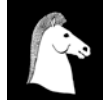




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# The Environmental Footprint of War

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## ABSTRACT

Warfare and the physical environment have always shared a close and interconnected relationship. Until recently, historical writings have mainly focused on the environmental factors influencing the outcome of battle and not the effects of war on the environment. While a growing body of literature has begun to address the effects of war on the environment, many aspects of the direct effects of battle on the environment still require attention. Warfare, a powerful agent of landscape change, is a unique form of landscape disturbance in that it is often larger in magnitude and size than other forms of anthropogenic disturbance, such as mining or logging. War is also unique as an anthropogenic agent of change because of its capability to render such widespread destruction over large areas in such short periods of time. Despite the magnitude of landscape disturbance associated with modern warfare, however, it is seldom recognised as a significant form of anthropogenic disturbance. The destruction associated with modern warfare is particularly catastrophic due to the extent, magnitude and duration of contemporary wars. These large magnitude disturbances radically alter the shape of the landscape, limiting the ability of the landscape to revert back to its original state. This article addresses the direct impacts of war on the physical landscape and why the magnitude of disturbance has increased significantly over the past century.

## KEYWORDS

War and environment, landscape disturbance, anthropogenic disturbance, military landscapes, modern warfare

## INTRODUCTION

In the realm of military history, no account of a battle is complete without a brief description of the physical environment. Detailed narratives of battles are replete with the woes of an unforeseen storm destroying an unprepared army, a commander's failure to seize the higher piece of ground, or a once mighty army vanishing into oblivion because they did not prepare for the upcoming onslaught of winter. These accounts are properly noted; throughout history warfare and the environment have indeed shared a close and interconnected relationship.<sup>1</sup> The outcomes of many battles and campaigns have been influenced, or even preempted, by the physical landscape. Numerous books concerning the philosophy of warfare, such as Sun Tzu's *The Art of War*, Clausewitz's *On War*, or more recently Van Crevald's *Transformation of Warfare*, attest to the importance of terrain, weather and climate.<sup>2</sup>

Without doubt, military history would not be complete without a focus on the effects of the physical environment upon the outcome of battle and/or military campaigns. However, whereas it is important to examine how the physical environment has influenced past military operations, along with studying how to cope with the physical environment in future military campaigns, examining the converse is also important; i.e. how and where military operations have *had an effect upon the physical environment*. An extended examination of this relationship – between battle and the environment – has the potential to expand the study of both environmental history and science into new and exciting directions.<sup>3</sup>

Warfare is, by its very nature, an inherently destructive activity linked to the history of humankind. Throughout the world, there exists no shortage of battlefields. Whether they are park-like memorials remembering a battle from long ago, or a contemporary battlefield riddled with the remnants of war, many landscapes affected by war remained scarred by battle. Not only are the weapons associated with warfare directly responsible for environmental disturbance, but the activities associated with war can severely tax the physical environment as well. Environmental disturbance occurs when armies intentionally eliminate the cover or resource base of an enemy, or more commonly, as an unintentional consequence associated with the war effort.<sup>4</sup> Based on these premises, environmental disturbances associated with war can be placed into three general categories:

- (1) Environmental disturbance and destruction from weaponry.
- (2) Direct consumption of resources such as timber, water and food to support armies.
- (3) Indirect consumption of resources by military industrial complexes that supply the war effort.

A common thread among all these disturbance categories is that, when viewed from ancient times up until the present, the scope of environmental disturbance

has continually and significantly increased in scale. The term 'scale' in this writing not only refers to spatial extent, or geographic scale, but also to the temporal scale of time. Human technological innovations from one war to the next have not only increased in terms of the level of harm inflicted upon the enemy, but also upon the environment as well. Every aspect of modern war is of greater magnitude than that of warfare prior to the industrial age; armies and battlefields are larger, munitions are more powerful, casualty rates are higher, battles (and wars) last longer, and the environmental disturbances are more widespread. Human intent to destroy the environment is not necessarily synchronous with advancements in the art of war. With few exceptions, such as US strategy in the Second Indochina War, damage to the environment has been incidental. Ancient armies had the same goals as modern armies – to destroy the enemy. The technology implemented to eliminate those enemy forces, however, has developed to the point where environmental disturbance has increased to a regional scale, well beyond the scope of an 'occupied' battlefield.

The technological improvements associated with modern warfare have created a vast array of environmental problems. Besides continual advances in explosive munitions technology, modern warfare contributes towards environmental disturbance in many other forms, e.g. heavy vehicle traffic, chemical defoliants and pollution of the atmosphere, water and soils. Each one of these topics deservedly requires a discussion in its own right and is covered in other literature addressing the effects of war on the environment. To cover every aspect of the environmental implications of warfare would require dizzying volumes of material. This author recognises that several notable works in the realm of environmental history have addressed the impact of war on the environment.<sup>5</sup> Other writings have covered the effects of war on the environment through legal, economic and various scientific perspectives.<sup>6</sup> While these writings help to illustrate the effects of war on the environment, they mainly focus on the indirect effects through a social perspective, and not the damage inflicted by the weapons of warfare upon the battlefield. This paper will focus mainly on the direct effects of battle, particularly those of munitions, on the physical landscape. The paper will also relate the ever increasing magnitudes of landscape disturbance to technological advances associated with the industrial age and the twentieth century.

