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## Modern Military Weaponry and (un)Sustainable Treatment of the Environment

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In the introduction of her analysis of trench warfare on the western front, Dorothee Brantz makes an important point about the battlefield. Brantz is a professor of metropolitan studies at the Berlin Institute of Technology and studies urban environments, often focusing on the impacts of war on those environments in the West. Brantz states that battlefields are not “artificial spaces.” In other words, the effects of battle go beyond our artificial designations of certain areas as “battlefields.” It is comfortable for us to detach ourselves from the consequences of war that go beyond the human body. We forget that war is a chaotic environment that shapes and is shaped by us. When a soldier marches into battle, the landscape visibly changes from pastoral views into a killing floor, it is the total environment of the battlefield that molds the soldier into a new being and makes the land into a shell of its former self. We cannot be so distant from our environment.<sup>1</sup> Pollution and global warming are the usual suspects when it comes to the degrading health of the environment, but what we don’t discuss as often are the harmful effects of war which can be sudden but enduring. The beginning of the 20th century showed a steep increase in ways that the weapons and tactics of war harm soil, ecosystems, and humans. With the industrialization of western warfare there has been an increase in immediate harm and the natural recovery time of the terrain and soil composition of battle, training, and testing grounds.

To discuss this, examples will primarily be pulled from wars that involve Rome, Greece, and the United States because the scope of their influence is roughly comparable. This paper will draw on the Peloponnesian War, World War I and II, the Vietnam War, and the 1991 Gulf War among others. The reader should understand that the impacts of war on soil and terrain are not limited to the weapons and tactics outlined in this paper (which largely stem from a western point of view). The ways that humans affect the earth beneath our feet are numerous and the lines between warfare and everyday activities are sometimes blurry. That being said, narrowing analysis to these specific causes of degradation, such as explosives and chemical warfare, allows paths of restoration to be clearer. This paper concludes that war after the western industrial revolution has been much more harmful to the environment, especially due to the chemicals used that create enduring effects. It also concludes that consideration of the environment needs to be a larger part of military strategies if we ever want to address the health of the planet effectively.

First, we will discuss the more surface level weapons, tactics, and influences of war that tend to be more common in ancient warfare. Then we will look at more modern forms of warfare like chemical and nuclear weapons. Last, we will discuss restoration programs and efforts.

When studying war, military historians often neglect the reciprocal relationship between the soldier and their environment.<sup>2</sup> Soldiers on the frontline are subject to environmental conditions; rain, heat, etc. Forgetting about the role the environment plays in wartime could prove to be a fatal strategic error, but it could also mean we forget to look at just how war damages the environment too. In teaching strategy, the authors of the Marine Corps Doctrinal

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<sup>1</sup> Brantz. “Environments of Death,” 69.

<sup>2</sup> Brantz, “Environments of Death,” 74.

Publication (MCDP) draw a comparison between strategic decision making and the domino effects of disrupting an ecosystem. They show that the smallest factor can dramatically alter a strategy, just as an ecosystem can be disrupted by the introduction of an invasive species.<sup>3,4</sup> Interestingly, when comparing the MCDPs of 1997 and 2018, both seem to acknowledge the relationship between strategy and the environment but fail to understand that the military itself is a disruptive force to those environments. There does not seem to be any significant attention paid to the footprint combat leaves on the environment.

This mindset could have been sustainable in ancient warfare but isn't anymore. Where wars were fought with swords they are now fought with explosives. Weaponry and military strategies were much more surface level (i.e. trenches) and had localized affects. Weapons today are more chemically harmful, and those effects are compounded by the globalization of conflict. As the world becomes more interconnected socially and economically it logically follows that conflict in one area of the world would have effects all over (disruptions in trade and access to information for example). Although the industrialization process continues for some countries, the west industrialized starting in the mid 1800s and continuing well into the 1900s.<sup>5,6</sup> Humankind has advanced to better understand atoms and chemicals and so we are more equipped (and inclined) to make weapons that are destructive at that level. In approximately the last 125 years, warfare has become environmentally unsustainable. While modern warfare became more proficient at killing humans, it also became more proficient at killing the environment.

