



The Environmental Legacy of Warfare

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Abstract

The acknowledgment of the environmental ramifications stemming from warfare and mass violence has recently gained traction as a recognized facet within environmental history. It draws upon various familiar disciplines, ranging from the history of state formations, social structures, and economics to military tactics, demographic shifts, disease history, and historical geography. Military historians have traditionally delved into the significance of terrain and weather in campaign planning and management. Furthermore, they have frequently documented military planners' considerations regarding the manipulation of natural resources crucial for their strategic objectives, and even the utilization of natural processes, such as fire, as tools of warfare. However, their focus primarily centers on the human aspects; they seldom extend their analysis to contemplate the resulting alterations in ecosystems. They perceive Nature merely as a backdrop, overlooking its role as a consequence of mass violence.



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INTRODUCTION

Environmental historians have frequently explored facets of warfare throughout history. However, until recently, they seldom delved into the intricacies of mass violence or the operational structures of militaries in relation to the state, society, economy, and ecology as the central focus of their studies. Primarily, attention has been directed towards the industrial era, commencing with the American Civil War, thereby predominantly examining the leading industrialized nations. Initially focusing on the global devastations of the two World Wars, research has expanded to contemplate the structures and repercussions of extensive permanent military establishments, notably during the Cold War era. Key themes include the global competition among major economies for strategic resources control, and the resulting impacts on economies and ecosystems. Nonetheless, a comprehensive perspective on the ecological aftermath of warfare worldwide is yet to fully materialize. Concise yet thought-provoking assessments of pre-modern regions and enduring historical themes have begun to surface, laying the groundwork for a comprehensive global history. Looking ahead, what broad outlines can be delineated? This essay elucidates several recurring themes observed in the evolving synthesis.

METHOD

This study employs a historical analysis approach to examine the environmental consequences of warfare across different periods and regions. By synthesizing primary and

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secondary sources, it identifies patterns of environmental destruction and adaptation, focusing on themes such as deforestation, soil erosion, resource depletion, and pollution. Case studies from ancient, early modern, and industrialized warfare provide comparative insights into how military strategies and infrastructure development have shaped ecosystems.

The analysis integrates perspectives from environmental history, military history, and political ecology. Key dimensions include resource exploitation, ecosystem disruption, and the technological impact of warfare. The study also considers human responses to war-induced environmental changes, particularly in post-war recovery and land use. While the study covers a broad temporal and geographic scope, limitations exist due to the availability and reliability of historical records, especially in pre-modern periods. Despite these constraints, this research offers a deeper understanding of war's long-term ecological consequences and its relevance to contemporary environmental and policy discussions.

RESULT AND DISCUSSION

Campaigns of Conquest and Frontier Wars

Expanding empires' shifting frontier zones have frequently witnessed significant environmental alterations. During the Roman Empire's expansion, as imperial forces advanced northward in the conquest of Gaul and later southern Germany and Britain during the initial centuries of the common era, their engineers constructed an extensive network of all-weather roads so impeccably crafted that several are still traversable today. Along the empire's northern boundaries, stretching to the Rhine and beyond, a series of fortified military outposts housed garrisons of soldiers. These military encampments served as the epicenters for the cultivation of entire landscapes, as farmers cleared numerous patches of forest for settled agriculture, amidst ongoing skirmishes between the Romans and their Germanic adversaries. Following the empire's decline and the dissolution of its military control, numerous settlements endured well into medieval times, testament to the enduring impact of imperial expansion on the environment and human settlements.

The environmental dynamics of Imperial China's borderlands bore resemblance to those of Imperial Rome in certain aspects, particularly in sparsely populated regions marked by interactions with nomadic groups. Along China's western frontier, confronting constant threats from nomadic tribes of the Mongolian steppes, Chinese rulers erected defensive structures epitomized by the extensive Great Wall, necessitating the clearing of forests in adjacent areas for security measures. They also safeguarded other forested zones to repel invading cavalry forces. In contrast, they pursued a policy of expansion in the southwestern frontier territories, where the rugged terrain of Guizhou province harbored diverse tribal communities, notably the Miao, who resisted Chinese influence for generations. Similar to the Romans, Chinese military expeditions constructed infrastructure such as roads and garrison outposts to facilitate troop movements and subdue the region, facilitating agricultural colonization and deforestation by migrants from the northern regions. Additionally, the imposition of administrative systems and the integration of local elites played crucial roles in the consolidation of Chinese authority over these frontier areas (McNeill, 1998).

