Population, Land Use and Environmental Impacts in Shucheng County, Anhui Province, China during the Ming and Qing Dynasties

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ABSTRACT

The paper considers the documented environmental history of Shucheng County, located in Anhui Province, eastern China, during the Ming and Qing dynasties. We take Shucheng County as a case study to reconstruct the variations of population and land use in the last 500 years, and to examine their influence on the environmental changes in this region. Data are compiled for population, land use, settlement, recorded climate hazards, and consequent disasters such as drought and flooding. The causative links between climate, human activities and environmental responses are not straightforward. At times, climate seems to have acted as a strong control on human activities, especially the timing of early agricultural expansion in the warm and wet late Ming period. But at other times human activities appear to have strongly modified environmental responses to climate. For example, while the overall incidence of flooding seems to be linked to periods of

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wetter climate the long term rising trend in the flood record on the Hangbu and Fengle rivers tracks the long term development of hydraulically engineered river systems, the expansion of paddy field agriculture and exploitation of the mountains.

KEYWORDS

Environmental history, Anhui, Ming, Qing, population, land use

INTRODUCTION AND AIMS

Recent decades have seen a renewed interest in the ways that historical information may provide a more complete understanding of how *modern* human activities interact with environmental systems. For example, palaeoenvironmental reconstructions have been used in combination with land use histories to examine and test alternative theories about the causes of long term environmental change, such as nineteenth and twentieth century surface water acidification.[1] Detailed examination of documentary evidence can provide critical information about the timing and reasons for innovations, such as irrigation networks,[2] or environmental crises, in the sense of flooding or erosion[3] that continue to impact on modern societies. Compiling past records of social, cultural, climate and other environmental records in these ways creates a suite of 'parallel histories'.[4] These allow a full examination of past socio-ecological processes and conditions, which can represent the essential element in determining the degree of contingency in modern systems, possible nonlinear ecological responses in the future and appropriate management strategies and modelling tools.[5] Several recent publications summarise international programmes and initiatives devoted to interdisciplinary research and the reconstruction of past human-climate-environment interactions over a wide range of spatio-temporal scales.[6]

There have been extensive reconstructions of environmental change using historical documents in China that provide a good basis for this type of study.[7] As early as 1927, Chu studied the relationship between flooding and the natural environment in the Zhi-Li region (the modern Beijing city, Tianjing city and Hebei province) where he suggested that population and agriculture were probably responsible for an increased flood occurrence during the past 300 years.[8] A subsequent work by Deng (1937) compiled, in detail, the disasters occurring in China from the most ancient times up to the 1930s.[9] In his book, he analysed the physical and social causes for disasters, the impacts of disasters on economy and society, as well as the policies oriented towards disaster countermeasures throughout history. After the 1950s, studies of Chinese environmental history, including historical climate hazards, received growing attention,[10] with outstanding publications including 'A preliminary study on the climatic fluctuations during the last 5000 years in China' by Chu (1973)[11] and 'Maps of droughts and floods in China for the past 500 years'.[12]

However, most studies have focused at national, provincial or prefectual level, and few investigations have provided county level investigation. Furthermore, the longer time scale of those studies may mask the variability of environmental events over shorter time scales. As a result, the conclusions drawn at the regional scale generally cannot be applied to a local area. Even though the historical archives at county level have been integrated into prefectual, provincial or national studies, the inherent complexity in historical documents requires careful examination.[13] For example, the statistical data of county population in Ming and Qing Dynasties compiled by Liang (1980)[14] can not be used directly, as it ignores the changing meaning of the population unit '*ding*' during middle Ming and early Qing. This error was partly corrected by Ho (1959),[15] but he did not notice the phenomena of 'Zhe ding' (ding equivalent) and its regional difference in population statistics.