## WARFARE AND ITS EFFECTS ON THE ENVIRONMENT

### *Warfare in Antiquity, Up to and Though Pre-Modern Warfare*

Fire and other incendiary devices were, arguably, the first weapons capable of rendering widespread environmental destruction upon the physical landscape. Fire has long been employed by belligerents to drive out enemy forces taking cover in forests, swamps or other forms of natural cover. Armies could take

advantage of prevailing winds by setting fire to an area upwind from an enemy, thereby creating confusion and fear, eventually smoking them out of their place of refuge. One account from a Roman general in the first century B.C. describes a massive forest fire set by Germanic Barbarian tribes that burned every bit of ground cover and scorched the soil down to the roots of the trees. The Roman army also employed widespread use of fire in its campaigns within the forests of what is now France and Germany. For the Romans, however, forest destruction was mainly employed against the barbaric tribes in the northern hinterlands of the Roman Empire; most uses of incendiary devices in antiquity were aimed at cities, naval fleets and other fortified positions.<sup>7</sup>

Ancient armies also practised other forms of deliberate environmental disturbance using the forces of nature as a weapon in itself. The Roman army, known for their pragmatic combat engineering skills, sometimes diverted the course of streams either to cut an army off from its water supply or to redirect the stream through an enemy encampment.<sup>8</sup> In some cases, the Romans actually dammed areas upstream from the enemy for a period of time, then deliberately destroyed the dam to create a catastrophic flood designed to wipe out the camp of the opposing army. Sometimes armies set out to destroy the irrigation networks of enemy nations, thereby eliminating their source of water. Such was the case when Ghengis Khan invaded Mesopotamia and destroyed the irrigation networks of the Tigris River. Disturbing the water supply of an enemy was, indeed, a common tactic employed by all armies in the ancient world.<sup>9</sup> Although frowned upon in most cases, deliberate poisoning of water sources, such as streams, springs and wells, was not unheard of among many ancient armies.<sup>10</sup>

Deliberate disturbance inflicted upon the agricultural landscape using incendiary and chemical means was also widely employed by armies in antiquity. Although not strictly part of the natural environment, agriculture and crops serve as a strong link between the human and physical landscape and continue to be a target of deliberate destruction in military campaigns. Salting an enemy's fields was not uncommon. Perhaps the most well known, albeit not exclusive, example of this practice was the salting of Carthaginian fields by the Romans to prevent Carthage from ever becoming a military threat again.<sup>11</sup>

Moving ahead in time, deliberate destruction of agriculture and other environmental resources was practised by the many colonial empires who were vying for control of the fur trade in the New World. One of the better known first instances began during the American Revolutionary War, when General Washington ordered the fields of the Iroquois Indians, who were allied with the British, razed so only bare earth was left exposed. This practice worked so well that part of US policy during the Indian Wars that spanned the 1800s was elimination of the Native American resources, including destruction of winter sheltering grounds and elimination of once vast herds of buffalo<sup>12</sup>.

Before C-rations and preserved food were available, an army on the march had to live off the land it was moving across. The swathe of destruction left by

General William Tecumseh Sherman and his march to the sea in the latter part of the American Civil War attests to what an army of several thousand men can do to a landscape. This march was hailed by northerners as a brilliant military tactic (for cutting off his supply lines, thus ‘living off the land’) and scorned by the South as one of the cruellest measures ever inflicted upon humankind. In this march, Sherman cut off his supply lines and literally marched across the south all the way to the sea. Troops were sent out to obtain food from the land and destroy everything in their path, leaving a massive swathe of destruction all the way to the sea.<sup>13</sup>

An army of several thousand men on the march places severe burdens on the resource base of any given area. That is to say, armies consume massive amounts of food and, before automobiles, the horses associated with an army on the march needed pasture grass as well. Nomadic raiders such as Ghenghis Khan and Attila the Hun were often forced to limit the size of their armies based the amount of pasture required to support their horses. Not only would consuming these resources ensure the army’s ability to continue its military campaign, it would also deprive the enemy of resources needed to fight against the invader. If an army didn’t consume the resource base of the area it occupied, then the existing population would often do it for them, destroying crops and resources of an invading army, thereby depriving the army of its lifeblood through a scorched earth policy.<sup>14</sup> The Romans implemented this practice widely by burning pasture and crops when the empire was faced with threat of invasion.<sup>15</sup> However dreadful these practices were to the agricultural landscape and the human population, the landscape and population did recover. Warfare in the ancient and pre-modern world did not leave any permanent scars on the landscape. The same cannot be said for what occurs in modern warfare when explosive munitions in all of their various forms leave scars on the landscape that, in some instances, have lingered for close to 100 years.<sup>16</sup>

### *History of Modern Warfare*

In today’s world, which is so influenced by modern cinema, it is easy to imagine that warfare was always a highly destructive epic event capable of widespread destruction. Images rendered by modern cinema that conjure up displays of exploding cannon rounds in nineteenth-century warfare – dislodging fountains of earth, blasting soldiers and trees skyward, inaccurately describe the technological capabilities of warfare at the time. For hundreds of years gunpowder, or blackpowder, was simply too primitive to be deployed as anything but a propellant of solid objects. The only change in technology was that, instead of mechanical device hurling an object at a fortification, now there was a chemical substance doing the work instead. Blackpowder was much weaker than modern day ‘gunpowder’, and the weapons in which it was used were highly inaccurate with fairly low range. Translating this into the dimensions of combat, prior to the

twentieth century battle was, with some exceptions, quite limited in its spatial extent and magnitude of disturbance.

