Linking Human and Natural History: A Review Essay*

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John R. McNeill, professor of history at Georgetown University, Washington, DC, has written an excellent environmental history of the twentieth-century world. The first two-thirds of his book are extensive and engaging reviews of changes in the Earth's soil and crust, atmosphere, hydrosphere, and biosphere. The last third attempts to identify the driving forces behind these unprecedented environmental changes. McNeill's account is broad, balanced, insightful, scholarly, and enjoyable to read. It will be valuable to anyone interested in how our environments have come to be as they are, whether as an educated layperson, student, or scholar. His many concrete descriptions suggest a richer picture of the engines of environmental change than is sometimes advertised elsewhere. This enriched picture will be useful and important to those seeking guidance on how to manage, understand, or simply live with environmental changes in the twenty-first century.

Environmental changes in the twentieth century were dramatic. Table 1, based on McNeill's Table 12.1 (pp. 360–361), estimates the magnitude of some of them. I have added some estimates from other sources. McNeill's note, appended to the table, that "some of the numbers are more trustworthy than others" illustrates his characteristic and laudable caution, and applies to the estimates I have added as much as to his. Not one of the environmental, economic, and demographic variables listed in Table 1 was the subject of an objective, reliable, global statistical system in 1900, and most still were not in 2000. (Now is the time to begin writing the environmental history of the twenty-first century, by getting global environmental and social data

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TABLE 1 Changes in selected environmental, economic, and demographic indicators during the twentieth century

Item	Increase Factor: McNeill's estimate, 1890s–1990s	My estimate, 1900s–2000
World population	4	3.7
Annual increment to world population		7.8
Life expectancy at birth		2.2
United States population		3.7
China population		3.3
Urban proportion of world population	3	3.6
Total world urban population	13	13.7
Population of single largest metropolitan area		4.3[c]
World economy	14	16
Gross domestic product per person		4.1
Industrial output	40	
Energy use	16[a]	10[c]
Coal production	7	
Air pollution	≈5	
Nitrogen released in NO_x from fossil fuels		21
Carbon dioxide emissions	17	14.6
Carbon dioxide emissions, 1900–1996[b]		12.2
United States carbon dioxide emissions, 1900–1996[b]		8
CO_2 partial pressure in the atmosphere		1.2–1.3
Sulfur dioxide emissions	13	
Lead emissions to the atmosphere	≈8	
United States nonfuel minerals consumption, 1900–1995[c]		29
United States nonfuel wood products consumption, 1900–1995[c]		3
United States metals consumption, 1900–1995[c]		14
United States fossil-fuel-based synthetics consumption, 1900–1995[c]		82
Water use	9	7–9
Marine fish catch	35	
Cattle population	4	
Pig population	9	
Horse population	1.1	
Blue whale population (Southern Ocean only)	0.0025 (99.75% decrease)	
Fin whale population	0.03 (97% decrease)	
Bird and mammal species	0.99 (1% decrease)	
Irrigated area	5	6[c]
Forest area	0.8 (20% decrease)	
Cropland	2	
World grain harvest		4.8[c]

NOTE: Some of the numbers are more trustworthy than others. Comments on their reliability appear in the text, from which they are all drawn.

Estimates by McNeill are from pp. 360–361. Unless here attributed to another source, my estimates are derived from Cohen (2002, pp. 30–32), where citations to original sources are given. [a]Revised to 13 in the 2001 British Penguin paperback edition. [b]Hunter 1999, p. 13. [c]Starke 1999.

systems in place.) McNeill notes (p. 361): "This table ignores expansions that took place entirely after 1900, such as CFC releases or tractor numbers. It ignores expansions for which the baseline of 1900 would produce astronomical coefficients of increase, for example, the world's total of automobiles, the quantities of chemical fertilizer applied, or the tonnage of synthetic chemicals produced. The table is an imperfect measure, but it gives the right impression."

McNeill titled his version of Table 1 "The measure of the twentieth century." That is a slight overstatement, considering the twentieth century's changes in science, medical, chemical, and information technology, women's rights, life expectancy, literacy, democratic governance, trade, and material intensity of production, for example. Nevertheless, McNeill is right: the table is both revealing and suggestive.