The present paper arises from a large research programme designed to examine the nature of water resources in a large lake-catchment systems across China. Here we focus on the documentary history of Shucheng County in Anhui Province, China (31°1´–31°34´N , 116°26´–117°15´E; altitude 22 m) during the Ming (1368–1644) and Qing (1644–1911) dynasties. Shucheng County is one of the main administrative areas within the Hangbu river sub-catchment of the lake Chaohu catchment, stretching from the Dabie mountains to the west and lake Chaohu to the east (Figure 1). This large river catchment lies just north of

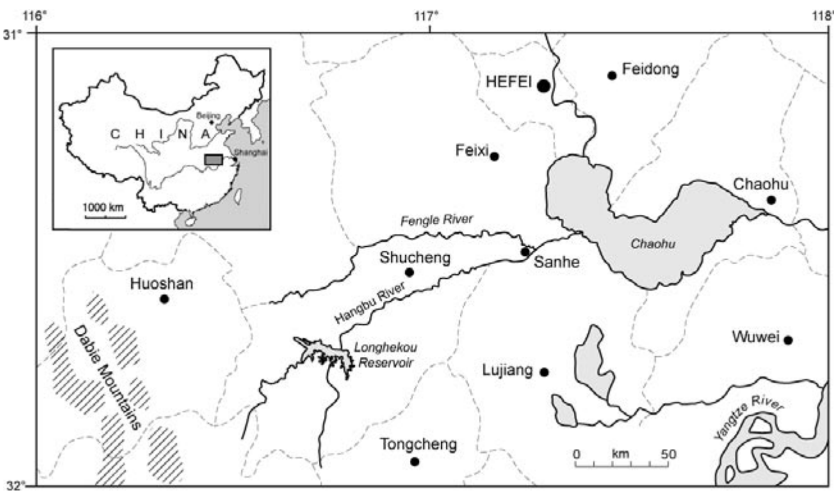

FIGURE 1. Part of Anhui Province, China, showing provincial capital (Hefei), county boundaries (dashed lines) and county cities (eg. Shucheng), with Longhekou reservoir, Hangbu and Fengle rivers, Dabie mountains, lake Chaohu and Yangtze river.

the river Yangtze and is today characterised by lowland wet paddy field farming and terraced hill land agriculture typical of eastern sub-tropical China. The history of Shucheng as a county dates back more than 2000 years (203 BCE) but it is not until the year 735 that the present Shucheng County was formally established and recorded. During the Ming and Qing dynasties, the boundary of Shucheng County changed little, enclosing an area of 2092 km^2 (present day area 2449 km^2). The landscape can be morphologically divided into mountain, hill and lowland plain, which cover areas of 178.3 km^2, 1051.1 km^2 and 861.9 km^2 respectively, along an altitudinal gradient that ranges from 1539 m above sea level in the south-west to 7 m in the north-east. Shucheng County experiences a subtropical monsoonal climate with annual rainfall of 1000–1600 mm, with most precipitation occurring in spring and summer (67 per cent of the annual total). The combination of high rainfall and steep mountain slopes (many greater than 25°) has frequently caused serious erosion, with rapid silting of the lower reaches of rivers. The two large rivers, Hangbu[16] and Fengle,[17] flow through the county and drain into lake Chaohu.

The intention here is to use the detailed environmental history of Shucheng County as a proxy for change across the larger catchment and region. Complementary research[18] focuses on palaeoenvironmental reconstruction of vegetation, land use, flooding and erosion from analysis of lake, reservoir and alluvial sediment sequences, and from monitored records and satellite imagery in the twentieth and twenty-first centuries. Ultimately, all the records will be integrated to provide a historical profile for this type of sub-tropical agricultural environment, from which to gauge and model the sensitivity and sustainability of modern socio-environmental conditions to climate and social pressures. Chinese written records represent an exceptionally rich source of information. Here, changes in population and land use are mainly obtained from local documentary archive sources, and supplemented where necessary by national documentary sources. However, as with other written records, great care is needed to identify and exclude errors and inaccurate descriptions. In the present study, only information that could be verified has been included, and details of the methodologies adopted are described in each section.

The research had the following specific aims:

- To provide time-series of human population figures, land use type and area, climate hazards, and environmental disasters over the past six centuries.
- To consider the population and land use changes in the context of known climate change and regional/national political change.
- To hypothesise about the nature of past social-environmental interactions and drivers of change in the County.

