Human Factors, Extreme Events and Floods in the Lower Po Plain (Northern Italy) in the 16th Century

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SUMMARY

Researches on climatic variations in the 16th century have stressed the *exceptionality* of extreme events, such as large and frequent floods, which are used as indicators of increased rainfall. The case of the lower Po basin, where lack of instrumental data renders the concept of *exceptionality* complex and relative, shows that this is not necessarily valid. There, various human factors determined a high environmental vulnerability. Since the lower Po Plain was a 'man-made' environment, past extreme events must be evaluated in strict relation with the territory's character. Thus the increase in floods constitutes a 'weak' indicator for an increase in rainfall.

INTRODUCTION

The aim of this research has been to identify ways in which human action substantially affected flooding of the lower Po area in the second half of the 16th century. The results obtained help to improve understanding of the nature of atmospheric variations occurring in this period in the Po Plain, and to draw attention to the extreme vulnerability of the local human situation. The factors examined are not directly and quantitatively relevant to an assessment of climatic deterioration at that time, but they can contribute to the establishment of a better local model by means of which an assessment of extreme climatic events in the area can now be made.

Up to now, there seem to have been two different approaches to the problem in Italy, due to different disciplinary points of view. On the one hand there are studies by economic historians, who are definitely loath to consider climatic aspects as dynamic factors in the *ancien regime* agricultural economies (Rotelli 1968; Galassi 1970; Romani 1975 and 1983) and on the other, there are studies in the history of climate which for their part have shown a certain lack of interest in the analysis of the dynamics of particular socio-economic contexts and their interaction with extreme climatic events.

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Floods are considered to be important 'climatic indicators', and they do not usually seem to be a problem for compilers of tabular information. However, in some particular situations, like that of the lower Po area, where human action has transformed the landscape into an 'artificial' countryside, it may be interesting to draw attention to the many factors, besides rainfall, which have contributed to water crises. Obviously the situation of the lower Po Plain cannot be extended without preface to the whole of Northern Italy; however, historical analysis can show the complexity of floods as climatic indicators in some specific contexts.

One of the most striking 16th century phenomena seems to have been the series of floods which struck northern Italy and the Po Plain in particular, but if these events are to be used as indicators of an increase in rainfall, a large number of interacting factors within the environmental, social and economic context should be taken into account. This is because floods are a complex indicator on which the real effect of an increase in rainfall is not directly measurable. In order to avoid a simplistic and deterministic interpretation, therefore, the 'inflexibility' of the economic system where these floods occurred has not been underestimated, and due weight has been given to those demographic, economic and institutional factors that were characteristic of the historical context in question, and that directly affected the environmental vulnerability of the area.

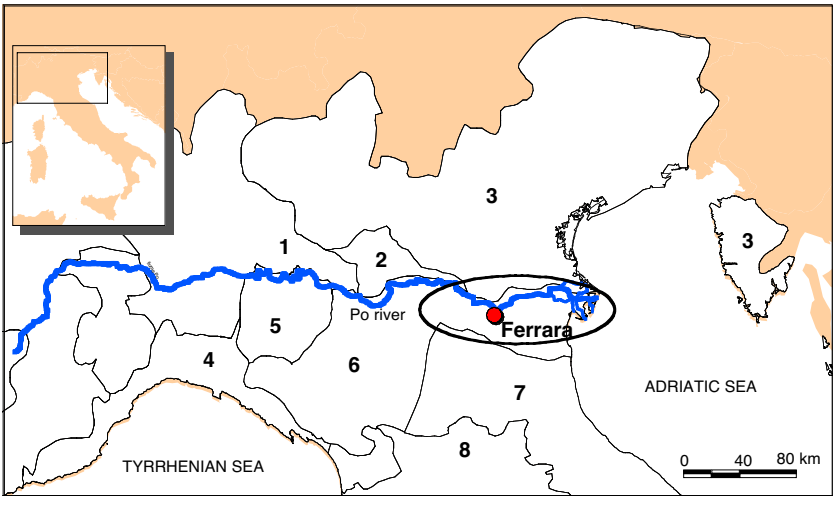

FIGURE 1. Political and administrative situation in Northern Italy in the 16th century: main states

= area examined in this study

1 Duchy of Milan
2 Duchy of Mantua
3 Republic of Venice
4 Republic of Genoa
5 Duchy of Parma
6 Duchy of Este
7 Papal State
8 Grand Duchy of Tuscany

The Po is Italy's longest river (652 km), and its lower reaches pass through what are now the regions of Lombardy, Emilia and the Veneto. In the period examined, this area belonged to some powerful, authoritarian, feudal duchies (fig. 1): the Duchy of Mantua (2 in fig. 1), ruled over by the Gonzaga family, and the Duchy of Ferrara, Modena and Reggio (6 in fig. 1), a fief of the Church held by the Este family. The small north-eastern corner of the region belonged to the Republic of Venice (3 in fig 1). The area concerned can be viewed as the final stage of a complex hydrographic system; for the Po Plain's hydraulic regime is governed by the behaviour of water descending from the Alps and the Apennines. By observing the hydrological behaviour of the Po, interesting conclusions can be drawn about any extreme climatic events resulting in abnormal water volumes either in the summer (from Alpine lakes and glaciers) or in winter, autumn and spring (from the Apennines). See in fig. 2 the situation of this basin in the 16th century, reconstructed by means of historical cartography and hydraulic studies.

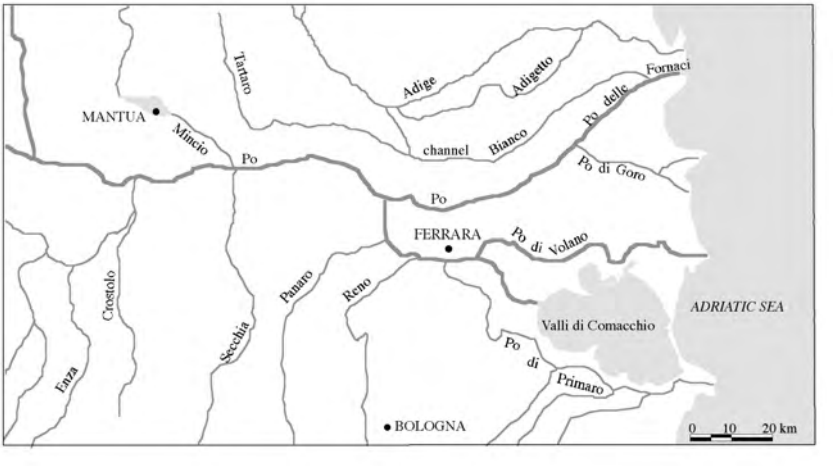

FIGURE 2. Hydrographic network in the lower Po Plain in the 16th century; the flows of the rivers mentioned in the text are located.

The breadth of subject matter involved in an examination of this area means that thorough individual analyses of an enormous quantity of documentary material are required. This research, however, is limited to identifying certain factors which throw light on the history of climate within an extremely 'turbulent' economic and social context. For information on population, prices, the economy of peasant families and matters of historical hydrogeology, previously published studies were examined; but a first-hand examination of the sources

was carried out in order to find contemporary accounts of floods and weather conditions, and the data have been placed in context so as to provide at least a partial understanding of the complex relationships between the effects of atmospheric events and the natural and anthropic features of the area examined.

HISTORICAL SOURCES

In this area, culture was supported by economically strong powers and protected in court circles, but it was not solely the élite culture of the Renaissance, for it now also influenced the widespread learning of the urban middle classes, who had previously been excluded. This is the reason why so many of the writers of sources used in the history of climate were lawyers, notaries, doctors, merchants or men of moderate literary culture, who often had an important part to play within the confines of their town. These new townsmen liked to keep family diaries, to write almost day-by-day chronicles of their town, and to record and comment on events whose horizons often went no further than the town walls or the frontiers of the *signoria* or duchy. Many of these texts are still preserved in manuscript in local libraries.

This 'elevated' historiography was much concerned with actual events, including natural disasters, and it later led to the erudite local historiography of which Italy has a very strong tradition. Writers involved in this minor historiographical genre tended to concentrate their attention on the political and civil history of their home town. Within a few generations – and partly as a result of the spread of printing – local history became a popular genre which proliferated in small towns as well as in cities with a long-standing historical tradition, and it often used sources which are no longer available to us. It has made a substantial contribution to the knowledge of the history of climate and natural disasters.

On a more popular level, too, there were important changes in the 16th century. Printing led to a gradual increase in new demands for information, involving urban classes which had previously been illiterate. Popular printed sheets – embryonic newspapers, one might say – began to appear in Italy in the second half of the 16th century. They are an indication of an increase in literacy and the importance of urban populations, and they satisfied a new demand for news, including reports of natural disasters. Such events were often considered to be 'prodigies' and occupied an important place in popular printed works.

The sources used in this research are of various kinds. Firstly, archival sources have been used (as for this aspect see also Camuffo and Enzi 1992). The ancient management of the states in the Po Plain devoted much care to the problem of waters and their control, on which depended agricultural yields and the territory's viability. They demanded from their local representatives reports and letters written by those with official responsibility for running the territory concerned. The reports concerned descriptions of floods, of hydraulic works

being carried out, and lists of the expenses to be born. Nowadays, the ancient Archivio Ducale Estense is located in the Archivio di Stato of Modena and the Archivio Gonzaga is located in the Archivio di Stato of Mantua. Diplomatic sources, too, were useful: since Italy consisted of numerous small states, ambassadors played an important part in inter-governmental communications, and their dispatches and reports provide a very valuable network of information. The correspondence between people of the Estense and Gonzaga courts have also been examined: often the letters are rich in very interesting details regarding the territory.

