This is the sixth issue of East Asian History in the series previously entitled Papers on Far Eastern History. The journal is published twice a year.
Charles Patrick FitzGerald
1902–1992

Photograph courtesy Be7 Zunde

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Two autograph pages from C. P. Fitzgerald’s diary of February 1928, reproduced with the permission of his daughters, Mirabel and Anthea.

February 25, Saturday
Temp. 50. Sunny. Very warm, the best day so far, quite extraordinary for February. The stream done 1 inch in 6 hours. No insects. Over the banks now only just around the middle bridge and greenhouse; and by the weir bridge.
In the morning we went into the woods for primroses. Christopher arrived in time for dinner.

Hanking which definitely sets the stamp of legality on National government, as opposed to the oligarchs in Hankow or Canton. This is a great political triumph for Chiang who is thus positioned. Feng is reported to be attacking Nanking.
The Nanking Bye Election resulted in the loss of 1000 out of 1500 of the previous majority, almost all of which went to the Central Committee.
CONTENTS

1  C. P. FitzGerald: a Memoir
   *Mirabel FitzGerald Ward and Anthea FitzGerald*

7  Three Thousand Years of Unsustainable Development:
   China’s Environment from Archaic Times to the Present
   *Mark Elvin*

47  Astronomical Data from Ancient Chinese Records:
    the Requirements of Historical Research Methodology
   *Noel Barnard*

75  Moses, the Bamboo King
   *Donald Daniel Leslie*

91  Some Reflections on Činggis Qan’s *Jasay*
   *Igor de Rachewiltz*

105  Tracks in the Snow—Episodes from an Autobiographical Memoir
    by the Manchu Bannerman Lin-ch’ing
   *Translated by Yang Tsung-han, edited by John Minford*

143  Political Leaders of Tokushima, 1868–1912
    *Andrew Fraser*

163  Ku Hung-ming: Homecoming
    *Lo Hui-min*
Cover calligraphy  Yan Zhenqing 顔真卿, Tang calligrapher and statesman

Cover photograph  Rubbing of a bas-relief, Hsin-ching, Szechuan Province  
(C. P. FitzGerald, Barbarian Beds [London: Cresset Press, 1965])
THREE THOUSAND YEARS OF UNSUSTAINABLE GROWTH: CHINA'S ENVIRONMENT FROM ARCHAIC TIMES TO THE PRESENT

Mark Elvin

Introduction

This essay looks at the history of China from about 1000 BC to the present day from the point of view of the interaction of politics, economics, and the environment. It shows that there have been three main phases: an archaic 'ecological' economic system until about 500 BC; a system of developmental economics primarily driven by the needs of state power that lasted until about AD 1000; and a relatively mature economic system primarily driven by the market since that time, that is following the 'mediaeval economic revolution' and on down to the establishment of Communist rule in 1949. The population expanded during this period, partly in the form of increased spatial density, and partly in the form of geographical expansion from a core in north China. To some degree, however, it was also effected by the incorporation of other peoples, so that the true rate of growth may not have been quite as spectacular as it appears. In (very) round numbers, the Chinese population grew from over 50 million before the end of the first millennium BC to over 100 million shortly after AD 1000, then to over 200 million early in the eighteenth century, to over 400 million by about 1850, and finally to over 1000 million at the present day. The apparent long-term pre-modern annual rate of growth thus rose from about 0.07% during the first millennium AD to 0.1% during most of the second millennium, to about 0.5% in the eighteenth and nineteenth centuries, and then to 0.65% during the early modern epoch. It has been over 1% for most of the Communist period.

The broad characteristics of production and exchange during the three periods were as follows: In the first there was a significant component of

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1 The materials in this essay are drawn from the course of lectures that I delivered in January-March 1993 at the Ecole Normale Supérieure in Paris on "L'histoire de l'environnement en Chine." I should like to thank the then Directeur Adjoint of the ENS, Dr Marianne Bastid-Bruguière, for her kindness in making available to me this opportunity to crystallize some of my ideas on this subject in interaction with a friendly but critical audience. Steve Dodds prompted the English version with his invitation to deliver a paper at his conference on 'Sustainable Well-Being' at the A.N.U. in July 1993, and I should like also to express my gratitude to him for this challenge. An especial acknowledgement, too, to Samson Rivers (Chiang Yang-ming 江陽明), without whose help in tracking references this work would have been hard to finish. My colleague Dr Su Ninghu 苏宁沪, as always, provided indispensable bibliographic guidance in the domain of Chinese scientific literature and professional help with the hydrology, and my debt to him is evident and substantial. The present version of this paper was the basis of the Annual Lecture of the Centre for Modern Chinese Studies at St Antony's College, Oxford, delivered 11 May 1994. Please note that Chinese is transcribed /OVER
into tonal pinyin: unsounded post-vocalic ‘r’ and ‘h’ indicate the 2nd and 4th tones, respectively, and a doubled main vowel the 3rd.


For example, that portion of the Yueh (or ‘Viet’) people who lived in what is now southern Zherjiang and Fujian on the south-east coast.

The correct historical name for the region that has become, in the present century, the so-called ‘Three North-eastern Provinces’ of China, but which was, aside from the valley of the river Liaor, barred to Hahn Chinese migration by the Manchu rulers until the later half of the nineteenth century.

See, for example, J. L. Buck, *Land utilization in China* (1957; reprint ed., New York: Paragon, 1964), p.226, which shows China, as of 1929–33 and agriculturally still unmodernized, significantly surpassed in average per-hectare rice yields only by Italy (where its cultivation was restricted to highly favourable areas), though Chinese wheat hunting, fishing, fowling, gathering, and herding in the economy, varying regionally, with millet being the staple cereal, hemp the main clothing fibre, and small-scale drainage and flood-prevention the focus of hydraulic works. In the second there were larger states (soon of ‘European’ size) and then—for just under half the period—a unified Empire, some massive cities (10^5 inhabitants), a shift to a more purely agricultural economy, still mainly based on dry-field farming, with large-scale artificial inland water-transport (often initially for military uses) and some large irrigation schemes, the limited and state-controlled market system being primarily driven by tax-extracted funds and the profits of large estates. In the third, as the demographic centre of gravity shifted southwards the Yangzii valley, wet-field rice agriculture dominated the most economically advanced regions, irrigation systems proliferated, cotton became the main clothing fibre, the economy was extensively monetized, and the market system was decontrolled and expanded enormously, with ordinary consumer demand now being the main driving force. In this third period there was quite significant literacy and numeracy, based on woodblock printing and the abacus, and a gradually developing process of ‘urban devolution’ that meant that additional urban population tended to be found mostly in settlements of small to medium size (> 10^3 and < 10^5 inhabitants). At the end of this third period, in the late seventeenth and eighteenth centuries, certain imported New World crops such as maize and sweet potatoes became extensively cultivated in upland areas, while extra land available for further effort-efficient late-traditional rice-farming or lowland dry-farming had virtually come to an end outside Manchuria, and a ‘high’ level of yields per hectare by ‘pre-modern’ standards—the average rice yield per hectare being of the order of 6 kilolitres with late-traditional technology—had been achieved in most regions. ‘Hot-spot’ modern economic growth, including an extensive acquisition by Chinese of what was then modern technology, began in the later decades of the nineteenth century in places like Shanghaai that had been opened by the modern West to international trade and linked into the world economy, but it hardly spread at all into the hinterland for a long time, and has only to a limited extent done so now.

Certain long-term patterns can be detected. For example, the climate in north China has been shown by Zhur Keezhen 趙鎧榛 and others to have fluctuated considerably during the historical period. From 3000 to 1000 BC the mean annual temperature was about 2°C higher than it is today. A clear shift to colder weather began around the start of the first millennium BC. By the third century AD the mean annual temperature was from 1°C to 2°C below the present level, and early in the fifth century the entire gulf of Borhaai渤海 froze solid in winter. By the seventh century this trend had been reversed, and a marked warming had occurred, reaching a brief maximum in the eighth century at about 1°C above present-day mean annual temperature.

The cold returned suddenly at the start of the twelfth century. Lake Taih
Taihu, at latitude 31° N, froze solid in the winter of 1111, as it did again in 1329 and 1351, and four times in the second half of the seventeenth century. From 1100 to just before 1900 the mean annual temperature, though varying considerably, stayed at approximately 1°C below its present level. The economic effects of climate change are multiple: yields of cereal crops are sensitive both to the level of insolation and to the quantity and timing of precipitation; the altitude of possible cereal cultivation varies with mean annual temperature; many fruit trees die at temperatures below a relatively sharply defined limit; cold winters can help to control insects pests and fungal diseases; winter freezing affects the use of water-transport systems (such as the Grand Canal), and so on. It may be noted that major downturns of the mean annual temperature very roughly coincided with three major pre-modern political and cultural transitions: (1) the replacement of the Shang state in North China by the Zhou at the end of the second millennium BC, and, perhaps more importantly, the breaking up of the Western Zhou dominion by the end of the first quarter of the first millennium BC; (2) the gradual disintegration of the early unified Qin/Han/Western-Jin empire, which was under way by the end of the second century AD, and definitive by the start of the fourth century; and (3) the decline of the middle empire of the Tang/Song, with the loss of north China to non-Chinese rule in 1126, and the loss of the south in 1279, together with the ending of the mediaeval economic revolution. Since climate is only one factor among many, and the size of the sample of cases is three, not too much should necessarily be made of this. It is worth noting, however, that E.S. Kulpin, stressing that “the ancestors of the Chinese” in the second millennium BC lived in a narrow, fertile strip of wetlands along the middle and lower course of the Yellow River, close to extensive virgin forests full of rhinoceros, elephants, tapirs, bamboo-rats and other subtropical and tropical animals, in a climate very humid compared to that of the present day, as the summer monsoon came further north at this time, assigns a major role in the formation of classical Chinese civilization to the traumatic shift to a colder climate in the period, that is, between, approximately, the eleventh/ninth centuries and the fifth/third centuries BC.11

Another long-term trend was drainage and reclamation. Thus the huge inland marshes near the mouth of the Yellow River and along the central course of the Yangzi were mostly drained in the first period and early in the second. Massive reclamation of sea-coast salt-marsh in and near the mouth of the Yangzi occurred at the end of the second and at the beginning of the third, leading to the creation of a dyked polder-land area in Jiangnan that was in many ways comparable to Holland. Likewise there was deforestation and stripping of vegetation cover in north China during the second period on a scale large enough to cause, in conjunction with strategically unviable systems of river levees, extensive man-made ‘natural’ disasters in the lower Yellow River. This process reached a first but lesser maximum early in the third period, when the river’s lower course shifted

/yields per hectare were only half of those in Great Britain at this time.

9 For the core of the first industrial revolution, the engineering and machine-building industry, the two volumes of historical materials, Shanghghai-shih Gong-shang Xirngzheh Guaanlii-jur, and Shanghghai-shih Dih-yi Ji-diahn Gongyeh-jur, eds, Shabnghai mirmzur jiqib gongyeh [The Chinese non-governmental machine-building industry in Shanghghai] (Beijing: Zhong-huar Shujur, 1979), provide documentary proof that Chinese-owned and Chinese-managed enterprises in Shanghghai had mastered all but a handful of the technologies then necessary for a modern economy (the exceptions being sectors like aviation) by the time of the outbreak of the Pacific War in mid-1937.

10 See the summary, Chu Ko-chen [Zhur Keezhen], “How China’s climate has changed over 5,000 Years,” China Reconstructs 22.9 (Sept. 1973). The Chinese-language original is idem, “Zhongguor jihn wuqian-niam-lair qihhouh biahnqian-de chubuh yarnjiuh” [Preliminary investigations into the changes in China’s climate during the last 5000 years], Kaaoguu xuerbaoh 1 (1972). Zhur’s methods, which are basically phenological (i.e. the analysis of the recorded chronological variations in the ranges and seasons of key marker plants and birds and animals), are described in Zhur Keezhen and Yuan Minweih 凡敏漪, Wubobb-xuer [Phenology] (Beijing: Kehxuer Chubaansheh, 1973). Some more recent studies of Chinese historical weather patterns are summarized in R.S. Bradley, Quaternary paleoclimatology. Methods of paleoclimatic reconstruction (Boston: Unwin Hyman, 1985), ch. 11, passim.

11 Eduard Salmanovich Kulpin, Cheloek i priroda v Kitae [Man and nature in China] (Moscow: Nauka, 1990), pp. 37–41, 196. I am grateful to Dr John Fincher for most kindly bringing a copy of this book back from Russia for me. This warm, moist phase should be seen in the context of the longer-term changes described in Wur Chem 奥忱 Huareei pingyuan sbweanh-niam-lair zibwam huarei jyinb jyanbaihm [Changes in the natural environment of the North-China plain over the last 40,000 years] (Beijing: Zhongguor Kexuer Jihshur Chu-baanshe, 1992), esp. pp. 105–14. I should like to thank Dr Lai Chi-kong for the gift of this book.
Calculations from the figures given by Xur Haailiahg 徐海亮, "Huamgher xiah-your-de dujii lihshii fazhaan qushih" [The history and trend of development of the sedimentary deposits in the lower reaches of the Yellow River], Zhongguor suo shu trial xuerbaoh 7 (1990) indicate that for the period 1194–1855 the total vertical accretion of deposited sediment at the mouth of the southern course was 9.88 meters. On the horizontal seaward extension of some 90 km during this period see Yeh Qingchao 叶青超, “Shihluhn Subeei feih-Huamgher sanjiaao-zhou-de fayuh” [On the development of the abandoned Yellow River delta in northern Jiangsu province], Diblib xuer­baoh 41.2 (June 1986).

