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War and the Environment[1]

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The environmental legacy of warfare and mass violence has recently emerged as a recognized dimension of environmental history. It draws on many familiar subjects, from the history of state formations, social structures and economics to military, demographic and disease history, and historical geography. Military historians have routinely written about the significance of terrain and weather for the planning and management of campaigns. Moreover, they have frequently traced military planners' concern for manipulation of the natural resources that are essential (or at least valuable) for their strategic purposes, and even the use of natural processes (such as fire) as weapons. But their interest lies almost exclusively with the human drama; they almost never go beyond that to consider the resulting transformations of ecosystems. They see Nature as context, but not as consequence, of mass violence.

Environmental historians have often discussed elements of the history of warfare. But until recently they rarely considered the dynamics of mass violence or the structures of military operations in relation to state, society, economy and ecology as the organizing focus of their work. To date, most of the work has centered on the industrial era, beginning with the American Civil War, and thus has addressed the leading industrial countries. Centering at first on the global devastations of two world wars, studies have broadened to consider the structures and consequences of massive permanent military establishments, especially during the Cold War. Themes include the global reach of the major economies for control of strategic resources, and the impacts on economies and ecosystems. Yet a full perspective on the worldwide history of war's ecological consequences is still to emerge. Brief but provocative surveys of pre-modern regions and long historical themes have begun to appear, as building blocks toward a

full global history. Beyond that, what outlines can be sketched? This essay illustrates several themes that appear in the emerging synthesis.

Campaigns of Conquest and Frontier Wars

Expanding empires' shifting frontier zones have often undergone major environmental transformations. Under the Roman Empire, as imperial armies moved northward in the conquest of Gaul and then southern Germany and Britain in the first centuries of the common era, their engineers built a system of all-weather roads so superbly engineered that some are still in use today.[2] On the northern frontiers of the empire, as far as the Rhine and beyond, a string of fortified military cantonments sustained garrisons of troops. These military installations were the nuclei of the domestication of entire landscapes, as peasants cleared hundreds of patches of forest for settled agriculture, even in the midst of chronic skirmishes between the Romans and their Germanic adversaries.[3] When the empire declined and its military control dissolved, hundreds of settlements remained into medieval times.

In the Middle East, the Arab Muslim conquest of the Tigris and Euphrates valley was very different, as a long-settled civilization came under conquest. The hot, semi-arid lands of the basin had been domesticated for thousands of years by the construction of elaborate irrigation systems which were prone to processes of waterlogging, siltation and salination.[4] Periodic warfare among city states and regional empires repeatedly disrupted the system's productivity. By the time the first Arab Muslim armies penetrated into the Fertile Crescent in the late 630s the region's irrigation system was in serious decline.[5] The Muslim overlords in the new city of Baghdad encouraged the revival of rural productivity, partly to enhance state revenues, which they used to finance military campaigns. But the long-term ecological decline of the irrigated lands could only be partially reversed. Mongol invaders raced through the Abbasid Empire's heartland and captured Baghdad in 1259, massacring the entire population of the city. "Baghdad and Iraq never again recovered their central position in the Islamic world. The immediate effects of the invasion were the breakdown of civil government and the consequent collapse of the elaborate irrigation works on which the country depended for its prosperity, even for its life."[6] Throughout the turbulent history of the Middle East since then, irrigation systems have been vulnerable targets for armies.[7]

The environmental history of Imperial China's frontiers was closer to that of Imperial Rome in some ways, in sparsely settled zones of contest with barbarians. On China's northwest frontier, facing perennial threats from nomadic warriors of the Mongolian steppes, Chinese emperors built defensive fortifications dominated by the thousand-kilometer-long Great Wall, clearing forests on some adjacent lands for security. They protected other forest zones, to guard against invading cavalry.[8] In contrast, they pursued a policy of imperial conquest in the southwestern frontier region, where mountainous Guizhou province was home to a wide range of tribal cultures,

especially the Miao, who resisted Chinese civilization for centuries. Like the Romans, Chinese armies built roads and garrison settlements to move military columns and pacify the region, opening it to agricultural settlement and forest reduction by immigrants from the north.[9]

Often protracted and intermittent, frontier wars were similar in many ways to modern guerrilla warfare and counter-insurgency, though they did not result in the devastation that is caused by today's counter-insurgency weapons. They were characterized by seasonal skirmishes and raids, fortified outposts, capture of loot including movable natural resources, and probably most significant, the dislocation of rural populations. Many were fought in mountainous or hilly areas, on forested slopes with easily eroded soils.