### ***Walls, Tunnels, Trenches, Wood, and Fire***

Pre-Industrial types of warfare largely altered the terrain through trenches, tunnels, and walls. These alterations were mostly defensive mechanisms like the Great Wall of China.<sup>7</sup> The Wall was constructed for defense against Mongols. While it was a powerful symbol of China's enduring strength, it has failed to prevent invasion throughout its history.<sup>8</sup> It was originally erected using packed earth and pieces of wood but was later reinforced using stones and fired bricks.<sup>9</sup>

Tunnels were used to transport food, water, and other supplies and could be used by both friend and foe during wartime. The ancient Mediterranean's developed tunnels to supply irrigation to their crops and drinking water at any given time and to maintain resource access when the city was under siege.<sup>10</sup> They were also viable methods of attack. Offensive tunneling

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<sup>3</sup> Department of the Navy, 1997.

<sup>4</sup> Department of the Navy, 2018.

<sup>5</sup> Oshima. "The Transition from an Agricultural to an Industrial Economy in East Asia."

<sup>6</sup> O, "The Evolution of Economy: Changes from the Agricultural and Industrial Revolutions."

<sup>7</sup> Certini et al.. "The Impact of Warfare on the Soil Environment," 1–15.

<sup>8</sup> History.com Editors, "Great Wall of China."

<sup>9</sup> Certini et al., "The Impact of Warfare on the Soil Environment."

<sup>10</sup> Labate, "Roman Tunnels."

was used by invaders to infiltrate besieged cities, leading to complex offensive and defensive strategies using tunnels in ancient warfare. Assaultants on a city under siege would tunnel under the defenses and weaken the walls, burning down fortifications and later using gunpowder to blow them up.<sup>11</sup> Defense against tunnellers utilized surface level water-filled moats which could force attackers to dig deeper and run into bedrock or flood tunnels from above. Defenders also built labyrinthine storage tunnels, booby trapped for collapse and staffed with troops during wartime to listen for attacking tunnellers. Tunneling was not an exclusively European tactic and has been used by Asian militaries as well. For a time in the 19th century the art of both offensive and defensive tunneling was rarely and poorly used.<sup>12</sup> An interesting modern example of siege defense is the Maginot Line; an exemplary display of French military engineering from World War II. While an incredible feat, the Maginot Line was unfortunately crafted for a bygone era of war and was too static to prevent the Germans from going around, into France, through Belgium.<sup>13</sup> Today, there are some fears of old tunnels collapsing. Collapses could lead to the release of pockets of bad air, perhaps infested with dangerous pathogens or chemicals.<sup>14</sup>

The use of trenches is present across western military history; both in Rome and Europe. Trenches used in ancient warfare were typically used for defense, to slow advancing armies. To surpass a trench, either army would need to fill it in and cross over it.<sup>15</sup> One notable trench was the Alban “Cluilian Trench.” It was named after the general of the Alban army who fought against the Romans in the 7th century BC and was the location at which the Alban King died.<sup>16,17</sup> Infamously, trenches were used during World War I. The trenches of World War I developed from linked foxholes into complex labyrinths that altered terrain drastically.<sup>18</sup> This style of warfare also drastically shifted how soldiers saw the world around them, from open battlefields to oppressive blindness.<sup>19</sup> The eastern front of WWI was an example of overwhelming defensive capabilities which encouraged the development of more destructive weaponry in an effort to override the defensive capabilities of trenches. Territory gain was unlikely but the technology around killing thoroughly advanced with the development of machine guns and chemical warfare. The stalemate between total defense and increasingly destructive weaponry most likely extended the war.<sup>20</sup>

As a defensive mechanism, trenches were successful. However, coupled with developing offensive capabilities, trenches became death traps. In addition to high death tolls, the early 20th

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<sup>11</sup> Springer, “Fighting Under the Earth: The History of Tunneling in Warfare.”

<sup>12</sup> Ibid.

<sup>13</sup> Ibid.

<sup>14</sup> McDougall. “Natives and Exotics: World War II and Environment in the Southern Pacific,” 208.

<sup>15</sup> Livius, “The History of Rome, Books 01 to 08,” 495.

<sup>16</sup> Ibid.

