



**Economic Crises, Land Use Vulnerabilities, Climate
Variability, Food Security and Population Declines:
Will History Repeat Itself or Will Our Society Adapt
to Climate Change?**

Evan D. G. Fraser

March, 2009

No. 15

SRI PAPERS

SRI Papers (Online) ISSN 1753-1330

First published in 2009 by the Sustainability Research Institute (SRI)

Sustainability Research Institute (SRI), School of Earth and Environment,
The University of Leeds, Leeds, LS2 9JT, United Kingdom

Tel: +44 (0)113 3436461

Fax: +44 (0)113 3436716

Email: SRI-papers@see.leeds.ac.uk

Web-site: <http://www.see.leeds.ac.uk/sri>

About the Sustainability Research Institute

The SRI is a dedicated team of over 20 researchers working on different aspects of sustainability. Adapting to environmental change and governance for sustainability are the Institute's overarching themes. SRI research explores these in interdisciplinary ways, drawing on geography, ecology, sociology, politics, planning, economics and management. Our specialist areas are: sustainable development and environmental change; environmental policy, planning and governance; ecological and environmental economics; business, environment and corporate responsibility; sustainable production and consumption.

Disclaimer

The opinions presented are those of the author(s) and should not be regarded as the views of SRI or The University of Leeds.

Economic Crises, Land Use Vulnerabilities, Climate Variability, Food Security and Population Declines: Will History Repeat Itself or Will Our Society Adapt to Climate Change?

© Evan D. G. Fraser 2009

Email: evan@env.leeds.ac.uk

Contents

Contents.....	3
Abstract	4
About the Author	4
Introduction	5
Case study	7
Discussion.....	19
Conclusion	23
Acknowledgements	23
References	24

Abstract

Although many of today's ecological, climatic and socio-economic problems seem unprecedented, similar events have occurred in the past. Western Europe's "middle ages" (circa 11-14th century) may be one such case. By the 12th century, medieval Europe had shifted from the subsistence agrarian economy that emerged following the collapse of the Roman Empire to one where spatially dispersed trade in agricultural commodities helped support a complex society that devoted considerable resources to cultural works. This shift was facilitated by new institutional arrangements centred on monastic orders that provided access to both new agricultural and food processing technologies as well as trade routes. This contributed to population growth and land clearing. All of these factors increased the wealth of society but also concentrated wealth in a small number of communities that were dependent on an ever-increasing and exploited hinterland for resources. Ultimately, this created a tightly coupled continent-wide subsistence system that was vulnerable to the weather, economic and disease shocks of the 14th century when Europe's population declined by perhaps 50%. In exploring this history, the goal of this paper is to draw on a diverse theoretical body of literature (that includes resiliency theory, landscape ecology, political science and ecological economics) to develop a series of hypotheses about how large-scale complex civilizations can become vulnerable to climate change and apply these lessons to the present day.

Key words: Land use and land cover change; Adapting to Climate Change; Food Security; Resilience

Submission date 13-01-2009; Publication date 19-03-2009

About the Author

Evan Fraser is a senior lecturer with expertise in food system and food security. He has experience in China, Thailand, Malawi, Belize, Canada and the UK.

1 Introduction: Using the past to understand vulnerability to climate change

Significant climate change. The collapse of major financial institutions. Widespread soil degradation. Deforestation. Population growth. Large institutions that own vast wealth and have offices around the world. Extensive trading routes that allow food to be imported and exported over large distances.

Although this sounds like a description of the world today, this is actually a précis of Europe at the end of the 13th century and describes the setting immediately before the calamitous 14th century when famine, war and disease killed 50% of Europe's population. History presents many such cases where food security (specifically) and society (more generally) were undermined during times of a "double exposure" to both economic and environmental change (O'Brien and Leichenko, 2000). While much contemporary academic work has focused on small spatial scales and the recent past (e.g. village level livelihoods analyses see: Bebbington, 1999), there are also many situations from earlier in history where entire societies have struggled to stay fed (Tainter, 1988).

The earliest example of social and climatic factors interacting to provoke a major change in the subsistence strategy used by a large number of people was the Neolithic Revolution. Our move from hunting and gathering to settlements and cultivation may well have been sparked by a combination of population growth (which increased resource competition between groups), technological innovations (the domestication of plants and animals) and climate change (that reduced the productivity of hunting and gathering) (Rindos, 1984). Current scholarship tends to posit that these factors likely "co-evolved" over centuries until society reached a point where previous subsistence strategies were no longer viable (Bar-Yosef and Belfer-Cohen, 1989). As a result, although scholars from a range of disciplines are quite sure that life was much harder for early farmers than for hunters-and-gatherers (Larsen, 1995, Boulding, 1976, Nolan, 2003, Shand, 1974) there was no opportunity to "go-back" to the way things were.

There are also abundant examples of complex societies failing to adapt when climatic and political conditions both changed. For example, the ancient Mycenae in Greece, best remembered for being depicted in the *Iliad* and the *Odyssey*, declined into archaeological obscurity and legend somewhere around 1100 BC. Although the causes of the decline are extensively debated, key themes include military invasion (Rutter, 1975, Vermeule, 1964), soil exhaustion (Hughes and Thirgood, 1982, Bintliff, 2002) and climate change (Zerefos and Zerefos, 1978). In particular, archaeologists hypothesize that the collapse of the Mycenaean culture occurred thanks to an over-dependence on trade (Betancourt, 1976) where an urban elite survived on an exploited periphery (Bintliff, 1997) that was vulnerable to disruption.

It is even argued that the French Revolution was sparked by a combination of climatic and socio-economic factors: the frustration felt by the rising middle class at being shut out of political power (Goldstone, 1991) boiled over during a time of extremely volatile food prices. This volatility was itself due to terrible harvests (Grove, 2007) caused by the worst El Niño event in the entire 2nd Millennium (Meggers, 1994).

It seems reasonable to suppose, therefore, that we can draw from history to learn lessons applicable to today. However, to draw analogies from the past and apply them to the present requires making huge assumptions. For example, using comparative historic cases to discuss the situation today inevitably involves implicitly or explicitly establishing large-scale “macro-theories” (Fraser and Stringer, 2009). This is extremely unpopular in many branches of the social sciences today (See the discussion following Rindos et al. (1980) for a sense of how some anthropologists react to a theory that attempts to explain the emergence of agriculture). For many social-scientists, a critical awareness of discourse and context has been of paramount importance and members of this community are understandably sceptical that any explanatory theory for something like “the rise and fall of civilization” or “how society is vulnerable to climate change” will be simplistic “just-so stories.” Furthermore, post-modern scholarship has immeasurably strengthened our understanding of how an individual’s perceptions of the world are shaped by their background, and how power, agency and positionality all influence the theories academics build. As such, we must be aware that the creation of any one theory or explanation may reveal more about the author of the theory than the “real” world (See Morse and Fraser (2005) for an illustration of how the position of scientists influenced the results of a “sustainability analysis”).

There is no disputing the seriousness of these concerns. Nevertheless, the goal of this paper is to explore a historical case in order to develop a series of hypotheses about how large-scale complex civilizations can become vulnerable to climate change. To justify this endeavour, the position of this researcher is that as we look forward to a future that many expect will be full of climatic surprises, economic shocks and political turmoil, we ought to look backwards. We ought to remember that our species has almost 10,000 years of experience living in urban societies supported by food producers in remote locations. Out of this history, I hope we may learn a range of useful lessons by analogy that may help focus our attention on useful solutions today (See Glantz (1991) for a discussion on merits and challenges to this approach). To draw these lessons out, however, requires making enough generalizations to allow us to compare the present predicament with past situations. As such, this paper draws on the work of comparative history for its ontological foundations (See the introduction to Goldstone (1991) for an extended discussion on the merits of comparative historical studies.).

In order to accomplish this goal, this paper will:

- (1) Explore the history of Medieval Europe focusing on the way food was produced and distributed. I will show how changing economic, technological and institutional factors combined with a generally productive climate to create a food production and distribution system that supported a large urban population and a society that invested considerable wealth in public works. I will also describe how this system was based on systemic social inequities and environmental degradation and that these problems made the society vulnerable to the changing economic and climatic conditions of the 14th century.
- (2) I will weave into this account of the Medieval period a number of different theoretical bodies of literature that I believe help explain key dynamics that became more or less important during different stages of this history.

- (3) I will conclude by using the theories presented during the narrative to propose an over-arching hypothetical account for why this “vulnerable food system” emerged speculate that many of the same dynamics are still at work today.

2 Case Study: Accounting for the rise and fall of the medieval food system

2.1 Overview

The rise and fall of Europe’s Middle Ages (a period epitomized by the Angevin Empire, a political unit that encompassed much of England, Ireland and France and was formed by the marriage of Henry Plantagenet of England and Eleanor of Aquitaine in 1152 AD (Fraser, 2000)) seems an appropriate place to seek lessons applicable to the present day because, following a decline of Europe’s population between 300-600 AD, the period 600-1300 AD witnessed the rise of a complex civilization where trade, wealth, education, urbanization, artistic endeavours, and public spending all grew (Cohn, 2002, Mercier, 1999). Between 1300 and 1400, however, disease, famine and warfare dominated, and this society lost as much as 50% of its population (Herlihy, 1997, Twigg, 1984, Aberth, 2001). Trade, public spending, and tax revenues also faltered and spending on cultural activities dropped significantly (Platt, 1996, Fischer, 1996).

