Renfrew, C. 1986. Introduction: Peer polity interaction and socio-political change. In: Peer Polity Interaction and Socio-Political Change, ed. C. Renfrew and J.F. Cherry, pp. 1–18. Cambridge: Cambridge Univ. Press.
Schopflin, G. 2002. Nations, Identity, Power: The New Politics of Europe. London: Hurst.
Soueif, A. 2004. Mezzaterra: Fragments from the Common Ground. London: Bloomsbury.
Stavrianos, L.S. 1981. Global Rift: The Third World Comes of Age. New York: Marrow.
Wallerstein, I. 1997. Insurmountable contradictions of liberalism: Human rights and the rights of peoples in the geoculture of the modern world-system. In: Nations, Identities, Cultures, ed. V.Y. Mudimbe, pp. 181–198. Durham, NC: Duke Univ. Press.

in: Costanza, Robert; Graumilch, Lisa J.; Steffen, Will (eds.) 2007: Sustainability of Collapse? An Integrated History and Future of People on Earth. Massachusetts; Berlin: 197-212.

12

Little Ice Age-type Impacts and the Mitigation of Social Vulnerability to Climate in the Swiss Canton of Bern prior to 1800

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ABSTRACT

This chapter relates large-scale patterns of climate in central Europe to regional food vulnerability in the Swiss canton of Bern, taking into consideration the adaptive strategies of peasant farmers and the buffering strategies of the authorities. First, a short survey of the main properties of climate during the Little Ice Age is provided. From the 14^{th} to the late 19^{th} centuries, cold winters were more severe and more frequent; some years passed without a summer season as a consequence of enormous volcanic eruptions in the tropics. It is argued that changes in average temperature and precipitation are not adequate measures to assess impacts of climate on human societies.

Next an alternative approach is presented in which an attempt is made to set up impact models from the known properties of agro-ecosystems to assess biophysical impacts. Such a model was worked out for the area of the northern Alpine foothills and compared to a long series of grain prices for Munich in southern Germany. Results showed that the coincidence of cold springs with rainy and cool mid-summers was simultaneously related to peaks of grain prices and major advances of glaciers. Extensive measures of poor relief were taken by the cantonal authorities in Bern during the 18^{th} century. From the example of the subsistence crisis in 1770/1771 it is demonstrated that a great number of people became permanently dependent on welfare. However, demographic effects of the crisis were virtually absent. More case studies of this kind are needed to explore the plurality of human responses in mitigating social vulnerability to climate variability.

PROPERTIES OF LITTLE ICE AGE CLIMATES

The Little Ice Age (LIA) is the most recent period when glaciers maintained an expanded position on most parts of the globe, as their fronts oscillated in advanced positions (Grove 2001). The LIA was a simultaneous, worldwide phenomenon; however, there was considerable regional and local variation.

In the Alps, three phases of maximum extension can be distinguished: the first occurred around 1385, the second in the mid-17th century, and the third around 1860 (Holzhauser 2002). Heinz Wanner (2000) coined the term of "Little Ice Age-type events" (LIATE) to designate the three far-reaching advances known from the last millennium. Each of the three LIATE was the outcome of a specific combination of seasonal patterns of temperature and precipitation (Luterbacher 2000). No single, long-term climatic trend supports the advanced position of glaciers during the LIA; rather, a multitude of interacting seasonal patterns of temperature and precipitation affected—either positively or negatively—the mass balance of glaciers. Extended cold spells during the winter half-year (October through March or April) characterized the climate throughout the LIA. Winter conditions were more frequent and severe—both in terms of duration and temperature—during the LIA compared to the Medieval Warm Period and the 20th century. However, the cold and dryness of winters did not significantly affect the mass balance of glaciers.

Far-reaching glacial advances occurred when very cold springs and autumns coincided with chilly and wet mid-summers. The last "year without a summer" occurred in 1816, but several others are documented to have occurred during the last millennium. They were the crucial elements underlying the LIATE. Most, if not all, were triggered by volcanic eruptions in the tropics, which generated a global veil of volcanic dust (Harington 1992). The spatial dimension of years without a summer was usually limited to mainland Europe north of the Alps, stretching from the Parisian Basin in the West to the Russian border in the East. Conditions in western France, Ireland, Iceland, and Russia were usually better, whereas those in the Mediterranean were fundamentally different (Luterbacher et al. 2002, 2004). The effect of years without a summer were counterbalanced periodically by clusters of warm and dry summers (e.g., in the 1720s) which caused a melt-back onto the glaciers.

Most historians became acquainted with the history of climate through the groundbreaking work of the French historian Emmanuel Le Roy Ladurie (1972). A student of Fernand Braudel (1902–1985), Le Roy Ladurie wrote his *History of Climate* according to the Braudelian scheme of historical temporalities. It is well known that Braudel defined three levels of history (*res gestae*), which were both chronological and operational. The superficial level is one of short-term historical events and individuals; the middle level comprises conjunctures (cyclical phenomena) that occur over medium-length timescales; the basal level consists of long-lasting structures. The short-term, rapidly changing levels of historical events, chance occurrences, and individual men and women comprise what Braudel viewed as the traditional approach to history, and it was against this that he reacted. He played down its importance, viewing events and individuals as the "ephemera" or "trivia" of the past. Among the temporalities of very long duration, Braudel (1972/1995) mentioned changes in climate.