For a preliminary orientation see the map on p.66 of Naval Intelligence Division [U.K.], China proper (Edinburgh: HMSO, 1945), vol.3.


The concept of property in late-imperial China was not that distant from the modern West European concept, in that it was individual (with a certain familial bias) and commercialized, though with a slightly stronger emphasis on the right to a particular technologically defined usage of a natural resource. Hence fishing with nets and with cormorants in the same given body of water might be quite distinct rights of property, and sold and bought separately. See Terada Hiroaki 寺田浩一, "Chugoku kinsei ni okeru shizen no ryōyū" [The ownership of nature in China in post-mediaeval times], in Rekishi ni okeru shizen [Nature in history], ed. Gotō Akira 高木広明 et al. (Tokyo: Iwanami, 1989).

Mongol nomadic stock-rearing, in contrast, was founded on the interlocking non-alienable usage rights of kin-groups. See Yoshida Jun'ichi 吉田順一, "Yūbokumin ni totte no shizen no ryōyū" [The ownership of nature among nomads], in the same volume.

I would like to thank Professor Shiba Yoshinobu 斯波義信 for his kind gift of a copy of this book.

south of the Shandong peninsula, and then a grand climax towards the end of the traditional empire (eighteenth and nineteenth centuries), the process to some extent restarting de novo after the shift in the river's course back north in 1853-55. In this last part of the third period, as the cultivation of upland crops—chiefly maize and sweet potatoes—spread, often on a shifting basis, there was a ‘holocaust’ of the forests in many parts of China that left most of the country short of accessible wood (Manchuria once more excepted) at the beginning of the modern age (that is, c.1900).13

If numerous details are ignored, it is possible to say that the long-term trend of basic exploitation of the environment was towards maximal ‘arabization’, that is for cereal cultivation as opposed to rearing stock in herds, or reliance on non-farm sources of food from forests and wetlands.14 Arable farming can support a denser population than other traditional modes of environmental exploitation. There was also a long-term trend, though with many complexities, towards the privatization of landed property, that is, away from state-run land-distribution systems, and de facto collective use of non-arable resources such as 'mountains and marshes' (shanzer 善澤), to use the traditional phrase.15 Only hydraulic systems, which tended to be run by the state where they were large and defensive in nature (such as sea-walls and levees along major rivers), and by collectivities under state supervision when they were for irrigation, escaped this trend.16 Private landed property, both in terms of units of ownership and units of actual operation, also tended to become more and more fragmented towards the end of the empire. As regards ownership, this was the result of the Chinese system of partible inheritance combined with a relatively new disinclination of the rich to put their money into farmland and so build up new large holdings, perhaps because other forms of investment now promised better returns. As regards operation, it was the consequence of the higher productivity per hectare of garden-style ultra-labour-intensive cultivation.

The title of the present essay is therefore only a paradox in appearance. The styles of economic exploitation of the environment adopted, at least after the ecologically self-conscious restraint of the first period were not, over the very long run, sustainable in a steady form, especially given the apparently uncontrollable tendency of the population not only to grow, but to grow at an ever-increasing rate. The Chinese economy survived these millennia, and in fact did remarkably well for a time, quite possibly leading the world in the middle centuries of the middle ages, because it mastered new technological skills such as hydraulically sophisticated irrigated rice-farming, and because it was continually expanding into fresh resource areas such as Taiwan in the later seventeenth century, the far south-west in the early nineteenth century, and Manchuria beyond the Liao river valley in the early twentieth century. The 'filling-up' of usable land, the erosion and degradation of soils opened up in unsuitable places, the difficulties of intensifying farming any further (prior to the availability of 'modern' scientific-industrial inputs), the exhaustion of profitable opportunities (in other words, of suitable places) for new
irrigation projects, the disappearance of a large proportion of the accessible forests—not balanced, even for wood supplies, which are only a part of the total problem caused by loss of trees, by the commercial response of growing new timber for sale—all testified to the seriousness of the environmental pressures under which the Chinese economy was labouring by the end of the empire, and before the ‘modern’ period.\textsuperscript{17}

‘Modern’ technology has enormously extended technological capability. For the moment China has escaped again, possibly at the cost of creating even more difficult problems for the not so distant future, including a greatly increased population.\textsuperscript{18} The most serious single immediate question (though there are others close behind it) seems to be the absolute shortage of water in north China, for which there appears to be no economically viable solution once the possibilities of improving a still inefficient management of this resource have been used up.\textsuperscript{19}

Such, in oversimplified form, is the general picture of the interaction between economy and environment in China over the last three thousand years. If there is a lesson to be drawn from it, when we look, as we shall later, at some of the details, it is probably that the most important single factor controlling what happens to the environment is the \textit{social structure of the power} that makes the key decisions affecting the economic and other activities that impact on the environment. To give one simple example: unlike almost all private proprietors, tenants, and even governments (when the latter were under pressure, as for example to build ships), Buddhist and Daoist monasteries looked after their trees. Their goals and their structure of decision-making, and, above all, their time-horizons, were different from those on the basis of which the others worked. Even the few collective groups who practised conservation chiefly did this to safeguard their own and their descendants’ long-term profits.\textsuperscript{20} Again and again, power—whether in the sense of a state’s requirements for the extra resources needed to achieve military superiority or simply the pattern of land-tenure—emerges as the most crucial variable, though population pressure comes not far behind it in importance.

Given this picture, however preliminary and approximate, the next question is: how do we think about it?

\textit{Conceptual Perspectives}

The subject-matter of environmental history is the interface where human beings have entered into a reciprocal relationship with the biogeochemical systems of the Earth. Behind the banal word ‘systems’ lies an almost unbelievably complex web of cycles—atmospheric, hydrologic, and sedimentary, as well as the more particular cycles of carbon, nitrogen, phosphorus, and sulphur. All of these, in varying degrees, are shaped to a significant degree by biota, in particular by bacteria and fungi, the growth and decomposition of plants and animals, and the recycling of their constituent

\textsuperscript{16} A short overview may be found in M. Elvin, “On water control and management during the Ming and Ch’ing periods,” in \textit{Ch’ing-shih wen-t’i} 3.3 (Nov. 1975).

\textsuperscript{17} See, for example, A. O. Osborne, “Barren mountains, raging rivers: The ecological and social effects of changing land-use on the Lower Yangzi periphery in late-imperial China” (PhD diss., Columbia University, 1989) (Ann Arbor, Mich.: UMI #9020586, 1991).


\textsuperscript{20} Yuan Qinglin, compiler, \textit{Zhongguorhuajiangbaobububishiah} [Historical discussion of the conservation of nature in China] (Beijing: Zhongguor Huajing Kehxuer Chubaansheh, 1990), pp.244–51. I am grateful to Professor Juju C. S. Wang of the National Tsing Hua University for kindly making a copy of this scarce book available to me.
elements. Human beings have long played a part in this, albeit a modest one, and there have been only a few landscapes even in the last few millennia of premodern times that can be characterized as having been wholly 'natural', that is completely unshaped by human intervention.

It is appropriate to say that we live in the midst of life. The elements just mentioned are essential for life—carbon for carbohydrates and almost everything, nitrogen for nucleic acid bases and hence DNA, as well as for amino acids and hence proteins, phosphorus for ATP, the basic ‘currency’ of biological energy, and for DNA phosphate groups, and so on.\(^{21}\) Biotic processes affect them all.\(^{22}\) The general interdependence of species populations upon each other (humans included), through a variety of causal networks, is also well known. The basic mechanisms—including symbiosis, predation, competition, and inhibition—tend to produce loosely defined local communities of plant and animal species that shade off into each other along multiple gradients, and are mostly undergoing one or more forms of change, such as community succession and cyclical variation, but of which the most important is response to shifts of climate.\(^{23}\) The concern of the political and ideological environmental movement with 'stability' is well-founded in many particular practical contexts, but cannot be justified as an absolute principle either of analysis or action.\(^{24}\)

What happens, then, when economic development of a premodern variety takes place? A Chinese-style rice-field is a useful initial example. It has to be levelled and dyked, which requires a substantial investment of human energy (in other words, ‘land’ in this context is quasi-capital). It has to be supplied with water, which means the creation of a hydraulic system of dams, storage basins and distributary channels. This system will almost always be to some degree unstable, mainly because of the progressive deposition of sediments in distribution channels (due to the slowing down of the flow of current), siltation upstream of barrages, and degradation of the bed downstream. Hence it will require indefinitely prolonged further inputs of energy for maintenance if the original investment is not to be lost. This latter is a form of premodern technological ‘lock-in’, the mortgaging of a proportion of future energy resources (and often some material resources, such as pine-tree trunks for the salt-water-resistant base-piles of sea-walls). In return, food production per hectare is increased, and stabilized with respect to fluctuations in rainfall. But there is more. Rice-fields produce methane, a gas whose ‘greenhouse’ effect is about twenty times more powerful per mole than carbon dioxide, and created by bacteria in the mud splitting acetate in organic material into methane and carbon dioxide.\(^{25}\) In China (in the past but also to some limited extent still today), the widespread use of untreated or minimally treated human faecal matter as a manure in rice-fields where peasants work in bare feet led to the spread of schistosomiasis. Motile Schistosoma larvae (called miracidia) emerge from ova excreted in human waste and enter snails from which they emerge in an infective swimming form (called cercaria) that penetrates human skin and infects the liver or bladder.\(^{26}\) All of the effects of this sort need to be taken into consideration.


\(^{24}\) As E. Goldsmith, a great pioneer, nonetheless tends to do in his The way. An ecological world-view (London: Rider, 1992).

\(^{25}\) Schlesinger, Biogeochemistry, pp.317–18.

THREE THOUSAND YEARS OF UNSUSTAINABLE GROWTH

into any, long-term economic history. What is the ‘true cost’, and in what sense, of developing riziculture? The conceptual tools to do this have yet to be fashioned.

If we look at economic development in a more general sense, we can note that agriculture and other human economic activities have reduced the net primary productivity of the biosphere by about 40%, defining NPP as the mean annual creation of new organic matter (assimilation minus respiration) without offsetting it against the annual loss of existing organic matter by decomposition and other means. (This reduction can be estimated by means of heavy-isotope analysis of datable organic material, since plants use heavy isotopes in less than their naturally occurring proportions. Accelerated destruction of vegetable matter by burning or decomposition can thus be detected as a time-specific dilution of the atmospheric concentration of certain such heavy isotopes.)

Soils are of course created partly by meteorological disaggregation of parent rock that is then washed downstream by fluvial processes, and partly by the action of microbial decomposers. When soils are opened for farming, however, the organic matter content tends to diminish. Agriculture is, among other things, the reduction of biomass in order to be able to control the use of what remains. Where soils with a high clay content (‘clay’ being defined by a diameter of constituent grains < 2μ) are concerned, deforestation on slopes upstream, a process that normally increases run-off, can, it seems, accelerate chemical denudation (by removing the useful cations held by the negative electric charge of clays), and hence limit the provision of the nutrients needed by biota.

It also seems probable that from a medical point of view the agricultural revolution was in some respects a disaster. Not only did it reduce the variety of the human diet, especially in New World cultures dependent on maize, but the denser populations that could now be supported, and their sedentarization, made it possible for ‘crowd diseases’ to flourish, since the micro-organisms responsible require quite a sizeable minimum accessible reservoir of potential hosts to be able to continue in existence; otherwise the death and acquired immunity of these hosts will prevent their continued propagation. Sedentarization also prevents the easy evacuation of heavily infected or polluted sites. Likewise a slow rate of pathogen transfer to new hosts tends to favour the evolution of less lethal forms, since this maintains a host in existence long enough for transfer to be effected; and the converse is probably true, namely that the concentration of a population of potential hosts favours the evolution of more lethal forms. Clearly this formulation has to be modified to allow for the mode of transmission of a particular infection—a droplet-borne microbe will be more sensitive to host concentration or dispersion than will a waterborne one, for example.

Nor, presumably, will...
it apply to incidental zoonooses not established in a human population on a permanent basis. Many of these crowd diseases seem, however, to have been originally associated with the domestication of animals: examples, among many, are tuberculosis (almost certainly derived from cattle, since Mycobacterium bovis infects humans whereas M. tuberculosis, the specifically human form, will not infect cattle), measles (which has been linked with canine distemper), and maybe even smallpox (which though it has no known animal vector may also have been linked with cattle). The historical balance-sheet of agriculture is thus complicated, there being many ‘pluses’ and ‘minuses’, often apparently incommensurable. What is clear, though, is that the simple triumphalism of the older economic history is misplaced. The many health costs of industrial production (such as the celebrated Minamata disease, due to the consumption of marine animals that had concentrated derivatives of the diethyl mercury discharged in factory wastes) are well enough known to need no special comment here. But how is health to be ‘costed’? The measures taken, often ineffectually, to restore it are hardly an adequate proxy; and—without going into the details, which are complex—diminished health surely diminishes the enjoyment of most other goods as well.