Foraging Armies

Until recent times armies lived off the land; their logistical support systems were so rudimentary that nothing else was possible.[10] This process provides the key to much of the damage caused by wars, from ancient times onwards. Classical Greece exemplified the process. The Mediterranean borderlands feature long hot summers and short wet winters; their topography is mostly mountainous, with soils that are light and easily eroded once natural vegetation is removed. Armies of the Greek city-states pillaged their enemies' farmlands, destroying annual crops and olive groves.[11]

Rural people fled to safety in the hill forests or fortified towns ahead of advancing military columns. In the Peloponnesian War (431–04 BCE), which ended the golden age of Athens, the Spartan army repeatedly ravaged the farmlands of Attica, Athens' agricultural base, destroying crops in an unsuccessful effort to starve the city into submission.[12] These campaigns were the grim precursors of modern "total war," obliterating the distinction between civilian and military targets. The short-term impacts were obvious to everyone involved; the longer-term environmental results are more difficult to measure.

Southern Italy suffered similar damage to its agricultural lands on a larger scale two centuries later, when the Carthaginian general Hannibal invaded the Roman Republic in the Second Punic War (219–01). In a long military stalemate, thirteen years of annual summertime fighting in southern Italy impoverished the land, as both armies attempted to deprive each other of provisions.[13] The environmental result was neglect of tilled lands, forest depletion in hill regions and watersheds, soil erosion into streams and rivers, and coastal siltation. In the disturbed coastal zone malaria became endemic, throughout the region's subsequent history until the DDT campaign that followed World War II.

In the monsoon climate belt the Indian subcontinent saw similar impacts of military movements. In the upper Indus and Ganges river basin, the Mughal empire's armies (1524–1707) led by elephant corps and cavalry devoured the food and fodder

resources of the land. The imperial army was a mobile city of nearly a million fighters, camp followers, and suppliers, who stripped wide areas of everything useful as they moved. Cavalry swept the countryside, depopulating villages; rural society and its biological base could take decades to recover from the disruption.[14]

Medieval European history showed similar patterns on the land during wartime. Until the late 1700s a perennial problem was how armies were recruited and compensated. Lords on manorial estates and the serfs who worked their lands were both warriors whenever military campaigning demanded. In the age of chivalry mounted knights on heavy horses dominated battles. Foot soldiers were of two sorts: local militias of impressed peasants, and mercenary bands organized by military entrepreneurs. Their rewards most often came in the form of booty, a chaotic process always disruptive to agro-ecosystems. The Hundred Years War in France (1337–1453) was a major example of undisciplined armies ravaging crop lands, marshlands and woodlands. Many campaigns were renewed for years, devouring both woods and croplands in the process.[15] In the twilight zone between mass violence and peaceful times, including after campaigns were over and temporary troops were disbanded, brigandage (hardly distinguishable from regular soldiering) festered.[16] Lands deserted when rural people became refugees reverted toward natural woodlands and wetlands, with concomitantly increasing species diversity. The short-term damage to partially domesticated landscapes was evident to anyone with eyes. The long-term ecological transformations of the early medieval period are difficult to assess, since the long term was a matter of peacetime recovery processes.

Fortifications and Sieges

Throughout medieval Europe, in the decentralized society that succeeded the Roman era, lords of the land built massive fortifications surrounded by earthen ramparts with wooden palisades. Each required rock from quarries and timber from forests; each had moats and ramparts that disturbed the soil. Hundreds of manorial castles and fortified towns dotted the land, and each was surrounded by crop lands, pastures and forests. Sieges of these fortresses and fortified towns often lasted for entire summer seasons, when invading armies could be maintained. Attacks and counter-attacks left more severe damage to surrounding lands than the simple passage of a moving army. Rebuilding settlements after the end of a war required yet another round of timber supplies.[17]

Warfare coincided with disease and helped spread epidemics of plague, typhus and other diseases; in tandem war and epidemics reduced population. The greatest example in Eurasian history was the 1348–51 bubonic plague, which killed something like one third of Europe's people in the midst of the Hundred Years War. The mortality was likely intensified for both military and civilian populations in the disrupted conditions of war zones.[18] In the postwar stillness once-tilled farms were deserted,

reverting to pasture or more gradually to secondary woodlands where wildlife flourished and local biodiversity increased in semi-wild habitats. But in the longer run these changes were usually reversed, for farmers sooner or later renewed agricultural landscapes with the return of peace and security.