COMPILED RECORDS

Human Population

Data and information on population, land use and climate hazards and disasters are derived from the list of local archives described in the Historical Documents below. Overall, population (Table 1) rose approximately tenfold from ~50,000 in the fourteenth century to a peak of over 550,000 in the early nineteenth century, with levels of around 360,000 in the last decades of the Qing dynasty. However, during the period 1571 to 1742, a period of dynastic change, population data are only available in terms of the numbers of *ding* (a unit for tax collection), which cannot be used to estimate the population,[19] whereas the figures before and after this period refer to the total population. In 1713 the decree of Emperor Kangxi that there would be no taxes on new males reaching adulthood resulted in population growth and, at the same time, made the disguising of population numbers for tax evasion no longer worthwhile. Therefore, the recorded population after 1741 probably represents far truer figures than those recorded between 1578 and 1736. Although data for the period of 1821–1850 are lacking, it is quite probable that the population was at least the same level as in the preceding decade. It is difficult to compare the two types of data, but extrapolation of the earlier trend suggests a minimum in population during the mid to late seventeenth century before the fairly continuous rise to the early nineteenth century, with annual increases ranging from 0.13 per cent to 3.32 per cent. The subsequent crash in population numbers up to 1869 was followed by a steady rise that has continued to the present day.

Fairly even population numbers during the Ming dynasty suggest a comparatively stable political and economic environment. The decline in population in the first half of the fifteenth century is documented as having been caused by a large famine, centred on 1408, after which time the population shows a trend of continuous growth until 1531. The ten years from 1635 to 1644 was a period of significant decline of population due to wars and famine as the Ming dynasty lost its sovereignty. When the Qing took over, the sovereignty recruited refugees for reclamation projects, resulting in a population rise. However, the population rise was restricted by a burdensome government levy imposed upon the population (numbering 48,130 *ding* in late Ming dynasty). The population increase between 1741 and 1820 was reversed due to peasant revolts[20] against the government that began in 1853 and lasted ten years. Together with serious environmental disasters (see below), the warfare caused a significant decline of population through death and outward migration. Although the subsequent population increased gradually, the levels of 1904 were still lower than those recorded in the early nineteenth century. According to modern census data, the total population of Shucheng County was ~360,000 in 1919, and 980,000 in 2005.

TABLE 1. Population changes during the Ming and Qing dynasties

Dynasty	**Year**	**Total Population**	**No. of ding***	**Annual increase rate (‰)**
Ming	1391	52,173		
	1412	46,280		-5.7
	1466	37,877		-3.7
	1502	52,811		9.2
	1512	60,093		12.9
	1522	61,668		2.6
	1531	66,668		7.8
	1561	65,215		-0.7
	1571		17,982	
	1578	31,615 (*male*)		
	~1644		48,130	
Qing	1648		12,172	
	1667		12,180	
	1682		12,689	
	1686		12,990	
	1691		13,458	
	1696		14,303	
	1701		15,064	
	1706		15,752	
	1711		16,004	
	1716		16,079	
	1721		16,230	
	1726		16,396	
	1731		16,569	
	1736		16,755	
	1741		165,182	
	1746	279,298		
	1751	283,273		2.8
	1756	286,372		2.2
	1761	288,419		1.4
	1766	290,431		1.4
	1771	292,307		1.3
	1776	345,164		33.2
	1781	352,422		4.2
	1786	368,903		9.1
	1791	384,437		8.2
	1796	392,059		3.9
	1801	395,609		1.8
	1802	396,334		1.8
	1819	553,249		19.6
	1869	107,196		-32.8
	1898	232,454		26.7
	1904	238,904		4.6

* *ding* is a traditional Chinese unit of tax collection

Land Use

Due to the limitations of the documentary records, we only consider arable land in the lowlands that comprises wet lands, dry lands and small ponds. Direct records of arable land are rather scarce during the Ming dynasty, restricted to discontinuous records of arable land and crop yields for the larger Luzhou Prefecture in the years 1393, 1502, 1534 and 1578. It is generally considered that there is a constant ratio between the taxable amount of crop and arable land for each county. Since the crop tax for each county, proportional to the prefectural crop tax, is known, we use the total arable land of Luzhou Prefecture to estimate the arable land of Shucheng County. Table 2 shows the amount of arable land and crop tax for Luzhou Prefecture in selected years. In 1578, Shucheng County in 1578 had a total crop tax[21] of 7,615.73 *shi* (including wheat tax of 936.89 shi and rice tax of 6,678.84 shi), which amounts to 9.9 per cent of that of Luzhou Prefecture. Therefore, it is estimated that the arable land in Shucheng County in 1578 is 6,770.16 *qing*, which is close to the 6,924.12 qing surveyed in the same year. In 1578, the arable land of Luzhou District Prefecture was 4.2 times that of 1393 (Table 2). If Shucheng County had a similar rate of arable land increase, then arable lands in other years can be estimated as shown in Table 3. The origi-

