this means that people at the time were singularly unlucky. More intriguingly, it raises the possibility that physical shocks and biological hazards may have been ecologically interconnected, with the result that there was a stronger environmental dimension to demographic and economic trends than endogenous models of socio-economic conventionally allow. These ideas are explored with reference to the early fourteenth century in general and the cattle plague of 1315-25 and human plague of 1346-53 in particular, drawing upon a combination of environmental and historical evidence.

Cause and effect? Physical shocks and biological hazards

Twice within little more than a generation, fourteenth-century Europe was swept by devastating outbreaks of plague. The first, a cattle panzootic, surfaced in Bohemia (from an origin possibly further east in central EurAsia) between 1314 and 1316 and thence rapidly spread throughout northern Europe, reaching northern France in 1317, the Low Countries, Brabant and Denmark in 1318, England in 1319, Wales and Scotland by 1320, and Ireland in 1321. The second, a human pandemic, may have shared a similar origin in EurAsia’s continental interior. It broke out in the steppelands to the north-west of the Caspian Sea in 1346, the next year crossed the Black Sea and penetrated the Mediterranean basin, in 1348 reached the shores of the North Sea, and finally came full circle and spent its force in European Russia in 1353. High levels of commercial intercourse and associated movements of livestock and people no doubt enabled both plagues to spread so far

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1 I am grateful to Tim Newfield and Philip Slavin for this information. See also, P. SLAVIN, The Fifth Rider of the Apocalypse: the Great Cattle Plague in England and Wales and its Economic Consequences, 1319-1350, this volume.

so rapidly, the pandemic travelling even faster than the panzootic. Each struck a
dense and virtually virgin-soil population with scant, if any, immunity, since
northern Europe had been effectively free of cattle and human plague for centuries.

Fatalities arising from these initial outbreaks were therefore massive and economic
output (already faltering under the impacts of war, commercial recession, and
falling real incomes) suffered accordingly. In the early 1740s, a cattle panzootic
which preceded the cattle panzootic of the mid 1740s. It must have exacerbated the economic hardship inflicted by the latter and thereby
prevented an even greater food-availability decline from escalating into a more terrible famine. 

Intriguingly, both plagues emerged and spread at times of acute physical
environmental stress and dislocation. The cattle panzootic originated at the height
of the Dantean Anomaly: the short-term climatic event responsible for the Great
European Famine of 1315-21. The human pandemic likewise commenced its
deadly diffusion during a similar climatic anomaly, marked by depressed tree
growth globally and the onset of intense cold over western Greenland. At the very
least, this concurrence of biological hazards with physical environmental shocks
must have exacerbated the economic hardship inflicted by the latter and thereby
have magnified their direct and indirect human impacts. Whereas cattle plague was
the biological sting in the tail of the Great European Famine which delayed full
recovery from that crisis, human plague, by killing so swiftly and indiscriminately,
prevented an even greater food-availability decline from escalating into a more terrible famine. 

Was this conjunction in each case of physical and biological hazards merely
doubly coincidental? Certainly, other instances have been observed when physical
and biological agencies appear to have acted either together or in close succession,
as, perhaps most significantly, in the case of the AD 536 environmental event
which preceded the AD 541-2 Justinian Plague and the 1740-2 weather anomaly
which preceded the cattle panzootic of the mid 1740s. 

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drawn attention to a general historical coincidence between the occurrence of volcanic dry fogs and plague outbreaks in the eastern Mediterranean.\textsuperscript{8} This emphasises the importance of considering biological hazards within their full physical environmental context.

And was it a further coincidence that these two pan-continental biological disasters — each in its magnitude a once in a millennium event — should have erupted within 30 years of each other? Patently, the two plagues had different pathologies and were chronologically separate events, and in that sense those who lived through both were simply desperately unlucky. Yet it is conceivable that both may in some way have been triggered by the unstable physical environmental conditions then prevailing. If so, cattle and humans may have been the victims of a joint physical and biological conspiracy of Nature, deadly in its collective human impact, and profound in its short-, medium- and long-term economic consequences.\textsuperscript{9}