The destructive power of weapons began to accelerate when gunpowder, was introduced into Europe in the 1300s, and was followed by the development of steadily more powerful cannons. In response, fortifications became far more elaborate by the 1500s. The Military Revolution was in full swing, accelerating arms races on both land and sea.[19] In the Thirty Years War (1618–48) northern Europe degenerated into chaos, as anarchic military bands repeatedly pillaged the land until the region reached a point of general exhaustion.[20]

In the aftermath much of Europe saw the emergence of centralizing states with ever-expanding professional armies, supported by vastly expanded fiscal administration and government revenues.[21] Disciplined armies with better organized supply lines meant reduced environmental damage in the lands of neutral populations. Though there had always been close relations between rulers and civilian suppliers, this era showed the clear emergence of a "military-industrial complex," in which governments coordinated closely with their suppliers.[22] Taxation became more regular, as military economies became more systematized and provided support for accelerating lethality.[23] Bankers and merchants could follow the temptations of profiteering on a previously unknown scale – a driving force behind warfare, though not always visible. In all, Europe's expanding imperial states would lead toward both global conquest and ever-greater scale of destructive power in the industrial era.

Globalization: The West's Modern Empires

Until the sixteenth century the ecological impacts of wars were largely limited to areas of conflict and their source locations for wood and metals. Then pressures on the biosphere rose, as the era of the imperial nation-state and large-scale capital and industry accelerated the technological impacts associated with global trade and transport.[24] The frontier wars of European conquest were the cutting edge. Over a half millennium European empires, later joined by the United States, dismantled non-state societies in temperate forests, savanna lands, and tropical rainforests. The Western empires commanded weaponry that ultimately overwhelmed all opponents by the late nineteenth century.[25]

Early ecological damage outside Europe reflected the navies' needs for construction timber and naval stores. By the 1700s European navies began cutting the hardwood and white pine stands of northeastern North America, the coastal hardwoods of Brazil, and later the teak forests of monsoon Asia, to find substitutes for the depleted English oak and Scandinavian conifers.[26]

The most fundamental ecological impact of Europe's global conquests occurred in the Americas, where Europeans brought with them epidemic diseases that were a holocaust for the indigenous people. Up to 90 percent of the indigenous American population had died by the late sixteenth century.[27] This depopulation led to widespread abandonment of cultivated lands and reversion to secondary forest, often for long periods.

In Latin America even in the 1500s the impacts of conquest registered on lowland coastal zones and riverine forests, the highlands of Mexico and the Andes, where sheep and goats came to rule degraded pasture lands, and the wide natural grasslands where cattle soon prevailed.[28] Aside from these cases, the systematic study of environmental changes caused by warfare in Latin America has barely begun.[29]

In an ironic case of warfare and epidemic disease, by the 1700s Iberian-Americans who had settled in the New World were relatively immune to malaria and yellow fever. The dreaded twin diseases were their allies in defending their colonial empires against newcomer challengers from northern Europe, until the collapse of the Old Regimes in Spain and Portugal during the Napoleonic Wars.[30]

In North American woodland settings the impact of endemic frontier warfare was somewhat different. There Europeans followed up their conquests by settling on the land and clearing temperate forests far more readily than they could anchor themselves in tropical forest zones. In contrast to Latin America, where populations did not recover to their pre-1492 levels until around 1800, the native populations of North America were fully replaced by North European immigrants in much shorter order, and croplands replaced forests.[31]

Wars of the Industrial Era

The great escalation of modern warfare and its environmental impacts began in Europe in the 1790s, when revolutionary France and Napoleon expanded both the intensity of warfare and its continent-wide reach.[32] Responding to counter-revolutionary military threats from other countries, the leaders of the revolution appealed to French patriotism (an emerging alternative to religious fervor) and mobilized huge semi-trained armies. From 1793 onward French mass armies moved into Belgium and beyond. Badly supplied, they ravaged rural lands to the north as they moved. The era of patriotic armies had begun, though disciplined logistics of the industrial era were not keeping pace.