Another type of source used is memoirs: diaries and chronicles written by individual citizens to record events on a personal, family or local level. The texts concerned were written by eyewitnesses of the events described, whose interest in meteorological events and related effects was almost always limited to the town where they lived.

A third type of sources is antiquarian and local historiography: this genre was much developed in Northern Italy in the 16th century, on the basis of the writer's interest in the origins of his home town or the vicissitudes of the prince's family. Historians of this kind were careful collectors of ancient memoirs, many of which are now lost. When they recorded natural events, a fair amount of detail was unusually included, and any disastrous effects were considered quite suitable for inclusion in civil history as 'historical' facts.

Finally, it should be stressed that Italy had an important tradition of scholarly catalogues and lists of calamitous events, as heritage of ancient culture. This group of writings consists of treatises and catalogue compilations which cannot be considered as providing primary information but are often based on specifically quoted sources. Such works are a valuable product of that Italian literary and historical scholarship which, from the 18th century onwards, displayed a keen interest in natural phenomena. They have been used only when substantial agreement with primary sources was found, and when they filled chronological gaps in primary sources.

POPULATION AND AGRARIAN ECOSYSTEMS

It has often been stressed that there is a close relationship in pre-industrial societies between population, area under cultivation, and food supplies. Hence any occurrence which affected food supplies normally went on to influence the demographic scale in the short or medium term. However, the availability of food supplies generally depends on other factors, foremost among them being the overall income of the society in question and the way it is distributed among the social groups involved. Furthermore, the nature of the controls imposed by a social system and its neighbours on the free movement of subsistence goods is of great importance.

As far as 16th century Italy is concerned, population growth had a considerable effect on the ratio of inhabitants to fertile land. In a country like Italy, where two thirds of the land consists of mountains and hills, population pressure could have two possible results. On the one hand it could lead to the deforestation and cultivation of hill and mountain slopes, with all the risks that that involved; and on the other it could lead to the creation of new cultivable land amongst the abundant fresh water flooded areas in the Po Plain, by means of land reclamation and water channelling. Both cases involved setting in motion mechanisms which affected the hydrogeological system of the area, with short and long term results which have not yet been fully assessed from a historiographical point of view, but which must have been considerable. It would be a matter of some interest to establish by means of quantitative data the extent to which the effects of human activity on the land interacted with the contemporary climate, as well as the extent to which human interference with wet zones and the hydrographic system was in turn influenced by climate (Wigley 1981). All that research can do for the time being is to draw conclusions based on qualitative data (Lamb 1982).

The destruction of woods to provide land for cultivation and pasture was usually carried out by burning. The cultivation of these fresh areas in the Apennines or on the other mountains was in the hands of peasants from the plains who had no knowledge of those terrace building techniques for cultivation purposes which were to be found in other areas of Italy (from Liguria and parts of Tuscany to Central and Southern Italy and the islands), where long-established settlements and cultivation systems (vineyards, olive groves, citrus fruit growing etc.) had created complex environmental responses which were more in keeping with agricultural needs. It was partly for these reasons that the increase in cultivated land in the Apennines and on other mountain slopes led to a long period of disturbance in the 16th century, and had a detrimental effect on the water regime.

According to Beloch's calculations (Beloch 1937-1939) the population of Italy was 11,600,000 by the mid-16th century. By 1600 it had reached 13,300,000. In half a century, the population had reached a hitherto unknown level, so that Italy was now one of the most heavily populated regions in Europe, at least in terms of relative density. Partly as a result of famine and disease, this trend was reversed in the following century, and the population began to decline until it reached 11,500,000 in 1650. This fall in population particularly affected northern Italy, where there was a drop of more than a fifth between 1600 and 1650. Mantua is a case in point: its urban population increased from 27,741 in 1511 to 34,281 in 1587, but the crisis of 1590 reduced it to 31,422 by 1592, after which the fall continued until the demographic collapse of 1630, which reduced the population to little more than 8,000 (Belfanti 1982).

This decline affected Italy as a whole, especially in the second half of the 17th century, but it was a modest decline, just as the rate of population growth had been modest in the period between 1500 and 1600 (Bellettini 1980; 1987, pp.23-30; Del Panta *et al*. 1996). In order to demonstrate the nature of demographic

change in the second half of the 16th century and the early decades of the 17th century, it will be sufficient to provide a few data for the Po Plain area. In the countryside around Bologna, the population density rose from 30 inhabitants per km^2 in the 15th century to 43 per km^2 by 1588 (Belletini 1951). The same rural population density can be found in the former Duchy of Ferrara in 1621, by which time the number of inhabitants was three times that of 1431. The rural population density around Modena and Reggio Emilia was roughly 53 inhabitants per km^2 around 1600. The population density for Romagna as a whole has been calculated as reaching 59 inhabitants per km^2 in 1656 (Beloch 1937-1939; Basini 1970).

Population density figures are only very rough indicators, however, because the regions they relate to include vast areas not yet in use for agricultural purposes, such as mountain terrain, the wooded slopes of the Apennines, and the fresh water lagoons and marshes of the low-lying plain. When examining in more detail the phenomenon of demographic pressure on land in the 16th century, one can find other interesting signs of critical levels reached in the lower Po Plain as regards the ratio between population and agricultural food resources. In the *contado* of Parma, population density increased from 55.4 to 58.7 inhabitants per km^2 between 1545 and 1593. Looking at high altitude population distribution, it emerges that in 1545 the population density in the hills and mountains around Parma was between 46 and 61 inhabitants per km^2 (Romani 1975). These are extraordinarily high levels in relation to the plain, where there were about 87 inhabitants per km^2 at that time (the figure today is 178).

The flight of so many people from the plain to high ground in the Apennines had been set in motion in the early 16th century by war; and the cultivation of these comparatively overpopulated mountain slopes had important consequences in the following decades. The population crisis which later affected northern Italy is to be linked not only to the plague epidemics of 1576 and 1630, but also to the considerable series of extreme meteorological events in the period 1590-1630, which led to a succession of poor harvests and famines of unprecedented severity.

DEFORESTATION BROUGHT ABOUT BY POPULATION PRESSURE AND ITS EFFECTS ON WATER CRISES IN THE LOWER PO PLAIN

Population pressure had resulted in the spread of arable land into hilly and mountainous areas at the expense of woods and forests. A great deal of evidence from the second half of the 16th century agrees in identifying as one of the sources of the serious hydraulic disturbances affecting the Po Plain (leading to major harvest losses) the fact that mountain slopes had been cultivated, thereby increasing erosion and the transportation of solid matter by watercourses.

Population pressure and the search for arable land were not the only reasons for the rapid destruction of forests in the northern Apennine and Alpine foothills

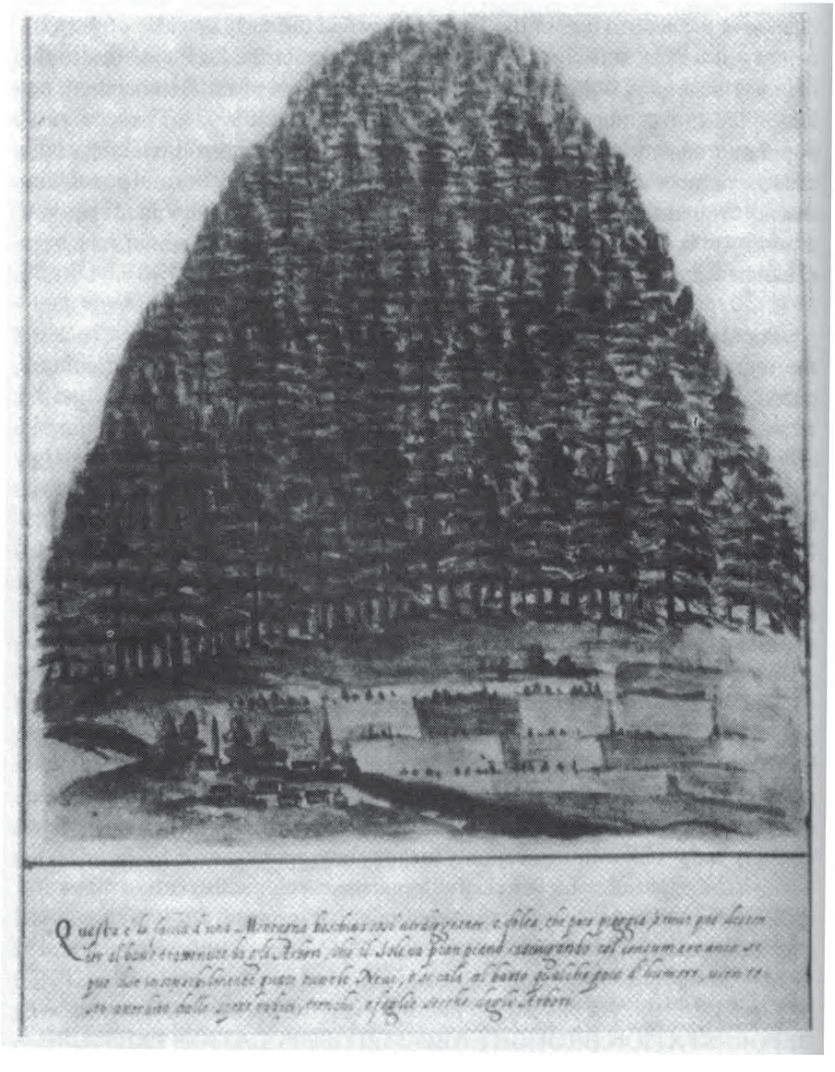

FIGURE 3.