\textit{The fourteenth century as a time of significant environmental change}

Historians have long agreed that the early fourteenth century witnessed mounting economic and political problems.\textsuperscript{10} It is now becoming clear from work by ice-core workers, dendrochronologists, environmental historians, and others that the same period experienced worsening environmental conditions on global and hemispherical scales (Figs. 1A, 1B, 2, 3A). Significantly, Jean Grove has dated the onset of the Little Ice Age to the marked cooling of global temperatures which set in from the mid-thirteenth century, while Christian Pfister, G. Schwarz-Zanetti, and M. Wegmann have identified a period of intense cooling over continental Europe, marked by the advance of Alpine glaciers, during the first three decades of the fourteenth century.\textsuperscript{11} These observations are borne out by a recent reconstruction of global temperatures from non-dendrochronological sources, which identifies a period of progressively cooling temperatures from c.1260 to c.1360 (Fig. 1A), the second of four episodes by which temperatures were steadily reduced from their peak at the climax of the Medieval Warm Period in the mid-ninth century to their trough during the Maunder Minimum in the second half of the seventeenth century when the Little Ice Age was at its coldest.\textsuperscript{12} These same episodes stand out in the record of World tree growth as reconstructed by M. G. L. Baillie (Fig. 1B) as cooler temperatures dampened down tree growth almost everywhere. Indeed, between 1320 and 1364 World tree growth entered a deep and prolonged depression, the longest of the last 800 years, rivaled in duration solely by the sustained growth declines of

\textsuperscript{8} R.B. Stothers, Volcanic Dry Fogs, Climate Cooling, and Plague Pandemics in Europe and the Middle East, in “Climatic Change”, 42, 1999, pp. 713-723.
\textsuperscript{9} B.M.S. Campbell, Nature as Historical Protagonist, cit.
\textsuperscript{10} Note 3 above.
\textsuperscript{12} C. Loehle, J.H. McCulloch, Correction, cit.
1440-76 and 1832-68. It is also worth noting that in 1350 — when global temperatures approached their fourteenth-century nadir (Fig. 1A) — global tree growth sank to a 5-year minimum lower than anything experienced over these same eight centuries (Fig. 1B). Evidently, environmental conditions were anything but 'normal' and stable as expansion of the European economy approached its late-medieval climax.

**Fig. 1A.** Reconstructed global temperature anomalies, 1150-1800

**Fig. 1B.** Global tree growth 1150-1800

Sources: (A) C. LOEHRLE, J.H. MCCULLOCH, *Correction to: ‘A 2000-year Global Temperature Reconstruction Based on Non-Tre Ring Proxies’*, in “Energy and Environment”, 19, 2008, 1, pp. 93-100. Data available at WWW document: URL http://www.econ.ohio-state.edu/jhm/AGW/Loehle/. (B) World 8 master chronology, combining chronologies for the Polar Urals (pine), Fennoscandia (pine), temperate Europe (oak), the Aegean (oak, pine, juniper), North America (bristlecone pine), South America (Fitzroya), New Zealand (cedar), and Tasmania (huon pine), supplied by M.G.L. BAILIE, The Queen’s University of Belfast.
Within the northern hemisphere the mounting instability of these years is evident in the record of North Atlantic sea-surface temperatures reconstructed by A. G. Dawson, K. Hickey, P. A. Mayewski, and A. Nesje from the Deuterium content of Greenland ice cores (Fig. 2). This identifies the onset from the 1280s of a succession of high-amplitude cooling events, which were at their most pronounced between 1318 and 1369. These were accompanied by a succession of high-amplitude warming events, which were correspondingly most pronounced between 1300 and 1333. This alternation of cooling and warming events — the former associated with winter storms, the latter with heavy summer rainfall — attained its fullest development between 1315 and 1342. The scale and frequency of these events then steadily abated until, by the close of the fourteenth century, high-amplitude cooling events had virtually ceased while high-amplitude warming events were much diminished in scale. On this evidence, therefore, physical environmental conditions changed progressively over the course of the fourteenth century, worsening in the first half of the century and ameliorating in the second.

Fig. 2. Reconstructed North Atlantic sea-surface temperatures 1270-1390

Source: A.G. Dawson, K. Hickey, P.A. Mayewski, A. Nesje, Greenland (GISP2) Ice Core, cit.

Analysis of Dutch temperatures, British Isles oak growth, and English grain yields offers a further perspective on these environmental changes on Europe’s

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13 A.G. Dawson, K. Hickey, P.A. Mayewski, A. Nesje, Greenland (GISP2) Ice Core, cit.
Fig. 3A. Indexed annual percentage variability of British Isles oak growth, Netherlands temperatures, and English crop yields 1275-1475.

Fig. 3B. Index of Environmental Variability — combined % variability of British Isles oak growth, Netherlands temperatures, and English crop yields 1275-1475.