Le Roy Ladurie's classical historiographical concept of the LIA fits into the Braudelian scheme of "long duration." From evidence based on glaciers and from vine harvest dates, Le Roy Ladurie concluded that all seasons more or less underwent a synchronous cooling at the end of the 16th century. Likewise he assumed that the warming from the late 19th century was more or less synchronous in all seasons (Le Roy Ladurie 1972). His book leaves the impression that there was a distinct LIA climate, which was predominantly cold and rainy. Consequently, Le Roy Ladurie was looking for human impacts of the hypothesized changes in long-term average climate. He concluded that "*in the long term* (my emphasis) the human consequences of climate seem to be *slight, perhaps negligible, and certainly difficult to detect*" (Le Roy Ladurie 1972, p. 119). For several decades this claim, made by an influential pioneer, served as a key argument to shun attempts to assess the human significance of past climate change.

Although the macrohistory of climate aims at reconstructing temperature and precipitation for the period prior to the creation of national meteorological networks, both in terms of time series and spatial patterns, a history of climate—tailored to the needs of the historian—should highlight *changes in the frequency and severity* of those extreme events that are known to have *affected everyday life* in the Early Modern period. Such extreme events include climate anomalies (e.g., droughts, long spells of rain, cold waves, untimely snowfalls) and natural disasters (mostly floods). They are usually coined in terms of weather histories, which address processes that have a duration from hours to seasons. In particular, weather is an overarching component in peasant memory because of its fundamental role in daily life (Münch 1992).

These two kinds of accounts on climate are difficult to reconcile. Reports on the microlevel focus on single climate anomalies and are close to the sources. They reveal the ways in which extreme events affected humans and their decision making. However, such episodes are too fragmented to be integrated into narratives of climatic change over long periods of time.

Histories of climate, however, supply impressive overviews of climate change without providing conclusive links to human history. Over several decades, differences in average temperature and precipitation are not convincing in this respect. They encounter the argument that in such situations people may adapt their way of living to a changing climate. Innovations may become accepted that are better suited to the new situation, whereas older outdated practices may tacitly disappear (Wigley et al. 1985). Nonetheless, climate history on the macrolevel can offer an interpretative framework in which significance may be attached to individual climate anomalies. It is important for human perception and interpretation—as well as for the measures being taken—to understand whether such episodes occur surprisingly after a pause of several decades, whether they remain isolated outliers, or whether they occur repeatedly.

According to Le Roy Ladurie, a conclusive investigation of climatic impacts should involve two steps. First, climate in the pre-instrumental period should be studied for its own sake, that is, separately from its impacts on the human world.

Second, the climatic evidence obtained should be used to explore the impacts of climatic variations on crops, food prices, demographic growth, and social disarray. Le Roy Ladurie suggested that a picture of climate without humankind in the pre-instrumental period might be reconstructed from data describing the meteorological nature of certain years, seasons, months, and days (i.e., from long series of documentary proxy data). The ultimate goal of such a reconstruction should be to set up a series of continuous, quantitative, and homogeneous climate indicators (Le Roy Ladurie 1972).

Historical climatologists acted upon Le Roy Ladurie's suggestion inasmuch as an approach to quantify qualitative observations in a more or less standardized way, was developed from the late 1960s. This consists of deducing continuous, quantitative, and *quasi*-homogeneous time series of intensity indices for temperature and precipitation from documentary data used as substitutes for instrumental measurements. In most cases, a reconstruction involves different kinds of documentary data supplemented by high-resolution natural proxy data. Thus far, such series have been set up for Germany, Switzerland, the Low Countries, the Czech Republic, Hungary, Andalusia, Portugal, and Greece (Brazdil et al. 2005).

A CASCADE OF EFFECTS

When series of continuous, quantitative, and quasi-homogeneous climatic indicators are set up for the pre-instrumental period, such series may be used to construct models that enable the exploration of the impacts of climatic variations upon economies and societies. The effects of climatic fluctuations on the "course of history," for instance, are difficult to demonstrate because most of the factors include many internal mechanisms that compensate for adverse climatic effects (Berger 2002).

It is frequently overlooked that both "climate" and "history" are blanket terms, situated on such a high level of abstraction, such that relationships between them cannot be investigated in a meaningful way according to accepted rules of scientific methodology. On a very general level, it could be said that beneficial climatic effects tend to enlarge the scope of human action, whereas climatic shocks tend to restrict it. Which sequences of climatic situations really matter depends upon the impacted unit and the environmental, cultural, and historical context (Pfister 2001). However, this statement needs to be restricted in the sense that the term "climatic shock" itself is ambiguous, as it is well known that some of the people and groups involved always take advantage of situations of general distress, both economically and politically.

To become more meaningful, "climate and history," as a collective issue, need to be broken down to lower scales of analysis, with a specific focus, for example, on food, health, or energy systems or on specific activities such as transportation, communications, and military or naval operations. Particular emphasis must also be given to short- and medium-term events. Moreover, concepts

need to be worked out to disentangle the severity of climate impacts and the efficiency of measures for coping with them. The closer details are investigated, the higher the probability will be of finding significant coherences (Roy 1982).