From an environmental perspective, the introduction of black powder did little to alter the destructive effects associated with military weaponry – that is, until smokeless gunpowder was introduced in the late nineteenth century. Although its origins are highly contested, it is generally accepted that black powder was developed by the Chinese and first used in firearms in the early 1300s.<sup>17</sup>

For a significant part of its history in western armies, black powder was mainly used to propel solid objects at high velocities from a barrelled device. Projectiles differed little from the solid stones thrown from mechanical catapult devices that had been used previously. The mass of the propelled object itself was used to inflict harm upon its given target; its use as a ‘bomb’ or an explosive munition was fairly limited. Explosive munitions of the time were hollowed out cannon balls with a fuse inserted into a hole. The fuse was lit akin to lighting a fuse on a modern day firework; i.e. the shorter the fuse, the less time before the device ‘went off’. These primitive explosives were considered unreliable and dangerous by individuals manning the artillery piece. Solid, round shot more often was delivered from a smoothbore artillery device, employed along the front lines and fired at low trajectories so the round would skip erratically into oncoming troops. Commonly, round shot would be fired until advancing troops were in close proximity; cannons were then loaded with canister fire, akin to a large shotgun round. Environmental disturbances associated with solid shot ammunition were limited to divots and burrows formed as the cannon fire hit or missed its mark.<sup>18</sup>

Although these types of artillery devices continued to improve in range and accuracy, it was not until 1783 when Lt. Henry Schrapnel invented the spherical bursting shell, a cylinder filled with many smaller balls, that exploding ammunition was used to any significant degree.<sup>19</sup> The Schrapnel round, as it soon came to be known, however, also was considered unreliable since the pre-cut fuse did not always burst in the intended location.

As should now be obvious, the footprint of battle during the early use of artillery left a relatively limited mark upon the landscape. Artillery technology right up to the American Civil War (1861–1865) relied upon visual contact with the enemy. The concept of indirect fire, or firing at an unseen target based upon predetermined coordinates, was in its infancy and considered unreliable. Although artillery pieces were theoretically capable of ranges exceeding 2000 metres, gunners nonetheless relied on direct fire by utilising sights on the artillery pieces.<sup>20</sup> Thus, battlefields were small compared to modern standards, and the impact exerted upon the physical landscape from such engagements was not limited due the primitive artillery, but also to the confined nature of the battlefield.

During the American Civil War, warfare began to take its first major advances regarding the scale of disturbance. The spatial extent of the battlefield increased

due mainly to the rifled infantry, forcing artillery to move backward from their vulnerable position on the front lines. Usage of ammunition went up in this war as well. Gunners normally allotted tens of rounds per battle now began to use ammunition by the hundreds; the increased production levels associated with the industrial revolution also filtered through to warfare. The size of armies went up from troops of several thousand to several hundred thousand. The size of the military theatre of operations went up due to the advent of railroad transport. For the first time in thousands of years of military conflict, troops could be moved across the land by means other than foot and horseback. Finally, the temporal nature of battle increased. Previous battles of the eighteenth and nineteenth centuries normally lasted several hours; a battle that began in the morning and went into the night was considered uncommon, but by the end of the war this was the norm.<sup>21</sup> However, the advancements in warfare technology introduced by the industrial age were still only just beginning. While great advances were made in infantry weapons and movement, technological advancements still paled into relative insignificance compared to the damage wrought by warfare of the twentieth century.

#### *Introduction of Smokeless Gunpowder into Modern Warfare*

Whereas many precursors to modern war ominously appeared in the American civil war, including rifled infantry weapons, trench warfare and rapid troop movements, war was still waged using tactics that had been employed for the previous several hundred years; the troops still practised line and column tactics, the infantry weapons were, for the most part, single shot muzzle loaders, and black powder was used in most of the weapons.<sup>22</sup> The most devastating environmental damage from this war derived from the incredible consumption of resources on both sides to support the war effort. Forests were levelled to produce railroad ties and fuel for railroad transport – a relatively new innovation that allowed rapid deployment of troops and greatly expanded the military campaign theatre. Also, coal and iron ore were mined with reckless abandon in order to produce the steel needed for the ‘war machine’.<sup>23</sup>

Armies continued to use weapons with black powder as a propellant for several decades following the American Civil War. Rapid fire, breech loading and rifled barrel artillery were introduced to compete with the longer range of rifled, long-range infantry weapons. However, the nature of the black powder propellant made them unreliable and dangerous due to build up of powder residue in the barrel. It was not until late in the nineteenth century when a breakthrough in weapons technology came about when Alfred Nobel introduced the world to smokeless gunpowder, blasting caps and a new ‘safer’ form of explosive called Trinitrotoluene, commonly known as TNT. Shortly after this development, in 1899 the French introduced the highly explosive (HE) artillery shell. This new weapon was a cylinder shaped shell, filled with highly explosive cordite and



fired from a rifled, breech loading, artillery device. The cylinder shaped artillery round was a long sought after development in munitions since it created less friction with the air as it travelled, making it a much more accurate and farther reaching weapon than the traditional cannon ball. Soon, the British followed with the more explosive melanite and through the use of chemistry the world came to know the possibilities of ever larger and more powerful HE rounds. These explosives, combined with the age of industrialisation, ushered in a new form of warfare capable of levelling forests and altering landscapes beyond recognition.<sup>24</sup>