Sources: (A) Dutch temperatures, A.F.V. VANGELEN, J. BUSSMAN, F. IJNSEN, *A Millennium of Weather*, cit.; British Isles oaks, data supplied by M.G.L. BAILIE; English grain yields, B.M.S. CAMPBELL, *Three Centuries of English Crop Yields*, 1211-1491. WWW document 2007: URL http://www.cropyields.ac.uk. (B) Fig. 3A.
western maritime margin (Fig. 3A). A. F. V. van Engelen, J. Buisman, and F. IJnsen have reconstructed annual winter and summer temperature series for the Netherlands from contemporary accounts and the historical record of canals that were impassable and mills inoperable because of either winter cold or summer drought conditions. Although mean annual winter and summer temperatures remained remarkably constant over time, the annual variability of those temperatures fluctuated significantly. The level of variability was higher for winter than summer temperatures, although the latter were more material to harvests, since a reduction of 1° centigrade in summer temperature reduced wheat yields by 5 per cent. As will be seen from Fig. 3, year-on-year temperature variability rose from c.1275 to c.1310, thereafter subsided to an absolute low in the final quarter of the fourteenth century (when the variability of North Atlantic seasurface temperatures was likewise abating: Fig. 2), and then increased again in the fifteenth century (as global temperatures and World tree growth slipped sharply downwards once more: Figs. 1A and 1B), before declining to another low point in the opening years of the sixteenth century. The episodic nature of these oscillations in the variability of Dutch temperatures implies that weather variations were partially driven by climatic shifts and cycles of approximately 100-150 years' duration. Thus, the third quarter of the thirteenth, fourth quarter of the fourteenth, and first quarter of the sixteenth centuries all experienced temporal lows in temperature variability, and the first quarter of the fourteenth and second quarter of the fifteenth centuries temporal highs in variability.

The variability of British Isles oak growth displays similar but non-identical oscillations over this same period (Fig. 3A). Oaks grew best when cold winters were followed by mild, wet, spring and summer weather. In fact, oak growth is positively correlated with summer rainfall. Marked annual variations in weather patterns, especially winter temperature and summer rainfall, thus heightened the annual variability of oak growth. That the annual variability of oak growth peaked during the second quarter of the fourteenth century therefore demonstrates that weather conditions over maritime Britain became significantly less stable at that time. As with Dutch temperatures, that variability subsided during the second half of the fourteenth century (the decline in temperature variability preceeding the decline in oak-growth variability by two decades), only to rise once more during the fifteenth century.

Analysis of the annual record of English grain yields, now available as a robust and continuous time series from the 1270s to the 1470s, reveals a story strikingly similar to that of oaks (Fig. 3A). The weather, in terms of the timing and levels of

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15 I am grateful to Professor Morgan Kelly, Department of Economics, University College Dublin, for this information.

16 B.M.S. Campbell, Three Centuries of English Crop Yields, 1211-1491, cit. Note that these two time series are derived from fundamentally different and indendent datasets: historical records in the case of grain yields, dendrochronology in the case of oak growth.
temperature and rainfall, was the single most important determinant of harvest quality and, self-evidently, was wholly outside the control of medieval husbandmen. Provided there had been sufficient rainfall in spring and early summer, grain crops responded positively to hot dry summers and negatively to cool, wet ones (other things being equal, wheat yields increasing by 5 per cent for every 1° centigrade rise in summer temperatures). That weather-induced yield variations were non-random in their magnitude and frequency is implied by the coefficient of variation calculated on the composite yield of the principal grains (wheat, rye, barley, oats, and legumes). As Fig. 3A shows, yield variability fell to a low point at the end of the thirteenth century, rose to a peak in the mid-fourteenth century, quickly subsided to a second and more pronounced low in the last quarter of that century, and then climbed ever higher over the course of the fifteenth century. Such clearly articulated trends suggest that there was a significant non-random component to the weather.

That Dutch temperatures, British Isles oak growth, and English grain yields should all exhibit marked temporal fluctuations in the amount of year-on-year variability implies that all three were responding to fluctuations in the stability of prevailing weather patterns. Unsurprisingly, trends in the variability of temperatures, oak growth, and crop yields were not exactly synchronised (Fig. 3A), since the chronologies on which their respective coefficients of variation have been calculated relate to different territorial units (the Netherlands, the British Isles, and lowland England) and are of unequal quality and precision. Nevertheless, all three time series point to an episode of heightened environmental variability between c.1280 and c.1340, succeeded by a phase of diminishing variability from c.1340 to c.1400, which then gave way to rising variability throughout the greater part of the fifteenth century.