Regardless of which event or impact is to be studied, an impacted group, activity, or area exposed to these events must be selected. In general, the focus is on individuals, populations, or activities in the form of livelihoods or regional ecotypes. Most examples provided in this chapter refer to the Swiss canton of Bern, which in 1760 comprised 8591 km^2 and had about 350,000 inhabitants. As of 1764, its statistical coverage is excellent (Pfister and Egli 1998). The canton may be roughly divided into three different ecozones. In the Lowlands (by Swiss standards), grain grown within the three-field system was the dominant crop. In the hilly zone, grain cultivation and dairy production had about an equal share. In the Alpine zone, dairy production was dominant; grain cultivation played a marginal role on a microscale.

The most difficult choices of study elements are those of impacts and consequences. Biophysical impact studies may help identify how climate anomalies affected crops, domestic animals, and disease vectors through a study of their climatic sensitivity. Social impact assessment studies can then examine how biophysical impacts (i.e., effects of climate anomalies upon biota) are propagated into the social and political systems.

Robert W. Kates (1985) suggested that such studies, in a first run, might be arranged in the order of propagation to events, although this arrangement may be arbitrary in the sense that the real-time process actually takes place simultaneously or that the sequence is unknown to climatic processes. Figure 12.1 depicts a simplified version of this approach, showing a cascade of effects for preindustrial societies.

Biophysical impacts focus on the production of food (e.g., yields per hectare, relation of seeded to harvested grains) and its availability for human production (including loss through storage). Economic impacts consider consequences on prices of food, animal feed, and firewood. Grain prices were by far the most important parameters for business activity; they also constitute the only economic data for which continuous series are widely available in Europe. Demographic and social impacts highlight consequences of subsistence crises such as malnutrition, social disruption, and food migration. A subsistence crisis is an integrated process in which nature and society interact. Its severity, however measured, depends on the magnitude of the biophysical impact as well as on the preparedness of the people involved and on the efficiency of the measures and strategies that are taken to address the crisis. The significance of human intervention in the process increased from top to bottom at the expense of climate impacts. There were few options available to dampen biophysical impacts, whereas economic measures and social assistance could considerably reduce social disruption. Of course, interactive models, including the societal responses to biophysical and economic impacts in terms of positive or negative

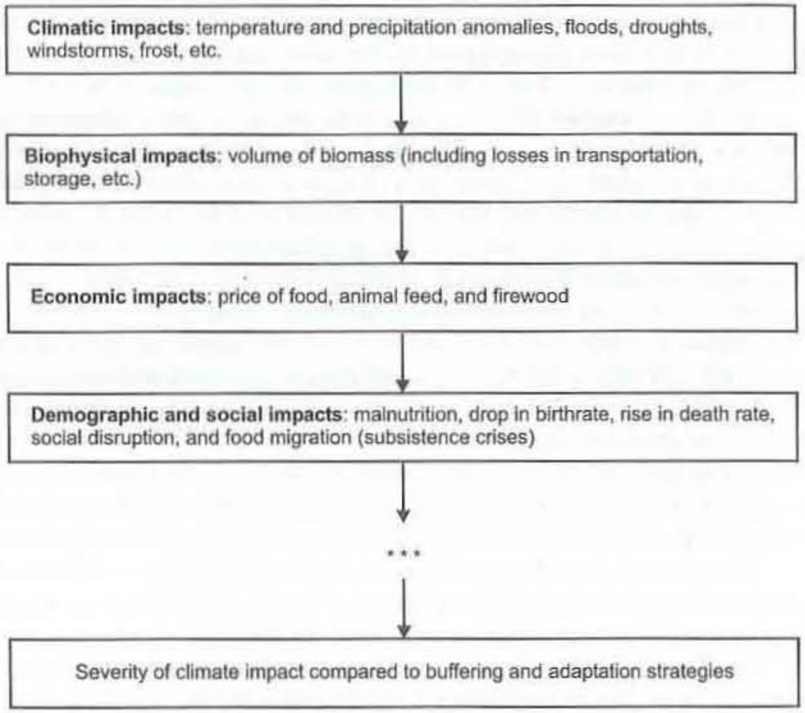

Figure 12.1 A basic model of climate impacts on society (modified after Kates 1985).

feedback, would be more realistic than linear models. Kates (1985, p. 14), however, correctly observes that it is easier to draw schematics than to describe what actually occurs.

ASSESSING AND MODELING LITTLE ICE AGE-TYPE IMPACTS

In western and central Europe, two kinds of impacts were detrimental for agriculture: cold springs and wet summers, where long wet spells during the harvest period prompted the most devastating impact. Continuous rains lowered the flour content of the grains and made them vulnerable to mold infections and attacks of grain weevil (*Sitophilus granarius*) (Kaplan 1976). During winter storage, huge losses were caused by insects and fungi, which increased grain prices in the subsequent spring. These effects can hardly be assessed today, let alone under the conditions of an Early Modern economy. In addition to long spells of rain in midsummer, cold springs harmed grain crops. From present-day agro-meteorological analyses it is known that grain yields depend on sufficient warmth and moisture in April (Hanus and Aimiller 1978). This implies that crops suffered from dry and cold springs, which were frequent during the LIA.

Extended snow cover was particularly harmful. When snow cover lasted for several months, until March or April, winter grains were attacked by the fungus *fusarium nivale*. Peasant farmers often ploughed the choked plants under and seeded spring grains to compensate for the lost crop.

To face the growing frequency of wet summers in the late 16th century, peasants changed their crop mix by growing more spelt instead of rye, since spelt ears bend and thus permit rainwater to drain off easily. Spelt is also moisture-protected by a sheath. In addition, in the Alpine area, production of hard (as opposed to soft) cheese spread rapidly during the late 16th century. This was perhaps an adaptive strategy, since hard cheeses can be stored for several years; thus they were better suited to bridge multiple bad summers in the 16th century, when cheese production was marginal (Pfister 1984). Whether these novel practices were indeed related to the changing climate and not to market incentives, however, remains to be confirmed.