In 1601 the Paulini brothers (Veneto landowners) sent a project to the Republic of Venice in order to explain the plain's water disorder and the consequent hydrological problems. By drawing a series of sketches, they represented the degradation of the mountain environment caused by the intense deforestation that occurred in the previous century.

FIGURE 4.

Those sketches are of great interest, since they display contemporary awareness of the environmental degradation and of its negative consequences upon the hydraulic system in the plain (from the Paulini codex, Venice State Archive, 1601, ed. Alberti and Cessi, 1934).

FIGURE 5.

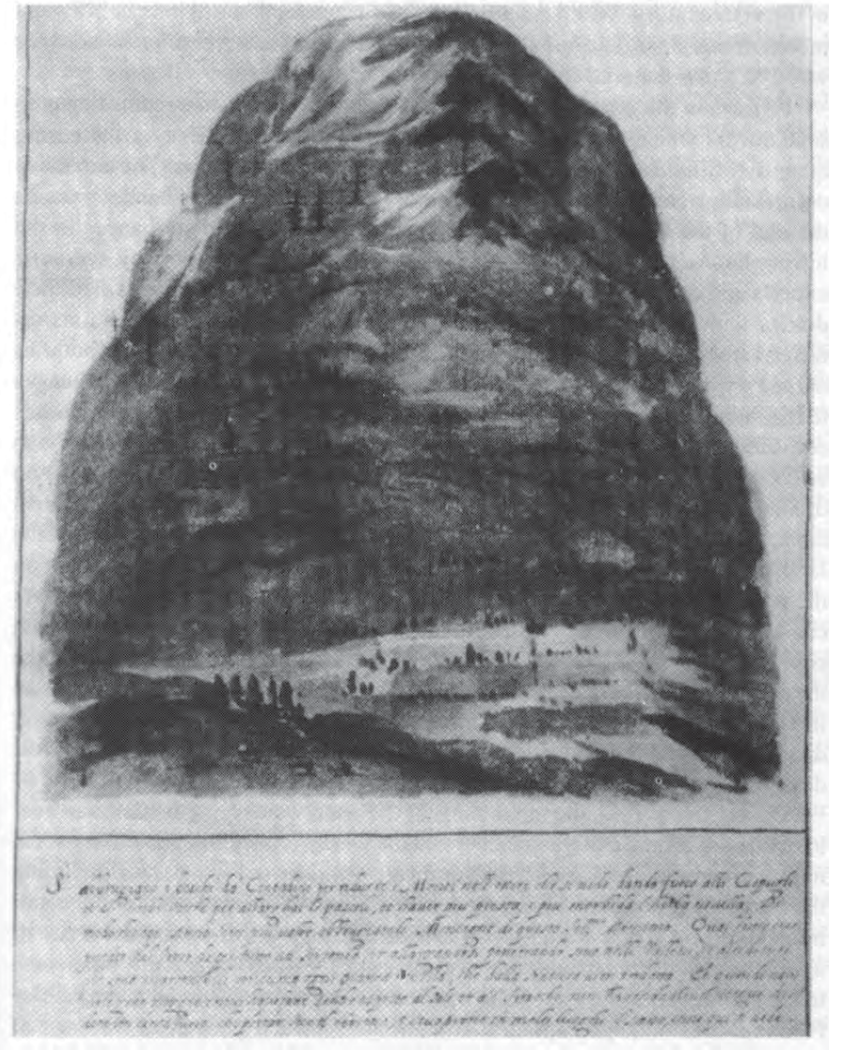

FIGURE 6.

in the 16th century. When assessing the environmental harm done in hilly and mountainous areas, one has also to take into account an increase in the need for wood as a raw material for energy production and building.

Erosion in the mountains meant that rivers and mountain streams began to send down to the low-lying plains of Emilia and the Veneto an ever-increasing quantity of floodwater which was rich in sand and silt deposits. The extensive deforestation carried out in the 16th century began to prick consciences towards the end of the century. Possible reasons for hydrological disturbances in the lower plain were the subject of reports and considerations not only by hydraulic experts and court advisers but also by ordinary citizens, who often filled their diaries with remarks about 'senseless' deforestation. These observations referred to the Alps and Alpine foothills as well as the Apennines, for the tributaries of the Po which had their sources in the Alps were affected by the drastic changes to the mountain woodlands. An example of the extent to which contemporaries considered this to be an important influence on water regimes and flooding can be seen in the project put forward by Giuseppe and Tommaso Paulini (Archivio di Stato, Venice; ed. Alberti and Cessi 1934). The Paulini brothers were Veneto landowners who, in 1601, presented to the Republic of Venice an analysis of the land changes which, in their opinion, had had a seriously detrimental effect on the water regime in the lower plain and hence in the Venetian lagoon as well. As can be seen from the extraordinary illustrations (Figs. 3, 4, 5, and 6) which constitute the analytical part of the project, they considered deforestation to be the principal cause of hydrological disturbances. Their suggested remedy was an intensive reforestation of the area, which would solve the problem of water disturbances and flood swollen rivers. The fundamental principles of present-day mountain forestry are based on similar observations.

During this period, the inhabitants of the plain were trying harder than ever to obtain additional cultivable land from the waters (Anselmi 1984). They set in motion impressive reclamation and drainage works in low-lying areas, including the channelling and control of river courses. This is the period when solid matter transported by rivers began to be used artificially to fill in sunken areas of agricultural land; and irrigation was even brought to areas of gravelly heath land in the Alpine foothills. The second half of the 16th century has been defined by F. Cazzola (1987), perhaps in a somewhat rhetorical phrase, as 'the age of reclamation and redemption'. Many land reclamation works were stimulated by large rises in rents and the price of land, partly resulting from substantial speculative activity on the part of urban investors and the merchant oligarchy of Venice.

In the second half of the 16th century, there was an increase in momentum in the construction of that 'artificial homeland' – to use L. Gambi's definition (1989) – consisting of land flooded by the waters of the Po and its tributaries. Flooded land was reduced in area and transformed into cultivable fields by means of natural drainage systems, which usually meant embanking all flood-

producing watercourses, and channelling them to hydrometric levels lower than those of the low-lying basins they passed through. In many cases, that meant taking water flowing out of higher level basins directly to the sea by means of expensive raised channels. It has been calculated that between 1540 and 1620 tens of thousands of hectares of land were drained by channelling off low-lying water and at the same time embanking water at higher levels (Rigobello 1976; Cazzola 1978).

CEREAL YIELDS

In pre-industrial agriculture, the problem of famine and the role of extreme climatic events usually has to be seen in close relation to that of average yields. The really weak point in the ratio of resources to population lay in the low overall yield of basic foodstuffs. For the lower Po area examined, few data are available for average long-term cereal yields. This is not an area of extensive vine cultivation, so that vintage data are almost completely lacking. However, the data at least agree in placing normal yields of wheat – the principal food crop – within limits ranging from 4 to 6 times the amount of seed sown (the figure for the Po Plain today is between 21 and 37).

During the period 1515-24, average wheat yields were fairly high, at about 7.5 times the amount of seed sown. During the following thirty years, five-year averages were in the region of 6.3 to 6.73. From 1555 onwards, average yields declined appreciably, descending to 5.23-5.95 in the following two decades. The average yield in the period 1585-94 was 5.62, and an even lower figure of 5.10 is found for the period 1595-1604.

Better average annual crops are recorded for 1605-14 (6.38), but the years that followed again produced low yields: no higher than 5.39 for 1615-24 and 5.57 for 1625-34. The lowest average yield is found in the period 1645-54, when it was no higher than 4.95 (Rotelli 1968). In pre-industrial agricultural systems, the lowest absolute annual yields usually coincide with unfavourable weather conditions. According to data published by Galassi (1970, II, p.106) for the area of Emilia to the east of Bologna , the years with yields lower than 4 times the seed sown were even more numerous during the twenty years at the end of the 16th and the beginning of the 17th century. Yields below 5 are recorded for the years 1589 (4.83), 1590 (4.08), 1591 (4.13), 1592 (3.34), 1594 (4.92), 1597 (4.49), 1599 (3.33), 1600 (3.83), 1606 (4.39) and 1611 (3.45) (see graph in fig. 7). However, wheat yields in cereal-producing land such as that of the area of Urbino seem to have been much lower, for Paci (1975) records yields there which rarely exceed 4 times the amount of seed sown up to the end of the 18th century, and in 1590 the exceptionally low level of 2.63 is recorded (Paci 1975, pp.92-93 and Table 1).