Frequently prolonged and sporadic, frontier conflicts bore resemblance to contemporary guerrilla warfare and counter-insurgency operations, albeit lacking the devastation wrought by modern counter-insurgency armaments. These engagements were marked by seasonal clashes and incursions, fortified encampments, acquisition of spoils including portable natural assets, and notably, the displacement of rural communities. Numerous battles unfolded in rugged, mountainous terrain or densely wooded slopes with soil susceptible to erosion. Additionally, they often involved indigenous populations and settlers vying for territorial control, exacerbating tensions over land rights and resources (Elvin, 2004).

Foraging Armies

In traditional eras, armies relied heavily on local resources for sustenance; their logistical capabilities were so basic that alternative means were impractical. This phenomenon elucidates much of the devastation wrought by warfare throughout history. Ancient Greece serves as a prime example. The regions surrounding the Mediterranean endure prolonged hot seasons and brief rainy periods; their terrain primarily consists of rugged mountains, with soils prone to erosion once stripped of natural foliage. The armies of Greek city-states routinely plundered enemy farmlands, decimating annual crops and olive orchards.

Expanding upon this, historical records reveal similar patterns in various conflicts worldwide. For instance, in the Roman Empire, military campaigns often led to widespread deforestation and soil degradation, impacting local ecosystems for centuries. Moreover, the devastation caused by armies during the Thirty Years' War in Europe (1618–1648) resulted in widespread famine and ecological disruption across the continent, highlighting the enduring consequences of warfare on the environment (Parker, 1959).

Southern Italy faced similar devastation on a larger scale two centuries later, during the invasion of the Carthaginian general Hannibal into the Roman Republic in the Second Punic War (219–201 BCE). In a prolonged military standoff, thirteen years of annual summertime clashes in southern Italy ravaged the countryside, as both armies vied to starve each other of resources. The consequence for the environment was the abandonment of cultivated lands, widespread deforestation in hilly areas and watersheds, soil erosion into waterways, and coastal sedimentation. Malaria became endemic in the disrupted coastal regions, persisting throughout subsequent eras until the DDT campaign post-World War II (Hoyos, 2003).

In the monsoonal climate zone, the Indian subcontinent experienced analogous effects from military campaigns. In the upper Indus and Ganges river basins, the armies of the Mughal Empire (1524–1707) – with their elephant corps and cavalry – consumed the food and fodder reserves of the land. The imperial army functioned as a mobile metropolis comprising nearly a million soldiers, camp followers, and suppliers, who stripped vast expanses of all useful resources as they traversed. Cavalry units swept through the countryside, leading to the depopulation of villages; the disruption inflicted upon rural society and its ecological foundation could require decades for recovery (Gommans, 2002; Gordon, 2004; Tucker & Russell, 2004).

Medieval European history exhibited similar trends in land utilization during times of conflict. Until the late 1700s, a persistent issue revolved around the recruitment and remuneration of armies. Feudal lords overseeing manorial estates and the serfs laboring on those lands were both called upon as warriors when military expeditions arose. In the era of chivalry, battles were largely dominated by mounted knights astride heavy warhorses. Foot soldiers comprised local militias of coerced peasants and mercenary bands organized by enterprising military figures. Their compensation primarily came in the form of plunder, a tumultuous process that invariably disrupted agrarian ecosystems. The Hundred Years' War in France (1337–1453) serves as a notable instance of uncontrolled military forces pillaging farmlands, wetlands, and forests. Many campaigns persisted for years, consuming both wooded areas and arable lands. Even during interludes between major conflicts, such as after troop disbandment, banditry (often indistinguishable from regular military activities) thrived. Abandoned lands, as rural inhabitants turned into refugees, reverted to natural woodlands and marshlands, resulting in a concurrent increase in species diversity. The short-term devastation to partially cultivated landscapes was evident to any observer. Assessing the long-term ecological impacts of the early medieval period is challenging due to the protracted nature of peacetime recovery processes.