Accepting McNeill's round numbers, total population grew nearly 4 fold. The only other indicator listed that also grew 4 fold was the size of the cattle population. Many other indicators of human impact on the environment grew by far more than a factor of 4: carbon dioxide emissions (17 fold), sulfur dioxide emissions (13), lead emissions to the atmosphere (8), water withdrawals (9), and marine fish catch (35). Some indicators that might have been expected (in 1900) to grow in proportion to human population size grew by less than a factor of 4: the horse population (1.1) and the area of cropland (2). Clearly human numbers were not the sole determinant of environmental change in the twentieth century. From the past lack of proportionality between human population growth and the magnitude of environmental changes, it seems reasonable to anticipate that if global human population growth ends in the twenty-first century, human impacts on the environment will not necessarily level off in parallel. What else was involved in past changes? Table 1 suggests some of the answers: economic growth (the increase of capital, production, and income) and technological change.

Economic growth, illustrated by the reported 40-fold increase in industrial production and 16-fold increase in energy use, was partly responsible for increased carbon and sulfur emissions to the atmosphere, as well as for a roughly 4-fold rise in global average income per person during the twentieth century. McNeill's text, but not Table 1, points out that economic growth has also enabled environmental clean-ups in wealthy countries that chose to clean up.

Technological changes displaced the horse. Technological changes also increased industrial water usage. An increase in irrigated area (up 5 fold) contributed to the 9-fold increase in water withdrawals. Irrigated cropland can be much more productive than rain-fed cropland. The spread of irrigated cropland since 1960 contributed importantly to keeping the total area of cropland under cultivation more or less steady since world population reached 3 billion in 1960; prior to 1960, cultivated cropland had increased nearly in direct proportion to population (Evans 1998, p. 205). Other factors besides increased irrigation that enabled the same amount of land that fed 3 billion people in 1960 to feed more than 6 billion in 2000 were new genetic varieties of major cereals, pesticides, artificial nitrogenous fertilizers, credit and market institutions, improved transport, and farmer education. Thus technological and other changes brought environmental tradeoffs in agriculture. More nitrogen (and methane) into the atmosphere, more nitrogen into groundwater, more water use, and massive global genetic change (evolution under human guidance) in cultivars of wheat, rice, and maize accompanied a leveling off of the area under cultivation and a savings by 2000 of cultivated cropland roughly equal to all currently cultivated cropland.

During the twentieth century, other environmentally influential technological changes included the invention and worldwide diffusion of stainless steel, the tractor, new varieties of other agricultural plants and animals, modern contraceptives, radio, television, films, computers, the Internet, antibiotics, vaccines, the chainsaw, the airplane, and physical, chemical, and biological weapons of unprecedented destructive power. Obviously technology affected the environment.

That the collective environmental impact of humans depended not only on how many people there were, but also on how wealthy those people were and on the technology those people used to generate their wealth was evident long ago to Barry Commoner (1971) and John Holdren and Paul Ehrlich (1974). They proposed and subsequently promoted a simple, very influential formula, widely taught, used, and criticized, which is commonly referred to as the IPAT formula: I=PAT, or

$$\text{Impact on the environment} = \text{Population} \times \text{Affluence} \times \text{Technology.}$$

Because McNeill's book is not explicitly theoretical, he never directly addresses the IPAT formula, for or against. But empirical description and interpretation reflect a theory, possibly implicit, about what factors are pertinent to understanding change. McNeill's interpretive section called "Engines of change," the last third of the book, has three main chapters: "More people, bigger cities" (here is P, in a sophisticated form that recognizes environmental impacts of migration and urbanization); "Fuels, tools, and economics" (here are A and T, but also observations about economic systems covered by neither Affluence nor Technology); and "Ideas and politics." The IPAT formula reflects some of the contributions of wealth and technology to environmental impact and makes it possible to organize several of the indicators of change in Table 1 as contributors. McNeill builds on, and goes beyond, the IPAT formula by adding to its right side (PAT) three important classes of factors, at least equally important but perhaps not so tidily quantified:

—Culture, including "big ideas," environmental ideas, domestic and international politics, war, and environmental policies;

—Market size and structure; and

—Autonomous or exogenous environmental change not caused by humans.