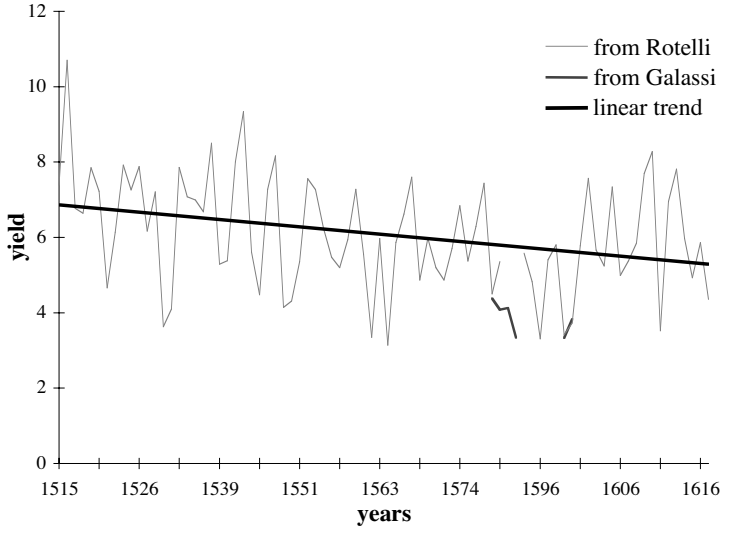

FIGURE 7. Average wheat yield in some areas of the country of Emilia between the 16th and 17th centuries. (Processed from Rotelli 1968 and Galassi 1970)

It is interesting to compare these values with the late 15th century figures given by Cazzola (1982, p.279, Table 5) for the large ducal estate of Casalia outside Ferrara – an area drained in the second half of the 15th century. Wheat yields range between 6 and 13 times the amount of seed sown.

FISCAL CONTROLS AND THE PO WATER SYSTEM

Most of the area examined belonged to the Duchies of Mantua and Ferrara, which had different fiscal and administrative systems. As regards territorial water control, the Duchy of Ferrara was organised more strictly than Mantua, for in the former the embanking of rivers by residents was obligatory, and there were fiscal sanctions for non-compliance. This complex fiscal and water system, known as a 'work system' (*del lavoriero*), was based on the obligation of peasant families to provide labour for the maintenance of hydraulic works in proportion to the quantity of cultivated land per family residing in rural areas. Some scholars have compared this obligatory system of embankment maintenance to certain aspects of the great water systems set up in the Asiatic empires. But in the Italian context, where there were no large, strong and stable states, this fiscal system created a disparity between the territories of two adjacent duchies, and that was,

in turn, responsible for two critical situations which are worth describing here:

1) the general weakness of river banks in the Duchy of Mantua to the north had a direct influence on the vulnerability of river banks in the Ferrara area.

2) the very substantial difference in fiscal pressure was tempered by means of the use of exemptions for new residents. This gave rise to substantial migrations of peasant families between the two adjacent duchies, as they sought better fiscal conditions.

The general consequence was a region with a highly unstable population, and one whose environment was safeguarded in different ways. This outline sketch illustrates the extraordinary importance, within the context examined, of the peasant family economy for the system of maintaining river banks and related hydraulic works (Guidoboni 1981, 1983, 1987).

EXTREME METEOROLOGICAL EVENTS, FLOODS AND ARTIFICIAL BANK CUTTING

Historical records for the area examined – consisting mostly of diaries and chronicles – often mention the effects of rain as a cause of the economic depression in the second half of the 16th century. But there are also references by contemporaries to periods they describe as 'very dry' (*siccitosi*): from May to November 1559, for example, from February to October 1562, and from May to September 1563. These dry periods were often followed by a series of years characterised by heavy spring and autumn rains which were considered to be responsible for damage from flooding rivers.

Amongst non-meteorological causes of flooding in this particular area at least two factors stand out: drastic human interference with river courses, and the deliberate cutting of their banks. As regards the first of these, it has to be remembered that between 1526 and 1540 the Po di Primaro (i.e. the branch of the Po in the south of Ferrara) flooded the countryside as many as 42 times. The reason for that, in the contemporary view, was the diversion of the Reno into the Po di Primaro between 1522 and 1526. As regards the second factor, it should be remembered that in April 1523 the waters of the Secchia flooded the countryside because its banks were deliberately opened up so that the river flood waters would flow into particular areas. This practice (called *tagliata*) was used to protect inhabited areas and noble estates. It should also be kept in mind that since the Po was a frontier between states (the Duchy of Mantua, the Duchy of Ferrara and the Republic of Venice), its banks were particularly subject to scenes of unrest: armed clashes involving spies and the taking of prisoners sometimes occurred over efforts either to cut open river banks or to prevent such an operation (see the trials and reports of the old Water Magistrate in the Gonzaga and Este archives).

This complex human situation occurred within the context of what was undoubtedly a deterioration in the climate; but the point to be emphasised here is the difficulty of exactly quantifying the extent to which floods are a climatic indicator.

Exceptional snowfalls are recorded for the winter of 1570-71, whereas 1571 and 1572 seemed to have been particularly warm and wet. From about 1576 to 1590 (with peaks in the years 1589-90), sources agree in describing the period as characterised by frequent rains and cold spells, accompanied by a general fall in temperature below what was subjectively held to be 'normal' for the season. In 1594, 1601 and 1660, heavy unseasonable snowfalls are recorded (in April and September, that is to say), as well as rain and hail during the summer months.

The substantial list of floods from the main rivers in Northern Italy provides evidence of generally disturbed hydrological conditions, resulting from the structural nature of the land and extreme meteorological events. The floods described in the sources involved a large part of the Po area and were destructive in their effects. A more detailed analysis of these aspects carried out by periods of 50 years has made it possible to show that there was an increase in these phenomena (also considering the extension of flooded areas) during the years 1530-1590 as compared with the preceding periods (see graphs in figs. 8, 9 and 10). According to some historical records examined, floods seem to be more

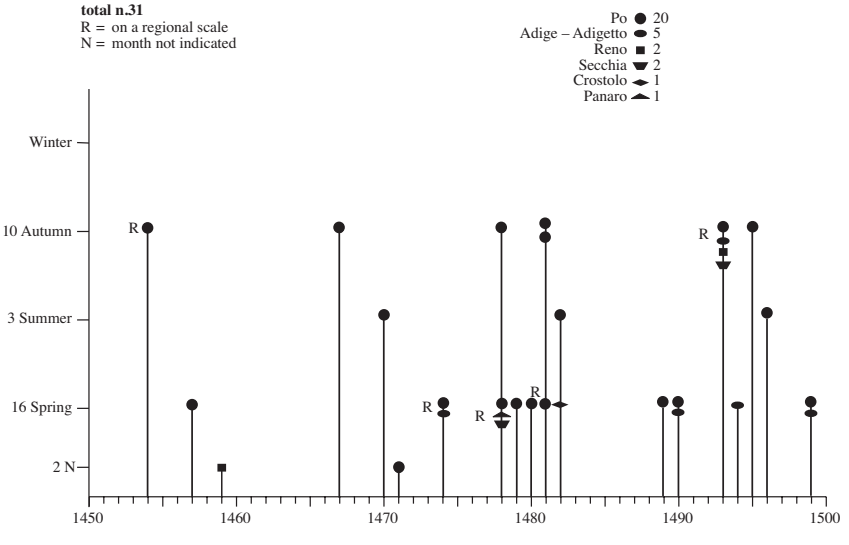

FIGURE 8. Local and regional floods in the lower Po Plain from 1450 to 1499 (Figures 8–10 processed from SGA Report, 1990).

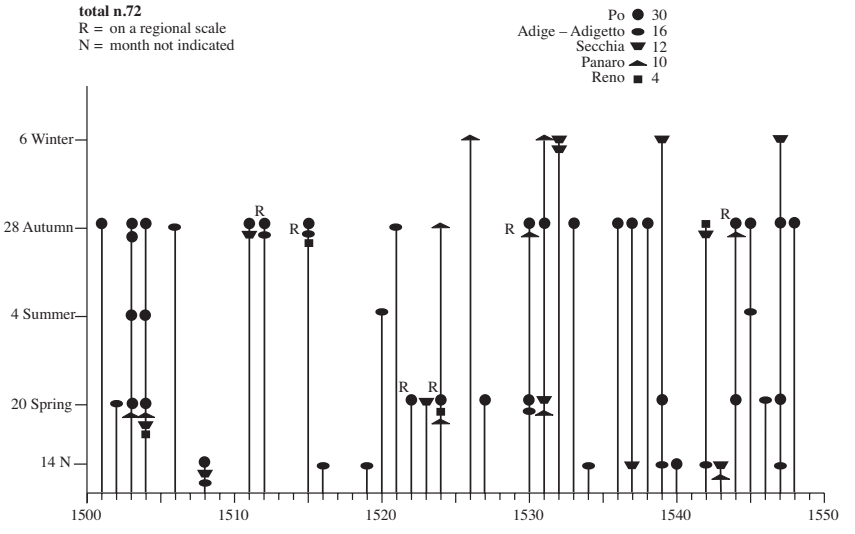

FIGURE 9. Local and regional floods in the lower Po Plain from 1500 to 1549

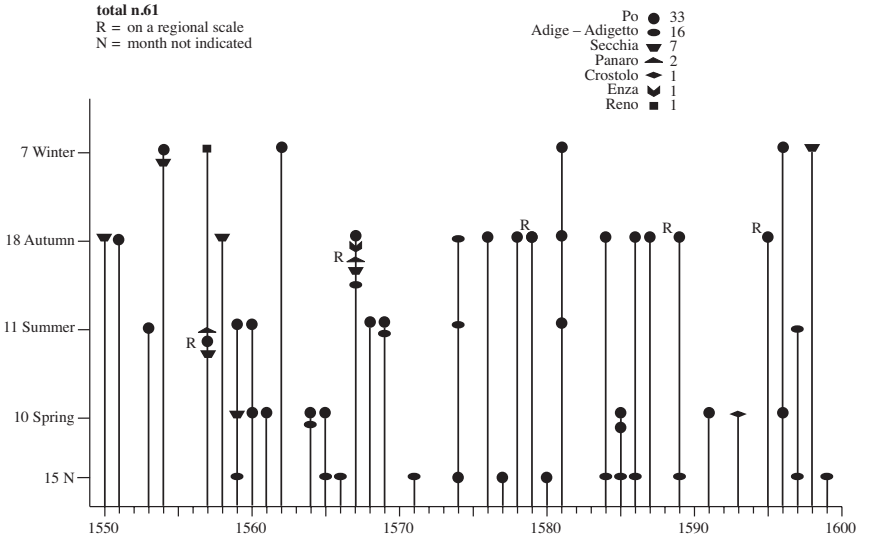

FIGURE 10. Local and regional floods in the lower Po Plain from 1550 to 1599

frequent in autumn in the 16th century: 10 floods are mentioned between 1450 and 1500; 28 between 1500 and 1550 and 18 between 1550 and 1600. Overall, there were 31 flood events in the first 50-year period examined, 72 in the second one and 61 in the third period.