In terms of the vulnerability of the main sources of food, based on present and historical knowledge, it appears that a given set of specific weather sequences over the agricultural year was likely to affect simultaneously all sources of food, leaving little margin for substitution. Table 12.1 depicts the properties of a worse-case crop failure and, inversely, of a year of plenty (Pfister 1984, 2005). It also summarizes the impact of adverse temperature and precipitation patterns on grain, dairy forage, and vine production during critical periods of the year under the following weather patterns: Cold periods in March and April lowered the volumes of the grain harvest and dairy forage production. Wet mid-summers (July–August) affected all sources of food production. Throughout September and October, cold spells lowered the sugar content of wine, and wet spells reduced the amount of grain sown, and lowered the nitrogen content of the soil. Most importantly, the simultaneous occurrence of rainy autumns with cold springs and wet midsummers in subsequent years had a cumulative impact on agricultural production. This same combination of seasonal patterns largely contributed to trigger far-reaching advances of glaciers. The economically adverse combination of climatic patterns is labeled Little Ice Age-type impacts

Table 12.1 Weather-related impacts affecting the agricultural production of traditional temperate–climate agriculture in Europe. *Italicized* text indicates weather conditions that affected the volume of harvests or animal production. **Boldface** text denotes weather conditions that affected the quality (i.e., the content in nutrients or sugar) of crops.

Critical months	Agricultural products		
	Grain	Dairy Forage	Vine
September–October	*Wet*	*Cold*	**Cold and wet**
March–April	*Cold*	*Cold*	*(Late frost)*
July–August	**Wet**	**Wet**	*Cold and Wet*

(LIATIMP) (Pfister 2005). Such biophysical impacts need to be understood as ideal types in the sense of Max Weber. They are heuristic tools against which a given body of evidence can be compared (Kalberg 1994).

The concept of LIATIMP provides a way to measure the severity of biophysical impacts. Compared to other parameters (e.g., grain prices and demographic data), it allows a direct assessment of the vulnerability of affected groups or societies to climate. The term of *vulnerability* represents a multitude of factors such as social stratification, the availability of substitute foods, the efficiency of provisioning buffers (e.g., private and public grain stores) as well as measures of poor relief.

Let us now consider the properties of a model used to simulate LIATIMP (Figure 12.2). The model is solely based on monthly temperature and precipitation indices. Biophysical climate impact factors (BCIF) were defined from the effect of weather on crops known from both contemporary reports and present-day scientific knowledge (Table 12.1). Grain prices were used as an indicator for socioeconomic impacts (i.e., subsistence crises). Since long-term multi-secular grain price series are not available for Switzerland, a series of rye prices from neighboring Bavaria were applied as a substitute. The weighing of terms in the equation was empirically done through fitting the BCIFs to the curve of grain prices (see Appendix 12.1).

Considering the graphical representation of BCIF from 1550 (not shown), it turned out that several breaks (1566/1567, 1629/1630, 1817/1818, 1843/1844) were statistically significant (see Appendix 12.1); multidecadal periods of low and high biophysical climate impact levels can be distinguished. This result challenges the view widely held by economic historians: Wilhelm Abel (1972, p. 35) assumed that climatic impacts on the economy need to be understood as a series of random shocks. Likewise, Karl-Gunnar Persson (1999, p. 98) does not envisage possible changes in climate over time. "That the price fluctuations… were triggered by output shocks is too obvious to dispute," he declared. Nobel laureate Robert Fogel (1992) even tried to disprove the existence of any relationship between climatic extremes and famine (i.e., between agriculture and climate) through questionable statistical manipulations. He simply claimed: "Famines were caused not by natural disasters but by dramatic redistributions of entitlements to grain" (see Landsteiner 2005, p. 99). James Jarraud, Secretary-General of the World Meteorological Organization (WMO), came to a somewhat different assessment. With a view to the present and the future, he wrote: "Climate variability affects all economic sectors, but agriculture and forestry sectors are perhaps the most vulnerable and sensitive activities to such fluctuations" (Jarraud 2005, p. 5). In addition, for historians who focus on people's perceptions and the established facts found in the sources instead of on equilibrium models and numerical data, climate variability mattered for the preindustrial economies. Its significance, however, cannot be simply implied. It needs to be established from case to case.