Fortifications and Sieges

During the mediaeval period in Europe, following the decline of the Roman Empire, feudal lords constructed imposing fortifications encircled by earthen embankments and wooden palisades. These structures relied on resources sourced from quarries for stone and forests for timber. They boasted moats and ramparts, which often disrupted the surrounding soil. Across the landscape, numerous manorial castles and fortified towns were scattered, each surrounded by cultivated fields, pastures, and woodland. The sieges endured by these fortresses and towns could extend through entire summer seasons, as invading armies sustained their presence. The resultant assaults and counter-attacks inflicted greater damage upon the surrounding lands than mere passage of a marching army. Consequently, the post-war reconstruction efforts necessitated yet another round of timber procurement to rebuild settlements (Brauer & Van Tuyl, 2008; Bruce, 2010).

Conflict intersected with disease, acting as a catalyst for the spread of epidemics such as plague, typhus, and other illnesses. This dual onslaught of warfare and disease resulted in significant population declines. One of the most notable instances in Eurasian history occurred during the period of 1348–1351, amidst the Hundred Years War, when the bubonic plague ravaged Europe, claiming approximately one third of the population. The mortality rates were likely exacerbated in the tumultuous conditions of war zones, affecting both military personnel and civilians (Kenneth, 1993; Pounds, 1977).

Following the cessation of hostilities, formerly cultivated lands lay abandoned as farmers fled, allowing nature to reclaim these areas. Fields reverted to pasturelands or gradually transformed into secondary woodlands, fostering wildlife proliferation and enhancing local biodiversity within semi-wild habitats. However, these environmental shifts were often temporary, as peace and stability prompted the return of farmers who revitalised agricultural landscapes (Muir, 2000).

The destructive capabilities of weaponry surged with the introduction of gunpowder to Europe in the 1300s, leading to the subsequent development of increasingly powerful cannons. Consequently, fortifications underwent significant enhancements by the 1500s, marking the height of the Military Revolution. This era saw rapid advancements in arms technology, fueling arms races on both land and sea.

The Thirty Years War (1618–1648) plunged northern Europe into chaos, characterized by the lawlessness of marauding military bands that pillaged the land incessantly, driving the region to a state of collective exhaustion.

In the aftermath, much of Europe witnessed the rise of centralized states with increasingly professionalised armies, bolstered by significantly expanded fiscal administration and government revenues. Disciplined armies, coupled with improved supply logistics, resulted in reduced environmental impact on neutral territories. While historically rulers had close ties with civilian suppliers, this period marked the explicit emergence of a "military-industrial complex," where governments closely coordinated with their suppliers (Kennedy, 2010). Taxation became more standardised as military economies became more organized, fueling the enhancement of lethality. Bankers and merchants seized unprecedented opportunities for profiteering, serving as a significant driving force behind warfare, albeit often concealed. Overall, the expansion of Europe's imperial states foreshadowed both global conquest and an escalation in the scale of destructive power during the industrial era. Furthermore, advancements in technology, such as the adoption of rifled barrels in firearms and the introduction of steam-powered machinery, revolutionized warfare and further fueled the military-industrial complex (Cammack, 1989; Tilly, 2017).

Globalization: The West's Modern Empires

Until the sixteenth century, the ecological ramifications of conflicts were primarily confined to the regions of warfare and their respective resource areas for timber and metals. However, as the era of imperial nation-states and large-scale capital and industry unfolded, technological impacts intensified with the acceleration of global trade and transport. The frontier wars of European conquest were at the forefront of this transformation. Across more than five centuries, European empires, later joined by the United States, dismantled non-state societies in temperate forests, savannas, and tropical rainforests. The Western powers wielded weaponry that eventually overwhelmed all adversaries by the late nineteenth century (Ferguson & Whitehead, 1992).

Early ecological degradation beyond Europe stemmed from the naval demands for construction timber and naval supplies. From the 1700s onward, European navies began exploiting hardwood and white pine stands in northeastern North America, the coastal hardwoods of Brazil, and later the teak forests of monsoon Asia to compensate for the dwindling English oak and Scandinavian conifers (Albion, 1926; Bamford, 1956; Miller, 2000; Wynn, 1983).

The most profound ecological impact of Europe's global conquests unfolded in the Americas, where Europeans inadvertently introduced epidemic diseases that decimated indigenous populations. By the late sixteenth century, up to 90 percent of the indigenous American population had succumbed to these diseases, leading to widespread abandonment of cultivated lands and the subsequent reversion to secondary forests, often for extended periods (Crosby Jr, 2003).