TABLE 2. Variation of arable land in Luzhou Prefecture during the Ming dynasty

Year	**Arable land (*qing*)***	**Wheat tax in summer (*shi*)***	**Rice tax in autumn (*shi*)***
1393	16,223.99	15,830.0	7,5360.0
1502	25,430.45	9,872.14	66,837.21
1534	25,435.21	10,280.24	66,939.78
1578	68,389.11	9,885.13	67,045.52

**qing* is a traditional Chinese unit of area equal to 6.6667 ha; *shi* is a traditional Chinese unit of volume in the Ming and Qing dynasties

TABLE 3. Arable land in Shucheng County during the Ming and Qing dynasties

Dynasty	**Year**	**Arable land (*qing*)**	**Arable land (km^2)**	**Proportion arable land (%)**
Ming	1393	1,622.39	99.68	4.76
	1502	2,543.05	156.24	7.47
	1534	2,543.52	156.27	7.47
	1578	6,924.12	425.42	20.34
Qing	~1653	3,962.26	243.44	11.64
	1675	6,631.32	407.43	19.48
	1736	6,944.3	426.66	20.39
	1801	6,948.77	426.93	20.41
	1898	6,775.47	416.28	19.90

nal arable land in Shucheng County in Ming times amounted to 6,919.26 qing, which is comparable to the figure calculated for 1578.[22] This value reduces to 3,962.26 qing in 1653 (early Qing dynasty), a reduction of 42.7 per cent in 75 years. Since the total area of Shucheng County has remained almost the same since then, we estimate that apart from during the early Qing dynasty the area of arable land within the lowlands and hilly lands has remained relatively stable at approximately 20 per cent over the 320 years since 1578.[23] Therefore, the amount of arable land in Shucheng changed mainly during the Ming and early Qing dynasties. As with the population decline, it has been suggested that the reduction in arable land area from 1578 to the end of the Ming dynasty was due to war. With the subsequent stabilisation of society, arable land increased to reach the original figure through the additional reclamation of 2,957 qing, and by 1736 it seems that the maximum extent of arable land was reached. However, war in the period of 1851–1861 probably led to the destruction or dereliction of a significant part of the arable land.

Urbanisation

Limited arable land and invariant agricultural technology drive people to reclaim land for an increasing population. Therefore, changes in population and their migration can indicate the changes in land use and associated ecological pressures. A review of the establishment and abandonment of towns in Shucheng County shows that the earliest towns date back to the Northern Song Dynasty (960–1127). In 1080 four towns are recorded: Jiujin, Xincang, Taocheng and Hangbu.[24] During the late Ming dynasty (1522–1566) the number of towns expanded from four to six, a process that continued through the Qing dynasty. Xiaotian was established to the west of Shucheng County 1736–1795, Meihe and Nangang were established to the south-west and south 1796–1820, and Ganshahe was established to the south-west 1862–1874. By the end of the Qing dynasty the number of towns reached 25[25] (Table 4). Only Jiujing existed to the south-west of Shucheng prior to the Ming dynasty, but by the end of the Qing dynasty, there were seven towns to the south-west. This changing pattern in the establishment of towns confirms not only the rapid increase of population during the Qing dynasty, but also suggests that the unclaimed Dabie mountain regions in the south and west were developed during the Qing dynasty due to population pressure. The distribution of hydrological works also suggests a migration of people towards the Dabie mountains: more than half of all the hydrological engineering works carried out by the end of the Qing dynasty were distributed in the southern and western mountain regions (Table 5), which is consistent with the needs of terracing and irrigation in the hilly lands. Most of the towns in Shucheng County are distributed along the Hangbu River and its tributaries. Those towns in the west and south-west are located along upstream reaches, and we may suppose that their development impacted upon the water and soil conservancy in the catchment and hence the flood regime in the lower reaches.

In 1864, among the largest 15 communities[26] that had a person written into the household register, four belonged to Shucheng city, six were located to the north, three in the east and two in the south. The arable lands of these communities amounted to one half of the total arable land, which was mainly distributed around the city and to the north of the city (Table 6). Thus although only one town is located to the north of the county in Qing dynasty, the level of hydrological engineering in terms of water conservation and irrigation works, and the extent of arable lands are relatively higher to the north. Water resources are critical to paddy field farming on the lowland plains, and land in the north benefited from its proximity to the Fengle River, while those around the city

TABLE 4. The distribution of towns relative to the city wall of Shucheng by the end of the Qing dynasty

Location	**East**	**Southeast**	**South**	**Southwest**	**Northwest**	**North**	**Total**
No. of towns	5	2	6	7	4	1	25

TABLE 5. The distribution of hydrological/engineering works relative to the city wall of Shucheng by the end of the Qing dynasty.