In this sense, McNeill's book is not a "PAT answer" to the challenge of understanding environmental change in the twentieth century. Let me illustrate.

Culture, especially politics

Agricultural changes in the twentieth century depended on culture as well as on technology. For example (p. 226), while the "biological, chemical, and mechanical transformations of modern agriculture took hold" in much of the West and much of Asia, the "Soviet Union partly missed out because modern genetics rankled the socialist sensibilities of Stalin and Khrushchev, delaying progress in plant breeding until the mid-1960s. Before 1960 the USSR partook of mechanization and irrigation, but only after 1965 did it undertake conversion to the doctrine of genetic manipulation and heavy use of nitrogen. Thus the total geopolitical effect of modern changes in agriculture improved the relative position of the West and Japan slightly, that of China, the Asian tigers (South Korea, Taiwan, Malaysia), and Latin America even more slightly, while contributing to the relative decline of Soviet status, and to the weakness of Africa." Culture kept modern genetics out of the Soviet Union for a time, and that lag weakened the Soviet Union geopolitically. (Could there be a lesson here for the United States in its approach to continued genetic research?)

Like this example, many of McNeill's historical cases, and nearly all the topics in his chapter on "Ideas and politics," involve culture, though the word "culture" does not appear in the table of contents or index of McNeill's book. To see why culture is a relevant concept, it is useful to recall some definitions. Richard Shweder, an anthropologist at the University of Chicago, writes (2000, p. 7): "By 'culture' I mean community-specific ideas about what is true, good, beautiful and efficient. To be 'cultural' those ideas about truth, goodness, beauty and efficiency must be socially inherited and customary; and they must actually be constitutive of different ways of life. Alternatively stated, 'culture' refers to what Isaiah Berlin (1976) called 'goals, values and pictures of the world' that are made manifest in the speech, laws and routine practices of some self-monitoring group." Shweder quotes with approval Robert Redfield's 1941 definition of culture as "shared understandings made manifest in act and artifact." All these definitions serve here, and all include politics.

Some of the great political changes of the twentieth century include: the end of colonialism; the end of legally sanctioned racial segregation; the establishment of political, social, and economic rights for women; the rise and fall of Communism; the spread of democracy; and the establishment of economic growth as what McNeill calls a kind of "state religion" in authoritarian and democratic nations alike. McNeill illustrates the environmental impact of these political changes.

In North America, politics affected the environment before the existence of the United States. The tall trees of New England were felled in part to provide masts for the ships of the British Navy. Politics influenced deforestation in the twentieth century, for example through government subsidies to logging, land clearing, and road building in forests. Politics also promoted the recovery of forests through subsidies for carbon sequestration and conservation.

The military draft of men to fight in the American Civil War in the 1860s caused a labor shortage, which accelerated the spread of horse-drawn threshers and reapers. These machines prepared the way for the American conversion to the tractor and other mechanized agriculture between 1920 and 1955. Wherever mechanization was powered by fossil fuels, fewer people and fewer draft animals were required to work the fields and bigger farm fields became economical. Mechanization released a vast agricultural labor force to go to cities.

In the former Soviet Union, an ideological commitment to big enterprises as demonstrations of the power of the state led to state farms that averaged, by 1977, 40,000 hectares, three times the size of Washington, DC. Often these vast treeless fields suffered intense soil erosion from wind.