The floods decreased between the end of the 16th century and 1610, perhaps owing to the many hydraulic works that were carried out in that area (Bottoni 1873).

THE FRAGILE STATE OF THE SOCIAL FABRIC

It appears from chronicles and other documentary sources of the period that the close succession of numerous extreme meteorological events was responsible for serious damage in the area. In the collective memory, these events were regarded as 'exceptional'. In addition, however, the *vulnerability* of the region had increased, for geomorphologic, economic and social reasons.

It is well known that within the context of pre-industrial food production, a poor harvest affected not only the immediate well-being of the local population but also the next year's crops, because of the scarcity of available seed. In pre-industrial economies, therefore, famines were not exceptional occurrences but recurrent phenomena resulting from poor agricultural yields (Rotberg and Rabb 1985). On the basis of present-day knowledge, it can be said that in medieval times – known for their *optimum climaticum* – famines occurred much less frequently. From the 13th century, on the contrary, they were pernicious**:** for Italy has reliable sources which mention cases of severe crop losses by drought or intense cold (SGA 1990).

During the 16th century, subsistence crises occurred almost every ten years: in 1505, 1539, 1549, 1560-62, 1571, 1590-92, 1596 (Biblioteca Ariostea di Ferrara, Rodi, ms.). In the second half of the 16th century, peasant debt reached such worrying levels that economic policy enactments became necessary. There is also plenty of evidence to suggest that the worsening of the crisis coincided with a deterioration in atmospheric conditions.

That a certain number of people required public assistance is indicative of inherent local poverty, but it was not a threat to the administrative structures of the time, and did not present particular problems of public order. On the other hand, 'economic crisis poverty' (for the meaning of expression, see Abel 1935 and Braudel 1979), such as can be found in the second half of the 16th century, was too much for the traditional structures of public assistance, and so resulted in fear, threats, and the closing of the city gates (Gutton 1974; Geremek 1980). That is indeed what happened in Ferrara: around 1570, the capital city of the Este duchy closed its gates to beggars and vagrants who were swarming into the city from the countryside in search of food. Extreme poverty was in fact to be found throughout Europe in the 16th century**.**

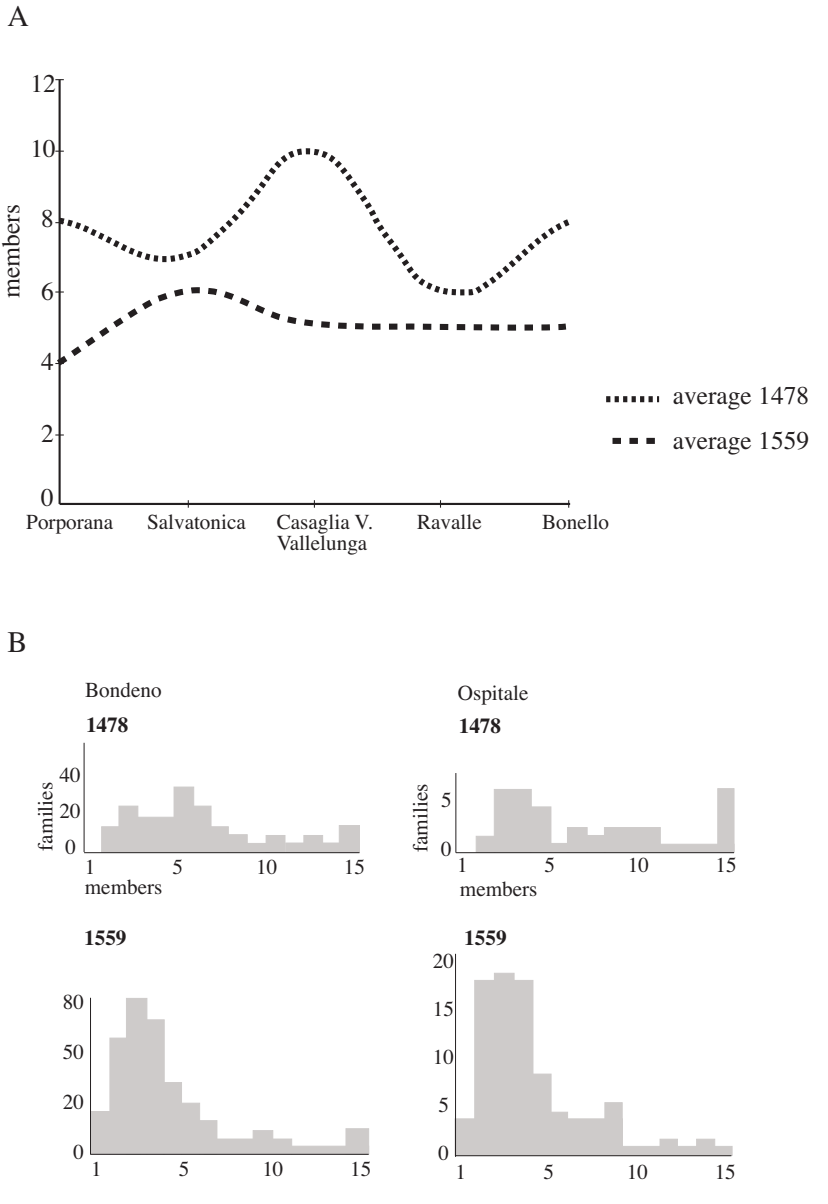

FIGURE 11. (A) Fall in the average peasant family size in 5 villages of the Ferrara area between 1478 and 1559. (B) Analysis of the composition of peasant families in 2 villages of the Ferrara area in 1478 and 1559. Processed from Guidoboni 1981 and 1987.

Battles and the passage of troops had also caused damage to the countryside since the end of the 15th century. A long period of political instability had led to numerous frontier wars and the passage of troops on a massive scale. The disasters of war were capable of bringing about appreciable changes in the demographic structure of the countryside, affecting the density, mobility and size of peasant families. In this region, one effect of disasters of this kind on the rural economy was the destruction of those man-made works (palisades, sluice-gates, embankments and ditches) which contributed to the usefulness of the land by draining the soil and making agriculture possible. The passage of troops, moreover, could trigger extensive epidemics (Penuti 1977). Thus, in the last decade of the 15th century and the first forty years of the 16th, there was a syphilis in a particular epidemic form that soon afterwards changed; it was hardly ever mortal, but it was dangerous to the production capacity of peasant families (Guidoboni 1981).

By the mid-16th century, the traditional peasant family, which had previously been characterised by its large size and a tendency to immobility, was already in the process of 'breaking up'. A survey of part of the Ferrara countryside (*Polesine di Casaglia*) shows that the average size of a peasant family fell from 8.5 members in 1478 to 5.2 in 1559, as shown in fig. 11.

Within the socio-economic context, therefore, there are various items of evidence to show that the whole food production system was in a very vulnerable state, with the result that it is difficult to assess the extent to which atmospheric phenomena were abnormal in the area. What can be said, however, is that they set off a 'chain reaction' within the whole local system.

THE GREAT FAMINE OF 1590-92 IN THE PO PLAIN

The famine which struck Italy and a large part of Europe in 1590-91 was caused by a complex set of economic and monetary factors which economic historians have defined as a 'revolution in prices', and which certainly played an important role in the general subsistence crisis (Romani 1983). These factors have been identified as monetary inflation, the greater availability of gold, and the inflexibility of pre-industrial market systems in coping with increases in demand on the one hand and serious agricultural product losses on the other. The extent to which climate played a part in the crisis, however, remains to be established (see again Clark 1985; Devidson 1985).

It has already been shown (Pfister 1978 and 1988) that in what are known as 'solar energy' production systems, recurrent rain in particular months will upset the functioning of the entire agricultural production system. Especially in the autumn and winter months, moreover, rain reduces the levels of calcium, phosphates and nitrogen in the soil, thereby leading to a poorer harvest. Since temperature also plays a part in fixing nitrogen in the soil (Hanus and Aimiller

1978), temperature oscillations in the various months of the year have a substantial effect on cereal yields. Furthermore, very wet weather at harvest time could lead to mycotic diseases in cereals, and that could in turn result in mould and various other kinds of deterioration during storage.