For simplicity, all three of these indexed trends can be combined into a single “Index of Environmental Variability” (IEV) (Fig. 3B). The broad temporal swings of the IEV — rising by almost 50 per cent between 1300 and the 1340s, then falling steeply by approximately 33 per cent to a temporal low in the 1380s, and then rising by more than 50 per cent over the next 80 years — imply that there was a strong climatic component to annual variations in weather conditions over this 200-year period. For agricultural producers, this meant that the risk of experiencing extreme growing conditions was not randomly distributed across time, while for biological micro-organisms it meant that ecological conditions were anything but stable. In this context, it should be noted that pathogens, in the form of the cattle panzootic of 1316-25 and human pandemic of 1346-53, were at their most virulent when environmental conditions — as measured by the IEV — were at their most volatile.

*The specific environmental contexts of the cattle panzootic of 1316-25 and human plague of 1346-53*

Research by Tim Newfield has now established that the cattle panzootic began its highly contagious European spread between 1314 and 1316 from a probable...
Fig. 4A. English gross grain yields per acre, 1275-1424
Fig. 4B. English salt prices as percentage of 25-year moving average, 1275-1424

Wheat (barley/oats) gross yield per acre (indexed on 1250-1349)

Salt price as % 25-year moving average

epicentre in Bohemia. These same years mark the onset of the pronounced short-
term climatic anomaly known as the Dantean Anomaly when the weather across
north-western Europe remained persistently overcast and wet. Clear testimony of
the abnormality of these weather conditions is provided by the quadrupling of
salt prices registered in 1316 (Fig. 4B), since the production and distribution of salt
were both seriously affected by the want of summer sunshine in 1315 and 1316.
This was not the only occasion when an excess of cold wet weather resulted in a
massive inflation of salt prices but on no other occasion was the price inflation as
pronounced. Grain harvests almost everywhere were also adversely affected by the

Fig. 5. Tree growth in the Old and New Worlds, 1275-1424

Source: data supplied by M.G.L. Baillie. The 'Old World' chronology is derived from independent
multi-site chronologies for the Polar Urals (pine), Fennoscandia (pine), temperate Europe (oak), and
the Aegean (oak, pine, juniper). The 'New World' chronology is derived from equivalent chronologies
for North America (bristlecone pine), South America (Fitzroya), New Zealand (cedar), and Tasmania
(huon pine).

17 Tim Newfield, A Great Destruction of Cattle: the Impact and Extent of Epizootic Disease in Early
of Toronto, 2005.
18 N. Brown, History and Climate Change, loc. cit.; W.C. Jordan, The Great Famine: Northern Europe in
bad weather (the Great European Famine of 1315-21 was the result). In England the double back-to-back harvest failure of 1315-17 stands out as a conspicuous negative deviation in the long-term chronology of grain yields, eclipsed only by the triple back-to-back harvest failure of 1349-52 (Fig. 4A). On this evidence there can be no doubting the scale of the climatic shock delivered at this critical early stage in the irruption and diffusion of the panzootic.

These are also the very same years when unusually warm sea-surface temperatures prevailed in the North Atlantic (Fig. 2), generating the rain-bearing winds that proved so harmful to European salt and grain production. By implication, some powerful environmental forcing agent was at work, as further witnessed by the record of tree growth in the Old and New Worlds (Fig. 5). Until 1314 tree growth in the two hemispheres had tracked a broadly similar course. Thereafter, until c.1340, their respective growth trends were inverted. Moreover, the inversion that prevailed from c.1314 to c.1324 was reversed from c.1324 to c.1340. Significantly, the former were the self-same years when the cattle panzootic was at its most virulent and the bulk of north-west Europe was in a state of acute agrarian crisis.

Fig. 6. **Tree growth in the Polar Urals, FennoScandia, and the Aegean, 1300-1400**

![Tree growth chart](chart.png)

Source: data provided by M.G.L. BAILIE, The Queen’s University of Belfast.