Location	**Weir**	**Pond**	**Small Pond**	**Shallow lake**	**Ditch**	**River**	**Lake**	**Meander**	**Total**
West	17	16	7	11			1	1	53
North	10	6		8	2	1			27
East	3	3	2	17	1	1			27
South	9	7		5	2				23
City	1								1
Total	40	32	9	41	5	2	1	1	131

TABLE 6. The location of the 15 largest communities (by arable land) with a person written into household register in and around Shucheng city in 1864, with columns showing the absolute and proportional areas of the total holdings. Only small communities were found in the 'West', and these are not shown.

Location	**Arable land (*qing*)**	**Proportion of all arable land (%)**
East	711.53	10.24
South	450.31	6.48
North	1,188.45	17.10
City	1,046.62	15.06
Total	3,396.93	48.89

could rely on the Qimenyan Dam reservoir. The distribution of towns towards the east and south-east indicates that population migration towards lake Chaohu had already occurred by the second half of the nineteenth century.

Natural Disasters

Here, natural disasters refer to flood, drought and other extreme meteorological events that were recorded during ~30-year periods (Table 7). The divisions for 'flood', 'extreme flood', 'drought', 'extreme drought', 'snow' and 'wind and hail' are based on descriptions of 'hazards' in historical documents.[27] During the 543 years of the Ming and Qing dynasties, 146 years are recorded with disasters, though in the 90 years from early Ming dynasty to 1458 only three disasters can be clearly identified.[28] Overall, the data suggest a higher mean occurrence of floods

TABLE 7. The incidence of recorded natural hazards/disasters in Shucheng County during the Ming and Qing dynasties. Data shown as recorded occurrences within ~30 year periods (except 1368–1404). 'Numbers of year with hazard occurrence' gives number of year from start of each period. (In one year there may have been several type of hazards, therefore this figure differs from the total hazards).

Dynasty	**Period**	**Flood**	**Extreme Flood**	**Drought**	**Extreme Drought**	**Snow**	**Wind and hail**	**To-tal**	**Number of years with hazard oc-currence**
Ming	1368–1404			1				1	1
	1405–1434	1						1	1
	1435–1464		1	1				2	2
	1465–1494	2	3	2		1		8	8
	1495–1524	2	3	3	2	2	2	14	11
	1525–1554		1	4	3	1		9	8
	1555–1584	2	4	2	1	3	2	14	10
	1585–1614		6	1	2			9	9
	1615–1644		3	7		1		11	11
	Total	**7**	**21**	**21**	**8**	**8**	**4**	**69**	**61**
Qing	1645–1674		4		4	1		9	8
	1675–1704		2	3	2	3		10	9
	1705–1734	2	4	6		1	1	14	13
	1735–1764	1	2	6	1	1		11	11
	1765–1794	1	3	2	1			7	7
	1795–1824	2	2	2	1			7	7
	1825–1854	1	8			1		10	9
	1855–1884	2	3	5	1	1		12	11
	1885–1911	2	5	3		1	1	12	10
	Total	**11**	**33**	**27**	**10**	**9**	**2**	**92**	**85**
	Grand Total	**18**	**54**	**48**	**18**	**17**	**6**	**161**	**146**

and drought in the Qing dynasty than in the Ming dynasty (one event per 4.25 years compared to one event per 3.14 years). The data are simplified further by amalgamating data categories into 'all floods', 'all droughts', and 'snow, wind and hail'. The frequency of 'all floods' reaches a peak in the period 1825–1854. Drought frequencies fluctuate with two periods of particularly low-drought frequencies during the periods 1368–1464 and 1825–1854. Drought and flood frequencies are out of phase through the periods 1555–1674 and 1825–1911. The proxy data for cold/stormy weather ('snow' and 'wind and hail') show high values in the periods 1495–1524, 1555–1584 and 1675–1704.