Although several wars, such as the Franco Prussian, the Russo-Japanese and the Spanish-American, allowed armies to 'test' and develop munitions that utilised the weapons of modern war, it was not until World War One that these developments were fully implemented at an industrial scale. In World War One, the same concepts associated with the Industrial Age were introduced into the philosophy of war. Instead of armies that numbered in the thousands, or hundreds of thousands, a nation needed armies in the millions in order to be a powerful, warring nation state. A nation required a well-built infrastructure and massive industrial complex just to support its massive armies. For example, several months into the 'Great War' (as World War One would soon be known), both politicians and the general staff realised that those nations capable of out-producing the other nation would have a distinct edge. Commanders also realised that the days of dashing cavalry charges and brightly coloured uniforms, used so armies could communicate in the thick smoke of battle, were over; new tactics needed to be implemented.<sup>25</sup>

The extremely long range of rifled infantry weapons and the fully automatic machine gun forced commanders to take artillery off the front lines after several devastating losses in the early stages of World War One. Artillery took up positions in the rear and perfected the art of indirect fire, based on the calls of forward observers. The role of artillery was to indurate an area with explosive shells in order to destroy enemy defences and shatter its morale. Terms such as the 'straight barrage', 'rolling barrage', 'piled up barrage' and 'creeping barrage' were coined to refer to curtains of artillery fire placed directly in front of advancing troops to obliterate anything on the surface.<sup>26</sup>

Before World War One, artillery units attached to armies were usually allotted, at most, several hundred rounds per day for combat operations. By the end of the war, artillery units were assigned several hundred rounds per *hour*. At the start of the war, artillery was seen as an arm to directly support the infantry and wars were won by *élan* or the courage of the infantry; by the war's end, the mantra of all commanders was, 'Artillery conquers and infantry occupies'. Artillery, therefore, emerged from World War One as the deciding factor in battle.<sup>27</sup>

The environmental consequences of this type of warfare obliterated forests and significantly altered the landscape, thus creating wide swathes of destruction, limited only by the range of artillery shells.<sup>28</sup> Perhaps the best-known example

of this swathe of destruction is the Western Front, a sinuous line of trenches, craters, bunkers and barbed wire averaging 20 km in width, and stretching from the English Channel to the border of Switzerland. However severe this disturbance may have been, the damage was limited to the range of the artillery devices. Although the footprint of the battlefield had increased significantly from the wars of previous centuries, the disturbance was still confined to the fairly predictable linear dimensions of the battlefield. The Western Front, and the resulting belt of disturbance, resulted from stalemate conditions along a linear front, albeit several hundred miles long and tens of miles deep. The war was unique, however, because for the first time, humankind realised that the weapons spawned from advances in technology were capable of rendering destruction beyond the scope of previous imagination.<sup>29</sup> The war was so devastating in terms of human life loss and environmental cost, that it was considered the 'War to end all Wars.' Nobody believed such destruction could ever happen again.

The destruction wrought in World War One was not overlooked by the scientific community. Foresters were some of the first to take note of the environmental disturbance wrought by war. By the end of World War One, European and American foresters began to assess the toll exacted on the environment. This assessment was accomplished primarily by determining forest damage in terms of board feet of lumber lost by: (1) outright destruction, (2) damage due to shrapnel impregnation, and (3) harvest to support the war effort.<sup>30</sup> Several studies estimated that 2.5 billion board feet of lumber in French forests had been destroyed during the course of the war. One American forester attached to the US army, reported that not only did the artillery bombardments reduce forests along the Western Front to splinters, particularly those in France, they also created a cratered landscape that reduced a once stable soil ecosystem into mounds of loose, unconsolidated sediment that was hardly worth calling 'soil'. Veterans of World War One described the landscape after an artillery bombardment as unworldly, and like a scene of incomprehensible destruction. Ralph Bagnold, an eminent soil physicist and veteran of both World War One and World War Two, provided an account of the landscape after an artillery bombardment in his autobiography, *Sand, Wind, and War*: '...On the main Passchendale ridge, whole villages were blown up, woods disappeared, and the courses of streams were changed.'<sup>31</sup> Beyond description of the horrendous effects to soils and the landscape, however, no scientific assessment was made beyond that of estimated losses of trees. Today, over 90 years after the fighting has ended, the landscape has been drastically altered in areas where stalemate conditions prevailed along the western front. Once diverse forest communities contain near monoculture plantings and, in some areas, the landscape is so cratered that only stunted trees grow upon hummocks dividing water filled craters. Soils that have developed in the disturbed crater areas differ completely in their developmental pathways from soils in undisturbed portions of the battlefield.<sup>32</sup>

After the brief interest displayed by foresters immediately following World War One, the Western Front was largely forgotten; humankind was so horrified by the death and destruction associated with the war that most preferred to leave it as a memory, never to be repeated. Unfortunately, World War One only set the stage for World War Two, and barely 20 years after the last shot of World War One Europe plunged into another round of warfare. This time, however, the damage to the landscape, or soils, (at least in the countryside) was much more limited. The lack of soilscape disturbance was due mainly in technological advancements in munitions and changes in battlefield tactics from the introduction of mobile armour and improved road networks. Despite the fact that in the years between, explosive munitions had become much more powerful, the toll exacted on the landscape was minimised due to the fluidity of the front lines. Instead of concentrating firepower in the form of an artillery bombardment along a line of stalemate, mobile armour (tanks) supported by infantry now moved quickly through an area and exploited gaps created by the confusion in armoured thrusts through a more porous front line. In addition, artillery shells, although more powerful, were newly equipped with fuses set to detonate above the surface and not upon impact.<sup>33</sup> Combative activities in World War Two Europe were also concentrated in urban areas, unlike World War One, where stalemate conditions took place in relatively unpopulated areas. Not all non-urban areas were spared the fighting, and many forested areas did receive considerable damage. Over 100 million acres were directly destroyed through combative activities in French forests alone during World War Two.<sup>34</sup>