Although the 14th century collapse is often attributed to a disease (The bubonic plague is the most common hypothesis, though some debate this. See Cohn (2002) for an assessment of the particular vector that may have caused the disease) most historians of this period argue that the plague was only the most deadly of a string of serious catastrophes that battered the European Medieval Civilization during the 14th century (See McCormick, 2003 for a review of the evidence behind the bubonic plague). For example, Bridbury (1977) argues the period before the Black Death was “...undoubtedly a period of unprecedented strain for the mass of the peasantry...” (p 401). He goes on to point out that problems in the banking industry (caused in part when Edward III of England defaulted on his loan to Florentine Bankers) and rising grain prices from 1309 illustrate both economic problems as well as providing suggestive empirical evidence that wide spread soil exhaustion may have been hurting yields. Twigg (1984), Dotterweich (2008), Cronin et al. (2003), and Sicre et al (2008) all present different climate reconstructions showing that although the height of the medieval period enjoyed a warm and productive climate that was similar to that enjoyed by the Romans at the height of their Empire (as well as by Europe during much of the 20th century), there was a serious deterioration of climate following 1300 (incidentally, a similar deterioration occurred towards the end of the Roman Empire). The pre-eminent scholar of the Black Death and its aftermath, David Herlihy, also cites considerable evidence from a range of historic sources to demonstrate that economic problems, soil degradation and over population were widespread before the plague hit in 1347 (Herlihy, 1958). Herlihy, however, stresses that the plague was not a Malthusian inevitability, but that the medieval population was likely locked in a sort of stalemate with the environment and the plague was an independent or external factor that hit a population with few reserves (Herlihy, 1997). While his analysis is somewhat dated, the majority of his conclusions are backed up by more contemporary sources of data including Dotterweich’s (2008) analysis of historic

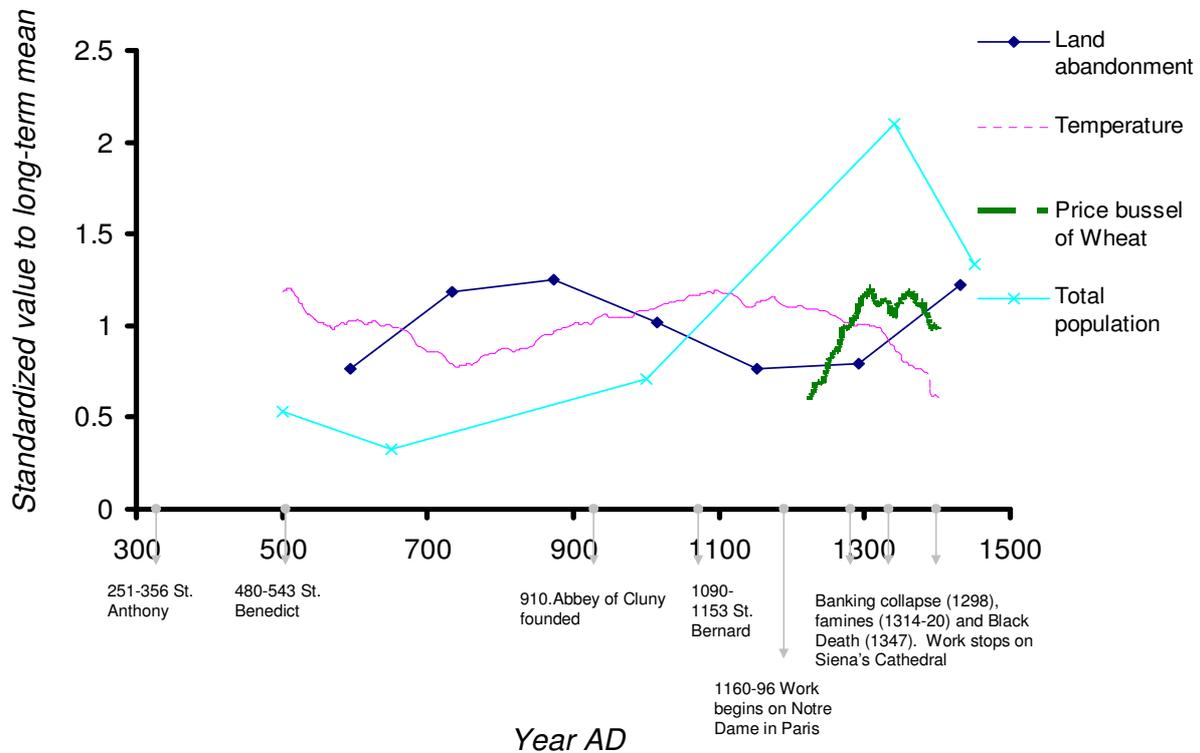
records that show an increase in soil erosion across much of Europe in the late 13th and early 14th centuries.

The fact that the crises of the 14th century can be attributed to a series of socio-economic and landuse changes that made the society vulnerable to economic, climatic, and epidemiological shocks leads to a number of very important questions relevant to today: (1) why was it that so many problems all boiled over during these generations? and (2) were there tell-tale signs that things were going wrong before the decline actually started?

To try to answer these questions, I have arranged the history of Europe's medieval civilization into six chronological (but overlapping) phases. In the following pages, I use this structure to present an account of the rise and fall of medieval Europe by developing five different lines of enquiry. The first line of enquiry is to explore the rise and fall of both the total population as well as other evidence of society's wealth and complexity. The second issue is to present climate data that show how the climate became increasingly productive between the post-Roman centuries and the high Medieval period, but that it deteriorated in the 14th century. Third is the evidence that deforestation and soil erosion increased during this period and made harvests vulnerable to climate change. The fourth is economic data that shows Europe experienced serious financial problems in the lead up and early part of the 14th century. Finally, these four themes will be framed in terms of the emergence of the monastic orders, an institution that went from being a counter-culture social movement established by radicals in the 4th century (Chew, 2008), to the largest and most concentrated centres of wealth in the early 14th century that drove much of the deforestation (Raftis, 1961). The development of the monastery was so central to economic development in this period that one modern scholar has stated that the monasteries were the "...determining factor of the most fundamental kind in the formation of medieval civilization..." (Chew, 2008 p. 34). As such, the rise of European monasticism provides an institutional context through which to understand the rise (and ultimately the decline) of medieval civilization.

The four empirical themes, and a brief time line of the monastic orders, are presented in figure one.

Figure 1: Reconstructions of pollen, temperature, price and population data and a brief time line of Europe's monastic history.



Note: Pollen, temperature, price and population data all standardized so the long-term mean of each data set = 1. (1) The data series “land abandonment” refers to abundance of *Calluna vulgaris* (heather) and *alnus* (alder) pollen from a site in Northern England where data provide seven observation (from AD 595, 734, 874, 1014, 1153, 1293, and 1432). High levels of these types of pollen is consistent with land abandonment while low levels are consistent with higher levels of cultivation (Fossil Pollen Database, 2008). (2) The data series “temperature” presents a rolling 50 year average of mean annual temperature from the Central Alps as reconstructed through an isotopic analysis of stalagmites (Mangini, 2005). (3) The data series “price” presents a 50 year rolling average of the price of a bushel of wheat in England. This is published by the Global Price and Income History Group at the University of California Davis (available at: <http://gpih.ucdavis.edu/> (accessed January 12th, 2009). See also (Clark, 2005). (5) The data series “population” is from (Russel, 1972). Finally, dates for the monastic time line came from (New Advent, 2007).

2.2 Phase I

Europe's medieval civilization owes its origins to the fall of the Roman Empire in Western Europe, a process that was well under way by the 4th century AD and marked by a significant decline in total population as well as indicators of what Tainter (1988) calls "social complexity." For example, the city of Rome, which always struggled to maintain its food supply, hit a crisis in AD 330 when the Empire was broken up into Eastern and Western components. At this point, the city of Rome stopped receiving grain from Egypt and the Roman food system became much simpler relying on local production rather than using aggressive foreign policy to maintain complicated trans-Mediterranean trade (Rickman, 1980) and extensive grain storage facilities (Rollo, 1934, Vitelli, 1980). This is illustrated by a policy dating to 364 AD that stipulated taxes had to be paid in grain (not coin) and the fact that the city was struck by a famine in 383 AD. The population of what had been the world's premier city fell from an estimated 1 million people in 300 AD to just 400,000 about 100 years later while population estimates for all of Europe suggest that the continent lost about 50% of its people between 200 and 600 AD (Chew, 2006). Land use across Europe changed at this time, with cultivated land declining and widespread reforestation (Dotterweich, 2008).