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There is much yet to be learnt about this environmental episode but already it is clear that irruption and spread of the cattle panzootic occurred within a sharply defined and distinctive physical environmental context. The same is true of the irruption and spread of the human pandemic a generation later. 1346 and 1347 were the critical years for the European diffusion of whatever the Black Death disease was. This was when plague spread from the shores of the Caspian Sea to those of the Black Sea and thence the Mediterranean basin; its invasion and conquest of the countries bordering the Atlantic, North Sea, and Baltic following in 1348-51. On the Loehle and McCullough index of temperature anomalies, these years mark the end of almost a hundred years of cooling (Fig. 1A), whose depressing effect upon growing conditions right the way across the temperate World is borne out by the major growth trough registered by trees between 1343 and 1355, with a collective minimum value at 1348-50 (Fig. 1B and Fig. 6). In northern Europe — in the Polar Urals and FennoScandia — the decline began around 1340, with minimum growth values respectively in 1345 and 1346 (when the first plague deaths were reported in southern Russia). Against this trend, trees in the Aegean displayed a surge of growth — a sure sign of abnormal climatic conditions — followed by an equally dramatic decline from 1344 to 1360 (Fig. 6).

The profound growth deviation experienced in the mid 1340s by trees from the Urals to the Aegean anticipated in its timing the spread of plague into the Black Sea and Mediterranean basins. A similar growth discontinuity also shows up in the southern hemisphere. Minimum growth values for Tasmanian huon pines, Chilean and Argentinian fitzroya, and New Zealand cedars are 1347, 1348, and 1350 respectively, dates which coincide exactly with the years when plague cut its way through Europe’s population from east to west and south to north. Such a pan-global and marked disruption of tree growth points to the influence of some powerful and over-arching environmental forcing agent. This was more than just unusual weather; it was a short-term climatic anomaly of global proportions.

Analysis of the Deuterium content of Greenland ice cores has recently provided further corroboration of the abnormal nature of these years and, especially, their unusual coldness. It has been shown that the fourteenth century witnessed several episodes of intense cold over western Greenland, most notably in 1312-14, 1323-7, 1336-8, 1349-53, 1378-82, 1389-90, and 1392-4. None, however, was colder than the 1349-53 event. Dawson estimates that in 1352-3 temperatures sank to a minimum lower than those at any subsequent point in history, including the notoriously cold 1690s — the coldest decade of the Maunder Minimum.

Onset of these ‘icy’ years coincides almost exactly with the pronounced downturn in global tree growth. In England, yields of grain crops during these same years are

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21 Onset of this particular climatic anomaly may possibly be marked by the notorious “Magdalenennflut” of 21 July 1342, which ranks as the most severe central-European flood event of the last millennium: O. BÖHM, K.-F. WETZEL, Flood History of the Danube Tributaries Lech and Isar in the Alpine Foreland of Germany, in “Hydrological Sciences–Journal-des Sciences Hydrologiques”, 51 (5) 2006 (Special issue: “Historical Hydrology”), p. 794.

22 M.G.L. BAILEY, New Light, cit., pp. 33-38; B.M.S. CAMPBELL, Nature as Historical Protagonist, cit.

the poorest on medieval record (Fig. 4B). The inferior harvest of 1346 was an augury of worse to come. The harvest of 1349 was an outright failure, and the worst since 1316. Moreover, it was the first of four consecutive harvest failures, during which net grain yields fell 40 per cent below their long-term average. In the two most disastrous years of all, 1349 and 1350, net yields were more than 50 per cent below that average, although this may have owed something to the disruptive effects of plague upon the agricultural labour force. In fact, contemporaries commented on little else, the greater catastrophe of plague overshadowing the inclement weather and dismal yields. Nevertheless, it is now clear that, as with the Great European Famine, this massive environmental disaster comprised both physical and biological agents which were either coincidental or conjoined in their operation.

**The respective impacts of the cattle panzootic and human pandemic**

It is one thing to reconstruct the physical environmental contexts of the panzootic and pandemic, it is another to quantify these plagues’ respective demographic impacts upon bovine and human populations. Research into the European cattle panzootic remains patchy. England is the sole country where its impact can be

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Fig. 7A. **Indexed trends in aggregate cattle numbers on lowland English demesnes, 1300-1350**

![Graph showing indexed trends in aggregate cattle numbers on lowland English demesnes, 1300-1350.](image)

Source: B.M.S. CAMPBELL, *Three Centuries of English Crops Yields*, cit. and Manorial Accounts Database.

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Fig. 7B. **England: relative livestock prices, 1310-1330**

Relative livestock prices


tracked with some precision thanks to the copious survival of manorial accounts, with their detailed inventories of livestock numbers at the start and end of each agricultural year and corresponding information on purchase and sale prices. These data relate solely to large, capital-intensive demesne herds, but it is unlikely that these were any more or less exposed to infection than cattle — a majority of the total — in non-seigniorial ownership. Fig. 7A reconstructs the annual numbers of demesne oxen, adult cattle, and immature cattle each Michaelmas (29 September), weighted to take account of regional variations in the course and virulence of the panzootic. When interpreting these aggregate trends it is important to take account of the fact that the cattle plague was accompanied by panic selling of as yet uninfected animals, which greatly magnified the scale of the demographic decline. Fig. 7B shows that in 1320-1 prices of cows and oxen fell sharply relative to those of other livestock.