<sup>17</sup> Ibid; “The Albans first made an irruption into the Roman territories with a large army. They pitch their camp not above five miles from the city, and surround it with a trench, which, for several ages, was called the Cluilian trench, from the name of the general, till, in process of time, the name, together with the thing itself, were both forgotten. In that camp Cluilius, the Alban king, dies; the Albans create Mettus.”

<sup>18</sup> Brantz, “Environments of Death,” 78.

<sup>19</sup> Ibid, 78.

<sup>20</sup> Boff, “Fighting the First World War: Stalemate and Attrition.”

century ushered in warfare that was progressively more dismissive of the environment. Trenches carved long lasting fissures throughout the battlefields of Europe during World War I.<sup>21,22</sup> They also required a lot of wood to keep their structure, and so substantial amounts of forest were demolished in the harvesting of lumber.<sup>23</sup>

Deforestation is significant in ancient and post-industrial warfare.<sup>24</sup> The destruction of forests as a resource or a byproduct is a common theme throughout military history. For example, as Rome increased its naval and trade ship capacity, the empire sought out more access to lumber.<sup>25</sup> Similar to crude oil today, lumber was a politically contentious resource that created a lot of tension between nations. The Peloponnesian War was fought, in part, to secure more lumber for shipbuilding. Ironically, a significant amount of wooden ships was sunk in the effort to obtain more wood.<sup>26</sup>

Forests were not only destroyed to get more wood. Burning down forests has been used since ancient warfare to deplete enemy resources.<sup>27</sup> Burning down forests and brush was also used to expose or kill hidden troops.<sup>28</sup> A likely example of this is the Battle of Pylos:

“Spartan warriors were isolated on a brush-covered island in the bay, and the Athenian soldiers landed without knowing the exact location or number of Spartans. A fire started in the Athenian camp and burned off the vegetative cover (Thuc. 4.29-30, 38), enabling the Athenians to find and capture 120 of the Spartiates, the first time Spartans had been known to surrender.”<sup>29</sup>

Using fire and deforestation as a weapon is often uncontrollable and destructive. Forests were a valuable resource and therefore a politically tense one. In times of war they would usually be logged or tactically burned down.

War is no longer necessarily fought with a ‘front line.’ Where once an invading force may have marched a battalion into enemy territory, western forces now emphasize more remote forms of attack like drones or explosives. However, the basic strategies of war stay the same. As most ancient warriors made their way through gained territory they would plunder and raze it. A standard tactic of warfare is destroying means of production; in most cases, agriculture. Where we now attack factories, ancient armies destroyed cropland. Identified across various accounts of warfare in the ancient world, ancient civilizations boasted and commented on their abilities to ravage cropland into wastelands.<sup>30</sup> It was very difficult for these territories to recover and would usually require long periods of time to return to normal. Basic infrastructure that was damaged or destroyed would need to be rebuilt and soil would need to rebalance itself.

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<sup>21</sup> Taylor, “The Fading Battlefields of World War I.”

<sup>22</sup> To my knowledge there is no evidence that trenches used in warfare pre-WW1 are still visible in the landscape today, but their existence is not implausible.

<sup>23</sup> Brantz, “Environments of Death,” 74.

<sup>24</sup> McNeill and Mauldin, eds. *A Companion to Global Environmental History*.

<sup>25</sup> Hughes, “Warfare and the Environment in the Ancient World,” 133-134.

<sup>26</sup> *Ibid*, 321.

<sup>27</sup> Certini et al., “The Impact of Warfare on the Soil Environment,” 4.

<sup>28</sup> Hughes, “Warfare and the Environment in the Ancient World,” 133.

<sup>29</sup> *Ibid*, 133.

<sup>30</sup> Hughes, “Warfare and the Environment in the Ancient World,” 131.

Fire, politics, and wartime pressures led to the destruction of a significant quantity of cropland in the ancient world. Destroying enemy crops meant a destruction of food supply for years to come.<sup>31</sup> Burning cropland creates a layer of hydrophobic topsoil that makes those areas “prone to runoff and erosion,” and “prevents or limits water infiltration.”<sup>32</sup> This makes crops more difficult to grow. Fire was the most similar to post-industrial weapons because both fire and modern weaponry alter soil at a significant chemical level. Even with all of this destruction, pre-industrial strategies were not as damaging as post-industrial strategies.