As far as agricultural production is concerned, a drastic reduction can be noticed in yields, resulting from what contemporary records describe as 'poor seasons of our times' ['male stagioni dei tempi']. The scarcity of available cereals meant that a substantial subsistence crisis struck those living in the area examined in 1590, and the lack of grain supplies reduced the population to a state of starvation. There were a great many deaths in Emilia. For Bologna and the surrounding area, the chronicles record 4,000 deaths – a figure which gives an idea of the scale of the disaster.

A further effect of the unfavourable climatic conditions (perhaps increased rainfall and reduced insolation) was the almost total loss of salt production along the Adriatic coast (Cervia). This caused a very serious 'salt famine', which is recorded in the sources as yet another aggravating factor. The serious subsistence crisis of 1590-92 in the lower Po area led to a series of ducal enactments. The ducal chancellery tried to deal with the situation by strengthening controls and imposing regulations which were issued as a matter of urgency in the form of ducal proclamations (Modena State Archive, *Chancellery of the Este Duchy,* 1590-97). Simply by reading these proclamations, the rapidly worsening situation can be followed. Here is a brief summary of their contents:

1590, 17-18 July: corn is declared to be very poor in quantity ('*grave sterilità delle biade*'), and corn growers are required to report how much they harvest in the fields.
1590, 25 August: providing lodging for strangers is forbidden, because of the lack of available corn.
1590, 5 September: all those living in the Duchy are ordered to sell their corn to the bakers in order to prevent unscrupulous stock-piling.
1590, 3-4 October: peasant debts are suspended until the next harvest.
1591, 11 February: punishments are set out for anyone pretending to be poor in order to obtain assistance.
1591, 16 February: the guards at the gates of Ferrara are ordered not to allow cereals to be taken out of the city, nor to allow vagrants and the poor to enter.
1591, 29-30 March: everyone must report what quantity of cereals they are keeping at home or in stores.
1591, 27 April: it is forbidden to take corn out of Ferrara, because of the famine.
1591, 30 April–1 May: new arrangements to expel beggars from the city.
1591, 14-15 May: everyone is required to report what quantity of cereals they possess and how many mouths they have to feed.
1591, 1-2 July: a fresh order to report corn in storage.
1591, 13 July: because of the current famine, a check must be kept on the amount of cereals entering the city.
1591, 24 August: hunting within the ducal estates is severely prohibited.
1591, 5 September: all *castellate* of grapes must be stamped and thoroughly checked.

1591, 19 September: strangers are to be expelled from Ferrara and its territory because of the current famine.
1591: ferrymen are ordered not to carry beggars.
1592, 28 June: orders are issued forbidding the export of cereals from Este territories in Romagna.
1592, 6-7 July: regulations to prevent any export of cereals from the territory of Ferrara because of the current famine.
1592, 15-16 August: a new proclamation against beggars from outside.
1592, 7 September: a proclamation against thefts of grapes from the countryside leading to early harvesting and poorer quality wine.
1592, 9 November: the Consuls for Foodstuffs [*Consoli delle Vettovaglie*] require cereals to be checked because the corn had been too wet when harvested and there could be weight variations during storage.
1592, 2 December: it is forbidden to take cereals out of the city and its territory.
1592, 10 December: first notification of the presence of plague.

In 1590, many small farms were abandoned by peasants in the Mantua and Ferrara areas and sowing could therefore not take place, with the result that the existing general state of crisis was exacerbated. The terrible effects of the famine on the living conditions and nutrition of the populace are mentioned by almost all contemporary writers in the area (see in particular Segni 1591 and 1601).

In the same year, 1590, there were 1,369 deaths from starvation and related diseases in the hospital of San Gregorio in Bologna. In Parma, too, as in other northern Italian cities, there were many deaths. The data provided by Romani (1975 and 1983) show that at the beginning of 1591 Parma had 26,000 inhabitants, but only 20,700 at the end of 1592. For Mantua, Belfanti (1982) worked out the data for the years 1590-91. It is possible to deduce from these data that there was a 15-20% increase in deaths and a 10-15% decrease in births, at a time when the price of bread rose by 50%.

THE CRISIS IN THE LOWER PO HYDRAULIC SYSTEM

At the end of the 16th century, as Cazzola (1990) points out, the whole hydraulic system in the lower reaches of the Po was very disturbed, or at least structurally altered, to the extent that, as contemporaries put it, the water did not know which way to turn. It apparently flowed in various directions, depending on the level of the Po Grande – that is to say the new branch of the river which had been created by the breach of the banks at Ficarolo (in the Province of Rovigo) in 1152.

During dry periods, much of the water flowing into the Po basin found its way into the bed of the river, but when the level rose, the waters returned to their old route towards Ferrara, filling the course of the old Po di Primaro and Po di Volano, which had had plenty of water in ancient and mediaeval times (see Lombardini 1840, one of the most notable scholars of the river Po hydraulic system before the 20th century changes). The hydraulic system deriving from the Po and the Panaro underwent a considerable change in the 16th century which

further compromised the delicate state of equilibrium between the two rivers; for in 1522, the Duke of Ferrara, Alfonso I d'Este, had allowed the Reno to be diverted into the Po di Ferrara, that is to say the stretch of river which came down from Stellata towards Ferrara and had in the past been a source of wealth and power for the city as an important way of passage (Bocchi 1879; Franceschini 1983).

Later on, however, the Reno choked the bed of the Po di Ferrara to such an extent that the main branch of the river was blocked, with the result that the Po could no longer take all the water flowing down from the Panaro. What is more, the Reno had also deprived of their function the channels which allowed water to flow out into the Burana canal, that massive channel which had played a part in the hydraulic system of the area ever since ancient times, affecting the whole of the Po basin from Bondeno to Reggio Emilia. At the close of the 16th century it was perfectly clear even to contemporaries that a hydrographic equilibrium which had existed ever since ancient times was now in a state of crisis. The Reno was considered the direct cause of the new situation, since it created a serious imbalance by depositing large quantities of sand and silt on the bed of the Po di Ferrara (Giacomelli 1983).

Some historians tend to identify interference with the course of the river as the chief reason for this deterioration in the hydraulic system. The situation may well have been substantially affected, however, by a number of other concomitant causes, such as the tendency of the whole Po to take its course from hidden geological structures or synclinal axes (Veggiani 1985; Bondesan 1985). Geomorphologists have shown that for the last hundred years, breaches in the banks of the Po have been oriented along structural lower areas. Below the Mincio, the course of the Po tends to follow the long Ficarolo-Copparo syncline. The modifications of the drainage directions in the Po Plain are generally controlled by limited tectonic activity, which is responsible for the creation of small but perceptible bulges and troughs, and by subsequent readjustments related to times of exceptionally large or small rainfall. It may be pointed out that the seismicity of that area is attested in written sources and that just between 1570 and 1574 the area of Ferrara was affected by a long seismic period (Guidoboni *et al*. 1985; Boschi *et al*. 1995).

No doubt this complex web of geological structures, surface morphology and extreme climatic events also involves the general tendency of the Po delta to migrate northwards, as well as the tendency of some of its right-bank tributaries to migrate from east to west. Perhaps, therefore, an explanation for the great mass of water drawn into the new course of the Po as a result of the breach of the banks at Ficarolo in the 12th century, as well as the progressive silting up of the Po di Ferrara is to be found rather in geomorphology and an increase in rainfall rather than in contingent human factors such as those which diverted the Reno into the Po (about the basin evolution in long terms, see Fano 1936; Gambi 1989).

As has been pointed out, there were indeed human factors involved in the deterioration of the Po's hydraulic system, such as the cultivation of fresh land

through the deforestation of mountain slopes from the early 16th century onwards in order to increase agricultural production. Deforestation had the effect of increasing erosion of the slopes and the speed of streamflow when rivers were in flood, and this was definitely a direct cause of the choking up of rivers and an increase in the accumulation of solid matter on river beds.

A first conclusion to be drawn from the above – and contemporaries were not unaware of it – is that there was a general crisis of the whole water drainage system in the eastern Po area. The need to re-establish somehow an equilibrium which had been lost during the 16th century led to repeated but vain attempts to find a solution to the problem of the various rivers (the Reno, the Panaro and the Po di Ferrara) and the Burana canal, whose 'destinies' were indissolubly linked. Given the state of contemporary technology, it was no easy task to apply successfully the solutions which were proposed and attempted in an effort to put a stop to the serious deterioration of the whole hydraulic situation and somehow stem the loss of drainage channels throughout the whole vast Ferrara area.

When Pope Clement VIII took over the government of Ferrara from the d'Este family in the late 16th century, a policy of 'general land reclamation' was set in motion. It was thus in that century that a decisive attempt was made to reorganise the whole of the final stretch of the Po basin into its modern form.