Fighting in World War Two did not only occur in Europe. A significant campaign was also being waged between the US and her allies against Japan in the Western Pacific. Unlike the fluid nature of battle along the western front of Europe, in the Pacific campaign many islands endured days of naval and aerial bombardments to 'soften up' the enemy before the beaches were stormed. Islands such as Tarawa, Iwo Jima and Attu were subjected to heavy naval and aerial bombardment prior to amphibious infantry operations.<sup>35</sup>

Following World War Two, many individuals in military circles believed that the widespread destruction associated with conventional weaponry of the twentieth century was a relic of the past. Out of World War Two sprang two global super powers, the United States and the Soviet Union. Warfare was seen by the allied commands from both countries as approaching a new age; one of rapid movement with urban areas as key military objectives (likely, over the eastern plains of Europe). If, by chance, stalemate conditions did occur, military planners believed the culmination would be mutual nuclear devastation. In sum, the mentality of those in the cold war was that any fighting with conventional weapons that did occur would be brief and urban based. These misconceptions would have been quickly disabused when those same individuals witnessed (or participated in) the awesome amount of environmental destruction created by

the Second Indochina War, or the Vietnam War as it is referred to in the United States.

The Vietnam War differed from previous wars of the twentieth century because now the destruction of key components of the country's physical environment became a deliberate military strategy. In World War One and World War Two, the damage inflicted upon the forests and soils of the nations involved was incidental, in that the damage was a side-effect of the intention to eliminate enemy forces. In Vietnam, a major portion of the US war effort was the elimination of forests.<sup>36</sup> Deforestation of the dense, tropical selva was performed to eliminate cover for enemy troops, provide bases of operation, and create landing strips for aircraft and establish landing zones (LZ's) for troops deployed by helicopter.<sup>37</sup>

Whether intentional or incidental, the Vietnamese physical landscape was mainly disturbed by the following three military activities: (1) explosive munitions, (2) herbicides (dioxins such as agent orange), and (3) land clearing operations from specialised bulldozers called 'Rome Plows'.<sup>38</sup> Although artillery bombardment was heavily utilised in this war, aerial bombardment inflicted damage to the forests and the enemy on a scale never before accomplished. Much of the damage inflicted upon the forests through highly explosive, shrapnel-producing munitions was the same type as seen in previous wars, except that it was accomplished with larger and more effective 500, 700 and 1000 lb. bombs, typically dropped from B-52 bomber formations, with a smaller percentage dropped by individual sorties by fighter bomber aircraft. Delivered bombs destroyed vegetation outright, tore it open with shrapnel, and left it impregnated with small pieces of shrapnel. US Air Force bombers in this war also widely practiced 'carpet bombing' in which B-52 bombers would fly over and lay down a blanket of bombs into an area thought to be occupied by enemy forces. The B-52 bombers left wide swaths of disturbance, dotting the Vietnamese landscape with millions of craters. Typically, these bombing runs consisted of 3 to 12 aircraft, each carrying 108 500 lb. bombs. The swathe of disturbance created by such missions saturated an area with bombs approximately half a kilometre wide and over 1000 metres long. Conservative estimates place the number of craters left behind from these carpet bombing missions at around 26 million.<sup>39</sup> For comparison with the previous wars of the twentieth century, during World War Two a total of 2,000,000 tons were dropped in all theatres of the war. In Korea, the total munitions dropped amounted to 1,000,000 tons. In Indochina between 1965 and 1971 the United States dropped over 14,000,000 tons of munitions.<sup>40</sup> In fact, during the siege of Khe Sahn, which lasted several months, the amount of munitions expended by US bombers and artillery was approximately 1,000,000 tons. This was more than all bombs dropped in the Pacific Campaign by allied forces.<sup>41</sup> The effects from these bombing runs can still be seen on the Vietnamese landscape today, a topic that is currently being addressed through preliminary field work by this author.

Carpet bombing by B-52 bombers was not only limited in use to the attempt of exposing the enemy taking cover in the forests, it was also used to destroy large expanses of agricultural land. One soldier remarked on the destruction, as seen from above, '... bombers and artillery pound the [land] into the gray porridge that the green delta land becomes when pulverized by high explosives.'<sup>42</sup>

Not surprisingly, many of the same activities employed by the U.S. Army to destroy enemy forests were used to destroy enemy agriculture. Herbicidal chemicals were dumped on large expanses of rice paddies while 'Rome Plows' were used to destroy the dikes associated with rice production. As should now be obvious, in Vietnam, the war against forests and agriculture was as much a component of the overall war effort as was the attrition against the Viet Cong.

Sometimes, specialised aerial bombs were dropped for the singular purpose of clearing a large tract of land in the thick forests of Vietnam. One such bomb frequently employed by the US military during this time was the infamous 'Daisy Cutter'. The bomb, about the size of a Volkswagen car, is dropped from a C-47 transport plane and drifts to the ground via parachute. A long detonation probe attached to the tip of the bomb causes detonation immediately upon contact with the ground. The parachute is employed to reduce air speed so when the bomb probe touches the ground, the bomb detonates above the surface, thereby directing the blast outward instead of into the ground. In this manner, a large diameter landing zone, about the size of a football field, is carved out of the forest without producing a crater. The cleared area of former forest can then be used for troop implant and extraction purposes.<sup>43</sup>

Incendiary bombs were also implemented in Vietnam at a larger scale than any previous war. In 1965, 'Operation Sherwood Forest' was implemented as a measure to destroy, through massive forest fire, almost 30,000 hectares of Vietnamese tropical forest. The results from this operation levelled hundreds of villages and left hillsides scarred to the present day. The US military soon realised that the tropical rainforests did not contain enough ground cover, nor were they dry enough to sustain large wildfires. Thus, a new strategy was needed to clear large tracts of forests, forcing the military to turn its attention to chemical agents. Herbicides known collectively as agents orange, white and blue were implemented at an industrial scale with the sole intention of eliminating massive tracts of forest vegetation.<sup>44</sup> Unfortunately, the chemicals in these herbicides not only harmed the vegetation they were intended to eliminate, but they had severely harmful effects on the people occupying the forests, including US troops and rural villagers.