A few orthodox economists, such as Repetto, have recently recalculated the national accounts for selected countries taking into consideration the loss of environmental assets valued by market or by shadow prices, and shown that the picture of ‘success’ or ‘failure’ can sometimes be significantly altered by so doing. This is useful, but does not touch the core of the conceptual problem. What is needed is a mental model of ‘nature’ that goes beyond the implicit idea that resources are somewhat like the distinct and separate goods on the shelves of a supermarket (‘environmental assets’) and takes into account the type of interdependencies described in the preceding paragraphs. Outside small-scale contexts of short duration in ecological terms, the environment is not an amenity that can be reasonably handled in terms of trade-offs. It is the foundation of all the systems of production and waste disposal through which an economy functions.

A new method of evaluating both past processes and decisions affecting the future is also needed. Such a method will probably have the following features: (1) There will no longer be ‘externalities’ (which is what half-glimpsed interdependencies have been in effect called in the past). (2) The powerful (and often useful) ‘Midas principle’ that assumes that everything is quantitatively intercomparable in terms of money will be critically re-examined and probably jettisoned as an overriding rule, though retained for use in limited contexts. (3) Some way will be found of handling long-term transtemporal comparisons that takes into account the horizon of predictability that chaos theory indicates, especially for systems described by non-linear equations; and some method will be found for the non-arbitrary assignation of a time-discount rate for long-term comparisons of values across periods of a length too great for there to be any meaningful transtemporal ‘futures’ market. (4) There will probably be other features, such as (perhaps) a
redefinition of the maximand(s) in terms other than an aggregate (based on some formally arbitrary aggregating assumption) of the ‘utility’ of individuals used by standard economics. An interesting guide to what such a new theory might in part look like is provided by what might be called the ‘quasi-economics’ (since many of its techniques are derived from conventional economics) that is used by behavioural ecologists to analyze, and in experimental situations to predict, the behaviour of animals, birds, and insects. Ecological quasi-economics takes as its ultimate criterion the survival of specific genes (via inter-allele competition), or assemblages of genes (the genotype, or continuously mutationally intertransformable sets of genotypes, so-called ‘quasi-species’), and as its proximate criterion the life-time reproductive success of individuals. It uses a variety of quasi-currencies, such as energy and time, as appropriate, and incorporates such features as the costs and benefits of varying patterns of competition and cooperation, the pay-off of resource-defence (the costs and benefits of maintaining a given size of territory, for example), and the evolution of predator-prey ‘arms races’. Group selection appears as at most a weak force—thus systems of voluntary birth-control for the good of the group, if they ever temporarily emerged, would be unstable, as it would usually ‘pay’ individuals to cheat—and an interesting question is how far this remains true of human populations.37

The economic historian who is serious about how the world actually works has no option but to try to absorb and incorporate what his or her scientific colleagues have to tell him or her about the probable effects of the technologies that are utilized in the economic systems that he or she studies. As a result, he or she learns to see processes differently. In the case of deforestation, for example, it will become obvious that his or her economist friends tend not to see the trees for the wood (in other words, the living system for the inanimate resource). Geologists’ perspectives add a modicum of reassurance: biogeochemical systems seem to have undergone greater changes in the course of geological time than even those that humanity is currently imposing on them—and survived, albeit often in changed form. What may be new is the speed of anthropogenic changes. Ecologists drive home the point, however, that unlimited population expansion in a system closed with respect to energy and resources inevitably leads to collapse, and the earth—apart from the influx of solar radiation—is such a closed system.38

For example, the annual use per person of fresh water supplied by run-off in the world grew between 1687 and 1987 by 4 times. In absolute terms, because population grew, it went up by 35 times, to a 1987 total of about 3.5 x 10^3 cubic kilometers a year.39 The absolute growth-rate for the three-hundred-year period is thus about 1.2% per year. The 1987 total is a little under one-eleventh of the world’s estimated total supply of fresh run-off water. It is therefore evident that if the same rate of absolute growth were to continue, the world does not have much more than 200 years—one major Chinese dynasty—before it is using every last drop.

The tool-kit inherited by the economic historian from economics, though it contains much that is still useful, is simply not adequate—and not even

38 Schlesinger, Biogeochemistry, pp.349–50.
remotely adequate—to incorporate scientific knowledge most of which is new over the last two generations. This leaves the economic historian who faces up to the challenge in a state of serious conceptual anomia. Without a relatively well-systematized set of adequate controlling concepts it is all but impossible to formulate internally coherent and logically integrated evaluations of past economic processes, or of future proposals. I have some sympathy with those who prefer to retain a measure of internal rigour even at the cost of empirical irrelevance even if, as must be apparent, I personally regard this conventional approach as a strategic dead-end.

**Powerless Wisdom: the Ecological Economy of Archaic China**

Archaic China (before about 500 BC) possessed a political philosophy that put at the centre of its conceptions the conservation of a well-ordered nature. It spoke of the “constant paths of Heaven and the public-spiritedness [or, in other words, the generosity] of the Earth [tianjing dibyih 天經地義].” To the regular movements of the stars, the dependable recurrence of the seasons, and the growth and death of plants and animals, there corresponded the ritually correct patterns of behaviour of human beings, which were of equal importance. The slightest deviation could provoke natural disorder, and until at least the end of the empire, natural disorder was seen as a symptom of moral turpitude at either a national or a local level. An example from the second quarter of the first millennium BC of this ideology may be found in the Guoryuu 国語 [Tales of the Various States] which was put together in the succeeding epoch. It is known under the title of “Lii Ger 李革 tears up the nets”:

One summer’s day, Duke Xuan [of the state of Luu] spread his nets in the deeps of the River Sih. [The grand officer] Lii Ger tore up the Duke’s fishing-nets and threw them to the ground. “In ancient times,” he said [to the Duke], “once the period called ‘The Great Cold’ had passed, the insects who had hidden themselves in the earth came forth, and the official who was the guardian of the waters [sbuuiyur 水虞] would concern himself with the practices used for netting fish and for catching them in traps. Large fish that were captured or turtles that were landed had to be sacrificed at the ancestral temple. The people of the state were enjoined to act according to these rules, so as to help the [bright-male-active] matter-energy-vitality [qib 氣] to rise.

“When the birds and the beasts were pregnant with young, but the aquatic tribes were maturing, the official guardian of animals [sboubyur 黙虞] would under these circumstances forbid the use of nets to catch four-legged beasts or birds. He would [command the people only to] harpoon fish and turtles for their summer provisions, so as to help [the smaller ones] to grow in abundance. When the birds and the beasts were maturing, and the aquatic tribes were ‘pregnant’ with young, the official who was the guardian of the waters would, under these circumstances, prohibit the people from using either large or small fishing-nets, but let them entrap beasts in pits to provide for the slaughterhouses of the
The reality of this age, and its practical wisdom, were otherwise. In order to mobilize resources and build up populations to man the armies that were engaged in a warfare that was rapidly shifting from a relatively ritualized sixth century pieties—statesmen turned to economic development. In the middle of the combat to a pitiless destruction—a transition that has left its literary traces in small city-states where gathering, hunting, and fishing still played a major part in the economy but the pressure of population on resources was beginning to make itself felt. Thus in 524 BC Duke Mu of Shan 單穆公, a minister at the court of the Zhou high king, observed:

If it should happen that the forests of the mountains are exhausted, and that of the forests of the piedmont only scattered remnants remain, or that they have disappeared, and that the thickets and marshes have come to the last days of their existence, the forces of the people will be weakened, the farmland where cereals and hemp grow will be uncultivated, and they will lack resources. The superior man should be concerned about this problem in a spirit of altruistic urgency, and without relaxation. How could it ever delight him?

The reality of this age, and its practical wisdom, were otherwise. In order to mobilize resources and build up populations to man the armies that were engaged in a warfare that was rapidly shifting from a relatively ritualized combat to a pitiless destruction—a transition that has left its literary traces in speeches attributed to realists mocking the folly of the old-fashioned military pieties—statesmen turned to economic development. In the middle of the sixth century BC, Zii Muh 子木, prime minister of the state of Chuu, entrusted the following tasks to his minister of war Yaan of Weei 鬯委:

- to put the payment of taxes in good order, and to make a tally of the numbers of suits of defensive armour and of offensive weapons. [So] on the jiaawuu day [of the sexagenary cycle] Yaan of Weei listed the cultivable land in a register, surveyed the mountains and the forests, grouped together the marshlands and the water-meadows [commentators suggest as hunting-grounds], distinguished between the heights and the hillocks, marked out the poor and saiy lands,
That is, the so-called ‘well-field’ [jiingiang 井田 system attributed to archaic China, in which eight families cultivated a central field in common to provide taxes for a feudal lord.

In late-archaic China at least, economic development was both the consequence and the cause of an intensified warfare.

The scriptural or quasi-scriptural works of the classical age that followed—in broad terms the third quarter of the first millennium BC—abound in prescriptions for the restrained exploitation of nature, but there is an evident undercurrent of anxiety. In the Yuehlihng 月经 (Ordinances for the Months) we read, for example, that in the middle of spring “one should not exhaust the rivers and the marshes. One should not empty the pools created by dams. One should not burn the forests on the mountains.” In other words they were to be kept in storage. In the sixth month the guardians of the forest (yuren 虚人) should go on patrol to stop people from cutting wood. Beneath these prescriptions lies the sense that the natural world is permeated by the flow of matter-energy-vitality, and that behaving in a fashion inappropriate to the season will cause natural disasters. At the end of the summer, for example, ‘it is impermissible to mobilize soldiers or set ‘the masses’ [zhobng 衅, in early times perhaps a particular military corps] in motion; nor may one undertake large-scale operations, lest one perturb the matter-energy-vitality that is providing nourishment [yuaangqil 義氣].’

With this perception that what we think of as the inanimate world was, in effect, alive, it is understandable that sacrifices of animals were regularly made to mountains, forests, streams, and marshes. What is of central importance, though, is that towards the end of this period there was a tendency on the part of state governments to transform the traditional policy of conservation and prudent management into one of limiting access for commoners to non-agricultural land, partly to create some degree of state monopoly that could be exploited to fiscal advantage, and partly to force the population to settle down to the pursuit of farming, the primary source of taxes and conscripts. A early example of this trend was the monopoly of the Duke of Qir over forests, reeds, and salt in the late sixth century BC, which was regarded as greedy. The texts are confused and contradictory, reflecting this transition and the multiplicity of objectives, and assuredly there was a vast range of circumstances differing from one locality to the next. We can, bearing in mind these cautions, take the Book of Master Guaan 管子, a composite work compiled towards the

47 That is, the so-called ‘well-field’ [jiingiang 井田 system attributed to archaic China, in which eight families cultivated a central field in common to provide taxes for a feudal lord.


49 Yuehlihng 月经 [Ordinances for the months], pp.83–100 in the Liijibjiruo (The record of the rites, with collected explanations), ed. Chem Haoh (Taipeei: Shihijieh Shujur, 1969), p.86.

50 Ordinances for the months, p.87.

51 Ibid., p.91, and cited in Yuann Qinglim, Conservation of nature, p.113.

52 A suggestion based on an analysis of the contexts in which the oracle-bone form of this character was used by Shirakawa Shizuka 白川静, Kakusabun no sekai [The world of the oracle-bone script] (Tokyo: Heibonsha, 1971), pp.204–13.

53 Ordinances for the months, p.91. For the 2nd millennium BC it would be more appropriate to say that the Chinese saw the natural world as permeated by and controlled by spirits. See Shirakawa, Oracle-bone world, pp.41–2, 46–9. Qib was a late-archaic and early-classical concept that partly fused with earlier ideas, and partly superseded them. Much of Shang spirit-lore—such as that relating to the phoenix (jebng 凤) as the spirit of the wind (jeng 風)—was forgotten, garbled, or rationalized by early classical times. See Shirakawa, Oracle-bone world, pp.52–3.

54 E.g., Ordinances for the months, p.84.

55 Commentary of Zuoo, xiab, Zhao-gong 20th year, p.1219, and Couvreur, Springs and autumns, 3,323. Yahhii told the duke: “The trees of the mountains are guarded by the [official known as the] Hernghuh 衙虞, the reeds and rushes of the wetlands are guarded by the [official known as the] zhongjiao 角觥, the firewood and kindling of the thickets are guarded by the [official known as the] yurbour 虚候, and the salt and the oysters are guarded by the [official known as the] girenwobng 折望.” In other words, the ordinary people were barred by state monopolies from access to all of these resources.

56 That is, the so-called ‘well-field’ [jiingjiang 井田 system attributed to archaic China, in which eight families cultivated a central field in common to provide taxes for a feudal lord.


58 Yuehlihng 月经 [Ordinances for the months], pp.83–100 in the Liijibjiruo (The record of the rites, with collected explanations), ed. Chem Haoh (Taipeei: Shihijieh Shujur, 1969), p.86.

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end of the pre-imperial age and later edited by Liur Xiaohng 劉向, as an illustration of the multiple perspectives in accordance with which the question was perceived.