If there was indeed an increase in rainfall and snow in the Alps and Apennines (Pfister 1980; Pinna 1984; Grove 1988), it must have caused the 'neutral' point in the Po basin rivers – that is to say the point beyond which erosion of the river bed ceases and silting begins – to move upstream. Reports by contemporaries suggest that there was an increase in silting; but these were local observations and referred to a situation which had already been affected by other factors. But it can perhaps be deduced that there was indeed a climatic input from the fact that the final reaches of the Po tended increasingly to take up a raised position in relation to the level of the surrounding countryside. This phenomenon made the system of embankments even more fragile and therefore flooding increased. At the same time, peasant families were no longer able to assist systematically in the work of reinforcing embankments, palisades and other hydraulic works intended to control cultivated areas. Important hydraulic works required for controlling and reinforcing the embankment system and the regular outflow of river waters were a burden on urban and rural economies in the late 16th and 17th century (Cattini 1982). In the Ferrara area there was also a massive and ruthless use of waged labour, whose availability was increased by new farming contracts and the reorganisation of large estates. The latter caused an increase in the number of landless peasants, and so brought a substantial new labour force on to the market (Cazzola 1977). It was within this context that the Republic of Venice also took drastic action, by carrying out the hydraulic operation known as 'the breach of Porto Viro' between 1600 and 1604 (Cessi 1898; Bassan 1972), in order to control the spread of marshland in its lagoon port system. The work concerned was enormous in its extent: every mouth of the north-east branch of the Po was closed off, and the Po delle Fornaci was diverted southwards. The course of the

Po was shortened by 5 km, thereby increasing its final velocity. The average annual increase in the size of the Po in the period 1300-1600 was about 53 hectares; but between 1600 and 1840 it was 135 hectares (Bassan 1972).

CONCLUSIONS

In conclusion, it may be stated that an analysis of the interaction between extreme natural phenomena and human activities in the lower Po Plain has identified certain basic factors, as set out briefly below. From a hydraulic and hydrogeological point of view, the Po delta is the final stretch of one of the most complex hydrographic basins in Europe. The area occupied by the hydrographic basin of the Po has been one of the most densely urbanised and intensely affected by human intervention in Italy, in spite of past difficulties in using it for agricultural purposes, especially in its lowest lying parts. The sources confirm the suggestion that when population pressure in the course of the 16th century led to the deforestation and cultivation of mountain slopes, the effects of flooding were aggravated. An increase in the quantity of solid matter carried down to the plain led to a raising of river bed levels and a greater risk of flooding. These phenomena belong to the climatic context of a broader area, attested by glaciological data. In fact, the Alpine glaciers were enlarged in the late 16th century. Those on the French side of Mount Blanc, for instance, advanced greatly between 1580 and 1600 (Grove 1988).

The need for more cultivable land also brought into play parts of the plain which had previously been wet, and their reclamation involved a massive reduction in areas occupied by marshes or floodwater. This produced a considerable increase in the amount of water channelled off from reclaimed land, and reduced the extent of the natural area into which rivers in flood overflowed. These factors obviously make it extremely difficult to assess in an objective way the extent to which floods were an exceptional phenomenon, due to the increase of water and snow. The intrinsic fragility of this system of agricultural production intensified the harmful effects of extreme climatic events. Crop losses during the period under examination coincided with rains in the autumn, spring and summer periods, which then influenced the sowing, growing and harvesting cycle. In addition, the previous fiscal system for river bank maintenance had been based on the traditional peasant family, which was no longer able to carry out the work systematically, owing to several economic and social factors pointed out here. The severest shortages of subsistence foodstuffs and agricultural produce in the lower Po Plain in the period 1550-1590 seems to have been caused by prolonged flooding either from rivers or in the form of standing pools of meteoric water.

In order to deal with this problem, towns and rural communities subsequently had to cope with a new period of expensive hydraulic works in order to control streamflow, and this was achieved largely by channelling river courses. The land

adjacent to rivers (levees) was the area primarily selected for settlement and cultivation, because it was at a comparatively high level. The first land to be used for agriculture, then, was that closest to rivers, at the expense of natural areas for river expansion. That meant that the section of watercourse confined within banks was historically made as narrow as possible. In the lower Po Plain there has been a long-term tendency to adopt channelling as the almost inevitable answer to the problem, and this has remained so up to present day.

All these factors taken together show that worsening climatic phenomena (especially the increase in rainfall) may have been quite moderate, and of less intensity in this area than in central Europe, but their effects proved *exceptional* in such a highly vulnerable context. It can therefore be stated that meteorological events affected a system which had already been damaged by the effects of substantial environmental, economic and demographic changes.

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REFERENCES

Archivio di Stato di Modena, Archivio Generale Estense

- Cancelleria del Duca d'Este (Chancellery of the Este Duchy)
  Gride a stampa sciolte [Loose printed proclamations], b.3, 1590-97.
- Amministrazione finanziaria dei Paesi (Village financial management)
  b. 264 (Letters to the Duke Alfonso II d'Este reporting the Po flood of 1568).
  b. 2473, f. II, n. 8 (Letter from the vicar Pendaglia reporting the Po breach at Quadrelle, 3 June 1508).
  b. 3257, cc. 602-3 (Letter from the Farmer Batta of Villonova to the Marchesa Barbara d'Este, describing the Po breach between Brescello and Guastalla – with drawing), 1466.
- Mappe e carte (Maps and surveys)
  Ferrante Franchi, 1670, *Dissegni generali e particolari del Stato di Ferrara dissegnati l'anno 1670*, Libro 1, Polesine di Ferrara.

Archivio di Stato di Mantova, Archivio Gonzaga

- Corrispondenze (Corrispondences)
  b. 2473, f. II, n. 8 (Letter from the Vicar Pendaglia reporting the Po flood at Quattrelle, 3 June 1508).
  b. 11, n. 177 (Letter from the Marchesa Isabella d'Este to her son Federico Gonzaga reporting the Po swell, 17 October 1522).
  b. 11, n.178 (Provisions by Ludovico Agnello indicating where to breach the Po banks, Ostiglia 1522).
  b. 11, n.179 (Letter of the *Podestà* of Sermide asking for labourers to close the Po breach of 9 May 1522).
  b. 11, n. 180 (Report about the 40 *pertiche* collapse in the Po banks at Serravalle, 30 November 1522).
  b. 11, n. 183 (Report about the villages damaged by the Po flood of April 1522).
  b.11, n.185 (Letter from the vicar of Revere reporting the breach of the river Secchia, Revere, April 1523).
  b. 11, n.187 (Letter of the *Podestà* of Sermide reporting the Po flood of 22 November 1524).
  b. 11, n. 189 (Notification of the *Podestà* of Sermide about swell and flood of the waters of the Modena Canal, Sermide 4 July 1525).
  b. 11, n.190 (Statement of the customs magistrate of Sermide, 23 February 1526)
  b. 11, n.197 (Statement of the customs magistrate of Revere about the Po breach, October 1526)
  b. 11, n. 198 (Pronouncement of inefficiency of the sluice of the Follonica Bastion, partly damaged by the Po, October 1526).
  b. 11, n. 200 (Statement of the Commissioner of Revere, May 1527)
  b. 11, n. 207 (Statement of the *Podestà* of Sermide, May 1527).
  b. 11, n. 208 (Statement of the *Podestà* of Sermide, 19 May 1527).
  b. 11, n. 209 (Statement regarding a cut to be done to the bank of the river Secchia at Borgoforte owing to the breach of 1527).

Biblioteca Apostolica Vaticana

Cronache facte e scripte per mi Ugo Caleffini notaio ferrarese, cod. chigiano I. 1.4, 15th century.

Biblioteca Comunale Ariostea di Ferrara

Rodi Filippo, *Annali di Ferrara dalle origini al 1598*, ms. cl. 1, 645, 16th century.
De Roberti Ippolito, *Cronichetta che comincia li 30 ottobre 1559 e termina li 10 maggio 1592*, ms. Antonelli n. 294, 16th century.
Ferrazzi Monaci F., *Annali di Ferrara dalle origini al 1632*, ms. Cl. 1, 674, 17th centurty.
Merenda Girolamo, *Annali della città di Ferrara fino al 1602*, ms. 63, 16th-17th century.
Anonymous, *Memorie di Ferrara dall'origine al 1586*, ms. Antonelli n. 133, 16th century.
Olivi Carlo, *Compendio cronologico della storia di Ferrara dall'origine al 1598*, ms. Cl. I, 743, 17th century.

Biblioteca Estense di Modena

Ploti G.F., *Cronaca della città di Modena (1546-1596)*, 16th century.

Biblioteca Universitaria di Bologna

Ghiselli Antonio Francesco, *Memorie antiche manoscritte di Bologna, dalle origini al 1709*, ms. 770, vol. 93, 18th century.

Published sources

Alberti A. and Cessi R. (eds.1934), *Un codice veneziano del 1600 per le acque e le foreste*. Ministero dell'Agricoltura e delle Foreste, Roma.

Bocca A. (ed. 1985), *Annali adriesi* (1506-1649), ms. 17th century, edited by A.Lodo, Rovigo.

de Bianchi Tommasino (ed. 1862), *Cronaca modenese (1506-1554)*, Parma.

Franchi C.Valentino, *Rotte del Po in quel di Ferrara*, ms. 16th century, edited in 1873, Ferrara.

Sanuto Marin, *Diari (1496-1533)*, eds F. Stefani, G. Berchet, N. Barozzi, 59 vols,.1879-1902, Venezia

Sardi G. (1584), *Libro delle Historie Ferraresi,* Ferrrara.

Segni G.B., (1591), *Discorso sopra la carestia e la fame*, Ferrara

Segni G.B.,(1602),*Discorso sopra la carestia e la fame: sue cause, accidenti, provvisioni, reggimenti*, Bologna.

Zambotti Bernardino, *Diario ferrarese dall'anno 1476 al 1504,* ed. G.Pardi, 'Rerum Italicarum Scriptores', t. 24/7, Bologna 1937.