DISCUSSION

The historical records describe a highly complex and changeable set of relationships between society and the natural environment in Shucheng County over the last ~500 years. Any attempt to explain the relationships in terms of forcing and response variables needs to recognise the potential nonlinear and non-unidirectional properties of these relationships. For example, the record of natural hazards and disasters in Shucheng County reflects the interactions between local hydrology, the regional climate, local human activities and changing social perceptions of extreme events. Deforestation in the mountain area could induce serious erosion and subsequent deposition in river channels, which could amplify flooding along the rivers downstream. Poor management of water resources or periods of extreme agricultural demand for irrigation water, perhaps linked to higher population demands, could trigger an effective drought as much as a lack of rain. The extent to which the documented disasters describe either a true record of the effects of climate or the consequences of pressures on subsistence agriculture brought on by changing social and environmental interactions may be explored by making comparisons with regional climate indices. Through a cross-comparison of climate, demographic, social and disaster records we can begin to unravel the key drivers of environmental change.

Winter anomaly data[29] reconstructed from phenological records for the lower and middle reaches of the Yangtze river basin show five exceptionally cold (>0.5^0 negative anomaly) periods: 1335–1365, 1425–1485, 1655–1675, 1805–1835 and 1875–1895 (Figure 2a). Comparison with the 'snow, wind and hail' hazard data (Figure 2d) does not show a strong positive correspondence except for the high incidence in snow events during the period 1675–1704 (Table 7) at the same time as a cold anomaly. The three other peaks in the data are more or less synchronous with periods of high temperature anomalies perhaps emphasising the importance of wind and storm events in this category (Table 7).

Whether the climate directly affected population numbers and land use is highly questionable. On the one hand, the mid-nineteenth century decline in population, clearly linked to revolts and outward migration, also coincides

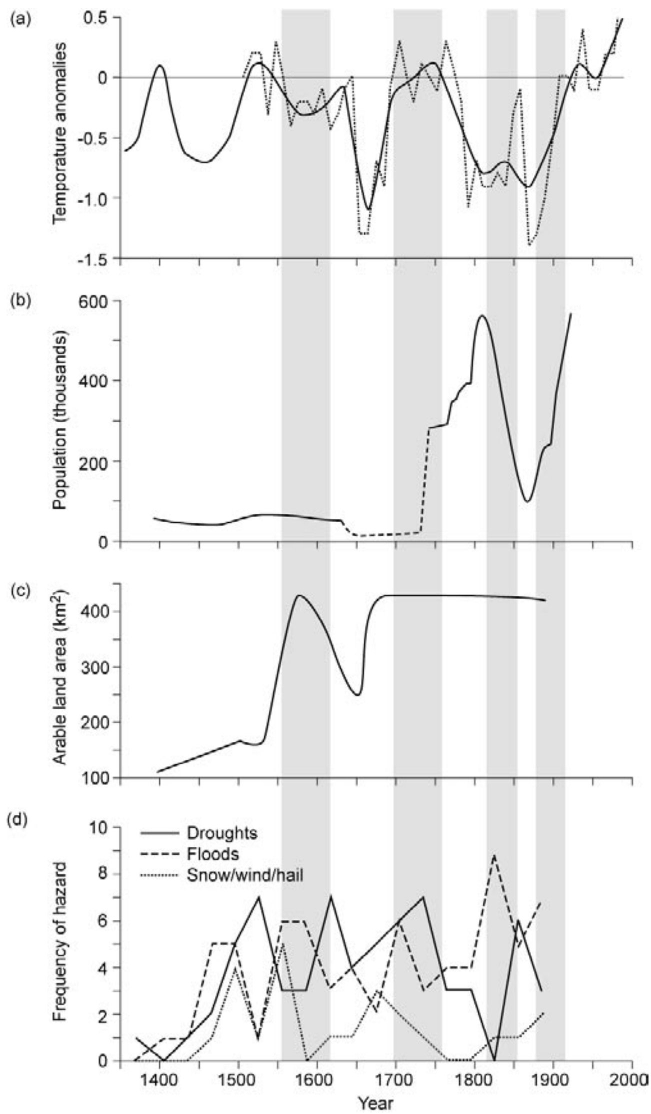

FIGURE 2. Compilation of climate and environmental history records 1350–2000. (a) regional winter temperature anomalies (negative and positive in °C) at 30 yr (1365–1999) and 10 yr (1505–1995) resolution [according to *Wanlikuijilu*]; (b) Shucheng County human population [Table 1]; (c)Shucheng County lowland arable land, km^2 [Table 3]; (d) frequency of Shucheng County recorded hazard occurrences (all floods, drought, snow, wind and hail) plotted at mid-point of each ~30 yr period (Table 7). Vertical bars define periods of relatively high wetness [according to the *Chorography of Luzhou Prefecture, Kang Xi period*, vol. 8].