Domestic political pressures in some ancient civilizations during wartime may have indirectly led to agricultural destruction. Farmers often knew what was required to return a plot of land to health but were unable to execute such measures (to combat siltation, salinization, and soil exhaustion) because of military taxes, uprooting, or Roman conscription.<sup>33</sup> Often, farmers were conscripted and killed in battle. Because of these disruptions, farmland was neglected or overworked and not given enough time to recover, leading to erosion, disease, and infestation.<sup>34</sup>

Destruction of farmland in the ancient world could have also had a strong impact on trade. While the destruction of the general agricultural system was highly damaging, some specific crops could have been targeted by armies to influence their enemy’s economy. The destruction of wine and olive oil exports by Spartans during the Peloponnesian War could have disrupted the balance of trade and deprived Athenians access to Laurium silver.<sup>35</sup>

Hughes concludes by saying that the result of these methods of destruction would be a landscape of abandoned lowlands and mountains bare of trees.<sup>36</sup> It was not uncommon to see huge swaths of abandoned land as a result of wartime strain. Strains on the land were largely due to active destruction of farmland to destroy sustainable food sources for the enemy, political pressures to overuse or mistreat soil, military needs for farmers to leave their lands and become soldiers, and possible economic needs for tradable goods during wartime.

### ***Biological Warfare***

Beyond traditional weapons of ancient war like swords (the gladius and spatha) and javelins (pilum) there were a few possible accounts of biological warfare in the ancient world.<sup>37</sup> During the Peloponnesian War, Thucydides reports that “the Athenians suspected that the Peloponnesians deliberately poisoned the city’s water supply, which led Papagrigrakis to suggest that spies introduced the pathogen.”<sup>38</sup> Seth Carus, author of *The History of Biological Warfare: What We Know and What We Don’t*, concludes that there is not enough evidence to

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<sup>31</sup> Ibid, 131.

<sup>32</sup> Certini et al., “The Impact of Warfare on the Soil Environment,” 4.

<sup>33</sup> Hughes, “Warfare and the Environment in the Ancient World,” 132.

<sup>34</sup> Hughes, “Warfare and the Environment in the Ancient World,” 132.

<sup>35</sup> Ibid, 131.

<sup>36</sup> Ibid, 132.

<sup>37</sup> Know the Romans Team, “Roman Weapons & Armor.”

<sup>38</sup> Carus, “The History of Biological Warfare: What We Know and What We Don’t,” 225.

confirm a successful biological attack. He proposes that the only reliably credible account of biological warfare was the use of infected arrow tips used by the Scythians.<sup>39</sup> Despite its proliferation in hunter gatherer communities, Mediterranean and other ancient civilizations “developed an antipathy toward the use of poison in warfare.”<sup>40</sup> Carus writes that there may have even been bans in some civilizations on the use of poisoned weapons. It is unclear whether the poison Carus refers to was biological or chemical; the difference being that chemical weaponry consists of chemicals while biological weapons use pathogens and organisms.<sup>41</sup> Regardless of their actual prevalence, fears surrounding possible contamination remained relevant as seen by Thucydides’ account.<sup>42</sup>

The use of biological weapons started to increase in the latter half of the 18th century. At this time humanity's understanding of pathogens was increasing and would continue to increase over the next century and a half. In 1763 British soldiers “gifted” Native American chiefs’ smallpox contaminated blankets and handkerchiefs.<sup>43</sup> Whether or not the infected items actually did that much damage is debatable, and it is more likely that the subsequent outbreaks were the result of repeated encounters with foreigners rather than the blankets themselves.<sup>44</sup>

The first official biological warfare (BW) programs began during World War I. Although strategists were aware of disease prior to this, scientific advancements allowed them to isolate and control specific pathogens. This led to the development of a variety of state biological warfare programs in countries like Germany and the United States. Japan and Germany were important programs of note, the former dropping fleas infected with the plague on enemy territory during WWII.<sup>45</sup>

Despite the Biological Weapons Convention (BWC) which banned the entire category of weapon, there was substantial evidence to support biological weapons program existing in Iraq.<sup>46</sup> Following the 1991 Gulf War it was revealed that Iraq, despite denials, had developed a BW program.<sup>47</sup> By the end of the conflict they had managed to weaponize anthrax, botulinum toxin, and aflatoxin. It was also found that the Iraqis had the delivery method; an arsenal of Scud missiles likely given to them by the Soviet Union, which were equipped for a biological attack. However, there is no evidence that Iraq ever used them.<sup>48</sup>

## ***Chemicals***

Chemical warfare programs also began to be developed alongside BW programs. Due to

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<sup>39</sup> Carus. *A Short History of Biological Warfare: From Pre-History to the 21st Century*, 4.