Studies

Abel W. (1935), *Agrarkrisen und Agrarkonjunktur*, Hamburg und Berlin.

Anselmi S. (1984), 'Disboscamenti e politica del grano fra Quattrocento e Settecento', in *Agricoltura e trasformazioni dell'ambiente secc. XIII-XVIII*, a cura di Guarducci A., pp. 419-53, Firenze.

Bassan P. (1972), *Il dominio veneto in bassopolesine*, Abano Terme.

Basini G.L. (1970), *L'uomo e il pane: risorse, consumi e carenze alimentari della popolazione modenese nel Cinque-Seicento*, Milano.

Belfanti G.M. (1982), 'Una città e la carestia: Mantova 1590-92', in *Annali della Fondazione Luigi Einaudi*, vol. XVI, pp. 99-140.

Bellettini A. (1961), *La popolazione di Bologna, dal secolo XV all'unificazione italiana,* Bologna.

Bellettini A. (1980), 'La démographie italienne au XVI siècle: sources et possibilité de recherche', in *Annales de demographie*, pp. 19-38.

Bellettini A. (1987), *La popolazione italiana. Un profilo storico*, Torino.

Beloch K.J. (1937- 1939) *Bevlökerungsgeschichte Italiens*, 2 volumes, Berlin, Ital. transl. *Storia della popolazione d'Italia*, by L. Del Panta e E. Sonnino, Firenze 1994.

Bocchi F. (1879), *Trattato geografico-economico comparativo per servire alla storia dell'antica Adria in relazione a tutta la bassa vallata padana* , Ferrara.

Bondesan M. (1985), 'Quadro schematico dell'evoluzione geomorfologica olocenica del territorio costiero compreso fra Adria e Ravenna', in *Il Delta del Po. Sezione geologica*, Bologna.

Boschi E., Ferrari G., Gasperini P., Guidoboni E., Valensise G.(1995), *Catalogo dei Forti Terremoti in Italia dal 461 a.C. al 1980*, ING-SGA, Bologna and Roma, pp. 974 (with cd-rom).

Bottoni A. (1873), *Appunti storici sulle rotte del basso Po dai tempi romani a tutto il 1839 e relazione di quelle di Guarda e Revere del 1872*, Ferrara.

Braudel F. (1979), *Civilization matérielle, économie et capitalisme, XVe – XVIIIe siècle*, Colin, Paris.

Camuffo D. and Enzi S. (1992), 'Reconstructing the climate of Northen Italy from archival sources', in Bradley R.S. and Jones P.D. (editors), *Climate since A.D. 1500*, pp. 143-54, London and New York.

Camuffo D. (1993), 'Analysis of the sea surges at Venice from A.D. 782 to 1990', *Theor. Appl.Clim.* vol. 47, pp. 1-14.

Cattini M., (1982) 'Strade liquide e arcipelaghi di terre: lo spazio estense visto da Ferrara', in *La corte e lo spazio estense*, by Papagno G. and Quondam A., Roma.

Cazzola F. (1977) 'L'evluzione contrattuale nelle campagne ferraresi del Cinquecento e le origini del patto di boaria', in *Il Rinascimento nelle corti padane. Società e cultura*, pp. 299-327, Bari.

Cazzola F. (1978) *Bonifiche e investimenti fondiari*, *Storia dell'Emilia Romagna*, vol. II, pp. 209-228, Bologna.

Cazzola F. (1982), 'Produzioni agricole e rendimento unitario dei cerealinel ferrarese a metà del Quattrocento: la castanderia ducale di Casaglia (1451-59)', in *Studi in momoria di Luigi Dal Pane*, pp. 239-300, Bologna.

Cazzola F. (1987), 'La bonifica del Polesine di Ferrra dall'età estense al 1885', in *La grande bonificazione ferrarese*, vol. 1, Ferrara.

Cazzola F. (1990), 'La terra costruita', in *Terre ed acqua. Le bonifiche ferraresi nel delta del Po*, Visser Travagli A.M. and Vighi G. editors, pp. 35-50, Ferrara.

Cessi R. (1898), 'Marin Silvestri e Luigi Groto a proposito del taglio di Porto Viro', in *Ateneo Veneto*, a.XXI, vol. 1, fasc. 1.

Clark P.(editor) (1985), *The Crisis of the 1590's*, Allen and Unwin,

Del Panta L., Livi Bacci M., Pinto G., Sonnino E. (1996) *La popolazione italiana dal Medioevo a oggi*, Bari.

Devidson N.S. (1985), 'Northen Italy in the 1590s', in Clark, 1985, pp. 157-76.

Fano L. (1936), 'Le vicende idrauliche del Polesine di Ferrara', in *Atti e memorie della Deputazione di Storia patria ferrarese*, XXX, pp. 63-82, Ferrara.

Franceschini A. (1983) 'Una storia di acque a Vigarano', in *Vigarano, Storia/attualità*, pp.21-49, Ferrara.

Galassi N. (1970), *Dieci secoli di storia ospitaliera a Imola*, 2 volumes, Imola (Bologna).

Gambi L. (1989), 'Una "patria artificiale" nata governando razionalmente le acque', in *L'ambiente nella storia d'Italia. Studi e immagini*, pp. 73-88, Venezia.

Geremek B. (1980), 'Povertà, Pauperismo', in *Enciclopedia Einaudi*, vol. X, Torino, pp. 1049-82.

Giacomelli A. (1983), 'Appunti per una rilettura storico-politica delle vicende idrauliche del Primaro e delle bonifiche nell'età del governo pontificio', in *La pianura e le acque tra Bologna e Ferrara: un problema storico* a cura del Centro Studi Baruffaldi, Cento (Ferrara).

Grove J.M. (1988), *The little Ice Age,* London and New York.
Guidoboni E. (1981), 'Terre, villaggi e famiglie del polesine di Casaglia fra XV e XVI secolo', in *Società e Storia*, n. 14, pp. 793-847.
Guidoboni E. (1983), 'Aggregati domestici nei villaggi del basso Po alla fine del Quattrocento: il Polesine di Ferrara' in *Strutture familiari, epidemie, migrazioni nell'Italia medievale*, pp. 305-27, Siena.
Guidoboni E. (1987), 'Demografia e mondo rurale: XV-XVI secolo', in *Storia di Ferrara*, n. 17, San Marino.
Guidoboni E., Ferrari G. and Postpischl D. (1985), 'The Ferrara earthquake of 17 November 1570', in *Atlas of isoseismal maps of Italian earthquakes*, CNR-PFG, pp. 30-33, Roma.
Gutton J.P. (1974), *La société et les pauvres en Europe, XVIe-XVIIIe siècles*. Presses Universitaires de France, Paris.
Hanus H., Aimiller O., (1978), 'Ertragsvorhersagen aus Witterungsdaten', *Beih. Z. Acker-und Pflanzenbau*, 5, Berlin.
Lamb H.H. (1982), *Climate history and the modern world*, London and New York.
Lombardini E. (1840), *Intorno al sistema idraulico del Po, ai principali mutamenti che ha subito e alle più importanti opere eseguite o proposte per il suo regolamento*, Milano.
Paci R. (1975), 'Rese, commercio ed esportazioni dei cereali nella legazione di Urbino nei secoli XVII e XVIII', *Quaderni storici* n. 28, X, I, pp. 87-150.
Penuti C. (1977), 'Carestie ed epidemie', in *Storia dell'Emilia-Romagna*, vol. II, pp. 189-208, Bologna.
Pfister C. (1978), 'Climate and Economy in eighteenth century Switzerland', *Journal of Interdisciplinary History*, 9/2, pp. 233-43.
Pfister C. (1980), 'The little Ice Age thermal and wetness indices for central Europe', *Journal of Interdisciplinary History*, 10, pp. 665-96.
Pfister C. (1988), *Klimageschichte der Schweiz:1525-1860*, Bern and Stuttgart.
Pinna M. (1984), 'Storia del clima. Variazioni climatiche e rapporto clima-uomo in età postglaciale', in *Memorie della Società Geografica Italiana*, vol. XXXVI, Roma.
Rigobello B. (1976), *Le bonifiche estensi in Polesine dopo le rotte di Malopera e di Castagnaro,* Lendinara.
Romani M.A. (1975), *Nella spirale di una crisi. Popolazione, mercato e prezzi a Parma fra Cinque e Seicento*, Milano.
Romani M.A. (1983), 'La carestia del 1590-93 nei ducati padani: crisi congiunturale e/o crisi di struttura?', in *Studi in onore di Gino Barbieri, problemi e metodi di storia economica*, vol. III, pp. 1305-23, Bologna.
Rotberg R.I. and Rabb T.K. (editors 1985) *Hunger and History,* Cambridge.
Rotelli C. (1968) 'Rendimenti e produzione nell'imolese dal XVI al XIX secolo', in *Rivista Storica Italiana*, LXXX, I, pp. 107-29.
SGA Report (1990), Gianus Project, 'Extreme events in Italy from year 1000 to 1980', Bologna, unpubblished.
Veggiani A. (1985), 'Il delta del Po e l'evoluzione della rete idrografica padana in epoca storica', *Il Delta del Po. Sezione geologica*, pp. 37-68, Bologna.
Wigley T.M.L. (editor 1981), *Climate and history. Studies in past climates and their impact on man*, Cambridge.