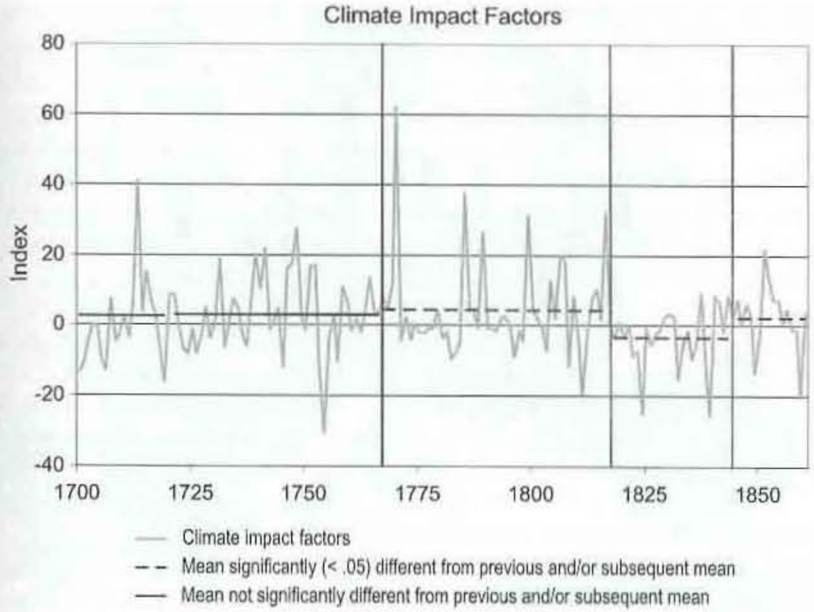

Figure 12.2 Biophysical climate impact factors (BCIF) in central Europe from 1700–1900. The well-known peaks of grain prices (around 1714, 1740, 1770, 1817, 1853–1855) clearly emerge.

The spatial dimension of a crisis is another important aspect (see below). Which regions in Europe were affected by LIATIMP, and which ones escaped?

Figure 12.3 compares the lowest and highest mean annual grain prices between 1760 and 1774 for 29 towns in Europe. The highest prices within this period are given as a percentage of the lowest, which are set to 100. The following characteristics are worth mentioning:

- North of the Alps, a clear West–East gradient stands out from the coast of the English Channel and the North Sea to the foothills of the Alps and the Carpathians.
- Whereas grain prices in Antwerp rose by 60%, in London by 70%, and in Paris by 110%, they more than tripled in Vienna and in Lwow (Poland).
- Price levels were generally lower south of the Alps with minima in Rome and Naples, where prices throughout the period remained almost at the same level (Abel 1972).

The zone of very high prices roughly coincides with the spatial dimension of the low pressure areas in the summers 1769 to 1771. People in areas close to the North Sea were less affected by the crisis because grain could be shipped there at low cost from surplus areas in the Baltic. The Mediterranean area was not affected by this kind of adverse weather; subsistence crises there were usually

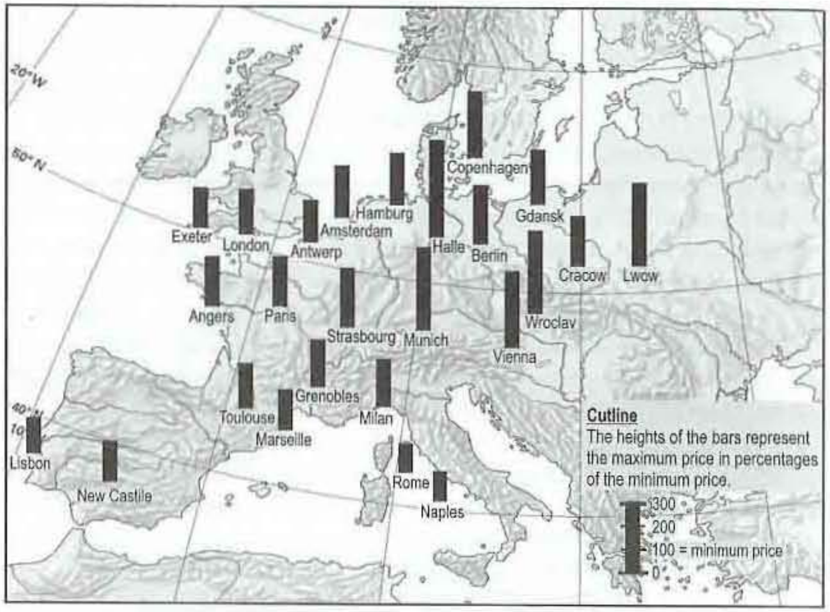

Figure 12.3 The rise of mean annual grain prices in Europe from 1760 to 1774. The highest prices within this period are given as a percentage of the lowest, which are set to 100. North of the Alps, a clear West–East gradient stands out from the coast of the English Channel and the North Sea to the foothills of the Alps and the Carpathians. Based on Abel (1972, p. 47).

caused by extended drought in the winter half-year (Xoplaki et al. 2001). Thus, the spatial dimension of climatic vulnerability depended to a considerable extent on the possibility of transporting imported grain at low cost on waterways. Mountainous areas in the interior of continents were particularly disadvantaged in this respect. On a local scale, price surges could still be more pronounced. In some areas of the Erzgebirge (Ore Mountains), which is the hilly borderland between the Czech Republic and Saxony, the price of a bushel of rye rose tenfold between spring 1770 and early summer 1772. To conclude from the report of a local parson, this led to outright starvation (Abel 1972).

MEASURES OF THE AUTHORITIES TO REDUCE VULNERABILITY IN THE CANTON OF BERN

Let us now turn to the crucial issue of social vulnerability. During subsistence crises, the ownership or disposal of agricultural land determined the availability of food resources. Wealthy peasant farmers and major landowners made disproportionately large profits, whereas the landless, cottagers, or peasants with only medium-sized holdings (i.e., about 80% of the population in the canton of Bern) spent a much larger proportion of their budget on food.

Outside of wars, the management of subsistence crises was among the most serious challenge faced by Early Modern authorities. Grain harvest shortfalls led to higher food prices, mounting unemployment rates, and an increase in the scale of begging, vagrancy, crime, and social disorder. Such conditions inevitably resulted in a welfare crisis of varying magnitude.