By around 650 AD, however, the population decline was reversed and growth returned to Europe (Russel, 1972). There were many causes for this shift. One of the drivers is likely climatic. Temperatures, which had been warm during the peak of the Roman Empire in Europe, but had declined towards the end of the Roman Empire, began to rise again (Desprat et al., 2003, McDermott et al., 2001). This would have helped boost yields and a small amount of initial population growth meant that people started to return to land that had been abandoned (and re-invaded with forests) for centuries (Twigg, 1984, Dotterweich, 2008).

Medieval population growth, however, was also driven by a new form of social institution: the monastic orders. The roots of medieval monasticism date to the "Desert Fathers," a group of ascetics who lived in the 4th century Egyptian desert. The Desert Fathers were reacting to both the moral as well as the economic and environmental crisis facing the Roman civilization and retreated from mainstream society. For example, one of the movement's founders, St. Anthony (unknown dates but between 250-350 AD), had inherited his parents' large Romanized farm at a young age. The farm was unprofitable thanks to serious and widespread ecological degradation, the changing climate, and a high tax rate (Athanasius, 1979, Butler, 1907). The failure of the economy to provide a decent livelihood likely combined with a sense of moral outrage at the decadence of the court in Constantinople, and drove people like St. Anthony to seek alternatives. As such, modern historians cite this as an example of how alternative counter-cultures often emerge in times of economic or social crisis (Lauderdale and Harris, 2008).

Monasticism expanded during the life of John Cassian, (360-435 AD) who used the austere ideology of the Desert Fathers as the basis for a formal institution that he established in the relatively prosperous Mediterranean port of Marseille (Hassett, 1908). Cassian's monastery in Marseille was at once the cause and the consequence of the city's success (Loseby, 1992). In all likelihood, Cassian settled

there because the city is surrounded by hills and has only a small hinterland. These traits isolated it from the unrest in Northern Europe at this time. Nevertheless, Marseilles also had access to both the Rhone valley and a deep water port on the Mediterranean and so was able to maintain trading links between the entire coastal Mediterranean and the interior of Europe. As a result, this city was one of the few places in Europe where trade and urban life prospered and expanded at this time (Loseby, 1992).

Following the fall of Roman administration, Europe as a whole lacked formal institutions, and the monastic order of St. Cassian provided a model to fill this vacuum. To realize this potential, however, took Saint Benedict of Nursia (circa 480-543 AD) who was heavily influenced by Cassian's community in Marseille. Much of Benedict's life was spent founding monasteries and writing *The Benedictine Rule*, a guide that promotes a simple life full of hard work, collective living, and emphasizes agricultural labour. One of his core ideas was that religious life was social, hence he disagreed with the Desert Fathers on the need to withdrawal from the world. He was also much more moderate in terms of austerity than Cassian (Alston, 1907, see also chapter 48 of "The Benedictine Code:" St. Benedict, 1949 edition).

The Cassian model of communal living combined with the relatively relaxed Benedictine code to provide a successful formula for early Medieval Europe. Add to this the fact that the monasteries were the only institution that offered social mobility at the time (they accepted members from all ranks) and it is unsurprising that they expanded rapidly (Lebecq, 2000). Key theoretical tools to help explain the emergence of the monastic orders include institutional economics (North, 1981, North, 1991) that shows how institutions can provide stability during times of turbulent social relations. In addition, mainstream economics (Stigler, 1966) provides a useful lens through which to explain the growth of economic stability at the time. In particular, it seems reasonable to hypothesize that monks generated increasing levels of utility by participating in a growing competitive market that sent price and cost signals. Thus, it is likely that the monks had incentives to specialize production by exploiting comparative advantages and further increased the efficiency of agricultural production by obtaining larger economies of scale. This would have allowed them to create food surpluses that they traded with other monasteries thereby increasing the overall wealth in the economy.

2.3 Phase II

Despite the Benedictine love of self sufficiency, at no point in this period did Europe have an entirely subsistence economy. Even in the relative vacuum left by Rome, trade still existed and monasteries kept regular contact with each other and the larger economy. For example, the monastery at St. Denis, near Paris had long term agreements to obtain salt, wine and oil from all over France and one medieval commentator remarked that for these monks, the Seine river was a "...channel for vessels..." that meant a brisk "...trade in many goods..."(Quoted in: Lebecq, 2000 p 129). Its annual fair was one of the most important commercial events of the year with merchants from all over the world descending on Paris. As a result, historians who study this period observe the development of complex financial and trading networks centred on monasteries. This all contributed to their growth and, in growing, the Monasteries became both the largest concentrations of wealth in Europe and a

catalyst for wide spread economic and cultural revival (Raftis, 1961). It is important to note, of course, that not all medieval monastic orders owned property and became powerful like the Benedictines. The mendicant orders (i.e. those who exist on alms) such as the Franciscans did not own property and took strict vows of poverty.

By the 10th century, the monastic communities were well established and able to generate a regular and reliable surplus of food with which they traded. The climate helped, and reconstructions of the climate from this time, as well as proxy observations obtained from rock and ice cores suggest warm and productive weather (Desprat et al., 2003, McDermott et al., 2001). This contributed to turning the monasteries into islands of learning and stability from which they set about clearing the forests from the old grain fields that had been left uncultivated since Roman times. Of course, politics played a significant role and monks were sent by political leaders such as Charlemagne to establish communities, bring political stability, and attract converts in remote locations (Sullivan, 1953). Royalty also established monasteries for more personal reasons. Following the conquest of England, each soldier was told to do 120 days penance for every person he had killed. Rather than doing this themselves, aristocrats founded and maintained abbeys where monks would do this penance on their behalf. For example, King William I of England had an abbey built at the site of the battle of Hastings, a location described by a medieval commentator as being "...in a desert surrounded by swampy valleys and by forests out of which only a few homesteads had yet to be carved..."(Quoted in: Miller and Hatcher, 1978 p. 33). The Domesday book, a record of landholdings in England that was compiled just after William was enthroned in 1066, has been contrasted with manorial accounts from a few hundred years later. These analyses point to a massive expansion of agriculture where "hundreds of thousands of acres" were brought under cultivation during this period (Miller and Hatcher, 1978 p. 33).

To account for this continued economic growth, it is reasonable to hypothesize that trading agricultural surpluses between monasteries increased, and this generated additional wealth, allowed for regional specialization, and helped create enough surpluses to support an economic class not tied to agriculture. At this stage, economic growth likely brought a range of benefits to medieval Europe contributing to the growing population. In terms of the environment, this growth also caused longer-term problems like deforestation and soil erosion. The tools of ecological economists provide a lens through which to assess these dynamics (Common and Stagl, 2005). For example, the "Environmental Kuznets Curve" (Panayotou, 1997) proposes that different types of environmental problem have different relations with wealth. First are local problems that threaten human life in the short-term like water so polluted that it causes dysentery (Fraser and Hubacek, 2007). These tend to be worst in poor agriculture communities but are quickly addressed as incomes rise. Second are less local and immediate problems that usually become worse as incomes grow, but beyond a certain point, these problems too are addressed. Urban air pollution is an example of this type of problem. Third are the global environmental problems that have delayed or remote effects (e.g. anthropogenic climate change). According to ecological economists, these problems tend to worsen as economies grow wealthy. Medieval Europe's significant population growth, in combination with deforestation in remote locations, is consistent with the way the literature on the Environmental Kuznets curve suggests environmental problems shift as affluence grows. More specifically, we can hypothesize that although initial levels of economic growth

helped people overcome the most immediate and life threatening problems (thus contributing to population growth), this same growth contributed to the longer-term and more remote problem of soil degradation and deforestation.

2.4 Phase III

The impact of the monks was not restricted to land clearance. They were also agricultural innovators and "...monkish inventiveness had acted as a spur in medieval agriculture and industry from the tenth or eleventh century onward..." (Lucas, 2006 p. 203). For example, monastic farms used triple crop rotation, which increased productivity, heavy mould bore ploughs, which allowed farmers to cultivate clay soils, a new stiff horse collar and nailed shoes, which allowed farmers to use horses rather than oxen for ploughing, and better axes that made short work of the forests (White, 1966). These innovations were both a cause and a consequence of population growth, providing a feedback between the economy, the population, land use patterns and agricultural technology.

Of these, the plough was likely the most important. Earlier, cultivation was generally done using a "scratch" plough that simply scratched the surface of the soil. These ploughs had the advantage that they were relatively easy to pull through the ground, and did not require great teams of oxen or horses yoked together. They also meant that the nutrients lower in the soil profile were never brought to the surface and that fields needed to be ploughed twice - ploughmen would plough first in one direction and then in the other, perpendicular to the first plough line. This created small square fields. Although the exact origins of heavier ploughs are obscure, they were extremely important to the monastic farms in the Medieval Period (White, 1966). First, they were bigger and cut deeper. This made it possible to cultivate the soils of Northern Europe that were unyielding to the scratch plough. Second, the mould bore plough had three parts: a vertical blade that cut downwards, a horizontal blade that cut roots under the surface, and a sloped section, coming off the horizontal blade, that turned the newly cut soil up to one side or another. This meant deeper furrows that made more fertile soil accessible to crops. Also, because this was all accomplished in one pass it was possible for smaller numbers of people to cultivate larger areas.