with an extreme cold phase. Similarly, the expansion in arable land during the late Ming, followed in the early Qing period (Figure 2c) by a sharp contraction, corresponds with a sequence of warm climate changing to a major cold phase. But on the other hand, the data suggest that the extent of arable land is apparently insensitive to climate after 1700 (Figure 2c). Published indices[30] for wetness/dryness in May–September at a latitude of 30°–32° N for eastern China from 1470–1997 show four relatively wet periods: 1555–1620, 1690–1770, 1830–1855 and 1880–1910 (Figure 2a). Where the timescales overlap (1470–1911), the regional records are fairly synchronous with the recorded frequencies of flood events in Shucheng County (Figure 2d), suggesting a climate control. Additionally, some of the Shucheng data record nationally recorded episodes, particularly the period of drought that existed from 1628 to 1644. However, the overall lack of synchroneity between records of drought in Shucheng and recorded dry summer periods for the region suggests that a higher temporal frequency of analysis is required, or that non-climate controls on the recording of drought have been important. Discrepancies between the different records may also arise through spatial variability within the county. For example, the Dabie Mountains in Shucheng County are susceptible to drought whereas the plains are more prone to flooding, even though the mountains have higher levels of precipitation. The varied geomorphology of Shucheng County thus results in a distribution pattern of flood and drought that contrasts strongly with neighbouring regions. In terms of matching peak occurrences we can argue that there is reasonably strong evidence for climate forcing of flood disasters, and circumstantial evidence for a temperature control on early agriculture.

It may be assumed that the order-of-magnitude increase of population since the fourteenth century (Figure 2b) has brought great pressure on ecological processes especially during the rapid expansion of arable land in the late Ming and early Qing periods (Figure 2c) and the rapid rises in population in the middle and late Ming periods (Figure 2b). But the effects of these agricultural phases on the frequency of recorded drought and flood disasters are unclear. From 1393 to 1502, the area of cultivated land shows a 57 per cent increase and, although the population remains low, the occurrence of floods increases rapidly. This may implicate initial hydrological works first recorded in 1482.[31] From the mid to late Ming dynasty, over-exploitation of land, inappropriate or ineffectual hydrological engineering and war may all have contributed to the occurrence of disasters. For example, after 1502, the population gradually increases but the arable land nearly triples in area by 1578, coinciding with the second peak in flood incidence. This was a period of major hydrological engineering on the reach of the Hangbu river and its tributaries close to the city. During the late sixteenth century, a new watercourse was built to draw water from the confluence of the Longwangdang and Hangbu rivers, at a point previously dammed to protect the city from flooding, to connect with the southern Qili River. This practice resulted in reduced runoff in the lower reach of Hangbu river and hence a lack of water for irrigation in the region around the city. The lack of water caused the middle reach to migrate constantly, causing difficulty in flood control. In the Qing dynasty, some new measures were introduced to control the river course, but they failed to reinstate the original river course.

The area under arable land remained more or less constant during the Qing dynasty, but there is a noticeably higher incidence of flooding, particularly during the period 1825–1854. This period follows the very rapid population growth in the early nineteenth century which led to deforestation and land reclamation in the Dabie mountain regions, and to the creation of polders and new wet arable fields on the shoreline around the lake Chaohu. The former led to erosion and enhanced runoff, while the latter led to the building of river levees, dykes and reduced river flow to the river: both increasing the siltation and flood levels in the lower reaches of the Hangbu system. In the 86 years following 1825, 16 out of a total of 21 large floods (Table 7) resulted from the bursting of the banks, and these 21 floods account for nearly half of the total floods (44) which occurred during the whole 267 years of the Qing dynasty. Although dredging was carried out from time to time, river siltation remained a serious problem demonstrating the compounded effects of land use changes taking place in both the mountains and lowlands.