In Latin America, even in the 1500s, the effects of conquest were evident in lowland coastal zones, riverine forests, the highlands of Mexico and the Andes, where sheep and goats replaced degraded pasture lands, and the vast natural grasslands dominated by cattle. Apart from these instances, comprehensive studies on environmental changes resulting from warfare in Latin America are still in their infancy (Worden, 2004).

In North American woodland environments, the impact of endemic frontier warfare took a somewhat different trajectory. European settlers, following their conquests, swiftly cleared temperate forests and established croplands, unlike their challenges in anchoring themselves in tropical forest zones. In contrast to Latin America, where populations did not rebound to their pre-1492 levels until around 1800, the native populations of North America were replaced by North European immigrants in a much shorter timespan, leading to the conversion of forests into croplands (Mann, 2005).

Wars of the Industrial Era

The significant escalation of modern warfare and its environmental ramifications commenced in Europe during the 1790s, as revolutionary France under Napoleon expanded both the intensity and geographic scope of conflict (Fremont-Barnes, 2013). Responding to military threats from counter-revolutionary forces, revolutionary leaders rallied French nationalism as an emerging alternative to religious zeal and mobilized vast semi-trained armies. Beginning in 1793, these French mass armies marched into Belgium and beyond, often pillaging rural lands in their wake due to inadequate supplies and logistical challenges. Thus began the era of patriotic armies, although the disciplined logistics characteristic of the industrial age were not yet fully developed.

One of the most noticeable ecological impacts of the Napoleonic Wars was the widespread deforestation and land degradation. The demands of war led to extensive logging for timber, which was essential for building ships, fortifications, and fueling military operations (Blackbourn, 1998). Forests were cleared at an alarming rate, leading to soil erosion, loss of biodiversity, and disruption of habitats for numerous plant and animal species (Grove, 1996).

The Napoleonic Wars disrupted agricultural practices across Europe, affecting food production and land management systems³. Many farmers were conscripted into military service,

leaving fields uncultivated and harvests uncollected. Additionally, the movement of troops and the requisitioning of supplies often resulted in the destruction of crops and livestock, further exacerbating food shortages and famine in some regions (Parker, 1959). The disruption of traditional farming methods also led to soil depletion and decreased soil fertility, impacting long-term agricultural productivity.

The movement of armies and trade during the Napoleonic Wars facilitated the unintentional introduction of invasive species to different parts of Europe. Soldiers, merchants, and travelers inadvertently transported plant seeds, animals, and pests across borders, disrupting local ecosystems and threatening native species (Mack et al., 2000). These invasive species often outcompeted native flora and fauna for resources, leading to habitat degradation and ecosystem imbalance.

The Napoleonic Wars brought about significant pollution and contamination of land, water, and air due to military activities, industrial production, and resource extraction⁹. Battlefield sites became polluted with heavy metals from munitions and other hazardous materials, posing long-term risks to soil and water quality. Moreover, the expansion of industries to support war efforts resulted in increased emissions of pollutants, contributing to air and water pollution in many urban areas.

Nineteenth century Africa witnessed the apex of Europe's globalization, driven by the burgeoning military prowess of European powers. In southeastern Africa, the Zulu wars of the early 1800s resulted in British dominance over the coastal lowlands and interior hills, gradually pushing the Zulu people to settle in the semi-arid high plains of the interior. Among the colonies claimed by Germany after 1885, Tanzania's forest resources fell under the management of the authoritarian German regime, severely curtailing the rights of local populations to access and trade these resources. In 1905, Tanzanians revolted, sparking the two-year Maji Maji rebellion, the first of many wars of national resistance against European colonial rule. The exploitation of flora and fauna resources in these colonies became a focal point of contention. However, initial studies on the environmental impacts of Europe's conquest wars in sub-Saharan Africa only provide fragmented insights into the overall scenario.

The U.S. Civil War provided a stark demonstration of the environmental hazards inherent in industrial warfare. Beginning in 1861, the unexpectedly prolonged conflict led to widespread destruction of croplands and fodder resources by Northern armies, including deliberate scorched-earth campaigns in the war's final years. While such strategies were not novel in military history, their scale and ferocity were unprecedented. Ultimately, the North's manpower, economic strength, and industrial capacity proved decisive. Northern armies were better supplied and supported thanks to the extensive railroad network connecting military operations to factories and farms in the North. The war against the southern landscape played a pivotal role, as northern soldiers were trained to target and destroy the food supplies of indigenous tribes in the American West, including their bison herds, as part of frontier conquest.