In the Po Valley in northern Italy, in the Tennessee Valley Authority and the Colorado River system in the United States, along the Volga River in the Soviet Union, in India, China, and Egypt and elsewhere, dams to extend irrigation, control floods, and generate electricity always also served larger political purposes. They demonstrated to the people the power of the state to control nature for the social good. This demonstration was helpful to whoever was in power at the time, be it Roosevelt, Stalin, Nehru, Nasser, Nkrumah, or many other leaders. In the 1960s, more than one large dam at least 15 meters high was completed every day on average. By 1990, two-thirds of all the world's streamflow passed over or through dams. The diversions of water from natural courses reduced the Aral Sea from the world's fourth-largest lake to its eighth-largest lake. The full environmental consequences of damming the rivers that drain into the Mediterranean Sea have yet to be felt.

Only the politics of distrust could account for Nasser's placement of the Aswan dam in southern Egypt, rather than further upstream in existing lakes in Ethiopia and Uganda. In southern Egypt, a region with one of the highest rates of evaporation on Earth, the reservoir increased the surface area from which Nile water evaporated.

Politics governed societies' responses to air pollution in Mexico City, Athens, London, Pittsburgh, Peru, Ontario, the Ruhr of Germany, and the industrial complex between Dresden, Prague, and Krakow. From the beginning of Japan's Meiji restoration in 1868, the central government's intense commitment to industrialization, militarization and imperialism sacrificed local livelihoods and overran local resistance. After World War II, economic power replaced military power as the state religion of Japan. In 1961 the Yawata steelworks dumped 27 tons of soot and dust from its smokestacks every day. A fisherman whose livelihood was destroyed by the steelworks lamented: "With the development of the Japanese nation, and the development of this region, it is us fishermen who have become the victims" (quoted on p. 95). Until about 1965 Japanese polluters were protected in the national interest. Remarkably, between 1965 and 1985 Japan completely reversed its pollution policies and practices. By 1985 its citizens had nearly the cleanest air of any industrialized country. According to McNeill (p. 116), "women played a conspicuous role" in successful efforts toward smoke abatement in the United States, the United Kingdom, and Japan.

The political, economic, and social status of women changed in most countries around the world during the twentieth century. In 1900 women had full suffrage in New Zealand, and in no other nation (Kerber 2001, p. 20), although a few American states allowed women to vote. The Constitution of the United States was amended to guarantee women the right to vote only in 1920, 42 years after the amendment was first introduced into Congress. Between 1970 and 1990 the worldwide labor force participation of women relative to men nearly doubled. The number of economically active women rose from 37 to 62 for every 100 men engaged in the cash economy. These dramatic changes in the cultural and economic roles of women coincided with the equally dramatic fall in global fertility since about 1970. The direction of causation, if the link is causal, is not obvious, but the importance of culture in the change of fertility is clear. Political and economic changes in the status of women affect and are affected by changes in the number of children they have. Changes in the number, size, and composition of individuals and households have environmental consequences, for example through the number of refrigerators, housing units, and fuel consumption per person (Hunter 2000).

Market size and structure

That increases in industrial production and increases in income or purchasing power can (but need not necessarily) have environmental consequences is obvious and familiar. Economic integration has had environmental consequences that go beyond those captured by Affluence and Technology in the IPAT formula. As McNeill observes (p. 320), "Economic integration focused the dispersed demand of millions upon limited zones of supply." When the object of purchase was biological, such as elephant ivory, rhinoceros horn, giant panda skin, or tortoise shell, the rate of production typically could not be accelerated to keep pace with the increased demand. In such cases, instead of taking only a sustainable yield, extraction drew down the productive stock, pushing many exploited species toward extinction. Technology interacted with economic integration. Information technology spread news about what could be bought. The invention of canning factories changed many salmon runs on the American West Coast from resources for local consumption to resources for global food markets.

In many regions, traditional regimes for managing common property prevented the environmental damage that results from overexploitation. "The buffeting winds of globalization brought new shocks to these small-scale social systems. In fishing, for example, bigger operators tapping distant markets [for both sales and capital investments] introduced trawlers and overwhelmed artisanal fisherman, whose common property regimes often collapsed. Free-for-alls ensued, and the fisheries collapsed too" (p. 321).

Where economic integration, war, and political uncertainty weakened local people's security in holding local productive resources (as in Ethiopia, China, and Russia), the incentives for speedy exploitation, even if unsustainable, increased.