As in Europe at the end of World War One, the forests of Vietnam were examined near the end of the war to assess the extent of disturbance. After flying over many areas that had just been subjected to an aerial bombardment, foresters reported a landscape that resembled the surface of the moon. It was estimated that 1.65 million hectares of forest had been completely destroyed. In addition,

foresters estimated that 4 per cent of the country's forests were so impregnated with shrapnel they had no lumber value whatsoever.<sup>45</sup>

In addition to forest damage, the impact of warfare on soils is also widespread, though much less studied. Following aerial bombardments in Vietnam, foresters and ecologists described the Vietnam landscape as a moonscape of craters and scorched earth. They proposed that after the soil loses its protective forest cover, it may undergo laterisation – a process that turns exposed soils into dry, rock-like laterite. Soil disturbance also has implications for the way vegetation and soils respond to changes local water table conditions wrought by disturbance. In some instances, impermeable bedrock and soil layers are breached by cratering, depriving the vegetation of its former source of water. In other instances, cratering exposes the water table and inhibits deep rooting of vegetation occupying that crater, limiting subsequent reforestation. The impact of munitions upon the soils and forests of Vietnam was severe both in magnitude and extent. Instead of damage confined to a given battlefield, or range of an artillery weapon, the war left millions of craters upon millions of acres of deforested landscape.<sup>46</sup>

Environmental disturbance is thus a constantly recurring theme of war. It started in antiquity and has continued right up to the present time. The only aspect of wartime that has changed is that weapons and armies become ever capable of creating disturbances that continue to increase in magnitude, type and, perhaps, frequency. Numerous conflicts across the globe attest to this increasing magnitude of disturbance, expanding the effects of war well beyond the battlefield. Using the recent 2006 war between Israel and Hamas in Lebanon as an example, environmental damage associated with this 'conflict' has been particularly severe. Thousands of acres of forest have burned due to rocket attacks while countless ecosystems have been decimated by the oil spills created by attacks on oil facilities. With time, a better picture of the environmental disturbances wrought by the current wars in Iraq and Afghanistan will be revealed, but for now the instability in these areas currently makes a scientific assessment of the damage difficult to obtain.

## CONCLUSIONS

In conclusion, a great deal of scientific and historical literature has focused on the ways in which the physical environment has altered the outcome of military campaigns. However, very little research has focused on the direct impacts of war upon the environment, particularly those impacts due to explosive munitions. This paper embodies a new avenue of research within the realm of history and environmental science by studying the direct impacts of warfare upon the environment. As any detailed study of non-military and military history will show, the ever-increasing advances humans have achieved to make their lives

better, or in this case, to end the lives of others has resulted in greater magnitudes of disturbance upon the physical landscape. It is in this author's hope that the contextual findings of this paper will spawn more interest in landscapes directly affected by the detrimental components of war. It is hoped that eventually, warfare will be as recognised as others forms of anthropogenic disturbance. Among mining, logging and industrial atmospheric pollution, warfare and its many forms of environmental damage need to be clearly seen as an infamous legacy in environmental history.

## NOTES

<sup>1</sup> Patrick E. O'Sullivan and Jesse. W. Miller, *The Geography of Warfare* (London: Croom Helm, 1983); Harold A. Winters, Gerald. E. Galloway, William J. Reynolds and David W. Rhyne, *Battling the Elements: Weather and Terrain in the Conduct of War* (Baltimore, MD: Johns Hopkins University Press, 1998).

<sup>2</sup> Numerous translations exist for both texts. In this case I used the following two translations: S. Tzu, *The Art of War*, translated by S. B. Griffith. (London: Oxford University Press, 1963); C.V. Clausewitz, *On War*, translated by A. Rapoport (Baltimore: Penguin Books, 1968). For a more recent overview of modern military theory please see: Martin Van Creveld, *The Transformation of War* (New York: The Free Press, 1991).

<sup>3</sup> Wendel C. King, 'Foreword', in *The Environmental Legacy of Military Operations*, ed. J. Ehlen and R. S. Harmon (Boulder, CO: Geological Society of America Reviews in Engineering Geology, 2001), pp. ix–x.

<sup>4</sup> Arthur H. Westing, *Warfare in a Fragile World: Military Impact on the Human Environment* (London: Taylor & Francis, 1980).

<sup>5</sup> Richard P. Tucker and Edmund Russell, *Natural Enemy, Natural Ally* (Corvallis, OR: Oregon State University Press, 2004); Edmund Russell, *War and Nature* (Cambridge: Cambridge University Press, 2001).

<sup>6</sup> Jay E. Austin and Carl E. Bruch (eds.), *The Environmental Consequences of War* (Cambridge: Cambridge University Press, 2000).