The Napoleonic wars also disrupted intercontinental transport of food supplies, in one case resulting in a major long-term change in cropping patterns. The British naval blockade after 1805 cut off supplies of cane sugar from the Caribbean to French ports. In response, new techniques of extracting sugar from beets led to an explosion of sugar-beet farming in the heavy soils and cool climate of northern Europe. Meanwhile the former slaves of Haiti turned their work from half-deserted cane plantations in the

fertile lowlands to subsistence cropping in the erosive hill woodlands, and Haiti became one of the most degraded landscapes in the Americas. In this way Europe's revolutionary wars had unintended ecological consequences across the ocean.[33]

From the mid-nineteenth century onward Western European and American industry produced a leap upward in destructive capacity, through revolutionary innovations in mass production. By the late 1800s highly accurate breech-loading Enfield, Mauser, and Springfield rifles and Maxim machine guns transformed the battlefield, and more powerful explosives were capable of ravaging both urban and rural targets. Moreover, railroads and steamships gave industrialized nations far greater mobility and international reach. In addition to their civilian uses, they moved troops and materiel rapidly, inexpensively, and far, making possible the conquest of the rest of the world.[34]

Nineteenth century Africa underwent the culmination of Europe's globalization, based on the increasingly dominant military capacity of Europe.[35] In southeastern Africa the Zulu wars of the early 1800s led to British control of the coastal lowlands and interior hills, and the Zulu people were gradually forced to settle on the semi-arid high plains of the interior.[36] Among the colonies that Germany claimed after 1885, the forest resources of Tanzania came under management of the authoritarian German tradition, sharply restricting the rights of access and trade for the local people. In 1905 Tanzanians revolted, and the two-year Maji Maji rebellion that followed until the German colonial army suppressed it was the first of the wars of national resistance against European colonial rulers.[37] The flora and fauna resources of the colonies would see many contestations. But these first studies of the environmental impacts of Europe's conquest wars in sub-Saharan Africa give only fragmentary hints at the overall picture.

The U. S. Civil War had already given a grim demonstration of the environmental dangers of the new industrial warfare. When it began in 1861, no one expected the war to grind on for over four years, but its glacial momentum toward exhaustion of the South produced widespread destruction of croplands and fodder resources by Northern armies, extending to deliberate scorched-earth campaigns in its last two years.[38] These strategies were not new in the history of warfare, but their scale and intensity were unprecedented. Ultimately the manpower, economic wealth, and industrial power of the North prevailed. Northern armies could be supplied and supported more consistently by the northern railroad network connecting military movements back to factories and farms. Even so, environmental war against the southern landscape provided the decisive blow. The experience trained northern soldiers to attack and destroy the food supplies of the indigenous tribes in the American West, including their herds of bison, as an acceptable strategy in the conquest of that great frontier.[39]

In Europe in the same decade, Germany harnessed the industrial revolution to accelerate military mobilization. Rapid victories over the Austro-Hungarian Empire and then France resulted from skillful movement of the German armies over the new railway

networks, with communications provided by the new telegraph, while more powerful artillery damaged woodlands and cities.[40] Great Britain, faced with the new challenge from Germany, strove to maintain its control of the seas by producing rapid innovations in naval technology, which required that military planners and industrialists work closely together.[41] In the process, petroleum emerged as a strategic resource; by the dawn of the twentieth century petroleum was the energy source that fueled warfare. In terms of ecological violence, mid-nineteenth-century wars and the concomitant arms race were merely overtures to the two world wars that followed after 1900, when the environmental impacts of warfare became truly global.