After World War II, "development banks" (such as the World Bank, the Inter-American Development Bank, the Asian Development Bank, and a few others) were charged with helping poor countries escape poverty. Using the funds generated by global economic integration, including funds from the oil trade, the development banks invested in infrastructure such as roads, power plants, dams, and extraction facilities for fuels and minerals. According to McNeill (p. 323), until 1987 the banks, with the consent and cooperation of recipient governments such as Brazil, India, China, and Indonesia, paid little attention to the ecological effects of their loans. Only after 1987, in response to American pressure, did the World Bank begin to require environmental assessments. Other banks changed their practices slowly.

Exogenous environmental change

Exogenous environmental change is part of the story of environmental change in the twentieth century. When drought hit Saskatchewan in the 1930s, the farmers were practicing cultivation techniques more appropriate to humid lands of eastern North America and Europe. Dust storms destroyed 3 to 4 million hectares of prairie wheat lands. By 1934 the dust blew as far east as the Atlantic. Farmers in Oklahoma and Kansas experienced similar distress in the Dust Bowl of 1931–38. The drought-stricken regions of western Canada and the United States saw farmers leave en masse. According to McNeill (p. 47), "two chief factors explain modern increases in erosion: migration or growth of population, and the intensification of market links."

True, if farmers had not brought European agricultural practices into the prairies of United States and Canada, the massive soil erosion experienced in the 1930s could probably have been avoided. However, if there had not also been sustained drought, there would not have been dust bowls.

Saline seeps, not caused by irrigation, retired about one million hectares of farmland in North America's high plains between 1945 and 1990—an area equal to Lebanon's (p. 47).

Before the twentieth century, the end of the three-century-long European Little Ice Age around 1850 "may also have had a minor role in permitting the great modern expansions" (p. 17) of human numbers, consumption of energy, and economic production. I find it irresistible to correlate the warmer and wetter climate of the European Medieval Warming of 1100–1300 (Roberts 1998, p. 215) with the onset and spread of European urbanization at the same time (Cipolla 1994, pp. 183–198). According to Roberts (1998, p. 214), "it is hard not to see a causal link between the medieval cooling of the fourteenth and fifteenth centuries and the extinction of the Norse settlement in Greenland around AD 1500."

Just as a single year is an insufficient basis to estimate the environmental variability of a century, so a century is an insufficient basis to estimate the environmental variability of the last hundred centuries. A longer perspective (Roberts 1998) is required to complement McNeill's story of the environmental changes in the last century. Geologists call the period of the last 11,500 years the Holocene. The 115 centuries of the Holocene have seen enormous changes in landforms and landscapes. Some coastal regions rebounded upward when released from the weight of glacial ice, while others were submerged as the seas filled with the melted ice and seawater expanded in the warmth. Forests spread over vast regions that had been bare tundra in the previous ice age, which lasted nearly 120,000 years. Soils were formed and transformed. Until almost the time when the pyramids were built in Egypt about 4,600 years ago, what is today called the Sahara Desert had been a land of lakes and streams for more than 4 millennia. Humans were greatly affected by all these changes, but began to have major effects on landforms and landscapes only in the latter half of the Holocene, as agricultural implements and agricultural fields were invented and fixed human settlements were established. (Human mass-hunting and burning had important biotic effects much earlier.)

A still longer perspective is required to see that even the dynamic Holocene has enjoyed an exceptionally placid and benign climate, compared with the rest of human prehistory. Multiplying 100 centuries by another factor of 100 reaches back a million years to the middle of the Pleistocene, when tool-making hominids already existed. In the last 800,000 years, there have been about eight major glacial-interglacial cycles, each lasting about 100,000 years, and for most of that time much more of the Earth than at present was covered with ice. For example, about 18,000 years ago, the Wisconsinan ice sheet reached northern Pennsylvania, Ohio, Indiana and Illinois. Modern humans (*Homo sapiens sapiens*) first appeared about 120,000 years ago, at or shortly after the onset of the last glacial stage, which ended with the beginning of the Holocene. While many genera and species of Pleistocene plants and animals still survive, many large land mammals and birds have vanished, including mammoths, mastodons, long-horned bison, saber-toothed cats, giant ground sloths, and great predatory birds with 25-foot wingspans. Native horses (now extinct) and camels crossed the plains of North America. Ice cores from Greenland and Antarctica demonstrate high levels of climatic variability on millennial and longer timescales (Turekian 1996, pp. 126–127). Abrupt transitions on the scale of decades may have been associated with major changes in oceanic circulation (Broecker 1997). Climatic variability has been hypothesized to have played a crucial role in the evolution of modern humans during the Pleistocene, although the details of this process remain controversial (Vrba et al. 1995; Richerson and Boyd 2000).