As will be noted from Fig. 7A, the incessant rains that precipitated the harvest failures of 1315-17 also had a negative impact upon pastoral husbandry, as sodden pastures and acute shortages of hay and fodder exacted their toll of cattle numbers, raising the prices of cows and oxen relative to those of horses and pigs (Fig. 7B). Overall, the national demesne herd shrank by at least 7 per cent over these years.
Improved weather in 1318 brought a respite and allowed a modest recovery, most apparent in recorded numbers of immature bovines. Then, from Easter 1319, cattle plague struck and over the course of the next 12 months rapidly spread through herds almost everywhere. The losses arising from this biological source, reinforced by sale (mostly at a massive discount – Fig. 7B) and slaughter, amounted to approximately half of all animals and, thus, were of an entirely different order of magnitude from those precipitated by the terrible weather of 1315-17. Here, therefore, is a graphic illustration of the impact of a highly contagious infection upon a dense and commercially closely integrated animal population with no previous exposure to it. Undoubtedly, local, regional, and national movements of cattle and oxen (since the latter were widely used for haulage and traction) played a key role in promoting rapid geographical diffusion of the disease pathogen.

In the immediate aftermath of the panzootic capital-rich landlords were undoubtedly in a stronger position to restock and reconstruct their herds than most, if not all, small-scale producers. With the immediate danger past and a revival of demand, relative prices of cows and oxen rose impressively (Fig. 7B). Priority was clearly given to bringing ox numbers back up to strength, since it was impossible to reinstate grain cultivation at its pre-panzootic level while ox numbers remained depleted. An active policy of purchase was therefore employed to make good at least part of the damage. A more general reinstatement of herds across all regions and all classes of producer took longer and, necessarily, had to be led by the breeding of replacement younger animals. As will be seen from Fig. 7A, a recovery in the numbers of mature animals then followed. At an aggregate level, none of this could proceed faster than biological reproduction would allow, with the result that even after a dozen years of purposeful reconstruction the national demesne herd remained approximately 25 per cent below its immediate pre-panzootic level.

The course of recovery did not, however, run smooth, and part of what had been achieved by 1333 was undone by a further, if lesser, mortality crisis in 1334-5 (Fig. 7A). Another occurred in 1345. Whether these were aftershocks of the original panzootic or represent the intervention of other pathogens remains to be established. They nevertheless constituted significant setbacks and ensured that by 1348 demesne cattle numbers still remained significantly below their 1314 peak level. In this respect, the biological effects of the cattle panzootic were far more enduring than those of the weather-induced massive grain-harvest failures of 1315-17 and 1321. In fact, when, in 1349, demesne cattle numbers did eventually briefly return to almost their pre-plague level, it was because of a windfall surge in heriot payments (a death duty in the form of the ‘best beast’ paid on behalf of deceased villein tenants) triggered by the national plague pandemic of 1348-9. Significantly, heavy famine mortality and associated heriot payments in 1315-18 had given no corresponding boost to demesne cattle numbers, which bears out the fact that human fatalities arising from the Black Death far eclipsed those that had resulted from the Great European Famine.25

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25 On five manors of the bishops of Winchester the number of animal heriots received in 1349 was 11 times greater than in 1317 (the peak famine year for heriot payments): M.M. Postan, J.Z.
Deadly as was the cattle panzootic for bovines, its consequences for humans were mostly indirect. Supplies of draught power, dairy produce, and other bovine products were all adversely affected and pastoral resources hitherto devoted to cattle husbandry were in relative abundance. Diets and living standards very likely suffered, for a major capital loss had clearly been sustained. Nevertheless, any rise in human mortality is likely to have been quite small, for, in the 1330s, as environmental conditions turned temporarily benign (marked by a reversal of the growth inversion between Old World and New World trees — Fig. 5), some of the worst after effects of cattle plague were offset by a run of unusually bountiful harvests (Fig. 4A). This respite was only temporary. Serious harvest failure in 1339 and the devastating central-European summer flood of 1342 proved to be auguries of greater hazards to come. Indeed, the back-to-back harvest failure of 1349-50 is the worst on medieval record. Although, that it was greater even than that of 1315-16 (Fig. 4A) probably owed something to the mass mortality of workers and managers in the plague pandemic of 1348-9.