The symbolic and religious aspect remains. Activities have to have the appropriate seasonal character. In the summer, for example, “you should not gather together great crowds of people, nor light great fires, nor cut down great trees, nor put to death the great officers of state, nor chop down [the vegetation on] the great mountains, nor cut the grass in the great plains. If you destroy the three great natural entities [probably trees, mountains, and plains], the state will thereby be damaged. Such are the interdicts of the Son of Heaven for the summer season.”56 Prudent estate management continued. Thus, “if the mountains and the marshes are opened at the appropriate season, the common people will not make irregular entry into them.”57 Likewise, in a chapter that implicitly uses the idea of the carrying capacity of a certain environment for a population of a certain size, it says that “even though the mountains and marshes [shanzer 山泽] are extensive, if there are no prohibitions on the use of plants and trees, and even though the soils are rich, if there are no quotas on the use of mulberry trees and of hemp, and even though the pasturages are numerous, if taxes are imposed on the six species of [domestic] animal, then—this situation will be [nonetheless] as if we had closed shut the door of goods and of resources.”58

But there is another note struck as well. The people must be sedentarized: Though the rivers and the seas are vast, and though the pools and marshes are extensive, and the fish and turtles numerous, it is necessary to have rules governing the proper use of nets, and people should not rely entirely on fishing to make their living [chuam-waang bubkee yi cair err cherng 船網不可一財而成]. It is not that We [the ruler] wish to treat the plants and trees as our personal property, or that We are grudging with respect to the fish or the turtles, but that We cannot endure that the common people neglect the cultivation of cereals. It is for this reason that it is said: “The kings of ancient times imposed prohibitions on the mountains and the marshes because they wished to oblige the common people to concentrate on cereal farming.”59

This last point was probably a misreading of the archaic age in terms of the new motivations of the classical age. In a similar spirit, the Shangjun shu 商君書 (Book of the Lord of Shang), a text of brutal physiocratic Realpolitik that preached a militarized peasant-soldier state based on the uncompromising and predictable use of rewards and punishments, argued that if the government “had the unique power over the mountains and the marshes, then the common people who detest farming, are lazy, and want doubled profits, will have nowhere to find something to eat. If they have nowhere to find something to eat, they will be obliged to engage in the cultivation of the fields. If they are obliged to engage in the cultivation of the fields, the unfarmed grasslands will have been opened up.” A traditional commentary explains that “unique power” meant interdicts on mountains and marshes, and that the people were “not permitted to gather wood, to hunt, or to fish in an uncontrolled manner.”60
With the creation of the Chinese empire towards the end of the third century BC, control over at least a substantial proportion of non-farmland was put in the hands of the emperor's personal treasury, so that taxes could be levied with the purpose of meeting the needs of the imperial household. At least in some areas, the common people continued to have access to forests and wetlands but under certain restrictions. A bamboo document of the third century BC, recently excavated in Hurbeei, and containing a section of the "field laws [tiarmiluh 田律]" of the Qin state, says:

In the spring, during the second month, they will not dare to cut wood for building or in the mountain forests, or retain water behind the dykes. Before the summer they will not dare to take armfuls of hay to make ashes [to put on the soil], nor gather the lib-grass that is sprouting, nor take the young of animals, eggs, or fledglings ..., nor poison fish or turtles, nor emplace pitfalls, traps or nets. During the seventh month, however, these restrictions are relaxed. If, though, afflicted by the misfortune of a death they need to cut wood for a coffin, they are not obliged to take note of the season.

As for the meadows near the walled cities and other parklands subject to interdicts, they will not dare to take their dogs there for hunting in the time when there are fawns about. Those of the people's dogs that have entered a parkland subject to interdicts, but have not chased or caught a wild animal, they will not dare to kill; but those that have chased or caught a wild animal, they will kill. Dogs killed by way of reprimand and repression will be surrendered in their entirety to the authorities. Of other kills made in the parklands subject to interdicts, they may eat the meat but surrender the skins to the authorities.

Zhu Maaichem 朱賀臣, an imperial official who lived in the second century BC, cut wood and hawked it about in order to support himself, and this would only have been possible if the forests of Wu 魯, where he lived, had been open all year. Nonetheless, the History of the Hahn notes the relaxing of the restrictions on the mountains and marshes (shii shanzer shii-wen 野外山澤) by Emperor Wern of the Hahn as an act of exceptional generosity during a time of drought and locust plague, and a Sohng-dynasty compendium on the Later Hahn dynasty states that "All the taxes on mountains, marshes, dams, and reservoirs were called 'interdict cash' (jihnqiarn 禁錢), and were under the control of the emperor's personal treasury (shaaojuu 少府). The story is more complicated than I have indicated, but it is broadly true to say that the first transformation of the regulations once designed to conserve nature as a sustainable production system was into a sort of partial state monopoly. As an indication of its subsequent continuation, we may note a decree issued by Emperor Wuu of the southern dynasty of the Liangm in AD 508:

It is from the thickets, marshes, mountains, and forests that come forth the resources that sustain us. Buildings erected side by side depend upon axes [to cut the required wood], yet for one generation after another now [the forests] have been under ever firmer prohibitions. How could one describe such a situation as sharing the profits [of Nature] with the people, or being benevolent towards the black-haired folk [that is, Our subjects]? Wherever the frontier colonies subject to Our Court (gangjia 公家屯戍) are debarred from
Fine sentiments, dosed action. When the Suir dynasty reunited the empire at the end of the sixth century, however, they put an formal end to prohibitions on access to mountains and marshes. Under the Tarng dynasty that followed, we find that the Department of Guardians (yurbūb 部) in the Ministry of Works (gongbūb 部) in the Office of the Affairs of State (shahngshusheeng 尚書省), the bureaucratic heirs of those long previously charged with the conservation of nature, were mostly concerned with looking after the needs of the Court and the capital. Apart from the expression of ritual sentiments that were largely empty of operational content, the rules governing what was and what was not allowed to the ordinary people applied only to special zones: the immediate environs of the capital cities, for example, and around sacred mountains and shrines.

The second transformation was that the guardians, in fulfilling their duties to supply the Court with materials, from time to time at least themselves became among the most effective destroyers of the natural environment. In a poem that is loaded with political allusion—including the idea that talented men have been cut down at the Court like axed trees—the essayist and historian Liur Zongyuam 柳宗元 (773–819) summoned up images that, although they can hardly be taken straightforwardly, must have had some reality if they were to have carried conviction:

The official guardians axes have spread through a thousand hills,
At the Works Department's orders hacking rafter-beams and billets.
Of ten trunks cut in the woodlands' depths, only one gets hauled away.
Ox-teams strain at their traces—till the paired yoke-shafts break.
Great-girthed trees of towering height lie blocking the forest tracks,
A tumbled confusion of lumber, as flames on the hillside crackle.
Not even the last remaining shrubs are safeguarded from destruction;
Where once the mountain torrents leapt—nothing but rutted gullies.
Timbers, not yet seasoned or used, left immature to rot;
Proud summits and deep-sunk gorges, now—brief hummocks of naked rock.

The wisdom of the ancients was powerless.

Power and Property: from Classical China to the Middle Empire

There is no rule that environmental wisdom can coexist with power, whether military, political, or economic. In most cases it seems that the contrary is likely to be true. The essential nature of power in the social sense is not all that far removed from its scientific definition as units of energy multiplied by units of time. Social power requires the creation of means to capture and direct the flow of energy in nature just as much as its flow in other human beings (sometimes known as 'exploitation'). In other words,
technological mastery combined with political domination. The capture of the flux of natural energy at any given time is usually easier if it is to some extent ‘stolen’ in the sense that it is removed more rapidly than natural processes can restore it. Socio-political power and the over-exploitation of the environment have a tendency to co-vary, though there may be exceptions in specific cases. The *Master Guaan* states explicitly that development is indispensable for the survival of the state: “Where the territory is extensive but the state impoverished, this is because the untilled land has not been opened up. Where the populace is numerous but the armed forces feeble, this is because the common people have no [great] income. If secondary occupations [such as trading] be not forbidden, the untilled land will not be opened up, ... and it will be impossible to hold out against enemies from outside, or to maintain security within the borders.”

The state of Qin, which was in due course to unify the empire, greatly increased the effectiveness of its war-machine in the third century BC by the improvement and creation respectively of two gigantic irrigation systems, using technology imported from the more advanced regions of eastern China, systems that permitted a greater, cheaper, and more reliable production of food. The first of these was that in the present province of Sichuan where the Mirn River leaves the mountains and flows out across a sloping (0.29% to 0.42%) fan-shaped plain. The principle was simple: water, moved by gravity, was first diverted from the main stream (in such a way as to stabilize, as far as possible, the quantity entering the system, whether at the Mirn River’s low water [about 500 m$^3$/sec] or peak discharge [5000 to 6000 m$^3$/sec]); then it was directed through a network of distribution channels, used for irrigation, and the residue returned to the main course far downstream. The details required solving the problem presented by the deposition of sediments, as the slowing of the current reduced the competence of the flow to carry suspended particles, and thus the system was threatened with the infilling of its channels over time. In oversimplified terms, the solution adopted was twofold. Regular dredging was carried out during low water in the winter (57% of rainfall occurs today in the June-September period) in accordance with the advice of the first director of the works, Lii Bing 李冰, to “clear out the mud-deposit deeply, and build the dykes low.” Second, a bend was engineered upstream of the main diversion outlet in such a way that a substantial proportion of the suspended sediments was deposited on its convex inner side, as a result of the slower flow there and the subsidiary helicoidal current in the plane at right angles to the main current. These deposits were then flushed out periodically by opening another channel that led back directly into the old main course of the river, but was normally closed off, while at the same time shutting the diversion outlet, which was normally open. The flushing channel was closed by a barrage of huge bamboo baskets filled with heavy stones resting on a fixed stone sill, which also served as a spillway regulating the height of the water in the system, hence as an emergency overflow during heavy floods (or even a safety-valve, since the gabions could be swept away). Removing,
and later replacing, these baskets, which were 3 feet in diameter and 10 feet long (at least in Tang times, from which these figures come),\textsuperscript{77} required the repeated use of a large quantity of labour, as did the annual dredging. This is an early example of pre-modern lock-in: the initial investment, on which the productivity of the entire system rested, could only be preserved at the cost of perpetual expensive maintenance. In fact, the Mmi system has proved unusually enduring, in spite of the repeated destruction of the main diversion head and the crescent-shaped dykes creating the artificial bend, and an expanded and altered version of it is still functioning today.\textsuperscript{78}

The Zhehng Guor Canal 鄣溝 to the north of the Wei River 渭河, in what is today Shaanxi province, and started in 246BC, took heavily silt-laden water from the Jing River 渭河 to the Luoh River 洛水, running along higher ground for the first part of its course so that the water would be released onto the fields below where, in the words of a Hahn-dynasty ditty “it serve[d] as both irrigation and fertilizer.” This was also an effective way of combating the salinity of much of the land. Its 200-kilometer course had an average slope of 0.64 per mil, which indicates a high degree of surveying skill. The canal needed continuous re-engineering because of siltation, including new adit channels, and its effectiveness seems to have declined markedly over the centuries. Its critical contribution, when it was created, was to feed the population of the area ‘within the passes’ where the Qin and the Hahn empires had their capitals. Simaa Qian, the great historian, not only attributed the triumph of the state of Qin over the other states of the third century BC, and hence the creation of the empire, to this irrigation system, but put words into the mouth of its creator, Zhehng Guor, that suggest that in the course of building it this latter had become conscious that, although he had started with the hope of distracting the ruler of Qin from war, this ascendancy was likely to be the consequence of his work. Without adopting any simple monocausal explanations, we can observe that economic development was inextricably linked with political and military hegemony.\textsuperscript{79}

Property is a fundamental form of social power, and in this context we may note that the early empire and the long era of political division that followed it (a period together running from the end of the third century BC to the end of the sixth century AD) was marked by a competition between the state and the owners of large estates to dominate the extraction of revenue both from the land and from the labour-power dependent on the land (which was mainly but not exclusively farmland) in the form of taxes, conscripted labour, and rents. This competition was too complex for summary here, but it is important to note that after the fall of the Hahn empire in the third century one of the main means used by the state was systems of government-directed land distribution to peasant farmers, or farmer-soldiers. Two passages will convey something of the nature of these forces that were opposed, but also linked, in that most bureaucrats and estate-owners were drawn from largely similar social groups, and could even function in both capacities in different contexts. In the third century, Zhohngchang Toong 仲長統 wrote:
The households of the powerful are [compounds] where one finds hundreds of ridgebeams linked together. Their fertile fields fill the countryside. Their slaves [nurbih 南婢] throng in thousands, and their [military] retainers [turhuh 徒附] can be counted in tens of thousands. Their boats, carts, and their merchants spread out in every direction... The valleys between the hills cannot contain their horses, cattle, sheep, and swine.80

It is worth observing, in passing, the importance of the part still played by herds of large animals in the Chinese economy at this date.