The Holocene and Pleistocene perspectives reveal that the environments of humans have always been dynamic on the grand scale and that the thousand-fold growth of the human population since the beginning of the Holocene has been fostered and sheltered by exceptionally favorable climate. Recent biological, chemical, and physical perturbations by humans of oceans, continents, and atmosphere amount to a global experiment with unpredictable outcome.

If the global cooling that has been the dominant trend of climate during the last 50 or 60 million years continues, and if humans continue to exist a few million years more, it seems plausible to expect humans to evolve and adapt further in response to climatic change.

Apart from a few minor errors of detail, McNeill's book is a trustworthy guide to the most recent century of humanity's global experiment. (The statement on page 31 that coal extraction grew tenfold in the nineteenth century is contradicted by the data in the table on the same page, which show a 76-fold increase. The percent increases on page 264 should all be reduced by 100. The statement on page 205 that "All tropical diseases are waterborne in a loose sense" would not seem to consider African trypanosomiasis (sleeping sickness) or American trypanosomiasis (Chagas' disease). The statement on page 212 that the land surface of the globe not covered by ice or sand is 133 million hectares should be 133 million km^2. Small errors like these are inevitable in a work of this scope and complexity, but suggest that it would be worthwhile for readers to check details with independent sources.) These small errors do not undermine the strength and value of this book.

Nature is variable. The Biblical story of the seven fat years followed by the seven lean years illustrates that the consequences for humans of natural variability in rainfall depend crucially on human preparations for and responses to such variability. Exogenous environmental change deserves recognition because it will be part of environmental change in the twenty-first century and thereafter.

Concluding remarks

In its report on development and the environment, the World Bank (1992, p. 39, Fig. 1.4) displayed a more general equation, based on the IPAT formula, to relate economic activity to its environmental impact. According to the World Bank's equation, the quality of the environment equals the product of four factors: the scale of the economy (itself a product of income per person × population) × output structure (what people demand as final products, such as private cars or public transport, beef or beans) × input–output efficiency (the amount of various resources consumed to produce each final product) × environmental damage per unit of input. Here Population, Affluence and Technology all appear explicitly. Culture appears implicitly in the output structure and input–output efficiency (what do people want the economy to produce? how important are formal education and economically productive work in the culture? how well do workers apply knowledge to their economic activities?) (Cohen 1995, p. 388). Moreover, culture affects policy: the World Bank recognized that economic policies affect productivity and the composition of output (the first three of these four factors) while environmental policies change incentives governing the use of environmental resources (the last three of these four factors).

The World Bank's implicit recognition of culture gives no representation to McNeill's accounts of the roles of high politics and global market structure in shaping the environmental impacts of economic activity. The World Bank's equation certainly does not take account of exogenous environmental change. The empirical riches of McNeill's book pose a conceptual challenge to general understanding that has not yet been met. Appreciation of the complexities he describes should save his readers from an unjustified faith in the promise of simple remedies to environmental challenges.

McNeill writes in closing (p. 362): "Modern history written as if the life-support systems of the planet were stable, present only in the background of human affairs, is not only incomplete but is misleading. Ecology that neglects the complexity of social forces and dynamics of historical change is equally limited. Both history and ecology are, as fields of knowledge go, supremely integrative. They merely need to integrate with one another." The science that integrates the human and natural history of the Earth remains to be created.

Note

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