The Century of Total War

Contemporaries called this the Great War, in which the military-industrial complex finally matured. The industrial capacity for warfare had accelerated rapidly since 1870, and all combatant economies had forged close ties between military commanders and industrial designers and managers.[42] By 1914 war in Europe could be pursued with railway and wheeled vehicles, and during the war the first air forces appeared. The consequences caught everyone strategically unprepared. As the war on the Western front bogged down in a three-year stalemate along hundreds of miles of trenches in Flanders and northern France, millions of bomb and shell craters left puddles, ponds, and mud where crop fields and woodlands had been before. On both sides of the war, improved long-distance food transport enabled mass armies to be sustained year-round, and battles to be fought almost endlessly. On occasion, armies deliberately deprived both enemy units and civilians of food, fiber, and fodder by ravaging land and destroying stored crops. In early 1917, as the German armies withdrew from the Somme battlefields, they systematically destroyed nearly every building, fence, well, bridge, and tree over an area sixty-five by twenty miles to deprive the advancing enemy of sustenance and cover.[43] In eastern Europe the wide and constantly shifting battle zone between the German and Russian armies opened remote areas to development and pointed toward vast damage to forests, marshes and agricultural zones in World War II.

The war also saw the first large-scale use of chemical warfare. Germany, France and Britain all attempted to develop chemical weapons before 1914. Germany's chemical industry, the world's leader, forged close cooperation with her military, enabling the German army to use massive amounts of chlorine and mustard gas on Allied troops. By the war's end chemical warfare produced 1.3 million casualties, including ninety thousand deaths; mustard gas and other chemical agents temporarily poisoned lands on and near the battlefields. It is difficult to assess the immediate environmental impact, because no one measured it, but its carryover effect was massive. Chemical warfare increased the size of chemical industries, demonstrated the value of scientific research to chemists and governments, and helped inspire postwar pesticides. And military

aircraft became the backbone of postwar crop dusting, increasing the scale on which pest control was economical.[44]

Throughout Europe and even overseas, forests came under unprecedented wartime pressures. Lengthy bombardments in battle zones shattered forests that had been carefully managed for centuries. For hundreds of miles behind the lines, massive emergency fellings of timber were carried out. Only the great forest zone of Russia escaped heavy exploitation, since imperial Russia's transport system was still rudimentary. The British, Canadians, and Americans organized large timber shipments from North America and even India's monsoon forests. But this war saw only the beginnings of tree cutting from tropical rainforests, since logging and transport facilities were still in their infancy, even in the colonial forests of British and French West Africa.[45] Perhaps equally important for the longer run, government forestry agencies in many countries took greater control over forest resources during the war. The immediate postwar period saw reforestation programs in both Europe and North America, in which single-species tree plantations replaced the greater variety of species in the former natural forests.

Between the two world wars further acceleration of military industry enabled militarized states to mobilize far greater resources from around the world than a quarter century before, and impose new levels of destruction. When Japan attacked China in 1937 and then Hitler's armies invaded Poland in late 1939, they unleashed a war in which seventy million people would die, and his own country ultimately suffered some of the most total devastation, particularly at the hands of the Allied air forces. By the summer of 1945 British and American bombers, dropping incendiary bombs produced by the rapidly maturing chemical industry, leveled one hundred thirty German cities, killing some six hundred thousand civilians. The postwar reconstruction, physical as well as social, would be daunting.

In combat zones the forests of Europe were once again badly damaged by fighting. Behind the lines of combat, timber was cut at the most urgent rates that the limited available workforce could achieve, and great forests of Norway and Poland were looted of their timber wealth. This time, even more than in the previous war, the battle zones of Europe, North Africa, and the Middle East could call upon timber resources from other continents. Both harvesting machinery and transport networks (from forest roads to harbor facilities to oceanic shipping) were more highly developed than in the previous war, though the vast forest resources of Asian Russia were still largely inaccessible.

In the Far East, Japan had pre-empted Soviet interest in the industrial belt of Manchuria by occupying it as early as 1931. Six years later Japanese armies, supported by Japanese aerial bombing of Chinese cities, advanced westward across China. In the war's most notorious action, the retreating Chinese Nationalist leadership broke the Yellow River dikes, flooding vast areas of intensely cultivated lowlands, drowning over

800,000 people and turning 2 million others into refugees.[46] Between them, the Nationalist and Japanese armies produced a scale of human and environmental damage by war's end that is still not fully measured.