Environmental stress, economic hardship, and social disarray fostered overcrowding and other changes in normal community spacing arrangements. These conditions often appeared in the form of mortality peaks (Post 1990). Authorities took an interest in combating the effects of crises, particularly following the Thirty Years War, as they sought to increase the number of soldiers as well as tax income, both of which were dependent on the number of productive workers.

On a macroscale, the extended areas of high grain prices mask enormous differences of people's vulnerability on a microscale. On the local level, other factors need to be considered, such as the kind of crops grown, the degree of social inequality, and the efficiency of relief measures taken by the authorities. Generalizations are thus not possible.

Short-term measures usually included the symbolic persecution of hoarders and speculators, who were made responsible for the crisis, as well as the distribution of grain to the needy people in the capital. On a longer term, as of the late 17^{th} century, a regional network of grain stores was implemented in the canton of Bern. Brandenberger (2004) concludes that the Bernese authorities shifted the focus of crisis management toward complementing traditional short-term measures with sustained efforts to promote agricultural productivity by facilitating the legal conditions for subdividing and privatizing communal pastures.

Poor relief was another strategy of reducing vulnerability: Bernese authorities oscillated between spending on welfare and taking economy measures. During the 18^{th} century they established an area-wide relief system for the poor in which all communities had to participate. Erika Flückiger-Strebel (2002) demonstrated that in the wake of the crisis of 1770/1771, a great number of people became permanently dependent on welfare. Obviously, many working poor who were at the margin of impoverishment were not able to buffer the shock from the fall in real income during the crisis. They needed to sell most of their belongings for food and were henceforth dependent on continual assistance. The cost of social security rose much faster than any other entry of the budget, and communities had to bear a rising share of the burden.

How successful was this paternalist social policy? The severity of the crisis in demographic terms was assessed from the aggregate number of baptisms and burials, which is available for every parish since 1730 (Pfister 1995). From this data it can be concluded that both indications of excess mortality and a pronounced deficit of baptisms—which would point to some nutritional problem—were nearly absent. This suggests that vulnerability was substantially reduced. However, to put this argument on a firm basis, the situation in the canton of Bern should be compared with conditions in neighboring areas, where it is hypothesized that the crisis management was less efficient.

CONCLUSION

Environmental history addresses the role and place of nature in human life. It studies the interactions that past societies have had with the nonhuman world. Most scholars primarily understand this paraphrasing of the field by Donald Worster (1993) as being an account of humans transforming their natural surroundings and encroaching on them. Few, however, look at the other side of the issue and ask about nature's role as an independent agent in history. One reason may be that such a position runs the danger of being stigmatized as determinist. Another could be the current low standing of quantitative and ecological approaches within mainstream history, which unilateraly favors microstories and anthropological approaches. Indeed, results from many early quantitative studies were rather trivial, but this was mostly due to insufficient data.

In this chapter I have attempted to view socioenvironmental interactions at different temporal and spatial scales to demonstrate their complexity and to explore a new modeling approach: macroscale reconstructions of monthly air pressure and temperature for the entire European continent provide the starting point. These were obtained from a variety of high-resolution documentary and natural data. During the LIA, climate impacts never affected Europe as a whole; they were limited to certain climatic zones of the continent. Impacts in western and central Europe, for example, did not extend to the Mediterranean. Furthermore, spatial differentiations of vulnerability within the impacted areas need to be made according to ecozones and for the period prior to the construction of the rail network and access to cheap maritime transport. During a crisis, grain prices increased two to three times higher in the landlocked areas of the continent than in regions close to the sea. In terms of the temporal dimension, the modeling of biophysical impacts suggests that the frequency and severity of climate impacts changed over time, thereby leading to multidecadal periods of favorable and adverse climate.

The story of human vulnerability to climate told along a chain of causation, which runs from natural forcing to economics to the level of political and social decision making, requires a change from the macroscale of generalizations to the microscale of case studies. From the case of the canton of Bern during the crisis in the early 1770s, we can learn about the motivations and strategies of an enlightened elite to mitigate the stress of subsistence crises for the lower strata in the final decades of the Ancient Regime. Drawing on the available wealth of demographic data for this canton, we may even speculate about the efficiency of this early social policy in terms of avoided demographic losses. However, at this level it is unthinkable to arrive at more general conclusions for Europe or even parts of it. Even if many more case studies could be made, a comparative approach might well come to the conclusion that the differences between case studies are larger than their common characteristics. More studies of socioenvironmental interactions should be encouraged, but not with the intent of arriving at a universal picture of social vulnerability to climate impacts, as has been repeatedly attempted for global climate change over the last millennium. Quite the contrary, it would be worthwhile to illustrate the plurality of human responses and solutions in mitigating social vulnerability to climate variability.

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REFERENCES

Abel, W. 1972. Massenarmut und Hungerkrisen im vorindustriellen Deutschland. Göttingen: Vandenhoeck und Ruprecht.

Berger, W.H. 2002. Climate history and the great geophysical experiment. In: Climate Development and History of the North Atlantic Realm, ed. G. Wefer, W.H. Berger, K.-E. Behre, and E. Jansen, pp. 1–16. Berlin: Springer.

Brandenberger, A. 2004. Ausbruch aus der "Malthusianischen Falle": Versorgungslage und Wirtschaftsentwicklung im Staate Bern 1755–1797. Bern: Peter Lang.