<sup>40</sup> Ibid, 5.

<sup>41</sup> Science Reference Services. “Chemical and Biological Warfare (CBW).”

<sup>42</sup> Carus. *A Short History of Biological Warfare: From Pre-History to the 21st Century*, 4.

<sup>43</sup> Ibid, 7.

<sup>44</sup> Ibid, 7.

<sup>45</sup> Carus. *A Short History of Biological Warfare: From Pre-History to the 21st Century*, 13.

<sup>46</sup> “Biological Weapons – UNODA.”

<sup>47</sup> “NOVA Online | Bioterror | History of Biowarfare (Non-Flash).”

<sup>48</sup> Ibid.

the loss of trade with Germany's advanced chemical industry, the US chemical industry expanded operations to fill the hole in the market.<sup>49</sup> The US developed chlorine and mustard gas and by the end of WWI the US had a substantially larger program than the Germans. This industry transferred into peacetime as the insecticide and pesticide sector of the US economy.<sup>50</sup>

Although international laws on biological and chemical warfare were introduced in 1925, development continued across the world. Over the next 50 years the United States would develop and use chemicals like DDT and Agent Orange. Agent Orange is a defoliant that reportedly deforested approximately 7,722 miles of Vietnamese forest during the Vietnam War. This defoliant forces plants to grow too quickly and dehydrate themselves down to the root.<sup>51</sup> Due to the absence of foliage, the Vietnamese topsoil eroded and invited in invasive species of grass which made it more difficult for the native population to repopulate the area. Furthermore, Agent Orange dumped large doses of dioxin (a highly toxic class substance) into the soil. These toxins not only corrupt the soil but can spread easily to water sources, harming nearby populations of plants, animals, and humans.<sup>52</sup> Given that a large portion of Vietnam's economy was built on agriculture, the deadly toxins had a massive negative impact on the health of people and the environment as well as the economy.<sup>53</sup>

Another source of dioxins is gasoline and oil which increased in weaponized uses and for use in factories in the early 20th century. Dioxins of byproduct (rather than synthetic dioxins created by Agent Orange) come as "unwanted byproducts of combustion and various industrial processes."<sup>54</sup> War over the 20th century increased both the likelihood of oil spills due to naval activities and other various military operations, and oil pollution from vehicles, introducing more dioxins into the environment.<sup>55</sup> Like fire, gasoline causes soil to become hydrophobic and like defoliants causes it to become more toxic to plants and biota.<sup>56</sup> Revitalization of contaminated soil can be difficult but not impossible. A group of scientists in Canada aerated a contaminated plot of land over the course of three years; while successful, it was expensive. Some scholars say that the best balance between economic sustainability and soil reclamation is temporary land use reallocation.<sup>57</sup>

An oil thickened with additives - napalm - was used during the Vietnam War to intensify incendiary bombing campaigns. Napalm is oil with additives like naphthenic and palmitic acids which was added to help the oil stick to its target.<sup>58,59</sup> Canisters of napalm were dropped from

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<sup>49</sup> McNeill and Painter, "The Global Environmental Footprint of the U.S. Military, 1789-2003," 18.

<sup>50</sup> Ibid, 18.

<sup>51</sup> Silverman, "How Agent Orange Worked."

<sup>52</sup> Silverman, "How Agent Orange Worked."

<sup>53</sup> Ibid.

<sup>54</sup> The World Health Organization. "Dioxins and Dioxin-like Substances."

<sup>55</sup> Certini et al., "The Impact of Warfare on the Soil Environment," 5.

<sup>56</sup> Biota: the plants and animals of a specific region.