It is not inconceivable that the pandemic of 1348-9 may have been as fatal for humans as the panzootic of 1319-20 had been for cattle, although in the case of England the conventional estimate is for an aggregate population reduction from this initial onslaught of plague of approximately one-third. Certainly, a wealth of contemporary evidence testifies to the heavy loss of life and the effects of the pestilence upon all social classes. Plague, unlike famine, was an indiscriminate killer. Disappointingly, however, there are no historical data comparable to those for cattle from which annual population totals may be reconstructed before, during, and after the plague’s passage. Instead, reliance has to be placed upon the annual chronologies of prices and wages, from which much may be inferred since plague had a massive impact upon both the supply of labour and demand for goods. Indeed, there is no exact parallel in recorded English price history to the Black Death’s double impact upon supply and demand.

Fig. 8 plots the relationships between harvests, grain prices and the real wages of farm labourers. As will be seen, grain prices were effectively a function of harvest quality, while real wages were essentially a function of food prices. Hence the typical effect of a disastrous harvest, as in 1315-17, was to inflate prices and depress real wages. In fact, so great was the harvest shortfall and consequent grain-price inflation in 1316 that farm workers’ real wages were driven to their single lowest level on Gregory Clark’s 700-year real-wage index. This strong inverse relationship between prices and real wages was, if anything, reinforced by the agrarian and economic effects of the cattle plague of 1319-20 so that continuity

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rather than discontinuity prevailed. It is a measure of the disproportionately greater shock of the Black Death that in 1349-50 this inverse relationship was briefly but decisively broken (witness the divergence in the movement of the real wage and inverted price trends in Fig. 8). In that year real wages and prices both rose, a sure sign that something quite out of the ordinary had happened: food had become scarce but labour had become even scarcer. Such behaviour by prices and wages was the opposite of that which had occurred during the Great European Famine a generation earlier.

Fig. 8. **English harvests, inverted grain prices, and farm workers’ real wages, 1300-74**


The harvest failure of 1349-50 was proportionately greater than that of 1315-16 and its effects were more prolonged, insofar as yields remained depressed for several years afterwards (Fig. 4A). On this measure, it was unquestionably the

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30 A yield reduction from 1348 to 1349 of 47% was followed in 1350 by a grain-price rise of 33% and, paradoxically, a real-wage gain of 77%. 

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PHYSICAL SHOCKS, BIOLOGICAL HAZARDS, AND HUMAN IMPACTS
greater of the two crises. Nevertheless, the price response was far less dramatic (Fig. 8). In fact, in the first year of the crisis prices remained close to the average for a normal year. Only in the second year of this disastrous back-to-back harvest failure did prices register a rise, but even then the response was far smaller than in 1316. More remarkably, in direct contrast to the Great European Famine and against all historical precedent, farm labourers’ real wages actually rose in 1349 and rose by proportionately more than in any other year on Clark’s real-wage index. Nor was there any reversion to the pre-existing status quo once the immediate crisis years had passed: the gain in real wages proved to be enduring. A step change had occurred. If there were no explicit accounts of the Black Death, economic historians would have to hypothesise some equally mortal event in order to explain the paradoxical behaviour of prices and wages in the midst of the worst harvest failure on medieval record.

Fig. 9. Quinquennial replacement rates of English male tenants-in-chief, 1256-1500


On the evidence of grain prices and farm workers’ real wages (Fig. 8), the Great European Famine clearly delivered the greater blow to subsistence levels and living standards, which, in “Black ‘16”, sank to their medieval and historical nadir. For labouring families and many others, no year would ever be worse. Nonetheless, following the crisis society remained as calamity-sensitive as ever, since the basic

relationship between harvests, prices, and real wages continued much the same as before. For all the indubitable demographic and economic impact of the Great European Famine, it was the Black Death which delivered the greater and more decisive demographic blow, to the lasting betterment of subsistence levels and living standards. Indeed, by killing on such an unprecedented scale, it averted a second, and potentially more terrible, 'great famine' arising from the disastrous harvests of 1349-52. Further, by bequeathing a lasting legacy of high and recurrent disease mortality, the Black Death, transformed the biological status quo in a way that, at least for humans, the Great European Famine had failed to achieve. For the next hundred years the population failed to reproduce itself and therefore shrank ever smaller (Fig. 9). In this fundamental respect, plague's advent was a watershed event and demographically, biologically, and genetically the world would never be quite the same again.