The monks were also heavily invested in food processing technologies and monastic farms re-introduced water-wheels to Europe (these had vanished with the Romans). This freed up enormous amounts of rural labour that otherwise would have been used processing grain by hand (Usher, 1988) and it was traditional for abbeys to be granted a monopoly on milling grain as part of their charter (Lebecq, 2000). Cheese making was also extremely important because this allowed milk to be kept longer. There are records from St Germain des Pres that the monks collected 12,000 kg of cheese/a in tax from their tenants, that Charlemagne taxed a bishop 2 cartloads of cheese, and a Monastery at Staffelsee had 40 cheeses in its storehouse during the early medieval period (Pearson, 1997). In the Monastery at Cluny, monks who had taken vows of silence used a complicated sign language that had many different signs relating to cheese (Ambrose, 2006). Hopped beer, which lasts longer than unhopped beer, also became a common aspect of monastic life during this period (Wilson, 1975) with regular records of monastic gardens from the 1000s onwards including hops (Unger, 2004). Finally, a reference in the Domesday book records

that the monks of St. Paul's Cathedral in London brewed almost 80,000 gallons of beer each year (Bamford, 2003).

In this, the development of monastic technologies was in all likelihood both the product and the result of the growth of the population and economy. Food that lasted longer could be traded further, thus increasing the opportunities for regional specialization that generated more wealth and stimulated further land clearing, food production and population growth. Simple cause-and-effect arguments are no use here, and what we observe is a co-evolution of factors that feedback and reinforced each other. Furthermore, it seems reasonable to hypothesize that monastic farmers were also adapting throughout this time, responding to feedbacks such as weather related variability, deforestation, erosion, population growth, and new market opportunities and that this also stimulated the development of new technologies. If this is the case, it may be that we can use the intellectual tools from the study of field of "dynamic complex systems" to account for this phase of development. In this body of work, scholars from a range of disciplines (including computer programming, ecology, meteorology, business, military strategy and the social sciences) suggest it is appropriate to view the world as made up of a series of agents that through interacting create complex systems that have "emergent properties" that include "strange attractors", "non-linear effects", "threshold effects" and "bifurcations"(Kauffman, 1995, Bar-Yam, 1992, Fraser et al., 2003). Through these emergent properties, complex systems often respond unpredictably, remote influences may have major effects, and the over all "system behaviour" may be different than that of individual actors. The study of complex systems demonstrates that systems may remain stable for long periods before switching and becoming chaotic before returning to a new "domain state" (Gleick, 1987, Peterson et al., 1998). Anticipating the so-called "tipping points" – i.e. the moment when a system may become chaotic such as the famines that started in the early 14th century – is very difficult (Meadows, 1999) since a system may "look" the same year upon year but be approaching a threshold that makes it especially vulnerable.

2.5 Phase IV

The Medieval period reached its peak in terms of population size, cultural investment, and artistic endeavours between 1100 and 1300 (Fischer, 1996). Thanks to agricultural management, land clearing, and post-harvest food processing, monastic farms were able to produce more food than they could consume (Hodges, 1989). These surpluses were traded through extensive networks across the continent. Trade shifted from being based only on luxury items to include bulky low-value commodities like grain and dairy (which along with timber were England's chief exports at this time) and this helped free people from having to produce food, catalysing wide spread social and economic renewal. It also meant the elite started to become involved in agricultural trade and, where before they had previously only really been interested in the trade of high value goods that were easy to transport (such as silk, gems, or spices), by the 12th century abbots and lords were working to control basic commodities (Miller and Hatcher, 1978).

The surplus of traded food pushed – with the monks at the fore – cultivation into very marginal land. In this, the Medieval period was helped with a benign climate (the medieval warm period) that was much like the climate that favoured Roman

expansion and made unproductive land worth cultivating (Jansen et al., 2007). These forces combined in the medieval renaissance and one modern scholar points to 1224 as the zenith of a period when France alone built 80 new cathedrals, 500 abbeys and 10,000 parish churches (Fischer, 1996). For example, work began on Notre Dame Cathedral in the late 12th century. Romanesque architecture hit its peak with Gothic flourishes appearing in stone buildings. Great Universities were also founded in Paris, Oxford, Bologna and Salerno amongst other places.

At the time, however, signs of problems started emerging. One of the first was a widening gap between the rich and the poor. New agricultural technologies, such as the heavy ploughs were beyond the reach of peasant farmers because they required much larger teams of draught animals. As a result, some scholars cite a range of medieval sources including the Bayeux Tapestry (from the late 11th century) that shows a peasant using a scratch plough pulled by a single donkey to suggest that these new technologies were beyond the reach of poorer members of society (Reading, 2004).

All of this paid very rich dividends to the monks and by the 13th century, many monastic orders had strayed from their roots of material simplicity and grown wealthy and powerful. The classic example of this is the Abbey of Cluny in France that dominated the political, economic and cultural landscape of Europe. The “Cluniacs” were a large federated order with many chapters mostly across today’s France. This was no self-sufficient retreat, but an almost franchised organization that specialized in prayers liturgy and commerce, reducing the role of physical labour and agricultural productivity and exercising political power. It was second only to Rome in influence as a centre for the Christian world and became a preeminent house of learning and a “training school for popes” (Alston, 1908). Its chapter houses were lavishly decorated and its members lived like aristocrats.

To maintain this privileged position, monasteries started to aggressively assert their position in terms of food processing. Monastic charters that granted monopolies on milling grain gave abbots the legal justification for forcing peasants to use their mills (Lucas, 2006). One study of the estates of the Bishopric of Worcester shows that in 1299, income raised from milling corn was the most important source of funds for the abbeys (Holt, 1987). In addition, evidence mounts during the Medieval period of abbots actively repressing the use of handmills. For example, in 1274, violence erupted when the monks of St Albans Abbey in Cirencester tried to enforce their monopoly on milling by confiscating and destroying the peasants’ handmills (Usher, 1988).

Therefore, we observe that by the 12th and 13th centuries, the mainstream monasteries had grown into very wealthy and powerful institutions and their demands created a core economy that led to the exploitation of land and labour. From this, it seems plausible to hypothesize that the increasing use of capital intensive agricultural management and the monopolistic behaviour of the monasteries with regard to food processing contributed to a rift in society where there were “have’s” and “have-nots.” This dynamic may even have created an increasingly large and peripheral hinterland where remote areas were cleared and brought to under the plough to support the affluent elite in the core. The most useful theoretical bodies of literature to explain these dynamics are drawn from political science. In particular,

“World Systems Theory” by Emmanuel Wallerstein (1975), the closely related “theory of dependency” by Andre Gunder Frank (2004), and “eco-colonialism” by John Crosby (1986) all explain how the unbalanced power between a core economy and a peripheral region will lead to land and labour exploitation and create what Dauvergne calls a “shadow ecology” (1997, 2008) where the demands imposed by the elite cast a shadow over the ecology of remote places.

2.6 Phase V

It is hardly surprising that the wealth accumulated by the Benedictine orders generated anger and jealousy. Probably the most vocal critic was St. Bernard of Clairvaux who is best remembered for his role in helping establish the Cistercians, an order of monks who initially reacted against Cluny and the Benedictine’s wealth but that also grew into a powerful land owning institution in their own right. The Cistercians were originally formed in 1098 but it was not until St. Bernard was elected abbot a few years later that the Cistercian movement really began. From his position as the chief rival and critic to Cluny, St. Bernard spent much of his career writing stinging attacks on the decadence of mainstream monasticism. While there is some debate as to how accurately he portrayed the wealth of Cluny (Rudolph, 1988), and there was a war of words between the rival monastic orders (Berman, 1986), the Cistercians became an extremely successful and wealthy order. Some medieval critics of the Cistercians saw them as land hungry farmers not all that different from the Benedictines:

... they [the Cistercians] obtain from a rich man a valueless and despised plot in the heart of a great wood, by much feigning of innocence and long importunity, putting in God at every other word. The wood is cut down, stubbed up and leveled into a plain, bushes give place to barley, willows to wheat, withies to vines; and it may be that to give them full time for these operations, their prayers have to be somewhat shortened.(Walter Map, twelfth-century archdeacon, satirist and critic of the Cistercians quoted in: The Cistercians in Yorkshire and the Humanities Research Institute, 2008)

In England, for example, the Cistercians were particularly important in Yorkshire. This was an economically and politically remote frontier that had been ravaged by repeated wars and rebellions following the Norman conquest (Hodgson, 1969). The Cistercians, who have been dubbed “the shock troops” of deforestation (Williams, 2000), changed this, and their monasteries pushed medieval civilization to the tops of the hills and into the hearts of forests (Pounds, 1994, Platt, 1969).