<sup>7</sup> Westing, *Warfare in a Fragile World*; Malvern Lumsden, *Incendiary Weapons*, SIPRI monographs (Cambridge, MA: MIT Press, 1975); Arthur H. Westing, 'Environmental hazards of war in an industrializing world', in *Environmental Hazards of War: Releasing Dangerous Forces in an Industrialized World*, ed. A. H. Westing (London: SAGE Publications, 1990), pp. 96–97.

<sup>8</sup> Adrienne Mayor, *Greek Fire, Poison Arrows, and Scorpion Bombs: Biological and Chemical Warfare in the Ancient World* (Woodstock: Overlook Duckworth, 2003), pp. 99–118.

<sup>9</sup> Destruction of dams was employed with great success in World War Two and the Korean War. This practice was also implemented in the Second Indochina war, but with limited success. Westing, *Warfare in a Fragile World*.

<sup>10</sup> Mayor, *Greek Fire*.

<sup>11</sup> Salting fields is also commonly referred to as 'poisoning fields'. The Carthaginian example, or what Rome did to Carthage is an almost worn out example and is commonly

cited in historical writings as well as literature discussing the impact of war on the environment. Some good sources on field poisoning related to the Punic wars would be Mayor, *Greek Fire* and Simon Aglim, Phyllis G. Jestice, Rob S. Rice, Scott M. Rusch and John Serrati, *Fighting Techniques of the Ancient World* (St. Martin's Press, 2002).

<sup>12</sup> Westing, *Warfare in a Fragile World*.

<sup>13</sup> Paul W. Gates, *Agriculture and the Civil War* (New York: Knopf, 1965). [1st edn, *The Impact of the Civil War*].

<sup>14</sup> O'Sullivan and Miller, *The Geography of Warfare*.

<sup>15</sup> These practices were not limited to ancient armies and have continued right on to present time; a classic example is Stalin's scorched earth policy on the eastern front against the Germans in World War Two. To deprive the German army of living off the Russian countryside, the Russian army and population were ordered to burn their own villages and fields. Never before or since in history has a country destroyed so much of its own land on an industrial scale, merely to starve the enemy. Erik Durschmied, *The Weather Factor* (New York: Arcade Publishing, 2000), pp. 167–214.

<sup>16</sup> Joseph P. Hupy, 'The Long-Term Effects of Explosive Munitions on the WWI Battlefield Surface of Verdun, France', *Scottish Geographical Journal* 122 (2006): 167–184; Joseph P. Hupy and Randal J. Schaetzl, 'Introducing Bombturbation, a Singular Type of Soil Disturbance and Mixing', *Soil Science* 171 (2006): 823–836, doi:10.1097/01.s.s.0000228053.08087.19.

<sup>17</sup> The earliest written account of firearm use in Europe is in an Italian document from 1326, whereas the oldest known Chinese firearm dates back to 1356. Until further evidence is uncovered, the origins of firearms will remain controversial. Jack Kelly, *Gunpowder* (New York: Basic Books, 2004); James R. Partington, *A History of Greek Fire and Gunpowder* (Cambridge, UK: W. Heffer, 1960).

<sup>18</sup> Jonathon Bailey, *Field Artillery and Firepower* (Annapolis, MD.: Naval Institute Press, 2004, rev. and expanded edn); Ian Hogg, *The Illustrated History of Ammunition* (Secaucus, NJ: Chartwell Books, 1985); Ian Hogg, *The Illustrated Encyclopedia of Artillery* (Secaucus, NJ: Chartwell Books, 1987).

<sup>19</sup> Numbers tallied in 1854 indicate that over 70 per cent of all artillery rounds fired in typical battlefield engagements were solid shot projectiles. The remaining were mostly canister fire and other similar 'shot gun' type munitions. Bailey, *Field Artillery*.

<sup>20</sup> Bruce Gudmundsson, *On Artillery* (Westport, Conn.: Praeger, 1993).

<sup>21</sup> Thomas Hammes. *The Sling and the Stone: On War in the 21st Century*. (St. Paul: Zenith Press, 2004); John Keegan. *A History of Warfare* (New York: Vintage Books, 1998); W. Lind, K. Nightengale, J. Schmitt and G. Wilson, 'The Changing Face of War: Into the Fourth Generation', *Marine Corps Gazette*, October 1989: 22–26.

<sup>22</sup> Hammes, *The Sling and the Stone*.

<sup>23</sup> The topic of resource depletion during the American Civil War and other wars of the twentieth century has been well covered by several different authors. Notable works include: L.M. Brady, 'The Wilderness of War: Nature and Strategy in the American Civil War', *Environmental History* 10 (2005): 421–427; J.R. McNeill, 'Woods and Warfare in World History', *Environmental History* 9 (2004): 388–410, doi:10.2307/3985766; Tucker and Russell, *Natural Enemy, Natural Ally*; Robert C. Whisonant, 'Linking Geology and Social Studies: Civil War Battles for Southwestern Virginia's Lead and Salt', *Journal of Geoscience Education* 46 (1998): 321–330; Westing, *Warfare in a Fragile World*.



<sup>24</sup> Hogg, *The Illustrated History of Ammunition*; Hogg, *The Illustrated Encyclopedia of Artillery*; Kelly, *Gunpowder*.

<sup>25</sup> Hammes, *The Sling and the Stone*; Keegan, *A History of Warfare*.

<sup>26</sup> Breech loading rifles and rapid firing weapons such as the Gatling Gun were in existence since the American Civil War, but army commanders were slow to adopt to changes brought about by these weapons, mainly because most countries did not upgrade their arsenals with these weapons until the advent of World War One. Gudmundsson, *On Artillery*.