In early 1942, immediately after the Pearl Harbor attack, Japan's war machine continued down the Pacific, quickly seizing the strategic forest and rubber resources of the Philippines, Indonesia and mainland Southeast Asia. For roughly three years, until they were beaten back, the occupying Japanese forces brutalized forests and plantations, leaving a seriously compromised environmental legacy.[47]

The war in the Pacific had impacts on island biota, coastal coral ecosystems and the aquatic environment that had no previous parallel in that ocean's web of life. Small islands support limited varieties of plant and animal species. Coral atolls have thin, fragile soils; they are exceptionally vulnerable to the impacts of human conflict. On both steep volcanic islands and coral atolls the fighting produced fundamental ecological degradation of forests, watersheds, coastal swamplands, and coral reefs.

World War II marked another watershed in the history of warfare: for the first time more soldiers died in battle than of disease. Diseases, of both humans and livestock, had spread into the Pacific with traumatic impacts ever since the 1770s, but the Pacific War ended with a dramatic reverse. Until 1943 malaria caused nearly ten times as many casualties as battles. Thereafter DDT almost totally controlled the disease among the troops before the war's end. No one at the time foresaw the massive environmental damage that DDT would produce in peacetime.[48]

For marine resources the war had paradoxical effects. Commercial fisheries and whaling fleets were largely destroyed, docked, or transformed into military uses until 1945, leaving fish stocks and marine mammal populations to recover somewhat, though submarine warfare killed some whales, and any increase in their numbers was very temporary.[49]

In Japan itself the war had tragic ecological as well as human impacts. For Japan's forest resources the loss of import sources (especially the northwest coast of North America) meant intensive cutting of domestic forests, even ancient stands that had been preserved for centuries, for charcoal, firewood, and construction. In many locations the direct result was loss of soil and damage to water regimes. On Japan's farms food production expanded urgently, especially on marginal lands.[50]

American incendiary bombing, following the attacks on German cities, almost totally destroyed Japan's urban areas, which had been built largely of wood. Finally, Japan suffered the ultimate environmental disaster, the impact of nuclear bombs, when Hiroshima and Nagasaki were leveled on August 6 and 9, 1945. The two cities were rapidly rebuilt after the war, and the local flora made a surprisingly rapid recovery from radioactive pollution, yet the human costs of the two bombs are still being counted.

By August 1945 the United States was triumphant, having suffered relatively little long-term damage to its domestic resources and ecosystems or to its additional source

areas in Latin America. Its military industry had grown exponentially, and military-industrial coordination had reached high levels. Hence that war sowed the seeds of later disasters, which began to be evident as the Cold War deepened after 1948.

The Cold War

The global arms race after 1945 produced incalculable accelerations of every tool of destruction.[51] One of the smallest weapons, though multiplied almost countless times, has been the land mine. Some one hundred million unexploded anti-personnel mines remain around the planet, littering rural Vietnam, Afghanistan, and many other war-torn countries, grievously retarding the restoration of postwar farms, pastures, forests, and water regimes. These and a Pandora's box of other weapons have spread through many unstable regions of the post-colonial world—Africa and elsewhere. Grim contributions to wars both civil and trans-boundary, they have also extracted a widespread ecological toll on forests, savannas, and farmlands.[52]

Equally widespread by the time the Cold War ended in 1990, long-term pollution effects of military industry left many locations severely poisoned. Weapons production sites and testing grounds in the United States required massively expensive cleanups of a broad spectrum of toxic wastes. Even more appalling, large areas of Soviet and Eastern European land and air had become virtual wastelands, and even the Arctic Ocean north of Russia was severely polluted.[53] Chemical warfare reached a new level of destruction in the Second Vietnam War (1961-1975), as the U.S. Air Force applied Agent Orange and other defoliants to the forests of Indochina. In addition to fourteen million tons of bombs and shells, American planes sprayed forty-four million liters of Agent Orange and twenty-eight million liters of other defoliants over Vietnam. The result was serious damage to 1.7 million hectares of upland forest and mangrove marshes, widespread soil poisoning or loss of soil, and destruction of wildlife and fish habitat.[54]