The second passage describes how in 243 the state of Weih 魏, in northern China, it was “desired to extend the cultivated acreage, and to accumulate a stockpile of cereals, in order to destroy the bandits [that is, its rival states].” According to Dehng Aih 鄒艾, a statesman of this time, speaking of the valley of the Huair River:

“Though the soil is good, there is not enough water to use to the full its productive power. It will also be necessary to dig canals to provide water for irrigation, so as to stockpile large quantities of military provisions, and to serve as transportation routes for the government... Our concern is with the area south of the Huair River. For each large-scale military expedition more than half of the troops have to be used for transport, which is highly expensive... Twenty thousand colonists should be stationed to the north of the Huair, and thirty thousand to the south. At any time, twenty per cent of the men will be off duty, and so there will be a regular force of forty thousand men who function simultaneously as farmers and as soldiers... Wur will be conquered.”81

Beneath the conflict opposing large estate-owners and the state was another battle, related but not identical, in which the common people, to some extent backed by the state, fought with the estate-owners for access to land, both arable and non-arable. In 306, under the Jihn dynasty, Shuh Xi 東晉 said, in a memorial stressing the responsibility of local officials to assign land to the landless, that:

In the thousand counties of the empire there are many who wander hither and thither in search of food. They have abandoned their own properties and have not in actual fact been assigned any by the state... What is more, in the ten commanderies of the metropolitan area the land is constricted yet the population dense... Nonetheless pastures for pigs, sheep, and horses are widespread in this region. They should all be suppressed so that we can provide for the needs of those who have no land... What is more, the marsh of Wur 油 in the commandery of Jir 汲 [in what is today Her'narn province] contains several thousand qing 21 of good-quality land, but the water there is stagnant and the people have not opened it up for agriculture. I have heard the people of this principality all declare: ‘It would not be difficult to drain them, so as to convert the saline wetlands into plains [yuam 魁], from which large profits could be derived, but the great and powerful families do not wish to give up the abundance of fish which they catch here, and they have known how to intrigue with the officials in such a fashion that in the end [this mutual complicity] has never been broken.83
Here, as sometimes happens, social justice for the poorer members of society and environmental conservation by the well-to-do were directly opposed. Another example comes from 336 in the region around Yeh in the north-east, which was then suffering from drought. The authorities, we are told, "ordered the local magistrates to lead strong grown men into the mountains and the wetlands to gather acorns and to catch fish so as to provide help for the old and sick, but powerful families had taken possession of these places and resources of this nature could nowhere be found." A crucial text from the middle of the fifth century, when the Liur Sohng dynasty ruled south of the Yarngzii, shows both the fever of non-governmental economic development that already gripped parts of east-central China by this time, and the confused state of property rights:

The Prefect of Yamgzhou ..., reported to the Emperor: "Though the prohibitions regarding the mountains and the lakes have been established since times past, the common people have become accustomed to ignoring them, each one of them following in this the example of the others. They completely bum off the vegetation on the mountains, build dams across the rivers, and act so as to keep all the advantages for their families ... . Rich and powerful people have taken possession of ranges of hills. The poor and the feeble have nowhere to gather firewood, or hay. These incursions are serious abuses that damage good government, and to which the administration should put an end. It should be reaffirmed that the old laws which defined what was beneficial and what harmful are still in force."

The authorities examined the edict of 336, which said: "To take possession of the mountains, or to put the marshes under one's (personal) protection is tantamount to robbery with violence. Those who steal more than 10 feet of land are to be beheaded in public."

Yarng Xi 羊希 stated: "This system of 336 contains prohibitions that are rigorous and severe. Since it has been difficult for the people to obey them, their principles have [in practice] been eased so as to be in keeping with the spirit of the times. Nonetheless, taking possession of mountains, and blocking rivers with dykes, have become more and more common. Because people copy each others' bad example, these places have, so to speak, become their hereditary property. Were we to take back these properties all of a sudden, this action would provoke anger and resentment. We ought now to repeal [the old rules] and create a system based on the five following provisions: (1) As regards the mountains and the wetlands, we shall not charge with an offense, nor confiscate the lands of those who have become accustomed to clearing them by burning the vegetation, and planting bamboos and all sorts of fruit in such a fashion that these can renew themselves, and to building dams and lakes, and also barrages to keep captive river and sea fish ... which they maintain in good repair ... ."

He then goes on to specify maximum limits of acreage for officials of various ranks, and for commoners, and prescribes that their holdings be entered in the land-registers.

What this passage makes clear—and I have nowhere found any evidence to the contrary—is that while there was a clear concept of a public economic

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Figure 2
Assarting (from the Qinding shouhshir tongkao, j. 32, p. 9a. Page 5a quotes the sixth-century Qinnirn yaoshu: "Essential arts for the governance of the people:
"Whenever you are opening up waste lands for farmland in the mountains and marshes, always cut down the vegetation in the seventh month. When the grasses are dry, set fire to them. When spring comes [the following year], open the land for farming. Large forest trees should be killed by felling [yingsha]. When the leaves are dead and no longer flutter, then you are at liberty to plough and sow. In three years, when the trunk is rotten and the twigs withered, burn them."

Domain, of forests and wetlands in particular, to which commoners had varying rights of usually limited access, and which had to be maintained by the state, and was in some sense state land, there was no de jure common land in the Western sense of land belonging to a specified community, but only de facto common land perpetually vulnerable to encroachments as population growth put natural resources under ever
THREE THOUSAND YEARS OF UNSUSTAINABLE GROWTH

greater pressure. In north China, in 485, the Northern Wei emperor Xiaowei lamented the apparent decline in the condition of the people since ancient times, commenting that in his day “the rich and powerful have appropriated the mountains and marshes, while the poor and the weak have lost hope of having the smallest plot of land.” In these last two passages we see the early stages of the remorseless process by which over the next millennium almost all the non-agricultural land in China eventually came into private ownership.

The details of this important story have still to be systematically researched, and there may have been several stages. One important aspect was the making available by the state of more and more of its reserved domain to the ordinary people to use as what has just been described as “de facto common land.” For example, it is said of the Ming emperor Rem, who ruled from 1425 to 1426, that “wherever the government had placed prohibitions on the mountain work-sites, gardens [fortea, etc], the forests, the lakes, the wetlands, [sites for] kilns and founderies, fruit trees and bees, all was given to the common people.” In fact this can only have been true to a limited extent. He is also said to have said to his top officials, when discussing the problem of firewood for Beijing:

In ancient times, the mountains, the rivers, and the wetlands were all shared with the people. Although there were the interdicts imposed by the guardians, and the people had to observe the proper times and seasons for gathering resources, the essential concern was to keep the people in good condition, and it was not the case that the state had a monopoly of these resources. There are several million inhabitants in the capital [in fact, closer to a million] and from where can they get their wood for heating except from the mountains? … What is more, the mountains and marshes have been produced by Heaven and Earth in order to benefit the people. The region to the east of Yongguan and next to Wahnshoush should remain closed to the gathering of firewood, but apart from this ban the people should be allowed to collect it everywhere without prohibition.

From this, and from the removal of further restrictions by Rem’s successor, the emperor Xuan, it can be seen that there was still not general access. It is also relevant to note that the use of the northern frontier forests as a barrier to barbarian cavalry began at this time—a form of environmental military defence. The processes by which these “de facto” commons were then converted into the private mountain land owned by the so-called “mountain lords” (shanzhuu 山主) that characterized most of the mountainous areas in Qing times is still to be studied.

In some places what almost amounted to “de jure” common land was created by communities towards the end of the empire. For example, in Tongdaoh in the south of the province of Hur‘nan(26°10’ N, 109°45’ E) and today an ‘autonomous’ county for the Dong minority, this happened in 1851 at a place called Camp Baaoshan. The elders here created a system to protect their trees from over-exploitation and left a record of their decisions engraved on a stele.
Was the vegetation of the forests of these mountains always the way it is today? No. It was not. A phenomenon whose age is of many centuries has met with a disaster.

On the mountain of Houhlorng in Shahngxiang we have always had several thousands of trees of vast girth. The people of the present time are not of a quality comparable to those of more remote ages. They have acted in their personal interest in cutting down trees in an unreasonable fashion. The result has been that the beauty of the mountain trees has undergone a change, and the mountains shine as if they had been stripped naked.

This means that we have reached a moment in time when the mountains have been ruined, the arteries of vitality drained dry, and the spirits of human beings become inconstant. Our locality is in a state of decomposition and decline for which there is no remedy. Seeing that this decline is already an accomplished fact, who possesses the power to remedy this situation of rottenness, or to find the means by which the springtime may return?

All the trees, on all sides of this Camp, must be cared for so that they can return to a good condition, and then surpass the past, flourishing, rich, and of a great age, and such that our children and our grandchildren may pass on their abundance from one to the other without end.

We have now resolved that all the land on Mount Houhlorng, up to the summit of its slopes and as far down as the reservoirs, gardens, fields, and houses, and towards the interior as far as the crest of Liinglour, and towards the exterior as far as the fields and reservoirs of Yarnchong, shall become communal land. [The term gongdi used here is more commonly rendered "public land," but this does not fit the context.] It will not be permitted either to buy it or to sell it. All the trees of these forests are to be conserved and placed under an interdict. It is forbidden to fell them in an unreasonable fashion. Those who do not obey this resolution approved by public discussion are wicked thieves. They will be held responsible and punished by collective action . . . .

We have decided that the trees around the source of the river at Camp Baoshan provide it with a comprehensive protection and that all of them must be cared for and placed under an interdict. It will not be allowed for them to be felled in an abusive fashion. Those who disobey will be punished.

We have decided that the second circumscription of Cunninghamia at Camp Baoshan, and the first of Cunninghamia on Mount Marqueh are to be communal mountains, and they are not to be sold or bought.

This unusual inscription is not easy to interpret. In the first place, cases are known of mountain cemeteries that were owned by kin-groups where the kin-group leaders put an end to the felling of trees, the collection of dead wood for burning, the gathering of chestnuts, and the growing of crops by the ordinary members of these kin-groups chiefly in order to be able to monopolize the profits for the kin-group organization, as distinct from its individual members, or in all probability for themselves. Whether this was what was going on in Camp Baoshan, under the rhetoric of collectivity and environmental salvage, is impossible to tell from the evidence. The use of the terms "unreasonable" and "abusive" suggest that some felling continued, under some sort of control, presumably that of the community leaders. In the
second place, it is evident that the formal constitution of collective land in the mountain forest areas came late here, and this has possible parallels in other contexts, such as the equally late formation in north China of collective village groups to handle the task of crop-watching. Prior to the middle of the nineteenth century, at least in this remote area, there seem to have been enough resources for everyone to take what they wanted or needed, and there may have been some past buying and selling of forest lands, at least outside the area that was reserved and placed outside such transactions. Lastly, the evident need to define the reserved area in a precise geographic sense, as well as the description of rapid timber depletion, give a hint of the pressure on these resources, presumably from those encroaching as private property owners, that was building up on the forests by this period. The foregoing commentary is speculative, but indicates the most probable pattern of events on the basis of our present limited knowledge.

Unsustainable Progress: the Destruction of the Trees

By the end of the imperial period (in round numbers, 1900), most of China Proper had been stripped of the forest cover that three millennia earlier had covered it in almost unbroken succession from the tropical rainforests of the far south to the conifer forests on the northern mountains. The only large forests that remained in areas that were relatively easy of access were in Manchuria, an area mostly debarred to Hahn Chinese immigration before the middle of the nineteenth century, and which had thus escaped Chinese-style exploitation. If we had to create a swift characterization of this Chinese style in the last centuries of the empire, it would be in terms of a dynamic but relatively poor society that was constantly driven by population expansion to attempt to master nature in new environments, and which often achieved this in a skilful manner, marked by a patient tenacity, but which in the long run more often than not damaged or even destroyed these environments. And yet, overall, a larger and larger population was supported. This can be seen, according to one's perspective, as either a disaster or a triumph. In central China two thousand years ago it was common to cut down a whole tree in order to fashion a single coffin. In 1983 a ban was placed on using wood for floors, staircases, electricity poles, mine-props, railway sleepers, bridges, and coffins.