CONCLUSIONS

Overall, the interactions between climate, population, land use and reported disasters are not straightforward, with a range of possible, and quite plausible, explanations. However, the evidence suggests that neither a fully deterministic nor a totally controlled environmental viewpoint affords an adequate explanatory model.[32] At different times in the past, climate forcings seem to have acted as strong controls on human activities, especially the timing of early agricultural expansion in the warm and wet late Ming period and the general incidence of flooding linked to periods of wetter climate. Although the extent of arable land has remained at a constant level since the late eighteenth century, population numbers peaked in the early nineteenth century and there is strong evidence for the exploitation of the mountains and creation of lake polders during the second half of the nineteenth century. Environmental processes have responded to climate changes, but with the superimposed effects of human activities. This is particularly the case for flooding, where the overall rising trend of the flood record (Figure 2d) tracks the long term development of hydraulically engineered river systems, the expansion of paddy field agriculture and exploitation of the mountains, suggesting a strong second order control by human activities. Further data derived from palaeoecological analyses of alluvial and lake sediment records will provide complementary records of vegetation, erosion and flooding, and water quality to allow testing of these hypotheses.

NOTES

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[1] For example, Battarbee et al 1985.

[2] For example, Crook 2001.

[3] For example, Elvin and Liu 1998; Crook et al 2002; Crook et al 2004.

[4] Atwell, 2001; Dearing 2007.

[5] Anderson et al 2006.

[6] Costanza et al 2007; Dearing et al 2006a and 2006b; Hornborg and Crumley 2007.

[7] Ge et al 2007 and references therein; Elvin 2006.

[8] Chu 1927.

[9] Deng 1937.

[10] Cf. Ho 1959; Liang 1980; Perdue 1987; Skinner 1987; Marks 1998; Elvin and Liu 1998; Elvin 2006.

[11] Chu 1973.

[12] Academy of Meteorological Science of Chinese Central Meteorological Administration 1981.

[13] Ge et al 2007 and references therein; Elvin 2006.

[14] Liang 1980.

[15] Ho 1959.

[16] Also named Qianhe, Bayanghe, Longshushui and Nanxi.

[17] Also named Jiehe and Houhe.

[18] Dai et al., submitted.

[19] Cf. Ho 1959; Liang 1980; Perdue 1987; Skinner 1987; Marks 1998; Elvin and Liu 1998; Elvin 2006.

[20] Known as the Taiping Heavenly Kingdom revolts.

[21] According to *Wanlikuijilu*.

[22] According to the Chorography of Luzhou Prefecture, Kang Xi period, vol. 8.

[23] For comparison, the area of arable land in 1984 was 21.4% of the total county area.

[24] These are now known as Jiujing, Xincang (belonging to Feixi County), Taoxi and Hangbu respectively.

[25] Excluding some towns that were destroyed by floods e.g. Shahe in 1779.

[26] Largest in terms of arable land.

[27] The two 'extreme' categories have been classified subjectively according to the context. For example, a 'flood' category for 'Year 1501, May, June and August' (Chinese tradi-

tional calendar) is based on the description of ‘heavy rain’ and ‘waterlogging’. Whereas the entry for ‘Year 1849, January through July’ describes ‘continuous heavy rain’, and ‘water flows into the city with a depth of several meters’ and is given the category of ‘extreme flooding’.

[28] In addition, there are records of disasters in 1408, 1428, 1435 and 1439 that are not specific and therefore not included.

[29] Ge et al 2003.

[30] Qi Hu, Song Feng, 2001.

[31] Documented in the ‘Chorography of Shucheng County’ written by Cheng Wen who was acting as magistrate.

[32] Cf. Dearing 2006.

HISTORICAL DOCUMENTS

The historical documents used in this study are mainly: (1) local and national gazettes and statistical books compiled in the Ming (1368–1644 CE) and ithe Qing Dynasty (1644–1911 CE) up to the creation of the People’s Republic of China; (2) official histories of the Ming and Qing dynasties. These include the following:

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Kangxi Shuchengxianzhi 《康熙舒城县志》(Gazettes of Shucheng County, published in Kangxi’s reign of the Qing Dynasty).

Yongzheng Shuchengxianzhi 《雍正舒城县志》(Gazettes of Shucheng County, published in Yongzheng’s reign of the Qing Dynasty).

Jiaqing Shuchengxianzhi 《嘉庆舒城县志》(Gazettes of Shucheng County, published in Jiaqing’s reign of the Qing Dynasty).

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