Braudel, F. 1972/1995. The Mediterranean and the Mediterranean World in the Age of Philippe II, transl. S. Reynolds (1972). London: Fontana.

Brazdil, R., C. Pfister, H. Wanner, H. von Storch, and J. Luterbacher. 2005. Historical climatology in Europe: The state of the art. *Clim. Change* **70**:363–430.

Flückiger-Strebel, E. 2002. Zwischen Wohlfahrt und Staatsökonomie. Bern: Chronos.

Grove, J.M. 2001. The initiation of the "Little Ice Age" in regions round the North Atlantic. *Clim. Change* **49**:53–82.

Hanus, J., and O. Aimiller. 1978. Ertragsvorhersage aus Witterungsdaten. *Z. Acker- und Pflanzenbau* **5(Suppl.)**:118–124.

Harington, C.R., ed. 1992. The Year without a Summer: World Climate in 1816. Ottawa: Canadian Museum of Nature.

Holzhauser, H. 2002. Dendrochronologische Auswertung fossiler Hölzer zur Rekonstruktion der nacheiszeitlichen Gletschergeschichte. *Schweiz. Z. Forstwesen* **153**: 17–27.

Jarraud, M. 2005. Foreword. Increasing climatic variability and change: Reducing the vulnerability of agriculture and forestry. *Clim. Change* (Spec. Iss.) **1–2**:5–7.

Kalberg, S. 1994. Max Weber's Comparative-Historical Sociology. Cambridge: Polity.

Kaplan, S.L. 1976. Bread, Politics and Political Economy in the Reign of Louis XV, vol. 1. The Hague: Nijhoff.

Kates, R.W. 1985. The interaction of climate and society. In: SCOPE 27: Climate Impact Assessment. Studies of the Interaction of Climate and Society, ed. R.W. Kates, J. Ausubel, and M. Berberian, pp. 3–36. Chichester: Wiley.

Landsteiner, E. 2005. Wenig Brot und saurer Wein.: Kontinuität und Wandel in der zentraleuropäischen Ernährungskultur im letzten Drittel des 16. Jahrhunderts. In: Cultural Consequences of the "Little Ice Age," ed. W. Behringer, H. Lehmann, and C. Pfister, pp. 87–147. Göttingen: Vandenhoeck.

Le Roy Ladurie, E. 1972. Times of Feast, Times of Famine: A History of Climate since the Year 1000, transl. B. Bray. London: Allen and Unwin.

Luterbacher, J. 2000. Die Kleine Eiszeit (Little Ice Age, A.D. 1300–1900). In: Klimawandel im Schweizer Alpenraum, ed. H. Wanner et al., pp. 101–102. Zurich: vdf Hochschulverlag.

Luterbacher, J., D. Dietrich, E. Xoplaki, M. Grosjean, and H. Wanner. 2004. European seasonal and annual temperature variability, trends and extremes since 1500. *Science* **303**:1499–1503.

Luterbacher, J., E. Xoplaki, D. Dietrich et al. 2002. Reconstruction of sea level pressure fields over the Eastern North Atlantic and Europe back to 1500. *Clim. Dyn.* **18**:545–561.

Münch, P. 1992. Lebensformen in der Frühen Neuzeit. Frankfurt: Ullstein.

Persson, K.G. 1999. Grain Markets in Europe, 1500–1990: Integration and Deregulation. Cambridge: Cambridge Univ. Press.

Pfister, C. 1984. Das Klima der Schweiz von 1525 bis 1860 und seine Bedeutung in der Geschichte von Bevölkerung und Landwirtschaft. 2 vols. Academica Helvetica 5. Bern: Haupt.

Pfister, C. 1995. Im Strom der Modernisierung: Bevölkerung, Wirtschaft und Umwelt im Kanton Bern (1700–1914). Bern: Historischer Verein des Kantons Bern.

Pfister, C. 2001. Klimawandel in der Geschichte Europas: Zur Entwicklung und zum Potenzial der historischen Klimatologie. *Öster. Z. Geschichtswiss.* **12/2**:7–43.

Pfister, C. 2005. Weeping in the snow: The second period of Little Ice Age-type crises, 1570 to 1630. In: Kulturelle Konsequenzen der Kleinen Eiszeit: Cultural Consequences of the Little Ice Age, ed. W. Behringer, H. Lehmann, and C. Pfister, pp. 31–85. Göttingen: Vandenhoeck und Ruprecht.

Pfister, C., and H.R. Egli, eds. 1998. Historisch-Statistischer Atlas des Kantons Bern 1750–1995. Umwelt–Bevölkerung–Wirtschaft–Politik. Bern: Historischer Verein des Kantons Bern.

Post, J.D. 1990. Nutritional status and mortality in eighteenth-century Europe. In: Hunger in History: Food Shortage, Poverty and Deprivation, ed. L.F. Newman, pp. 241–280. Oxford: Blackwell.

Roy, E. 1982. Environment, Subsistence and System: The Ecology of Small-scale Social Formations. Cambridge: Cambridge Univ. Press.

Wanner, H. 2000. Vom Ende der letzten Eiszeit zum mittelalterlichen Klimaoptimum. In: Klimawandel im Schweizer Alpenraum, ed. H. Wanner et al., pp. 12–37. Zurich: vdf Hochschulverlag.

Wigley, T.M.L., N.J. Huckstep, and A.E.J. Ogilvie. 1985. Historical climate impact assessments. In: Climate Impact Assessment: Studies of the Interaction of Climate and Society, ed. R.W. Kates, J. Ausubel, and M. Berberian, pp. 529–564. Chichester: Wiley.