As such, the expansion of the medieval period was likely driven to some extent by exploiting natural capital that had accumulated since the post-Roman land abandonment. But it could not last, and according to Fischer, by 1224 deforestation and soil erosion were causing the price of charcoal and timber to rise, the price of flour was fluctuating widely, and wages were declining (Fischer, 1996). The boom in population put pressure on resources, and soil deterioration led to falling yields. As arable land moved up into the marginal pastures of places like Yorkshire, and these new fields lost the nutrients added by grazing animals, they quickly became unproductive.

As a result, a key dynamic of this phase was that growth was likely based on significant negative environmental externalities (Panayotou, 1993). Furthermore, it also seems likely that the ecology of Europe became increasingly vulnerable to weather and disease related problems. The field of landscape ecology provides useful tools to understand and test this hypothesis. Based on work studying ecosystems like the boreal forest, which go through cycles of renewal and collapse, academics like C.S. Holling and Lance Gunderson suggest many ecosystems cycle through periods of resilience and vulnerability and it is possible to observe vulnerability emerging based on three landscape characteristics: the biodiversity present (more diverse systems are less vulnerable), productivity (landscapes productive in terms of biomass are more vulnerable since they have considerable fodder for pests, hosts for diseases, or biomass for fires), and how connected individuals in a landscape are in space and time (highly connected landscapes are more vulnerable since problems can more easily spread if there is little distance in space, time or distance in food/chemical webs) (Gunderson and Holling, 2002). Using Gunderson and Holling's work as a lens, we can infer that the landscape of Medieval Europe became more vulnerable because the landscape in the period leading up to the early 14th century lost diversity, was increasingly productive (in terms of food) and was tightly connected thanks to trade and population.

2.7 Phase VI

These forces culminated in a wave of inflation that spread across Europe and lasted for as much as 200 years. The inflation hit regions and products differently. Basic necessities – food, energy, materials for shelter – were most affected. The cause is clear: the deforestation of the 10-12th centuries was catching up with Europe and wood for building and making charcoal becoming scarce. Close behind was the price of food. The price for luxury items and manufactured goods, which are not so dependent on raw materials, increased relatively little and stayed stable (Fischer, 1996). By the end of the 13th century, the growth of population meant people were pushing hard against the limits of their resources.

States, cities and manors teetered on bankruptcy and borrowed money at ruinous rates of interest. As they failed, so to did the banks that had extended them credit. For example, in 1298, Gran Travola of the Buonsignori, the world's premier bank with operations all over Europe, failed. Siena's Cathedral, which was undergoing a massive expansion at the beginning of the 14th century, was never completed. Florence's banks picked up the slack, but by within decades they too were in trouble (Fischer, 1996).

Climate played a role, and modern climatologists have evidence that the "Medieval Warm Period" came to an end around 1300, and it seems clear that around this point, the North Atlantic grew colder and this ushered in a protracted period of unstable weather patterns (Cronin et al., 2003). This trend is particularly pronounced in data derived from around Iceland and likely contributed directly to the fall of Viking communities in Greenland (Sicre et al., 2008).

Then, a mid summer rain lashed the crops in 1314 and food rotted in the field. In England, Edward II imposed price controls and across Europe the peasantry tightened their collective belts. 1315 was worse. Dikes collapsed, fields vanished,

and livestock died in huge numbers thanks to a new disease, Rinderpest, which had been introduced by invaders from Asia into Eastern Europe but was spread across the continent on trading routes (Spinage, 2003). In England, the price of wheat jumped 8 fold (Fischer, 1996). In 1316, the late summer rains came again and Europe experienced the worst famine in its history. Reports of cannibalism are rife, with families consuming the bodies of the dead and corpses dug out of graveyards to be eaten. John de Trokelowe, a British Monk, wrote an account of the time where he describes the illnesses that people succumbed to:

A dysentery-type illness, contracted on account of spoiled food, emasculated nearly everyone, from which followed acute fever or a throat ailment. And so men, poisoned from spoiled food, succumbed, as did beasts and cattle [who] fell down dead from a poisonous rottenness...(Quoted in Aberth, 2001 pp. 6-7)

Possibly 10% of Europe perished. Crime, insurrection, and war broke out across the continent. The catalogue is long and even Venice, that most stable of regions, suffered its only major insurrection in its 1000 year history. As described by an eye witness:

*When God saw that the world was over proud,
He sent a dearth on earth, and made it full hard.
A bushel of wheat was at four shillings or more,
Of which men might have had a quarter before...
And then they turned pale who had laughed so loud,
And they became all docile who before were so proud.
A man's heart might bleed for to hear the cry
Of poor men who called out "Alas! For hunger I die..." (Wright, 1321 or 1327)*

Worse was in store and in October 1347 the Black Death established itself in Sicily. By January, 1348 it was in Venice, by June it had crossed the Alps and the Pyrenees. England went down in December and Scotland and Scandanavia were hit by 1349.

Some modern scholars debate the exact nature of the disease, bringing into question the commonly assumed link between rats, fleas and the bacteria *Yersinia pestis* (Cohn, 2002). Some suggest that there was only a limited link between the famine in the earlier 14th century and plague since even relatively well fed monks and lords were just as likely to die as the poor peasantry (Aberth, 2001). While specific epidemiological mechanisms are debated, few disagree that some sort of pathogen found a vulnerable population that was tightly connected and deeply impoverished, malnourished, and desperate (McCormick, 2003, Platt, 1996, Herlihy, 1997).

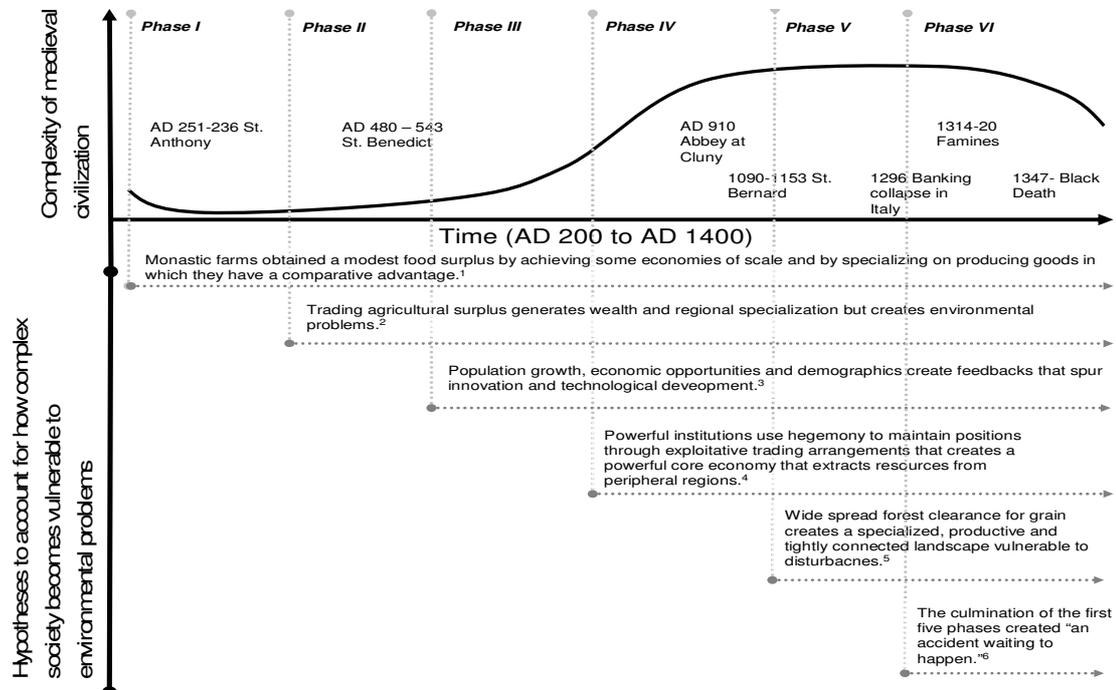
Accounts of mortality suggest that 20-45% of Europe's population probably perished. The culture of Europe collapsed, foreigners were massacred in acts of desperate xenophobia, towns and villages were abandoned, and farms never again worked (Platt, 1996). This has massive economic consequences. During the famines, the price of food, which was already rising, shot up tremendously. Then, in the aftermath of the Black Death, there were fewer mouths to feed and prices began to immediately decline. With much less labour, the price of workers and manufactured goods rose and economic conditions were the reverse of pre-famine Europe. Suddenly, it was

not so profitable to keep planting grain crops in marginal agricultural land, and less labour intensive livestock rearing, which had been on the decline in the 13th century, increased again. Even trivial crops such as rabbits, which had been only eaten by the elite because they took up a relatively large amount of space relative to the number of calories they produced, became common amongst all walks of life as people reinvented the economy based on a model with much less labour but more abundant land (Thirsk, 1997).