The Century of Total War

In early 1917, as German armies retreated from the Somme battlefields, they systematically obliterated nearly every structure, fence, well, bridge, and tree over a sixty-five by twenty-mile area to deprive the advancing enemy of sustenance and cover. In eastern Europe, the expansive and constantly shifting battle zone between the German and Russian armies opened up remote areas to development and foreshadowed extensive damage to forests, marshes, and agricultural zones in World War II.

The war also marked the inaugural large-scale use of chemical warfare. Prior to 1914, Germany, France, and Britain had all sought to develop chemical weapons. Germany's chemical industry, the global leader, collaborated closely with its military, enabling the German army to deploy

massive amounts of chlorine and mustard gas against Allied troops. By the war's end, chemical warfare had inflicted 1.3 million casualties, including ninety thousand fatalities, while temporarily poisoning lands on and near the battlefields. The immediate environmental impact was challenging to assess due to a lack of measurement, but its long-term effects were substantial. Chemical warfare expanded the chemical industries, underscored the importance of scientific research for chemists and governments, and contributed to the development of postwar pesticides. Moreover, military aircraft became integral to postwar crop dusting, thereby increasing the scale of economical pest control (VE & VM, 1971).

Throughout Europe and overseas, forests faced unprecedented wartime pressures. Prolonged bombardments in battle zones devastated forests that had been meticulously managed for centuries. Extensive emergency timber felling occurred for hundreds of miles behind the lines. Only the vast forest expanse of Russia remained relatively untouched, as imperial Russia's transportation system was still rudimentary. The British, Canadians, and Americans coordinated significant timber shipments from North America and even from India's monsoon forests. However, this war only marked the initial stages of tree cutting in tropical rainforests, as logging and transportation infrastructure were still nascent, even in the colonial forests of British and French West Africa. Equally significant for the long term, government forestry agencies in many countries assumed greater control over forest resources during the war. The immediate postwar era witnessed reforestation programs in both Europe and North America, with single-species tree plantations replacing the diverse species found in natural forests.

In active combat zones, European forests suffered significant harm yet again. Beyond the front lines, timber extraction occurred at an urgent pace, depleting the rich timber reserves of Norway and Poland. This time, the battlefronts across Europe, North Africa, and the Middle East tapped into timber resources from distant continents to a greater extent than in the previous conflict. While harvesting equipment and transportation networks were more advanced compared to World War I, the vast forest reserves of Asian Russia remained largely inaccessible.

In the Far East, Japan preempted Soviet ambitions in Manchuria by occupying it in 1931. Six years later, Japanese forces, aided by aerial bombings of Chinese cities, pushed westward across China. Among the war's atrocities, the Chinese Nationalist leadership, in retreat, breached the Yellow River dikes, resulting in catastrophic flooding that claimed over 800,000 lives and displaced 2 million individuals. The combined efforts of Nationalist and Japanese forces wrought immense human and environmental devastation by the war's conclusion (Chang, 2014).

Following the Pearl Harbor attack in early 1942, Japan swiftly seized the vital timber and rubber resources of the Philippines, Indonesia, and mainland Southeast Asia. Over the subsequent three years, until their eventual defeat, Japanese occupiers inflicted severe environmental damage through exploitation of forests and plantations, leaving a lasting ecological impact (Muscolino, 2011).

The Pacific conflict brought about unprecedented ecological degradation, particularly on small islands and coral atolls. These fragile ecosystems endured profound harm to forests, watersheds, coastal wetlands, and coral reefs due to warfare (McNeill, 2022).

World War II marked a significant shift in the nature of warfare, as more soldiers perished in combat than from disease for the first time. While diseases, both human and livestock, had afflicted the Pacific region since the 1770s, the war's conclusion saw a remarkable decline in disease-related casualties, largely due to the widespread use of DDT, which effectively controlled malaria among troops. However, the unforeseen environmental consequences of DDT in peacetime would later emerge (Bennett, 2009).