Deforestation in China presents a complex historical and geographical pattern which is only partly known and cannot be even summarized here. The process can however be illustrated by two of the most important episodes of the story: (1) the effects of the stripping of trees and the vegetation cover, as the result of economic development, in the middle reaches of the Yellow River—the region, broadly speaking of the loess, a fine yellow aeolian dust—in increasing the sediment load carried by this river, and (2) the consequences of the invasion of the wooded uplands in the eighteenth and early nineteenth centuries by poverty-stricken people

94 Richardson, *Forests*, p. 115.
95 Lim Hongrong 林鴻榮, “Sihchuan guudai senlim-de biaihqian” [The transformation of Sihchuan's ancient forests], *Nomgyeb kaoqiu* 1985.9 and 10, is a preliminary sketch of a single province. He shows how climatic change, replacement growth following logging, partial forest recovery during periods of human economic and demographic decline, the development of commercial siliculture (tea, mulberries, lacquer, fruit-trees, and so on), styles in grave-construction and palace-building that made extravagant use of wood, the demands for fuel for such activities as brine-boiling and metallurgy, and of course the extension of farming as techniques changed (as from mobile slash-and-burn to permanent hill-slope terracing), all interlocked to create a particular pattern. It is noteworthy that as early as Qim/Hahn times the catalpas (zii 柿) and cypresses (bor 柏) of the upper Min River valley were being assembled into rafts and floated down to the Yangtze as “timber easily obtained at slight effort and of an abundant usefulness.” Lirn, “Sihchuan's forests,” p. 166. Chern Qiaoryih 陈桥驿, “Guudai haoxhing divuian senlim-de pohhuaik jir qir duuh nomgyeb-de ying-xiaang” [The destruction of the natural forests of the ancient Sihchuan region and its impact upon agriculture], *Diblit xuerbaob* 31.2 (1965) shows how poems can be used to recreate a picture of the trees and fauna of past times in this area, which was the birthplace of Chinese nature-poetry. His later “Lihshii-shaheing Zherjiangsheeng-de shandih keenzhir yuu shanlin pohhuaih” [The place in history of the opening of the hill lands of Zhejiang province and the destruction of the forests], *Zhongguor shexhuik kezxue* 1983.4, is mostly about the introduction of New World crops and (on p. 215) quotes the *Mingshuh* 明史 to the effect that “for the first time people cleared land by burning in the mountains of Zherjiang, and the vegetation and trees on all sides were swept away.”
96 The 'middle reaches' may be defined as north-western Shanxi, northern Shaanxi, eastern Gansu, the desert Ordos region, Dongseng, and the mountainous parts of southern Nimgxiah.
who destroyed an enormous, if for the moment unquantifiable, proportion of the remaining forests in order to practise a transient slash-and-burn agriculture that sent fragile topsoils pouring downstream.

Pollen analyses have shown that 5000 years ago the north China plain had a warmer and more humid climate than it has today. It was covered with wetlands and in many places the woods came down to the banks of the river. It should therefore be remembered that natural, climatic effects played an important part in the changes that are about to be described; not every new development was anthropogenic. Regions that are today semi-arid, or even arid, were then substantially wooded. Forests covered about three-quarters of Gansu province, slightly less than half of Shaanxi province, and almost two-thirds of Shanxi. In the plain lower down, Her'nam province was about two-thirds wooded, Shandong province somewhat under half wooded, and Herbeei province more than two-thirds wooded. Erosion is thought to have been slight in this period. The Yellow River was not called "yellow" at the start of the historical era slightly more than three millennia ago, but simply "The River" (Her 镶); the adjective was added toward the end of the first millennium BC, a time when the History of the Hahn Dynasty says that sixty per cent of its water was "mud". The present-day mean solid content, measured slightly upriver from the mouth of the delta, is just over 25 kg/m³).

It is no more than a plausible guess at the moment, but the likelihood is that the reason for this change was the policy of promoting the agricultural development of the north-west by the Qin and Hahn dynasties, including forced transfers of population. The grasslands that were the principal vegetation cover of the middle reaches were opened up for farming, and temperate-zone forests in the south-eastern part of this area were cut to satisfy the need for timber created by the great capital cities in the north-west, accelerating erosion. During the last century or so of the first millennium BC the bed of the Yellow River, now enclosed by man-made levees, rose for the first time above the level of the surrounding plain. In the absence of man-made levees, of course, periodic overflowing of the banks would have led to the deposition of sediment outside the main bed as the overflow slowed down and its carrying power was reduced. One of the motives that had led to the techniques required for the creation of these huge embankments during the Warring States period preceding the unification of the empire had been military: several of the states of the plain used them to direct floodwaters across their rivals’ territories. The levees of the Warring States period were set back about ten kilometers from the riverbank, in order to provide adequate space for floodwaters, but the History of the Hahn tells us that within these levees "the sediments were so rich that the common people cultivated them. It would happen that [for a time] they would suffer no evil consequences, and so they would build houses there, and later these would form villages. When there were large floods, these villages would be drowned, but they would again make new dykes to defend them."100

During the great part of the Former and Later Hahn, 186 BC–AD 153, there was approximately one disastrous break in the Yellow River levees every 16
years, with a concentration during the period 66 BC–AD 34 when the frequency was one major break every 9 years. The burden of annual repairs on the ten commanderies along the banks around the year 6 BC was described by Jiaa Yih 賈誼 as “ten thousand ten thousands” (if taken literally, $10^8$) copper cash; and he added that “when there are major breaches, countless people die.” During the more than 400 years that followed the cessation of population transfers to the north-west and of agricultural colonization c. 140, as the weather grew colder, and the frontier between pastoralists and farmers shifted south with the regrowth of a grass and forest cover, the frequency dropped to about one breach in every 50 years. Barbarians were good for the environment.

During the later part of the Northern Wei dynasty 北魏 (c.500), the arabilization of parts of the middle reaches recommenced (for example, in Hetao 河套 on the north-west corner of the great bend of the river), and then, after the middle of the eighth century, the midpoint of the Tang, the conversion of grazing-lands to cereal cultivation accelerated. During the early part of the Tang dynasty, even with the Chinese becoming re-established in the north-west, the Yellow River continued to be peaceful, but the capital at Chang’an made heavy demands on the area for wood and food, and economic activity intensified. Pressures for development in the North-west gradually intensified, however. Thus, in 788, when Lü Yuanlhahng 李元諫, the military governor of Loongyouh 隴右 circuit (approximately modern Gansu), was restoring the ruined city of Liangyuarn 良原, the vital territory in the eastern part of the circuit [Loongdong 隴東] was being raided by the [Tibetan] barbarians who regularly pastured their horses there and rested their soldiers. Yuanlhahng set up warning beacons on mounds some distance away, filled in the gaps in the city walls and repaired the parapets. He led his soldiers in person, sharing both hard toil and leisure moments with them. They felled the forests, mowed the grasses, and cut down the thickets, waited until they had dried out and then burned them all. Over an area several tens of lǐ square all was farmland, beautiful to behold. He urged his soldiers to plant trees and crops; and their yearly harvest of millet and vegetables came to several hundred thousand bu. During the last 160 years of the Tang, 746–905, however, breaches in the levees along the lower course of the Yellow River happened once every 10 years. During the Five Dynasties and Ten Kingdoms in the first half of the tenth century, it was one every 3.6 years.

During the first phase of the mediaeval economic revolution under the Northern Song dynasty, 960–1126, the Yellow River broke its levees with an average frequency of once every 3.3 years. This is an underestimate, as only cases where the breaking of hydraulic defence-works is explicitly stated to have occurred (sometimes in two separate places in a single year) have been included, which has meant leaving out disasters only recorded as severe floods. Official statistics, which should be taken cautiously, state that the worst of these floods, that of 1117, drowned more than a million people. Even if these data are regarded as giving no more than a rough...
The frequency of "breaches and floods" in the "Mongol dynasty" in the thirteenth century and the first half of the fourteenth has been given by Yuam Qinglim, Conservation of nature, p.72, as one every 3.4 years, but this figure is suspect for a number of reasons (such as implicitly starting the dynasty around 1218, when it did not rule China, including floods, and not even applying throughout to the same lower course of the river).

Matsumoto Yoshirō 松田光隆, "Shindai no Kōka shisui kikō" [The structure of flood control on the Yellow River under the Qing dynasty], Chūgoku suguru shikenkyū 16 (1986), pp.34-40.

Sediment yield in the Yellow River above the Sanmen narrows (the terminus of the middle reaches) has risen by 32% since 1949, according to Richardson, Forests, p.235.

Critics have however noted that increasing lower-course scour between 1578 and 1592 by increasing current velocity caused increased deposition of suspended sediment at the mouth of the river where the current was slowed by its encounter with the sea, hence a reduction of the overall channel gradient and renewed flooding. See Tani Mitsutaka 谷光隆, Mindai Kakōshi kenkyū [Studies on the history of the hydraulic works done on the Yellow River during the Ming dynasty] (Kyoto: Dōhōsha, 1991), p.392. I am most grateful to Professor Tani for the gift of a copy of his book.

Matsuda, "Yellow River under the Qing," p.38.

It was also during this period that the river began intermittently to take a course to the sea south of the Shandong peninsula. It divided into two, one branch going north and the other south, towards the end of the twelfth century, and towards the end of the thirteenth century it shifted exclusively to the southern route. From 1324, when the definitive southern course was established, to 1853-55, when it moved north again, the lower Yellow River was, for the purposes of counting the frequency of breaks in the levees, a new river.111

In 1420, the Ming moved their capital to Beijing, and the attack on the forests in the north and north-west intensified as Hahn Chinese populations re-expanded here after a period of abrupt demographic decline under the Mongols. After the middle of the sixteenth century, for example, we read of a county in Shansi, in the basin of the Fen River 汾水, which empties into the mid-course of the Yellow River, that because of the cutting of the forests, the hills "shone in their nudity". Under the Qing dynasty that followed, the opening up of the loess lands in Gansu province in the far west of China Proper, and through which the upper part of the middle course flows, is said to have doubled the area under cultivation there between the middle of the seventeenth century and the early nineteenth. According to one analysis, over the more than half a millennium of the river's southern course, the average frequency of breaks in the levees was once every 1.6 years, or close to two in every three years. Another puts the frequency for the period of the Qing dynasty before the course changed (1645-1855) as one disaster every 1.89 years.112 By either reckoning, abnormality had become the norm.

The foregoing is a crude sketch that will require extensive refining, including a systematic examination of the different locations on the river at which disasters occurred at different times.113 Among possible causes other than the stripping of the mid-course vegetation cover and forests it is also necessary to consider changes in hydraulic practice and changes in climatic conditions. For example, the methods of Pan Jihxuhn 潘季軹, the celebrated but probably overrated hydraulic engineer of the late sixteenth century, namely unifying the multiple riverbeds and then constricting the channel in order to accelerate the current and hence increase the scour, were widely admired,114 and the Yongzhehng emperor in 1729 ordered the implementation of Pan's idea of increasing the height of the dykes by 5 inches each year (not a sensible long-term strategy),115 and so we should perhaps be careful not to assume that the technology necessarily always improved over time. The transitions from a relatively warmer to a relatively colder climate in (very approximately) the second century of both the first and second millennia AD correlate with opposite patterns in the occurrence of disasters in the lower Yellow River (improvement and aggravation respectively), and any simple climatic explanation therefore looks difficult. A study of the period 1471 to 1970, most of it falling within the later 'Little Ice Age', which also affected
China, but which may not represent patterns found in earlier historical times, has however shown that in relatively colder winters the climate was drier than average in the west of China and wetter in the east, and that in relatively warm winters this pattern was reversed. This suggests that any effects at work are likely to have been rather subtle and beyond our present power to detect with certainty.

Clearly, though, the historical balance-sheet of the pluses and minuses of north-western agricultural expansion in imperial China has to take into account these hydrological consequences. Simply as an illustration of the kind of costs directly involved—an example chosen simply because there are some figures for it, and not because it was of any special importance—consider the dredging of deposited sediments and the new dyking that had to be done in 1606 at Xuzhou, where the Grand Canal—supply artery for the capital—crossed the Yellow River, to keep the crossing workable. Half a million men had to be conscripted to work for six months, and the state

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116 Zhehng Sizhong 鄭斯中, “Woo-guor lihshi shirqi leeng-nuaan niarn daihgan hahn-xirng” [Patterns of dryness in cold and warm decades during the historical period in our country], Diblit yarnjub 24 (Dec.1983).

Figure 3
The middle reaches of the Yellow River (from Fub Zerborng леп зборнг comp., Xirngshuui jinjiahn 行水金翼 [Mirror of the passing streams], ‘Huarngher tur’ [colophon 1725; reprint ed., Tairbeei, 1969], vol.1, pp.38-9)
had to pay 0.8 million ounces of silver. This was not routine, but it was not exceptional for large-scale intermittent maintenance.\footnote{117}

The second of our examples, the late-imperial forest holocaust, is a major part of the explanation of why, today, China's reserves of wood per person are about one-eighth of the world average.\footnote{118} This process was a longterm one, but it reached its pre-modern peak under the Qing dynasty in the last two centuries of the empire. An acute conflict had gradually developed between the needs of short-term economic survival and long-term environmental protection. Fahn Chemgdah 范成大 of the Song dynasty says in the preface to his poem on the cultivation of dry fields recently opened for farming:

> These newly-assarted fields are lands in the defiles between the hills and they have to be ploughed by the blade [of the axe] and then burned before the seeds are sown. At the start of spring people fell a multitude of trees in these mountains until they have all been brought low. When the time comes for sowing, they wait until it is rainy weather; then, on the day before sowing, they burn [the fields] so as to use the cinders as fertilizer. The following day, when it is raining, they use the prepared soil to plant their seeds, and thus the shoots flourish and the yields are doubled. If no rain falls, the opposite occurs. The mountains are by and large of a low fertility, and the soils have little strength ... \footnote{119}

In the same fashion a monograph on the local products of the province of Hun'narn published in 1840 says:

> Between the River Yuarn 沅 and the River Xiang 湘 there are many mountains. People only grow millet there, and many of them live on the ridges or buttes. Every time they want to sow grain broadcast they first cut down the trees and make a general conflagration. They wait till the wood has become ashes and then sow in these latter. In this way the yields of their harvests are doubled. This is what the history-books call 'ploughing with the blade [of the axe] and sowing in fire.' \footnote{120}

Clearing the hill-slopes for farming, followed by setting fire to any small trees that remained, had a harmful effect on the hydraulic systems downstream, as may be seen by reading a letter written by Meiir Boryan 梅伯言 (1786–1856) about the 'shed people' (pengmirm 棚民) or migrant squatters and settlers in the uplands south of the Yarngzii valley:

> When [the late Doong Wenkeh 董文恪 was governor of Anhui province he wrote a memorial ... on the opening up of the mountains by the shed people. The thrust of his argument was that all those who had attacked the shed people were steeped in geomantic theories [lorgnmaih fengshuui zhi shuo 龍脈風水之說] to the point that they let the riches in several hundred mooou 鈾 or so of mountains run to waste, and neglected to behave in the normal and proper manner, in order to safeguard land harbouring a single coffin [fearing to damage the occult forces thought to run through the earth]. The shed people were nevertheless capable of confronting difficulties and being content with insipid food in the high mountains and places that but rarely saw any traces of human beings. They knew how to assart and sow dry-field cereals in such a way as to supplement rice and sorghum. Not one of them was lazy, and the land gave
forth all its benefits to them. Encouraging them was an appropriate policy and it was wrong to put obstacles in their way with prohibitions, which gave rise to quarrels.