<sup>57</sup> This basically means leaving the contaminated area to recover naturally, a leisure that some people do not always have. (see Certini et al.)

<sup>58</sup> Certini et al, "The Impact of Warfare on the Soil Environment," 7.

<sup>59</sup> Silverman, "How Napalm Works."

planes which, when dispersed and oxidized releases a sticky jelly that burns at about 1000 °C (1832 °F).<sup>60</sup> Napalm has similar effects to fire but at a steeply increased degree. It creates a thicker top layer and crusting of hydrophobic soil. This causes soil erosion and decreased gas exchange which decreases the ability of the environment to repopulate.<sup>61</sup> The leftover oil can also further penetrate the soil, leaving lingering dioxin deposits.

There are other significant ways in which gasoline has directly polluted ecosystems. Oil is an inflexible resource with limited access which makes its control and distribution a tense issue among countries. In the 1991 Gulf War, the United States stepped into the Persian Gulf in reclaim massive Kuwaiti oil fields occupied by Iraq.<sup>62,63</sup> Iraqi forces opened the Sea Pipeline and released oil into the Persian Gulf in an effort to impede a US landing.<sup>64</sup> In addition, “more than 700 oil wells were blown up, with most igniting, burning 6m barrels per day for nearly ten months.”<sup>65</sup> Oil contaminated 800 kilometers of coastline and the deposits from smoke plumes contaminated approximately 1,000 square kilometers of desert. It cannot be exaggerated “the impact of the oil on air and land quality, terrestrial and marine habitats and biodiversity was immediate, severe and long-lasting, damaging natural resources and threatening human health.”<sup>66</sup>

### *Explosives*

Another weapon of modern war that presents ramifications similar to the increased fire effects of napalm are explosives. Bombs dropped on war zones create craters and what is called “bombturbation” on the terrain. Minefields also have similar effects, as they are explosives, but can remain hidden long after the conflict has ended.

When bombs create craters it visually and chemically alters the landscape. When an explosive is detonated, the soil is dispersed to create a pit with raised sides which is a process called cratering. The soil at the rim of the crater is “turbated (mixed), compacted, and contaminated by metallic fragments and ash.”<sup>67</sup> This unique type of turbation is called bombturbation. The bottom of bombturbated craters have higher levels of vegetation which suggests that the bottom of these pits are more moist and may permit less access for cattle to graze.<sup>68</sup> Areas that have been subjected to high heat are more prone to run off while the bottoms of the craters grow more vegetation and develop more soil which creates imbalances on the terrain.

Minefields are supposed to hide explosives but often stay hidden even after the conflict

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<sup>60</sup> Certini et al., “The Impact of Warfare on the Soil Environment,” 7.

<sup>61</sup> Ibid, 7.

<sup>62</sup> Merritt, *Special Report: the U.S. Army in Operation Desert Storm*.

<sup>63</sup> Glaser and Kelani. “Getting Out of the Gulf: Oil and U.S. Military strategy,” 122-131.

<sup>64</sup> Castellani, “The Gulf War Oil Spill: A Man-Made Disaster.”

<sup>65</sup> Menhinick, “What the Environmental Legacy of the Gulf War Should Teach Us.”

<sup>66</sup> Ibid.

<sup>67</sup> Certini et al., “The Impact of Warfare on the Soil Environment,” 2.

<sup>68</sup> Ibid, 2.

has ended. Landmines and other unexploded ordnance from wars over 100 years ago still remain. They even detonate, taking lives with them.<sup>69,70</sup> A French bomb team in the Alsace region have reportedly disarmed and removed “around 20 tonnes of shells, grenades and other mortars dating from the two world wars.”<sup>71</sup> The world wars aren't the only lasting disruptive use of landmines. Regions of less celebrity like Cabio, Angola struggle daily with leftover mines from their civil war. The inhabitants were not made aware of the remaining mines when they were allowed to reenter the city and lost precious cattle.<sup>72</sup> What's worse is that removal efforts remain expensive and extensive. Luckily for Cabio, a charity called the Halo Trust deployed their team of mine clearers to help return the land to use.<sup>73</sup>