In Japan itself, the war had devastating ecological as well as human consequences. With the loss of import sources, particularly from the northwest coast of North America, Japan resorted to

extensive logging of domestic forests, including ancient stands that had been preserved for centuries, for charcoal, firewood, and construction purposes (Pauer, 1999). This reckless exploitation led to widespread soil erosion and disruption of water regimes in many areas. Additionally, the urgent need to ramp up food production on Japan's farms led to intensified cultivation, especially on marginal lands.

The devastating American incendiary bombing, following the blueprint set by attacks on German cities, nearly obliterated Japan's predominantly wooden urban areas. Adding to this ecological catastrophe, Japan endured the ultimate environmental calamity with the deployment of nuclear bombs, which leveled Hiroshima and Nagasaki on August 6 and 9, 1945, respectively. Although the two cities were swiftly rebuilt after the war, and local flora surprisingly rebounded from radioactive pollution relatively quickly, the human toll of these bombings continues to be tallied.

By August 1945, the United States emerged triumphant, having suffered comparatively minimal long-term damage to its domestic resources and ecosystems, as well as its additional source areas in Latin America. Its military-industrial complex had experienced exponential growth, with high levels of coordination between military and industrial sectors. However, the seeds of future disasters were sown, becoming increasingly evident as the Cold War intensified after 1948.

CONCLUSION

The battle of Teutoburg Forest marked a significant setback for Roman expansion in Germania, highlighting the challenges posed by local resistance to imperial ambitions. The Sassanid Empire (224–651 CE) heavily relied on the effectiveness of its irrigation systems for agricultural productivity. However, internal conflicts and external pressures contributed to the gradual deterioration of these networks, leaving them vulnerable by the time of the Arab Muslim conquest. The Mu Us Desert, located north of the Ordos Loop, played a crucial role in hindering nomadic cavalry advancements and served as a natural line of defense alongside the Great Wall.

The concept of total war, exemplified by the devastation of civilian resources during conflicts, emerged during ancient times and continues to shape modern warfare. The long-term environmental consequences of such practices remain difficult to assess accurately. Greek city-states, owing to their reliance on local resources, frequently resorted to plundering enemy farmlands during conflicts, resulting in widespread agricultural destruction.

British naval innovation: Great Britain, as a maritime power, focused on maintaining naval supremacy through technological advancements, which played a crucial role in shaping its military strategy. Petroleum as a strategic resource: The increasing reliance on petroleum as an energy source for military operations highlights its significance in shaping warfare during this period.

World War I witnessed the emergence of new technologies such as aircraft, which played a significant role in warfare. Strategies such as scorched earth tactics were employed to deprive the enemy of vital resources. The environmental impact of World War I, particularly in terms of damage to natural resources, had lasting consequences that were evident in subsequent conflicts, such as World War II. The environmental impact of World War I, particularly in terms of damage to natural resources, had lasting consequences that were evident in subsequent conflicts, such as World War II. This refers to the period between World War I and World War II, during which military technologies and industrial capacities significantly advanced, leading to heightened militarization globally. The figures cited here highlight the immense human cost of World War II, particularly the civilian casualties resulting from aerial bombardments. Despite advancements in technology and logistics, certain regions, like Asian Russia, still faced challenges in accessing and exploiting their natural resources during World War II. The full extent of environmental damage in China by 1945 remains to be measured.

The atomic bombings of Hiroshima and Nagasaki marked the first and only use of nuclear weapons in warfare to date. Despite the extensive destruction, Japan's post-war reconstruction efforts were remarkable, leading to the rapid rebuilding of infrastructure in Hiroshima and Nagasaki. The collaboration between the military and industrial sectors during World War II laid the groundwork for the complex relationships that would define the military-industrial complex in the post-war era.

Following the Gulf War of 1991, Saddam Hussein's retribution against the tribal sheikhs and Shia population led to the diversion of the Tigris and Euphrates rivers, resulting in the transformation of approximately 90% of the marshes into a desolate wasteland. However, following his ousting in the early stages of the subsequent Iraq war, a collaborative effort involving local communities, private volunteer organisations, and the United Nations Environmental Program embarked on a marshland re-flooding initiative. Despite ongoing violence in the region, approximately one third of the marshes have been restored to a semblance of their former vitality, benefiting both the Marsh Arabs and the biodiversity, including fish, migratory birds, and other species.

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