Most potent of all in the post-1945 years, nuclear technology became the most ominous environmental threat in history, though its greatest impact resulted from the peacetime armament race rather than from actual war. Until international nuclear-testing freeze conventions came into effect, weapons testing sites, such as Soviet sites in Central Asia and Britain's testing grounds in central Australia, became uninhabitable for almost all forms of life. And in the southern Pacific Ocean, islands and their coastal reefs, their civilian populations entirely removed by force, became unfit for life as a result of American and French nuclear weapons testing.[55] Beyond that, in the nuclear industrial complex, many weapons production and storage sites became highly radioactive. In the United States, nuclear facilities in Washington state, Colorado, and elsewhere became radioactive sewers. Soviet nuclear weapons sites were even more highly radioactive.[56]

Finally, twentieth-century warfare has made a major contribution to warming of the global atmosphere. Military establishments consume great amounts of fossil fuels,

contributing directly to global warming. The Persian Gulf War of 1991 was the most notorious case of atmospheric pollution in wartime, as the plumes of burning oil wells darkened skies for months far downwind. It now seems that the fires caused less regional and global air pollution than was feared in their immediate aftermath, though they dropped heavy pollution on nearby deserts, farmlands, and the Gulf's waters.[57]

Conclusions

In the present state of research there is a wide need for more studies of the long-term ecological legacies of warfare. The immediate impacts of conflicts are far easier to assess, especially since the wars of the nineteenth century. But they do not necessarily represent the ecological or agro-ecological viability of the longer run, for this also reflects the great capacities of societies to restore damaged landscapes to productivity. The great marshes of southern Iraq are a dramatic recent example of restoration. In the aftermath of the Gulf War of 1991, Saddam Hussein retaliated against the tribal sheikhs and Shia population of the south by diverting the flow of the Tigris and Euphrates rivers, turning some 90% of the marshes into a desert wasteland. After his overthrow early in the present Iraq war, a coalition of local people, private volunteer organizations and the United Nations Environmental Program began a program of re-flooding the marshlands. In spite of continued violence in the region, roughly one third of the marshes have been restored to something like their previous health for both the Marsh Arabs and the fecundity of fish, migratory birds, and other species.[58] As this example suggests, the long history of restoration work deserves greater emphasis than most of our narratives of wars' impacts acknowledge.

In sum, by now it is widely recognized that human history has to be understood in the wider context of interactions between societies and the natural world. But we are only beginning to recognize that mass conflict – a pervasive and distinctive dimension of human affairs – has had complex and portentous consequences for the biosphere, and for the human place in it.

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Notes

[1] A subsequent version of this article will be published in a forthcoming book, J. R. McNeill and Erin C. Stewart, eds., *A Companion to Global Environmental History* (Blackwell Publishing).

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[23] See the view of the militarized state as predatory, in Charles Tilly, "War Making and State Making as Organized Crime," in Peter B. Evans, et. al., eds., *Bringing the State Back In*(Cambridge: Cambridge University Press, 1985), 169–91.

[24] Christon I. Archer, et. al., *World History of Warfare* (Lincoln: University of Nebraska Press, 2002), chap. 11: "The West Conquers the World."

[25] For a debate among historical anthropologists over the changes in indigenous societies in response to European penetration, see R. Brian Ferguson and Neil L. Whitehead, eds., *War in the Tribal Zone* (Santa Fe: School of American Research Press, 1992).

[26] Robert G. Albion, *Forests and Sea Power* (Cambridge: Harvard University Press, 1926); Paul Walden Bamford, *Forests and French Sea Power, 1660–1789* (Toronto: University of Toronto Press, 1956); Shawn William Miller, *Fruitless Trees: Portuguese Conservation and Brazil's Colonial Timber* (Stanford: Stanford University Press, 2000); Graeme Wynn, *Timber Colony: A Historical Geography of Early Nineteenth Century New* Brunswick (Toronto: University of Toronto Press, 1981).

[27] The broad patterns are traced in Alfred W. Crosby, *The Columbian Exchange: Biological and Cultural Consequences of 1492* (Westport, CT: Greenwood Press, 1972), and his *Ecological Imperialism: The Biological Expansion of Europe, 900*–1900 (Cambridge: Cambridge University Press, 1986). On the demographic collapse in sixteenth-century America, see Kiple, *Cambridge World History of Human Disease*, 305–33, and several authors' chapters in Kenneth F. Kiple and Stephen V. Beck, eds., *Biological Consequences of the European Expansion, 1450–1800* (Aldershot, UK: Ashgate Publishing, 1997).