3 Discussion: An overarching hypothesis with which to explore the present

Taken, together, I propose the following hypothetical account for why a vulnerable food system emerged in Western Europe during the time known as the Middle Ages. A subsistence agrarian economy replaced the Roman Empire in the West and over time, communities formed around the early monasteries and were able to generate and trade surplus food based on exploiting comparative advantages (phase I). This resulted in land clearance and (likely) some environmental problems but generated enough prosperity to allow for a rising standard of living, supported a growing population (phase II). This reinforced the Monastery's position as an anchor in society and although problems like soil erosion and deforestation mounted during this period, the additional wealth and prosperity enjoyed by the Monasteries allowed them to innovate with agricultural technology, thus increasing harvests (phase III). This process further reinforced the wealth and power of the monasteries and this, combined with population growth, meant that cultivation was pushed into very marginal land, creating an exploited periphery that supported the wealthy core economy (phase IV). This process was facilitated by a relatively productive climate that helped keep yields high despite mounting evidence of soil degradation. These dynamics created what ecologists consider a vulnerable landscape in that it was highly productive but also homogenous and bound tightly together (phase V). When systemic problems of over-population and economic turmoil emerged at a time when the climate became less productive, the food system of Medieval Europe was unable to adapt. It had become on the even of the 14th century an accident waiting to happen. New disease threats, which were easily transmitted along the trade routes, hit a population with few reserves and little in the way of buffers (phase VI). This broad account of the rise and fall of western Europe's society during the Middle Ages is presented as a heuristic graphic in figure two.

Figure 2: Theoretical explanation for why so many problems struck Medieval Europe in the 14th century presented as a broad hypothetical framework to determine signs that things were going wrong before the decline started.



Note: The six phases represent roughly chronological (but overlapping) periods when different socio-economic and ecological theories help explain the development of society. This figure is intended as a heuristic hypothesis and should not be interpreted as deterministic. (1) Phase I draws on the work of classical economics, comparative advantage and economies of scale (Stigler, 1966). (2) Phase II draws on the work of ecological economists and is consistent with finding relating to the environmental Kuznets curve (Panayotou, 1997, Common and Stagl, 2005). (3) Phase III draws on the work of scholars who try to explain the behaviour of complex dynamic systems by understanding feedbacks within socio-ecological systems (Bar-Yam, 1992, Epstein and Axtell, 2001). (4) Phase IV draws on political science theories such as world system (Wallerstein, 1975), dependency (Frank, 2004) and shadow ecologies (Dauvergne, 2008). (5) Phase V draws on landscape ecology that characterises landscapes vulnerable to exogenous shocks (Gunderson and Holling, 2002). (6) Phase VI is the period of decline that is a cumulative effect of phases 1-5.

To broaden this discussion beyond the specifics of Europe's Middle Ages, the dynamics I propose as dominant in these six phases should be seen as a very broad hypothetical account for the rise and fall of complex society in general. In short, I propose that whenever we see economic, institutional and land use dynamics all conspiring to create a large-scale subsistence systems that depend on a homogenous and exploited periphery we have reason to be very concerned. It seems possible that this account is applicable to other situations. For example a causal examination of two Victorian cases suggests a similar set of dynamics. During the Industrial Revolution, population growth and Colonial policy led to land-use specialization and economic marginalization across the periphery of the British Empire. These landuse systems proved fragile in the face of climate variability and economic change. The rainy 1840s in Ireland (Fraser, 2003) and the El Niño droughts in Southern Asia in the 1870s and 1890s (Fraser, 2007) both caused massive famines from which these societies have never really recovered (O'Grada, 1989, Davis, 2001).

Most importantly, I believe that the themes outlined in this paper reflect aspects of today's food system. For example, the period of time following World War II saw rapid economic growth based on policies to promote the trade of agricultural commodities (World Trade Organisation, 2008). In many parts of the world this economic growth was based negative environmental externalities (Panayotou, 1993) but also has allowed for technological innovations (i.e. the Green Revolution) that have helped populations to rise around the world (Smil, 1999, Smil, 2001). It has also provided the basis for enormous, vertically integrated, agri-industrial firms to emerge (Morgan et al., 2006a, Morgan et al., 2006b, Winson, 1992). These firms provide many of the same roles as the monastic orders did 700 years ago. Overall, therefore, trends since the mid 20th century have created a food system that is also very much like the one studied in this paper. Our food system is based on very productive landscapes that are tightly connected and produce a small number of key commodities, many of which are exported from an exploited periphery to meet the demands of a wealthy core (Fraser, 2006). As a result, I both worry and hypothesize that our food system is – much like the Medieval food system was on the eve of the 14th century – vulnerable to disruption.

Events in the first half of 2008 were especially worrying in terms of these trends. Linked with rises in the price of oil, international financial speculation, currency volatility, bioenergy crops, and a drought in Australia, food prices soared (Zoellick, 2008). As a result of this volatility, people around the world took to the streets and riots were reported in Mexico, Pakistan, Egypt, Haiti, Burkina Faso, Cameroon, Senegal, Mauritania, and India (Walt, 2008). The UN's Food and Agriculture Organization estimated that the escalated costs of buying food added 75 million hungry people to the planet (Food and Agriculture Organisation, 2008). Since early 2008, prices have come down but are still far higher than in previous years. Paradoxically, however, 2008 saw a 5% increase in food stocks over 2007 and a total harvest of 2.24 billion tons – this made 2008 the world's most productive year ever (Food and Agriculture Organisation, 2008).

But what if the weather had not cooperated in 2008? Recent work done on the relationship between rainfall and grain productivity in China indicates that some key grain producing areas are becoming more sensitive to rainfall anomalies (Fraser et

al., 2008, Simelton et al., 2009). This suggest that our system may be becoming more sensitive to climate change and makes the situation in 2008 even more worrisome. What if the weather in 2008 had been more like that which occurred in 1314? Would the food system we all enjoy have kept working?

It is impossible to answer these “what-if” questions and this sort of scenario stands outside our economic and climate change models. It is possible to imagine, however, that if the food price shocks of 2008 had occurred during a year of real food shortages, then millions might have starved or migrated.

But is this all to suggest that we should fear a repeat of the 14th century? Perhaps. But, the modern world is not the medieval one, and while there are similarities, there are also enormous differences. We have an immeasurably better understanding of the economic and biophysical processes that govern life than our ancestors did. We can track economic fluctuations like inflation and although we do not have the tools to anticipate changes in inflation or have the ability to control it, the monetary policy of central banks is (hopefully) key to preventing it from becoming too a huge problem. We track climate change. We can use the skills and technology we have developed since the Industrial Revolution to adapt to problems and can breed drought tolerant grain crops, use fertilizer (etc.) to maintain soil fertility in the face of rising demand for food, and establish irrigation to protect against drought.

As a result, I do not want this paper to be read as a deterministic piece of soothsaying. After all, there is a long history of academics proposing to have discovered inevitable trajectories that account for complex social phenomena including economic growth (Rostow, 1990) the development of religion (Frazer, 1998 edition) and business cycles (Kondratieff, 1984). Generally, these theories are discredited today. I also do not want this paper to be read as a simplistic argument by analogy that suggests since history was “just-so” so too must be the present.

Rather, I think we have a tremendous capacity to adapt to problems and increasingly (thanks to computer modelling) a good ability to predict problems before they arrive. In terms of the dynamics that I believe drive the six phase framework presented above, I am of the opinion that the key to today’s predicament lies in the way we respond to the feedbacks identified as part of phase III. Will our ability to adapt mean we will respond effectively to these feedbacks (which includes our awareness of likely future climate changes) or will we simply continue to exploit peripheral regions and create even more vulnerable subsistence systems?

What happened during the medieval period was that rich and powerful institutional players – namely the Benedictine and Cistercian monasteries – entrenched their privileged position by further exploiting the periphery and while this strategy worked when the climate was productive, it simply could not be maintained during a downturn in the weather. We need to acknowledge this potential in today’s world and establish appropriate policy to stop this happening and to ensure that rather than responding to shocks by entrenching our current unsustainable subsistence patterns, we respond to feedbacks by actually adaptive by creating a food system that is more diverse and less connected. In a world of 6-9 billion people, achieving this may be the challenge that defines the next generation.

4 Conclusion

This paper has presented an account of Western Europe's history between AD 300 and 1400 as an analogy for today's world. Europe's mediaeval period is a useful place to draw this analogy since many of the problems associated with today's society (deforestation, economic upheaval, climate change, the exploitation of an economic hinterland, and population growth) were also associated with the lead up to the 14th century when disease, famine and warfare killed about 50% of the continent. From this history, I propose there were key dynamics that accounted for the development of a vulnerable food system in the Middle Ages and that these dynamics are active in shaping our subsistence strategies today.

Acknowledgements

Thanks to Professor David Fraser (UBC), Professor Andrew Gouldson, Dr. Lindsay Stinger, Dr. Joseph Murphy, and Dr. Jouni Paavola (Leeds) for their thoughts on this manuscript. This work was funded by the ESRC through an interdisciplinary research fellowship, the ESRC's Centre for Climate Change Economics and Policy, and NERC QUEST: Global Scale Impacts programme.