<sup>27</sup> In the age of smooth bore artillery, artillery units often brought one round per gun into battle, siege guns firing more than 5 rounds per day were considered exceptional. Bailey, *Field Artillery*.

<sup>28</sup> Hupy, 'The Long-Term Effects of Explosive Munitions'.

<sup>29</sup> John Keegan, *The First World War* (New York: Vintage Books, 1998).

<sup>30</sup> J. Demorlaine, 'Strategic Importance of Forests in the War', *American Forestry* 25 (1919): 1040–1043; Percival S. Ridsdale, 'Shot, Shell and Soldiers Devastate Forests', *American Forestry (now American Forests)* 22 (1916): 333–340; H.S. Kernan, 'War's Toll of French Forests', *American Forests* 51(1945): 442.

<sup>31</sup> Ralph A. Bagnold, *Sand, Wind, and War: Memoirs of a Desert Explorer* (Tucson, AZ: University of Arizona Press, 1990).

<sup>32</sup> Hupy and Schaetzl, 'Introducing Bombturbation'.

<sup>33</sup> Stephen E. Ambrose. *Citizen Soldiers: The U.S. Army from the Normandy Beaches to the Bulge to the Surrender of Germany, June 7, 1944–May 7, 1945* (New York: Simon and Schuster, 1997).

<sup>34</sup> European forests also underwent heavy exploitation during both World War One and World War Two. Wood products were heavily utilised during these wars to construct rail lines, provide posts for barbed wire entanglements and telegraph lines, strengthen fortifications, and many other war related activities. During both wars, occupied countries were heavily exploited for their resources in order to supply the war effort. It is estimated that nearly 17 billion board feet of lumber was harvested from the forests of France during World War One. The cedar tree on the flag of Lebanon is now merely a symbol of what was a once mighty forest, after being obliterated by the Ottoman Empire during World War One to supply fuel for their railways. During World War Two, German forces occupying France increased harvesting activity by a full 50 per cent more than French harvesting in times of peace. Britain also heavily exploited her forests during both wars and many majestic timbers from protected parks and recreational areas were sacrificed for the war effort. Once again, this information is well covered in other writings and is not the main component of this paper. For more on forest resource depletion during war, please consult the following: McNeill, 'Woods and Warfare in World History'; Tucker and Russell, *Natural Enemy, Natural Ally*; Percival S. Ridsdale, 'French Forests for Our Army', *American Forestry (now American Forests)* 25 (1919): 962–972; Kernan, 'War's Toll of French Forests'.

<sup>35</sup> Eugene Palka, 'World War II in the Aleutian Islands: Physical Geographic Challenges in the Battle for Attu', in *The Scope of Military Geography: Across the Spectrum from Wartime to Peace*, ed. Eugene Palka and Francis A. Galgano (New York: McGraw Hill, 2000), pp. 9–30.

<sup>36</sup> A.H. Westing and E.W. Pfeiffer, 'The cratering of Indochina', *Scientific American*, 226, 5 (1972): 20–29; A.H. Westing, *Ecological Consequences of the Second Indochina War* (Stockholm: Almqvist and Wiksell International, 1976).

<sup>37</sup> John Lewallen, *Ecology of Devastation: Indochina* (Baltimore: Penguin Books, 1971); Westing, *Ecological Consequences of the Second Indochina War*.

<sup>38</sup> Arthur H. Westing, 'Forestry and the War in South Vietnam', *Journal of Forestry* 69 (1971): 777–783.

<sup>39</sup> G.H. Orians and E.W. Pfeiffer, 'Ecological Effects of the War in Vietnam', *Science* 168 (1970): 544–554, doi: 10.1126/science.168.3931.544; E.W. Pfeiffer, 'Ecological Effects of the Vietnam War', *Science Journal* 5 (1969): 33–38.

<sup>40</sup> Raphael Littaur and Norman Uphoff (eds.), *The Air War in IndoChina* (Ithaca, NY: Cornell University Press, 1972).

<sup>41</sup> John Prados and Ray W. Stubbe, *Valley of Decision: The Siege of Khe Sanh* (New York: Dell Publishing, 1991).

<sup>42</sup> Westing, *Ecological Consequences of the Second Indochina War*.

<sup>43</sup> Arthur H. Westing, 'The Super Bomb', *American Report*, Sept 8, 1972, p. 3. Note: This bomb and others more powerful than this are seeing use in our current wars being fought in Iraq and Afghanistan. Contemporary use of this bomb is mainly to suck the oxygen out of caves where enemy forces are believed to be located. There is much debate over the effectiveness of this technique. Deployment of this bomb and other more advanced versions were a large part of the 'shock and awe' campaign in mountainous region of Tora Bora in 2001.

<sup>44</sup> Lumsden, *Incendiary Weapons*.

<sup>45</sup> B.R. Flamm and J. H. Cravens, 'The Effects of War Damage on the Forest Resources of South Vietnam', *Journal of Forestry* 69 (1971): 784–789; Orians and Pfeiffer, 'Ecological Effects of the War in Vietnam'.

<sup>46</sup> The resilience of the Vietnamese landscape, or whether the imprint of battle still significantly remains, is an unresolved question and requires more attention from both the historic and scientific communities. This author hopes to answer the questions brought up by many of the foresters assessing the damage during the later part of the Vietnam War. Discussion of the immediate effects of war on Vietnamese forests is well documented in: A.H. Westing and E.W. Pfeiffer, 'The Cratering of Indochina', *Scientific American* 226 (1970): 20–29