When I read what he had to say, I thought he was right, but when I went to Xuancheng 宣城 [near Wuhu 無湖 in Anhui] and asked the country people [about this question], they all of them said that when the mountains had not been developed the soil had held firmly in place and the stones had not budged. The covering of plants and trees had been thick and abundant, and that after the rotting leaves had been heaped up for a few years they might reach a depth of two or three inches. Every day the rain passed from the trees to these leaves, and from these leaves into the soil and the rocks. It passed through the cracks in the rocks and drop by drop turned into springs. Downstream, the rivers flowed slowly. What was more, the water came down without bringing the soil along with it. When the rivers flowed slowly, the low-lying fields received their water without suffering from disaster. Furthermore, even after half a month without rain, the fields lying high up still obtained an influx of water.

These days, people used their axes to deforest the mountains. They employed hoes and ploughs to destroy the coherence of the soils. Even before a shower of rain had come to an end, the sands and gravels were coming downstream in its wake. The swift currents filled up the depressions. The narrow gorges were full to the brim, and could not retain the mud-filled water, which did not stop until it reached the lowest-lying fields where it was then stagnant. These low-lying fields became completely filled, but the water did not continue to flow in the fields up in the mountains. This was opening the sterile soils [buh maar zbi tua 不毛之土] for farming, and damaging the fields where the cereals grew; and profiting ‘servants’ who did not pay taxes [wur shuih zhi yong 無税之僗, or, more exactly, squatters on others’ lands], and impoverishing [registered] households who did pay taxes.

I also listened to their words and found them to be correct. It has—alas!—always been impossible for benefit and harm to be either one of them unmixed.121

The practical understanding of the environment on the part of the peasants with the permanent fields downstream was well-developed, and there is at least one detailed description in an agricultural treatise of the early nineteenth century, Bao Shihchern’s 包世臣 Qimnirn sib-shu 齊民四書 [Four arts needed for the governance of the people], of how to limit the loss of soil fertility in mountain lands by means of contoured ditches, the retention of a cap of unfarmed land at the top of each slope, and careful crop rotation.122

The environmental destruction was not, basically, due to ignorance but to short-term economic pressures. A mobile and fragmented population of cultivators with little or no security of tenure could not afford to take long-term consequences into consideration. Growing trees for timber, fuel, fruit, lacquer, and oil, and bamboos for the markets, was in principle quite profitable, but only a practical option for those with secure property rights, and the financial reserves to cover the long period of maturation, to absorb partial losses due to fire, and to defend themselves against robbery and threats to ownership in the law-courts. Thus, once again, the structure of power in the society, here in the form of the pattern of land-tenure, shaped
the pattern of decision-making that had immediate effects on the environment. It should be noted, though, that owners of large tracts of hill-lands were often attracted by the quick gains to be made from leasing allotments to farmers as opposed to the long-term gains of prudent silvicultural management. Silvicultural contracts were only given to tenants for the quickest-growing trees, such as *Cunninghamia* and *Pinus massoniana*, which on good soils can be profitably cut after twenty to thirty years, though up to fifty may be needed on the poorest land.

The mountain soils of the provinces of Zherjiang, Anhui, and Jiangxi are mostly very acid (pH ~ 4 in modern times), with an annual rainfall that ranges from 1000mm to 2000mm, with a marked seasonal concentration in spring and summer. This acidity could only be tolerated by sweet potatoes, ordinary potatoes, and peanuts, which were first imported into coastal China from the New World around the end of the sixteenth century and then spread inland. The subsequent opening up of these mountains led to the destruction of the layer of humus, a complicated substance composed of the products of the mineralization and humification of organic residues, with a consequent reduction in the capacity of the soil to retain water. Podsolization occurred—that is, the formation of a hard layer in the sub-soil composed of leached-down minerals. There are also references to soils becoming “hard and red,” which was presumably what is (loosely) called ‘laterization’, a process which leaves soil high in oxides of iron and aluminium, and with a shortage of accessible phosphates. Alternatively, what may have occurred was the stripping away of the thin humus layer to reveal the lateritic subsoil that already existed beneath. 123 When soils were ruined, the hill-farmers just moved on. The consequences downstream were irrigation systems and fields covered with the largely infertile deposits that had followed the initial fertile topsoil layer, and often a reported rise in the price of firewood. 124

A lament for loss of an ecosystem can be found in the local history of Yuhshan, which lies on the frontiers between the provinces of Zherjiang and Jiangxi in the south-east:

The rural districts to the north-west [once] produced *Cunninghamia* [shan/sha*杉*] in abundance. During the Yongzheng reign [in the second quarter of the eighteenth century] the places opened up near to the mountains, moreover, furnished the city of Hangzhou [with wood]. Recently the population has grown, and the fertility of the soil has become exhausted. Nowhere do they wait [now] till the trees that remain have reached a hand’s span in girth before the axes resound zheng! zheng! Only old *Liquidambar* trees [feng*楓*], if they are useless, are to be found in association with places shaded over by pines and camphor-trees [zhang*樟*], growing with them to old age in the recesses of the mountains … .

Old farmers say that at the beginning of the Qianlong reign [1736], when people were opening up the mountains of Huair and Yuhshan, trees grew there in abundance, the thickets of bamboos were dense, and herds of deer wandered by or rested at the side of the paths. Pheasants and hares were
everywhere in the mountains, and could be caught without difficulty. Mandarin ducks and egrets（鶴鶴）frequently flew back and forth along the margins of Stone Drum Creek. Human beings and animals were used to one another, and paid each other no attention, though, on the other hand, wild boars, 'field pigs'（田猪）, bears, black bears（狗熊 = Ursus tibetanus）and other, unknown, wild beasts, often did harm. Recently bamboos and trees have been ever more widely cleared, and human settlement grown denser. The wild beasts have not waited to be driven away, but have departed of their own accord.125

Dreams of a better age, gilded by nostalgia, no doubt; but too many tales from around the world tell a somewhat similar story for it to be simply dismissed out of hand.126

By the last few centuries of the empire there were many regions where the only oases of forest were those of sacred sites or around monasteries. The traveller Xur Xiarkeh（徐霞客）(1586–1641) left the following account of the countryside around Mount Taihher（太和山）, a Daoist peak in south-eastern Shaanxi:

Rocky walls surround Mount Huar（華山）on all sides, and it is for this reason that there are no [trees with] lofty branches or more than commonplace trunks on the lower slopes of the peaks. When one reaches the summit however, there are pines and cypresses（松柏）many of which would require three persons to encompass [with their arms]. As to Taihher the mountains surround it on all sides. Dense forests stretch for a hundred lī（里=60 kilometers). They make the sun disappear, they reach the sky. Ten kilometers or so away from the mountain there are strange pines and ancient cypresses so vast that


Figure 4
This picture of a stream in southern Anhui province conveys something of the violence of a peak discharge run-off in south-eastern mountains (from the Hornzuee yinyuam turjih 漢語因緣圖記/Shenbaohua, Shenbaohuaan, 1880). This is the consequence of the monsoon rains in the summer months, but afterwards a stream might run dry. Systems of water control were therefore usually aimed at storing the run-off for gradual use in the rest of the year.
several persons would be needed to put their arms around them. They extend across all the valleys. The reason for this is the prohibitions imposed by the state (guorjijn 国禁). [In contrast] among the peaks of Song and Shaoh 少 [in the province of Her'harn] one sees no trace of forests from the plains and foothills right up to the ultimate summits, because of the felling and cutting of firewood.127

It is noteworthy that Xur, familiar with so much of China, should have thought Taibher's forests worthy of comment.

The foregoing has merely sketched a picture, not proven a case, but it seems a reasonable working hypothesis that this endless quarrying of resources, driven by population growth, could not have been safely or successfully prolonged—at the late-imperial level of technology—indefinitely. Hence one of the justifications for my title.

Unsustainable Progress: Hydraulic Lock-in and Limited Water-Supply

It was not possible to double-track the Grand Canal. Nor to increase the size of the boats that travelled on it. The reason for this was an insufficiency of water with an acceptably low sediment load in certain places along the route that it took in Ming and Qing times from Hangzhou in the south-east to just outside of Beijing in the north-east. Where the Canal crossed the western flanks of the Shandong hills, it went north up a staircase of 27 (later 38128) locks to the summit at Namwhang 南旺, where there was also a storage reservoir, and then down a staircase of 21 locks to Lianqing 隆清. As the system had evolved by 1503 it was mainly controlled by the Daih Village Barrage 萬村壩 on the Wehn River 汶河 in the hills above Namwhang. The low discharge of winter and spring water had all to be directed into the Canal, because it was relatively sediment-free, but the higher summer discharge, with its heavy load of sediment that would quickly have clogged the waterway, had to be deflected into an alternative channel, the Kaan River 坎河, that descended directly to the sea. This was done by building a spillway across the mouth of the Kaan at an appropriate height. At the same time, it was necessary, when the flotilla of ships carrying the tax rice was on its way north (usually in late summer and early autumn) temporarily to direct all available water into the Canal, in order to ensure that they did not ground. This was achieved by building a temporary dyke each year across the entrance to the Kaan, and then demolishing it as soon as its work was done. This required a heavy and continuous input of labour and money. The situation was complicated by the tendency of the Wehn to shift its course entirely to the Kaan, and an embankment had to be built downstream of the spillway to prevent this.129 Thus the Canal was not fully operational all the year every year, and as there was not enough water here to use pound-locks with opening gates (a technique first invented in Sohng China130), because
a substantial amount of water is flushed down every time a vessel passes through one, simple closed cross-dykes had to be used here, and the boats hauled over ramps alongside them to get past. The Canal, one of the key technological foundations of the unity of the empire, since it linked southern resources with northern defences, and hence—one might say—held the empire together with engineering, had reached the limits of its possible expansion long before the end of the imperial period. For basically environmental reasons.

This example can be taken to symbolize the distinctive combination of impressive premodern economic potential, since inland water transport is remarkably cheap in terms of cost per kilometer-ton, and of environmentally conditioned long-term limitations, that was inherent in the water-based economy that underpinned the most economically advanced parts of later traditional China. The historical creation of many Chinese functional

**Figure 5**

*Dividing the water supply to the Grand Canal at Nanwuangling in the Shandong hills. The map is orientated towards the east (upwards), and the Grand Canal crosses from right to left. Locks along the channel are represented by paired cusped tooth symbols.* (Mirror of the passing streams, vol.1, pp.162–3)
regions was due primarily to the mastery of hydraulic techniques, especially drainage of wetlands, river-levee and sea-wall defences against floods and tidal incursions, a variety of types of hydraulic system supporting high-yielding wet-field rice agriculture to sustain dense concentrations of population, cheap water transport to enable trading centres to access large marketing areas (in approximate terms, radii > 100 km), and systems of urban water-supply and sewerage to service large urban concentrations (populations \( \approx 10^5 \)). A ‘functional region’ may be defined, following G. W. Skinner,\(^{131}\) as a space within which the frequency of human interactions and transactions—commercial, political, social, and intellectual—is markedly higher than with the immediately neighbouring spaces. The functional regions of China were not in general (pace Professor Skinner) physiographically given, but created, the most striking example being that of Jiangnan, the Chinese Holland, which 1500 years ago was little more than a vast saltmarsh ringed by settlements on the alluvial fans at the feet of the surrounding mountains. It is impossible to understand the economic history of China without an understanding of hydrology and hydraulics.