References

- Aberth, J. (2001) *From the Brink of the Apocalypse: Confronting Famine, War, Plague, and Death in the Later Middle Ages*, New York, Routledge.
- Alston, G. C. (1907) Rule of St. Benedict. In *The Catholic Encyclopedia*. New York, Robert Appleton Company and New Advent.
- Alston, G. C. (1908) Congregation of Cluny. In *The Catholic Encyclopedia*. New York, Robert Appleton Company and New Advent.
- Ambrose, K. (2006) A Medieval Food List from the Monastery of Cluny. *Gastronomica*, 6, 14-20.
- Athanasius (Ed.) (1979) *The Life of Antony and the Letter to Marcellinus*, Mahwah, NJ, Paulist Press.
- Bamford, C. (2003) *Beer: Tap Into the Art and Science of Brewing*, Oxford, UK, Oxford University Press.
- Bar-Yam, Y. (1992) *Dynamics of Complex Systems*, Reading, Adison-Wesley.
- Bar-Yosef, O. & Belfer-Cohen, A. (1989) The origins of sedentism and farming communities in the Levant. *Journal of World Prehistory*, 3, 447.
- Bebbington, A. (1999) Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. *World Development*, 27, 2021-2044.
- Berman, C. (1986) Medieval Agriculture, the Southern French Countryside, and the Early Cistercians: A study of forty-three monasteries. *Transaction of the American Philosophical Society*, 5, 1-194.
- Betancourt, P. (1976) The End of the Greek Bronze Age. *Antiquity*, 50, 40-47.
- Bintliff, J. (1997) Regional Survey, Demography, and the Rise of Complex Societies in the Ancient Aegean: Core-Periphery, Neo-Malthusian, and Other Interpretive Models. *Journal of Field Archaeology*, 24, 1-38.
- Bintliff, J. (2002) Time, Process and Catastrophism in the Study of Mediterranean Alluvial History: A Review. *World Archaeology*, 33, 417-435.
- Boulding, E. (1976) Familial Constraints on Women's Work Roles. *Signs*, 1, 95-117.
- Bridbury, A. R. (1977) Before the Black Death. *The Economic History Review*, 30, 393.
- Butler, E. C. (1907) St. Anthony. In *The Catholic Encyclopedia*. New York, Robert Appleton Company and New Advent.
- Chew, S. (2006) *The Recurring Dark Ages: Ecological Stress, Climate Changes, and Systems Transformation*, Lanham, Md, Altamira Press.

- Chew, S. C. (2008) Historical Social Movements, Ecological Crisis and 'Other' World Views. *Journal of Developing Societies*, 24, 31-56.
- Clark, G. (2005) "The Condition of the Working-Class in England, 1209-2004. *Journal of Political Economy*, 113, 1307-1340.
- Cohn, S. K., Jr. (2002) The Black Death: End of a Paradigm. *The American Historical Review*, 107, 703-738.
- Common, M. & Stagl, S. (2005) *Ecological Economics: An Introduction*, Cambridge, UK, Cambridge University Press.
- Cronin, T. M., Dwyer, G. S., Kamiya, T., Schwede, S. & Willard, D. A. (2003) Medieval Warm Period, Little Ice Age and 20th century temperature variability from Chesapeake Bay. *Global and Planetary Change*, 36, 17.
- Crosby, A. (1986) *Ecological Imperialism: The Biological Expansion of Europe, 900-1900*, Cambridge, UK, Cambridge University Press.
- Dauvergne, P. (1997) *Shadows in the Forest*, Cambridge, MA, MIT Press.
- Dauvergne, P. (2008) *Shadows of Consumption*, Cambridge, MA, MIT Press.
- Davis, M. (2001) *Late Victorian holocausts: El Nino famines and the making of the Third World*, London, Verso.
- Desprat, S., Sánchez Goñi, M. F. & Loutre, M.-F. (2003) Revealing climatic variability of the last three millennia in northwestern Iberia using pollen influx data. *Earth and Planetary Science Letters*, 213, 63.
- Dotterweich, M. (2008) The history of soil erosion and fluvial deposits in small catchments of central Europe: Deciphering the long-term interaction between humans and the environment -- A review. *Geomorphology*, 101, 192-208.
- Epstein, J. & Axtell, R. (2001) *Sugarscape*.
- Fischer, D. (1996) *The Great Wave: price revolutions and the rhythm of history*, Oxford, Oxford University Press.
- Food and Agriculture Organisation (2008) Record harvest but troubles loom ahead: Financial crisis will hurt agricultural markets. Rome, Food and Agriculture Organization.
- Fossil Pollen Database (2008) Fossil Pollen Database. Fossil Pollen Database.
- Frank, A. G. (2004) The Development of Underdevelopment. IN Wheeler, S. & Beatley, T. (Eds.) *The Sustainable Urban Development Reader*. New York, Routledge.
- Fraser, A. (2000) *The Middle Ages*, London, Castell and Co.

- Fraser, E. (2003) Social vulnerability and ecological fragility: building bridges between social and natural sciences using the Irish Potato Famine as a case study. *Conservation Ecology*, 7, 9: on line.
- Fraser, E. (2006) Agro-ecosystem vulnerability. Using past famines to help understand adaptation to future problems in today's global agri-food system. *Journal of Ecological Complexity*, 3, 328-335.
- Fraser, E. (2007) Travelling in antique lands: studying past famines to understand present vulnerabilities to climate change. *Climate Change*, 83, 495-514.
- Fraser, E., Mabee, W. & Slaymaker, O. (2003) Mutual dependence, mutual vulnerability: the reflexive relation between society and the environment. *Global Environmental Change*, 13, 137-144.
- Fraser, E. & Stringer, L. (2009) Explaining agricultural collapse: macro-forces, micro-crises, and the emergence of land use vulnerability in southern Romania. *Global Environmental Change*, 19, 45-53.
- Fraser, E., Termansen, M., Sun, N., Guan, D., Simelton, E., Dodds, P., Feng, K. & Yu, Y. (2008) Quantifying socio economic characteristics of drought sensitive regions: evidence from Chinese provincial agricultural data. *Comptes Rendus Geosciences*, 340, 679-688.
- Fraser, E. D. G. & Hubacek, H. (2007) International dimensions of landuse change. IN Cogoy, K. S. A. M. (Ed.) *The Economics of Global Environmental Change: International Cooperation for Sustainability*. Edward Elgar, Cambridge, UK.
- Frazer, J. (1998 edition) *The Golden Bough*, London, Oxford University Press.
- Glantz, H. (1991) The use of analogies in forecasting ecological and societal responses to global warming. *Environment*, 33, 10-33.
- Gleick, J. (1987) *Chaos: making a new science*, New York, N.Y., U.S.A., Viking.
- Goldstone, J. (1991) *Revolution and Rebellion in the Early Modern World*, Berkley, University of California Press.
- Grove, R. (2007) The Great El Niño of 1789–93 and its Global Consequences: Reconstructing an Extreme Climate Event in World Environmental History. *The Medieval History Journal*, 10, 75-98.
- Gunderson, L. & Holling, C. S. (2002) *Panarchy: understanding transformations in human and natural systems*, Washington, Island Press.
- Hassett, M. (1908) John Cassian. In *The Catholic Encyclopedia*. New York, Robert Appleton Company and New Advent.
- Herlihy, D. (1958) The Agrarian Revolution in Southern France and Italy, 801-1150. *Speculum*, 33, 23-41.

- Herlihy, D. (1997) *The Black Death and the Transformation of the West*, Cambridge, MA, Harvard University Press.
- Hodges, R. (1989) *Dark Age Economics: The Origins of Town and Trade AD 600-1000*, London, New Approaches in Archaeology and Duckworth.
- Hodgson, R. I. (1969) Medieval Colonization in Northern Ryedale, Yorkshire. *The Geographical Journal*, 135, 44-54.
- Holt, R. (1987) Whose Were the Profits of Corn Milling? An Aspect of the Changing Relationship Between The Abbots Of Glastonbury and their Tenants 1086–1350. *Past and Present*, 116, 3-23.
- Hughes, J. D. & Thirgood, J. V. (1982) Deforestation, Erosion, and Forest Management in Ancient Greece and Rome. *Journal of Forest History*, 26, 60-75.
- Jansen, E., Overpeck, J., Briffa, K., Duplessy, J.-C., Joos, F., Masson-Delmotte, V., Olago, D., Otto-Bliesner, B., Peltier, W., Rahmstorf, S., Ramesh, R., Raynaud, D., Rind, D., Solomina, O., Villalba, R. & Zhang, D. (2007) Palaeoclimate. IN Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., Tignor, T. & Miller, H. (Eds.) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press.
- Kauffman, S. (1995) *At Home in the Universe: the search for laws of self-organization and complexity*, New York, Oxford University Press.
- Kondratieff, N. D. (1984) *The Long Wave Cycle*, (tr. Guy Daniels), New York, Richardson and Snyder.
- Larsen, C. S. (1995) Biological Changes in Human Populations with Agriculture. *Annual Review of Anthropology*, 24, 185-213.
- Lauderdale, P. & Harris, R. (2008) Introduction: In the Light of Andre Gunder Frank. *Journal of Developing Societies*, 24, 1-11.
- Lebecq, S. (2000) The Role of the Monasteries in the Systems of Production and Exchange. IN Hansen, I. & Wickham, C. (Eds.) *The Long Eighth Century: Production, Distribution and Demand*. Boston, Brill.
- Loseby, S. T. (1992) Marseille: A Late Antique Success Story? *The Journal of Roman Studies*, 82, 165-185.
- Lucas, A. (2006) *Wind, Water, Work: Ancient and Medieval Milling Technology*, Boston, Brill.
- Mangini, A., C. Spötl, and P. Verdes (2005) Reconstruction of temperature in the Central Alps during the past 2000 years from a d18O stalagmite record. *Earth and Planetary Science Letters*, 235, 741-751.