[28] There are indicative references to these trends in many works, though no one has yet studied the subject systematically. See Carl Sauer, *The Early Spanish Main* (Berkeley: University of California Press, 1966); Elinor Melville, *A Plague of Sheep* (Cambridge: Cambridge University Press, 1994); Murdo J. MacLeod, *Spanish Central America* (Berkeley: University of California Press, 1973); Warren Dean, *With Broadax and Firebrand: The Destruction of the Brazilian Atlantic Forest* (Berkeley: University of California Press, 1995).

[29] For elements of this subject, see Maarten Ultee, ed., *Adapting to Conditions: War and Society in the Eighteenth Century* (Tuscaloosa: University of Alabama Press, 1986).

[30] J. R. McNeill, *Mosquito Empires: Ecology and War in the Greater Caribbean, 1620–1914* (Cambridge: Cambridge University Press, 2010).

[31] Michael Williams, *Americans and Their Forests* (Cambridge: Cambridge University Press, 1989).

[32] For the transformations of industrial warfare initiated in those campaigns, see van Creveld, *Supplying War*, chaps. 2–3.

[33] For background, see Sidney Mintz, *Sweetness and Power* (New York: Viking, 1985); for a summary of the process and its environmental impact, see Richard P. Tucker, *Insatiable Appetite: The United States and the Ecological Degradation of the Tropical World* (Berkeley: University of California Press, 2000), 25–36.

[34] Daniel R. Headrick, *The Tools of Empire* (Oxford: Oxford University Press, 1981).

[35] Daniel R. Headrick, *Power over People: Technology, Environments, and Western Imperialism, 1400 to the Present* (Princeton: Princeton University Press, 2010).

[36] Roger Levine, "'African War in All Its Ferocity": Changing Military Landscapes and Precolonial and Colonial Conflict in Southern Africa," in Tucker and Russell, *Natural Enemy*, 65–92.

[37] Thaddeus Sunseri, *Wielding the Ax: State Forestry and Social Conflict in Tanzania, 1820–2000* (Athens: Ohio University Press, 2009).

[38] See Mark Fiege, "Gettysburg and the Organic Nature of the American Civil War," in Tucker and Russell, *Natural Enemy*, 93–109; Lisa M. Brady, "The Wilderness of War: Nature and Strategy in the American Civil War," *Environmental History* 10 (July 2005), 421–47; Gerald Linderman, *Embattled Courage: The Experience of Combat in the American Civil War* (New York: Free Press, 1987), chap. 10: "A Warfare of Terror."

[39] Mark E. Neely, Jr., *The Civil War and the Limits of Destruction* (Cambridge: Harvard University Press, 2007), chap. 5.

[40] For the broad setting, see Geoffrey Wawro, *Warfare and Society in Europe, 1792–1914* (London: Routledge, 2000).

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[42] Paul A. C. Koistinen, "The 'Industrial-Military Complex' in Historical Perspective: World War I," *Business History Review* 41:4 (Winter 1967), 379–403.

[43] Roger Beaumont, *War, Chaos and History* (Westport: Praeger, 1994), 140.

[44] Edmund Russell, *War and Nature: Fighting Humans and Insects with Chemicals from World War I to Silent Spring* (Cambridge: Cambridge University Press, 2001).

[45] Richard P. Tucker, "The World Wars and the Globalization of Timber Cutting," in Tucker and Russell, *Natural Enemy*, 110–41.

[46] For the broader picture of this disaster, see Micah Muscolino, "Violence Against People and the Land: Refugees and Environment in China's Henan Province, 1938–1945," forthcoming in … The full extent of environmental damage in China by 1945 remains to be measured.

[47] Greg Bankoff, "Wood for War: The Legacy of Human Conflict on the Forests of the Philippines, 1565–1946," in Charles E. Closmann, ed., *War and the Environment: Military Destruction in the Modern Age* (College Station: Texas A&M Press, 2001), 41–42; Tucker, "World Wars," 132–35.

[48] Judith A. Bennett, *Natives and Exotics* (Honolulu: University of Hawaii Press, 2009).

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[51] J. R. McNeill and Corinna R. Unger, "Introduction: The Big Picture," in McNeill and Unger, eds., *Environmental Histories of the Cold War* (Cambridge: Cambridge University Press, 2010), 1–18.

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