Worster, D. 1993. What is environmental history? In: Major Problems in American Environmental History, ed. C. Merchant, pp. 4–15. Lexington, MA: Heath.

Xoplaki, E., P. Maheras, and J. Luterbacher. 2001. Variability of climate in meridional Balkans during the periods 1675–1715 and 1780–1830 and its impact on human life. *Clim. Change* **48**:581–615.

APPENDIX 12.1 Assessing biophysical climate impact factors and their significance for grain price fluctuations.

Basic Assumptions

A model of biophysical impacts on grain markets was empirically assessed comparing biophysical climate impact factors (BCIF) for the Swiss Plateau to rye prices in Bavaria measured in grams of silver. Positive BCIFs are thought to agree with high prices and vice versa. Whereas selection of terms was guided by agronomical knowledge contained both in historical sources and present-day textbooks, the weighing of the terms was empirically done by fitting the impact factors to the curve of grain prices.

Computing Biophysical Climate Impact Factors

The basic climate data are monthly temperature (T) and precipitation (P) indices on a 7° classification (Pfister 1998):

3 = extremely warm/wet,	–1 = cold/dry,
2 = very warm/wet,	–2 = very cold/dry,
1 = warm/wet,	–3 = extremely cold/dry.
0 = normal,	

BCIFs are known to be nonlinear. Thus, temperature (T) and precipitation (P) indices were recoded as follows:

5 = extremely warm/wet,	–1 = cold/dry,
3 = very warm/wet,	–3 = very cold/dry,
1 = warm/wet,	–5 = extremely cold/dry.
0 = normal,	

The annual BCIFs were then computed and can be summarized as follows:

$$\begin{aligned}
&\mathrm{IF}\left(T_{Mar}+T_{Apr}\right)<\left(T_{Mar}(N+1)+T_{Apr}(N+1)\right);\\
&\mathrm{THEN}\,\frac{2\times T_{Mar}+3\times T_{Apr}}{-2};\\
&\mathrm{ELSE}\,\frac{T_{Mar}(N+1)+2\times T_{Apr}(N+1)}{-2}\times\\
&\quad\mathrm{IF}\left(P_{Jul}+P_{Aug}\right)<-6;\\
&\quad\mathrm{THEN}\,\frac{3\times P_{Jul}+P_{Aug}}{-4};\\
&\quad\mathrm{ELSE}\,\frac{3\times P_{Jul}+P_{Aug}}{3}\\
&\qquad+\frac{2\times P_{Sep}+3\times P_{Oct}}{5}\\
&\qquad+\frac{3\times T_{Sep}+3\times T_{Oct}}{-2}\\
&\qquad+\frac{2\times P_{Mar}+2\times P_{Apr}+P_{May}}{5}\\
&\qquad+\frac{T_{May}+T_{Jun}+T_{Jul}+T_{Aug}}{4}
\end{aligned}$$

The first two terms require the most explication. The first term reflects spring temperatures. For grain prices, both the spring temperatures within a current meteorological year and those in the subsequent year need to be considered. The higher value goes into the equation. As spring temperatures are known to be significant for grain production, March and April temperatures are weighed.

The second term concerns precipitation patterns during the harvest period, which was from early July to early August. Extremely rainy conditions during this midsummer period had the most devastating impact and they had to be accordingly weighed.

The first and the second terms are then multiplied to simulate the summation effect, which resulted from the coincidence of a very cold spring and a very rainy midsummer in the same or in the subsequent year.

Four terms represent factors of minor importance: precipitation and temperatures in September and October, precipitation in spring and temperatures from May to September.

Results

For the years 1566/1567, 1629/1630, 1817/1818, and 1844/1845, breaks in the series of BCIFs proved significant. To establish the significance of these breaks, we utilized a statistical method known as *intervention analysis*, which Box and Tiao (1975) recommended for environmental time series that often show strong autocorrelations. Intervention analysis is an extension of autoregressive integrated moving average (ARIMA) modeling (Box and Jenkins 1976), a technique of time-series analysis in modern econometrics. According to this implicit model, average exposure shifted, although we only applied an intervention test in a stepwise fashion to the time as well as grain price series (Table 12A.1).

This result challenges the assumption of most economic historians: climatic shock on agricultural production was random. We have to assume that multidecadal periods of low and high BCIFs need to be distinguished.

Table 12A.1 Level of significance for tests of step changes in the mean level of biophysical climate impact factors (BCIFs) and rye prices in Munich. P-values greater than 0.05 are labeled as being not significant (n.s.).

	1566/67	1629/30	1678/79	1720/21	1766/67	1817/18	1844/45
BCIF	0.01	0.05	n.s	n.s.	n.s.	0.01	0.05
Rye prices	0.05	n.s.	n.s.	n.s.	0.05	0.05	0.05

References

Box, G.E.P., and G.M. Jenkins. 1970. Time Series Analysis: Forecasting and Control. Cambridge: Cambridge Univ. Press.

Box, G.E.P., and G.C. Tiao. 1975. Intervention analysis with applications to economic and environmental problems. *J. Am. Statist. Assn.* **70**:70–79.

Pfister C. 1998. Raumzeitliche Rekonstruktion von Witterungsanomalien und Naturkatastrophen 1496–1995. Zurich: vdf Hochschulverlaag.