- Mccormick, M. (2003) Rats, Communications, and Plague: Toward an Ecological History. *Journal of Interdisciplinary History*, 34, 1-25.
- Mcdermott, F., Matthey, D. P. & Hawkesworth, C. (2001) Centennial-Scale Holocene Climate Variability Revealed by a High-Resolution Speleothem delta 18O Record from SW Ireland. *Science*, 294, 1328-1331.
- Meadows, D. H. (1999) *Leverage Points: places to intervene in a system*. Hartland, VT, The Sustainability Institute.
- Meggers, B. (1994) Archaeological Evidence for the Impact of Mega—Niño Events in Amazonia during the Past Two Millennia. *Climatic Change*, 28, 321-338.
- Mercier, S. (1999) The Evolution of World Grain Trade. *Review of Agricultural Economics*, 21, 225-236.
- Miller, E. & Hatcher, J. (1978) *Medieval England: Rural Society and Economic Change 1086-1348*, London, Longman.
- Morgan, K., Marsden, T. & Murdoch, J. (2006a) *Place, Power and Provenance in the Food Chain*, Oxford, UK, Oxford University Press.
- Morgan, K., Marsden, T. & Murdoch, J. (2006b) *Worlds of Food: Place, Power, and Provenance in the Food Chain*, Oxford, UK, Oxford University Press.
- Morse, S. & Fraser, E. (2005) Making dirty nations clean: The nation state and the problem of selecting and weighing indices as tools for measuring progress towards sustainability. *Geoforum*, 36, 114-127.
- New Advent (2007) The Catholic Encyclopedia. Available from the world wide web at: <http://www.newadvent.org/cathen/index.html>, Accessed July 27th 2007.
- Nolan, P. (2003) Toward an Ecological-Evolutionary Theory of the Incidence of Warfare in Preindustrial Societies. *Sociological Theory*, 21, 18-30.
- North, D. (1981) *Structure and Change in Economic History*, New York, W.W. Norton and Company.
- North, D. C. (1991) Institutions. *Journal of Economic Perspectives*, 5, 97-112.
- O'brien, K. & Leichenko, R. (2000) Double Exposure: assessing the impacts of climate change with the context of economic globalization. *Global Environmental Change*, 10, 221-232.
- O'grada, C. (1989) *The Great Irish Famine*, London, Macmillan.
- Panayotou, T. (1993) *Green Markets*, San Francisco, International Center for Economic Growth, The Harvard Institute for International Development, and The Institute for Contemporary Studies Press.
- Panayotou, T. (1997) Demystifying the environmental Kuznets curve: turning a black box into a policy tool. *Environment and Development Economics*, 2, 465-484.

- Pearson, K. (1997) Nutrition and the early medieval diet. *Speculum*, 72, 1-32.
- Peterson, G., Allen, C. & Holling, C. (1998) Ecological resilience, biodiversity, and scale. *Ecosystems*, 1, 6-18.
- Platt, C. (1969) *The monastic grange in medieval England: a reassessment*, London, Macmillan.
- Platt, C. (1996) *King Death: The Black Death and its Aftermath in Late-Medieval England*, London, UCL Press.
- Pounds, N. (1994) *An Economic History of Medieval Europe*, London, Longman.
- Raftis, J. A. (1961) Western Monasticism and Economic Organization. *Comparative Studies in Society and History*, 3, 452-469.
- Reading, M. O. (2004) Britain's Bayeux Tapestry. Reading, UK, Museum of Reading.
- Rickman, G. (1980) *The Corn Supply of Ancient Rome*, Oxford, UK, Clarendon Press.
- Rindos, D. (1984) *The Origin of Agricultural Systems: An Evolutionary Perspective*, New York, Academic Press.
- Rindos, D., Aschmann, H., Bellwood, P., Ceci, L., Cohen, M. N., Hutchinson, J., Santley, R. S., Shaffer, J. G. & Shaw, T. (1980) Symbiosis, Instability, and the Origins and Spread of Agriculture: A New Model [and Comments and Reply]. *Current Anthropology*, 21, 751-772.
- Rollo, W. (1934) Ostia. *Greece & Rome*, 4, 40-53.
- Rostow, W. (1990) *The Stages of Economic Growth*, New York, Cambridge University Press.
- Rudolph, C. (1988) Bernard of Clairvaux's Apologia as a Description of Cluny, and the Controversy over Monastic Art. *Gesta*, 27, 125-132.
- Russel, J. (1972) Population in Europe. IN Cipolla, C. M. (Ed.) *The Fontana Economic History of Europe, Vol. I: The Middle Ages*. Glasgow, Collins/Fontana.
- Rutter, J. B. (1975) Ceramic Evidence for Northern Intruders in Southern Greece at the Beginning of the Late Helladic IIIC Period. *American Journal of Archaeology*, 79, 17-32.
- Shard, D. (1974) The Neolithic Revolution: An Analogical Overview. *Journal of Social History*, 7, 165-170.
- Sicre, M.-A., Jacob, J., Ezat, U., Rouse, S., Kissel, C., Yiou, P., Eiriksson, J., Knudsen, K. L., Jansen, E. & Turon, J.-L. (2008) Decadal variability of sea surface temperatures off North Iceland over the last 2000 years. *Earth and Planetary Science Letters*, 268, 137.

- Simelton, E., Fraser, E. & Termansen, M. (2009) Quantifying vulnerability to drought. *Environmental Science & Policy*, Available on line.
- Smil, V. (1999) Detonator of the population explosion. *Nature*, 400, 415.
- Smil, V. (2001) *Enriching the Earth: Fritz Haber, Carl Bosch, and the transformation of world food production*, Cambridge, MA, MIT Press.
- Spinage, C. (2003) *Cattle Plague: a history*, New York, Kluwer Academic.
- St. Benedict (1949 edition) *The Holy Rule of St. Benedict*. Translated by Rev. Boniface Verheyen. St. Benedict's Abbey, Atchison, Kansas.
- Stigler, G. (1966) *The Theory of Price*, London, MacMillan Company.
- Sullivan, R. (1953) The Carolingian missionary and the pagan. *Speculum*, 28, 705-740.
- Tainter, J. A. (1988) *The collapse of complex societies*, Cambridge, UK, Cambridge University Press.
- The Cistercians in Yorkshire and the Humanities Research Institute (2008) *The Cistercians in Yorkshire*. Sheffield, Humanities Research Institute at the University of Sheffield.
- Thirsk, J. (1997) *Alternative Agriculture: A History*, Oxford, Oxford University Press.
- Twigg, G. (1984) *The Black Death: A Biological Reappraisal*, London, Batsford Academic and Educational.
- Unger, R. (2004) *Beer in the Middle Ages and the Renaissance*, Philadelphia, University of Pennsylvania Press.
- Usher, A. (1988) *A History of Mechanical Inventions, Revised Edition*, New York, Dover Publications.
- Vermeule, E. (1964) *Greece in the Bronze Age*, Chicago, The University of Chicago Press.
- Vitelli, G. (1980) Grain Storage and Urban Growth in Imperial Ostia: A Quantitative Study. *World Archaeology*, 12, 54-68.
- Wallerstein, I. (1975) The Present State of the Debate on World Inequality. IN Wallerstein, I. (Ed.) *World Inequality: Origins and Perspectives on the World System*. Montreal, Black Rose Books.
- Walt, V. (2008) The World's Growing Food-Price Crisis. *Time Magazine*.
- White, L. (1966) *Medieval technology and social change*, Oxford, UK, Oxford University Press.
- Williams, M. (2000) Dark ages and dark areas: global deforestation in the deep past. *Journal of Historical Geography*, 26, 28-46.

Wilson, D. G. (1975) Plant Remains from the Graveney Boat and the Early History of *Humulus lupulus* L. in W. Europe. *New Phytologist*, 75, 627-648.

Winson, A. (1992) *The Intimate Commodity*, Guelph, Garamond Press.

World Trade Organisation (2008) Understanding the WTO: The Basics - The Uruguay Round. World Trade Organization.

Wright, T. (1321 or 1327) Poem on the Evil Times of Edward II, also known as The Simonie. In Medieval English Political Writings. IN Dean, J. M. (Ed.) Kalamazoo, Michigan, Medieval Institute Publications.

Zerefos, C. & Zerefos, E. (1978) Climatic change in Mycenaean Greece: A citation to Aristotle. *Theoretical and Applied Climatology*, 26, 297.

Zoellick, R. (2008) A Challenge of Economic Statecraft. The World Bank.