At the heart of historical Chinese hydraulic systems there was a paradoxical combination of increased stability and increased instability. The paradox can be explained in the following way. The central fact of the environment of northern and central China is the variability of the weather, and the natural disasters that arise from this variability. As a result it is difficult to stabilize agricultural yields. In so far, therefore, as farming serves as the fiscal basis of the state, instability of agricultural yields makes state revenues, whether taxes or corvées, unstable in turn. Hydraulic installations functioned, in the phrase used in the early first millennium AD, as reliable "artificial clouds and rains."\(^{132}\) For about four hundred years following the end of the Hahn dynasty early in the third century, for example, a period studied in detail by Sakuma Kichiya, the majority of the hydraulic systems that appeared were created and run by the state, its generals, or its bureaucrats, often with the explicit intention of improving logistic capacity and stabilizing revenues. An example is the renovation in 444 of the dried-up Official Canal 官渠 in Ningxia, where the Yellow River turns from a northerly to an easterly direction. Diao Yong 劉雍, the Northern Wei official who proposed this project, explained his motives as follows:

If we think of the farmers, although they still live on the lands around the Official Canal, they are not able to grow any great quantity of crops because it lacks the water for them to do so. Long before my arrival they were failing to pay their taxes in full. There are many soldiers here, all of them either famished or inadequately nourished .... If we wish to look after the interests of the commoners, and assure that the state is well supplied with resources, we need a large quantity of arable land. Since there is a shortage of rain in this region, we must meet this problem by diverting [a part of] the Yellow River.\(^{133}\)
He is said to have succeeded in irrigating about four million *moou*, or rather less than a quarter of a million hectares. Thus, agricultural, demographic, fiscal, and military stabilization; but probably only for a limited time. The reason that the Official Canal had earlier dried up seems to have been a gradual change in the relative heights of the Yellow River and the distribution channels.

When I examined the old canal and its embankments, it was clearly a work of high antiquity, and not of recent date. ... Hills] had been cut through to make a passage for the [water from the] Yellow River. On both banks they had constructed large channels more than 10 paces wide for irrigating the fields.

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**Figure 6**

*Dredging. The massive use of manpower for hydraulic maintenance—an aspect of technological lock-in. A nineteenth-century woodcut reproduced in K. Flessel, Der Huang-ho und die historische Hydrotechnik in China, p. 135*
South of the hills, the water was drawn into these channels. I calculated that when they had been built in ancient times [their beds] were only 10 feet above [that of] the water [coming from the Yellow River]. The waters of the Yellow River [at that time] had moved swiftly through them and carried away the sediment. Today [the beds of] these channels are 23 feet above [the bed of] the water from the Yellow River. What is more, when the water from the Yellow River does gradually make its way in, it often loses its momentum [lit. "subsides suddenly"—bēngtuî 崩塌]. The channels and the irrigated land are now elevated high [above the Yellow River, because of the sediment thus deposited, and the down-cutting of its main course by the river over the centuries], and the water cannot make its way up into them.\textsuperscript{134}

Diao cut a new inflow channel from a point higher up than the original one, but it is unlikely that this remedied the inherent long-term hydrological instability, and the need for a heavy burden of maintenance—in perpetuity—if the system was to continue to survive.

An illustration from the Ming dynasty, about a thousand years later, is a more specific demonstration of this second aspect. According to the local history for the prefecture of Huair’an, where the Grand Canal had to cross the Yellow River (then on a southern course and debouching south of the Shandong peninsula):

When the transport route was opened for the first time [in other words, in the early fifteenth century for this particular section], the Canal was at a higher level than the Yellow River and the River Huair. For this reason it suffered little damage. ... As the levees along the Yellow River, and the lakes alongside [the Canal, fed by the Huair], grew higher and higher, the Canal was progressively at a lower and lower [relative] level. Since the middle of the Ming dynasty we have witnessed disasters caused by flows in the reverse direction [i.e., from the rivers into the Canal], to such a degree that there has not been one year when we have not been burdened with the need to clean it out, dredge it, construct [dykes], and block [off these inflows].\textsuperscript{135}

In other words, simply preserving the existing situation consumed ever more resources.

During the sixteenth century the Chinese authorities tried to go round the rapids in the Yellow River near Xuzhouchu and a nearby section of the river that was frequently blocked with silt, by excavating the Jia River 汗河. This succeeded but at the cost of new difficulties. Here is a description of the President of the Minister of Public Works surveying the route:

He led the public servants with the responsibility for managing the Yellow River up onto the plateaux and down into the swamps in order to calibrate the relative heights. Their route went around the Ge hills, and west of the Xiêngyîh mountains where the topography of the land is flat over a wide area. To the south of the Zhongxin Canal [a name for the older River Jia before this project] there was a lot of blue stone.\textsuperscript{136} He went further south to avoid it and reached a place called Hamzhuang. The terrain here became more and more marshy, and it was possible to cut a path [for the canal]. He thereupon had them dig six
boreholes to 'test the pulse'. When they had gone to a depth of several feet they found small stones and gravels, as well as soil with a texture like curdled milk, and which broke into crumbs when raked over with a hoe ... . “These are the soils we need,” he said, “for cutting a canal.”137

The unfortunate hydrological effects only appeared later. The local history for Peirzhou 皮州 made the following comments:

There is no river greater than the Yellow River, and no river more prone to flooding than the River Yir 沂 [in south Shandong province]. These days the Yellow River flows along the ancient bed of the River Sih 沂, and ever since the River Sih was captured by the change of course by the Yellow River, the River Yir has not flowed out to the south. [In other words, it had become blocked off.]

Since the Jia Canal has been opened, all the rivers in Shandong province have been forced south-eastwards. The River Yirng 莱, the River Wuu 武, the [old] Jia, and the River Yir have been cut off at one and the same time. There is a multiplicity of embankments and of locks, and it has been troublesome finding how best to open and close them. [The water] has been obstructed both to the east and the west, and the pulses of the rivers thrown into confusion ...

Lake Guan … and Lake Liangwang near the mouth of the River Yir, and Lake Wahn … and Lake Zhou and Lake Liur … have all become silted up as a result of these rivers overflowing into them. In the downstream section of the River Zhir 直河 no banks or irrigation channels have survived because of the influx of sediment laden currents.

Thus it is that the transport canal [i.e. the Grand Canal] is a sickness of our stomach and heart, while the Yellow River is a robber who has come into the courtyard of our house. Our stomach and heart are afflicted by choking up, while the courtyard of our house has been thrown into confusion.138

Thus stabilization—of the Canal, and hence of the regular delivery of the imperial tribute in grain—and destabilization—of the hydrological régime of much of southern Shandong—went hand in hand.

Local conflicts over who gained and who suffered from the way in which a hydraulic system was operated or restructured were not uncommon. The Lii Canal 李渠, built in 809, and which provided the city of Yuarnzhou 袁州 (perhaps 20,000 to 25,000 inhabitants during the early Sohng) in Jiangxi province with drinking water, water for washing, water for fighting fires, and transportation, was also used for a time upstream of the city to drive watermills, and, at the other end, as a sort of all-purpose sewer. The watermills were in due course forbidden, as they slowed down the current, and the encroachment by houses eventually made the urban part of the waterway too narrow for boats, while there was a continual battle, necessitating a permanent organization under Canal Chiefs (qurzhaang 渠長), to stop people from throwing rubbish and filth in the stream. It was, for example, forbidden to build kitchens or privies that abutted onto the water.139 In other words, the use of water, as almost always, depended on the distribution of power. Another example, which is interesting as being a sort of zero-sum hydraulic game, is the long-running battle in the middle of

137 Tani Mitsutaka, Yellow River under the Ming, p.165.
138 Ibid., p.247.
the nineteenth century—at times an actual battle, with weapons—in Miaanyang 淇陽, where the Hahn River debouches into the central Yangzii. The clash was between those who favoured allowing the south side to be flooded during periods of peak discharge by the Hahn, this being the preferred option of the government party, and those, the more populist hydraulic rebels, who favoured flooding the north. The rebels won for a while, and built illegal dykes to protect the south, which thereby enjoyed better harvests.¹⁴⁰

Dwight Perkins has shown that by the end of the imperial period, suitable possibilities for new irrigation schemes—of course given the existing level of technology—were probably running short in China.¹⁴¹ To this extent, the old style of growth can be said to have become unsustainable. A less immediately obvious problem, but perhaps of equal importance, was that of pre-modern technological lock-in. What this amounted to was essentially the committing for an indefinite future of the use of a proportion of income and resources simply for the maintenance of existing hydraulic systems, if the previous investment in construction and maintenance was not to be lost. It would seem that the proportion of income, resources, and organizational capacity required was large, but no systematic quantitative study has been done, and this is, for the time being, an impression only. It is also true that the evolution of an environment could, according to circumstances, either remove the burden, as when the seawards extension of a coast made it unnecessary to maintain old seawalls, or increase it, as when storm surges increased in severity. One can find examples of both in the history of Hangzhou Bay. Technological lock-in is a feature of most large-scale premodern Chinese hydraulic systems, and it seems likely that it pre-empted the use of a significant proportion of the economic surplus that might otherwise have been directed to other ends.

As an illustration of the sort of magnitudes involved, consider the rebuilding of 20,000 feet¹⁴² of seawall in Shahngyur 上虞 county on the south side of Hangzhou Bay in 1347. The foundations required more than 60,000 pinetree trunks of a foot in diameter, presumably because pine-resin offered some protection against rotting, and more than a million cubic feet of stone. This was only one one occasion, though interlocked stone lasted longer than earth, and it was only for on the order of 6 kilometers.¹⁴³ The total length of the seawall protecting southern Jiangsu and northern Zhejiang was of the order of 400 kilometers. Repair work on seawalls, often done at the height of summer, are also said to have been responsible for numerous deaths in the labour-force.¹⁴⁴ Bearing in mind that the seawalls were only a part of the total hydraulic system in this area, the overall social cost is unlikely to have been negligible.
Conclusion

The effects of human activities on the environment in China can be seen almost as far back as recorded history in this part of the world (which may be regarded as starting some time not long before or after 1000 BC, depending on how one defines 'history'). They are not intrinsically a modern phenomenon. Already in 276 AD, for example, we find Duh Yuh 杜預 arguing that a substantial part of the irrigation system was environmentally inappropriate overdevelopment:

Those who maintain waterfields [shuuitiam 水田] find it convenient to "plough by burning and weed by flooding" [huoogeng shuuinoh 火耕水耨]. It has always been thus. This operation is, however, only applied to new farmland full of grasses and wild herbs, and located at some distance from where people live. In times past the south-east was only at the beginning of its development, and the human population was sparse. It was for this reason that they found it advantageous to farm by burning. With the continuing expansion of the population in recent times, and the breaches that occur every year in reservoir barrages and dams, good fields have been turned into reed-swamps, people dwell on the brinks of marshes, dry land and water have lost the characteristics proper to them, [livestock] put out to pasture have died off, and trees have rotted where they stood. Such are the disastrous consequences of reservoir barrages.

If reservoir barrages are numerous, the soil becomes 'thin' [baor 淺] and the water 'shallow' [qiaan 浅 – lacking in nutrients?], so that floods do not deposit a fertilizing richness … . A clear edict ought to be issued to the effect that while old reservoir barrages and dams dating from Hahn times, and small private reservoir barrages up in the mountain valleys, should be kept in good order so that they retain their water, all of those constructed since Weih times, and all of those that have broken and flooded because of rain and are full of reeds and maacharn 草[145] are to be breached and drained.146

We should need to know more than we do at present about the effects of the fall in mean annual temperature that was under way at this time before judging how far his position was well-founded, but the call for deinvestment on environmental grounds is noteworthy.

Second, some of the consequences of premodern human activity, though developing at a slow tempo compared to their modern counterparts, were on a huge scale. Long-term deforestation (especially in the eighteenth and nineteenth centuries), and the worsening hydraulic problems of the Yellow River on each new lower course to which it shifted, during periods when the stripping of its mid-course vegetation cover had intensified, and arising from the enclosure of its varying lower courses between levees, are two examples. From the point of view of the local human society these anthropogenic effects contained a complex mixture of benefits and costs that are all but impossible to evaluate overall in any reasonably objective way. In practice, after the end of the archaic period (which varied from region to region but which we may think of as occurring in general about 500 BC) two forces
tended to dominate patterns of decision-making that had a major impact on the natural environment: (1) the search for state military and political power through the creation and appropriation of a growing and dependable supply of tax-resources, soldiers, and conscripted labour—especially in the early period; and (2) the pressure of a population growing at an ever-increasing rate—especially in the late period. Both forces can be said, with only slight and obvious qualifications and nuances, to be still at work today.

Third, in several respects the pre-modern Chinese economy also became 'locked in' to the patterns in which its technology interacted with the environment. This term can be defined by three criteria: (1) the exit costs to different and perhaps ultimately better patterns tend to be high (the inhabitants of an unmaintained polder starve even if they do not drown), (2) further expansion runs, after an initial boom period, into environmentally imposed constraints (limited supplies of water prevent the double-tracking of Grand Canals), and (3) large and often increasing amounts of resources and income have to be devoted to maintaining existing systems if the original investment incurred in creating them is not to be lost (thus seawalls can come under intensified pressure from tides and storm surges). This complex of phenomena has been illustrated from various aspects of the premodern Chinese hydraulic economy, with its massive but perpetually unstable installations, and while these are probably the most striking examples, they are not the only ones that could be given.

While the final premodern incarnation of the late-traditional Chinese farm economy had skills in soil-maintenance, and a per-hectare productivity by premodern means, that rightly impressed pre-World War Two Western agronomists like F. H. King, who were aware of the self-destructive aspects of high-technology Western farming, it should not be romanticized. The overall system was not indefinitely sustainable, chiefly because of its population growth, but also because of what it was doing to its forests and upland soils.

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