A 'Malthusian world'? Physical shocks, biological hazards, and human impacts

Late-medieval demographic and economic trends have hitherto been interpreted for the most part within the theoretical frameworks provided by neo-classical economics, Marxist analysis, and, latterly, the New Institutional Economics. Stress has therefore been placed upon the endogenous inter-relationships between population, resources, technology, power structures, property rights, and those institutions and events which determined transaction costs in national and international trade. Debate, accordingly, has focused upon whether the most essential relationship was that between population and resources (as expressed by real wages) or that between the owners and the users of resources (as expressed by the rents and restrictions imposed by lords upon serfs).32 Far less consideration has been given to the independent influence of environmental agencies upon the reproduction, health, and life expectancy of crops, livestock, and humans. Conventional analyses of the fourteenth-century agrarian, economic, and demographic crisis therefore tend to pay more attention to the calamity-sensitive state of society than to the natural causes of the physical and biological hazards which struck with such destructive and untimely force.33 On this reading of the crisis, the the Great European Famine and Black Death served the function of Malthusian positive checks and derived much of their historical significance from the sudden release provided to pent-up endogenous pressures.


The evidence advanced here suggests, to the contrary, that the human impacts of the Great European Famine of 1315-21 and the Black Death of 1347-53 owed more to the unprecedented scale and extraordinary nature of the natural forcing agents than to the straitened economic circumstances of the day. Both were major and complex events with global environmental dimensions.

As befits one of history’s greatest killers, the Black Death has attracted considerable scholarly attention in its own right, to the extent that debate about its diagnosis, spread, and demographic impact has become a growth industry. In recent years, much received wisdom about this most mortal of pandemics has been questioned. It is therefore all the more surprising that comparatively little attention has been paid to its physical environmental context. For their part, historians of disease have stressed the ‘continuous inter-action and mutual adaptation between ….. humans, pathogenic microbes, and animals’. Similarly, historians of climate have underlined the fact that ‘the climate has always been changing. On every timescale, since the Earth was first formed its surface conditions have fluctuated’. What has been lacking is much discussion and examination of the possible links — indirect as much as direct — between the two. Notwithstanding that any changes in the physical attributes of an ecosystem will have had repercussions for its biological components, systematic examination of the interactions between biological and physical/climat change remains in its infancy.

Although the evidence presented in this paper is largely circumstantial, and therefore far from conclusive, it does suggest that exogenous environmental factors may have played a greater and more direct role in causing the crisis of the fourteenth century than most conventional accounts of the period admit. Thus, timing of the irruption of the cattle panzootic appears to have been intimately bound up with greatly disturbed weather conditions right across northern Europe as a result of the so-called Dantian Climate Anomaly. Likewise, a generation later, the human pandemic coincided almost exactly with another pronounced short-term climate anomaly of global dimensions. In both cases, physical shocks and biological hazards acted in concert and did so at a time of generally heightened environmental uncertainty. What the key prime movers were in this complex environmental scenario remain to be investigated, but potential agents include variations in solar activity, bolide impacts, and volcanic and other tectonic activity, along with associated shifts in atmospheric circulation and ocean currents.

37 M.G.L. Baille, New Light, cit., is a notable exception.
The Malthusian Model places at its core the economic relationship between population and resources. By treating the physical and biological environments as *de facto* constants, this, however, misrepresents the true character of the complex inter-relationship between humans and resources. A more ecological, and consequently more realistic, reading of Europe’s pre-industrial past would therefore include both the physical and biological environments as independent variables in their own right. Such a view is in accordance with Ronald Lee and Michael Anderson’s recent verdict on the post-1540 period, that ‘Most of the long-term change in fertility and mortality was non-Malthusian in origin (that is, unrelated to changes in wages), and instead was a response to other influences such as weather, disease, or institutional change’. All that need be added is that weather and disease do not appear to have acted completely independently of each other and both, as sources of uncertainty, begot institutional responses.

Acknowledgements:

Research for this paper was funded by the British Academy, the Economic and Social Research Council, (Award: RES-000-23-0645), the Leverhulme Trust, and the Sussex Archaeological Society. Assistance with data collection and data analysis was provided by Anne Drewery, Bas van Leeuven, Marilyn Livingstone, Tim Newfield, Kate Nye, Philip Slavin, Christopher Whittick, and Elaine Yeates. Data and advice on dendrochronology were supplied by Mike Baillie.

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