### *Nuclear Weapons*

Another category of explosives, nuclear weapons, have had varied effects on warfare; not only has their invention ushered in a new political landscape around war, but their testing and use have led to intense contamination of the sites where they are used. While the detonations in Japan during WWII are well known, nuclear weapons were also tested extensively throughout the 20th century in places like Nevada Test Site, Nevada, United States; Novaya Zemlya, Russia; and Bikini Atoll, Marshall Islands (discussed later). Nuclear elements have also been adapted for continued use, just not in the familiar ways of Fat Man and Little Boy.<sup>74</sup> According to Giacomo Certini, Riccardo Scalenghe, and William Woods, authors of “The Impact of Warfare on the Soil Environment,” there have been 2,056 nuclear weapons tests worldwide since 1945. The latest was in 2017 and was performed by North Korea.<sup>75</sup> The authors go on to state that “no other warfare contaminant involves soil as long as radionuclides.”<sup>76</sup> The last US test was done in 1992. In 1994 the Comprehensive Nuclear Test-Ban Treaty (CTBT) was proposed to the UN. Although the treaty has not yet entered into force, it, along with international norms, seem to have dissuaded the testing of nuclear weapons overall.<sup>77,78</sup> Still, the US was recorded using uranium tipped explosives during the 1991 Gulf War which are still in use today.<sup>79</sup> The use of nuclear weapons has not stagnated; it has advanced in more subtle and insidious ways.

Not only do the tests of nuclear weapons contaminate the environment but their storage does as well. The storage and disposal of nuclear experiments is extremely harmful for long

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<sup>69</sup> Agence France Presse, “People Are Still Clearing Out Deadly World War I Mines From Northeastern France 100 Years Later.”

<sup>70</sup> McNeill and Mauldin, eds. *A Companion to Global Environmental History*, 331.

<sup>71</sup> Agence France Presse, “People Are Still Clearing Out Deadly World War I Mines From Northeastern France 100 Years Later.”

<sup>72</sup> Cooke, “Inch by Inch: How Angola Is Clearing Its Killing Fields.”

<sup>73</sup> *Ibid.*

<sup>74</sup> Fat Man and Little Boy are nicknames for the nuclear bombs dropped on Nagasaki and Hiroshima in 1945.

<sup>75</sup> Certini et al., “The Impact of Warfare on the Soil Environment,” 7.

<sup>76</sup> *Ibid.* 8.

<sup>77</sup> The CTBT has not yet entered into force because 3 of the 44 required signatories have not signed.

<sup>78</sup> Nuclear Security Index. “Comprehensive Nuclear-Test-Ban Treaty (CTBT).”

<sup>79</sup> Koepfel, “How the U.S. Made Dropping Radioactive Bombs Routine.”

periods of time. The impact of the testing of increasingly stronger nuclear bombs by the United States in the Marshall Islands was astounding, leaving craters on the ocean floor.<sup>80</sup> Nuclear waste from both the Marshall Islands and contaminated soil from the Nevada testing grounds was dumped into a large crater on Runit Island which was covered by a concrete dome in 1979.<sup>81</sup> The nuclear substances in that crater are some of the most toxic with the longest half-lives (24,000 years). And the 18-inch-thick Runit Dome, is cracking open. Oceans are rising and threaten to wash away the paper-thin protection the Marshallese people have.<sup>82</sup>

### ***Waste***

The amount of surplus generated by novel war cannot be exaggerated. From chemical residue to abandoned mine fields, war creates an alternative environment to live in and once it's over leaves a lot of toxic residue for future generations to manage.<sup>83</sup> The idea of litter as we know it today did not come about until the mid 18th century when it began to be associated with trash.<sup>84</sup> When military forces litter it often has to do with what soldiers throw away or with typical garbage of large settlements. In the preface of *Natives and Exotics* Judith Bennett recounts an experience where, on a visit to Lae, New Guinea, was told that there were remnants of whole hospitals that...the Americans had simply abandoned."<sup>85</sup> Not only are these remnants of war obstacles to reclaiming the land in places where reclamation efforts might not be economically viable, they are also a reminder of the pain and destruction that war brought to the region. These are both roadblocks to healing for the land and the people who live on it.

Metal is one of the contaminants that last longest in soil. When explosives detonate there are metal fragments that litter the soil which are much more difficult to take out by natural processes unlike most chemicals.<sup>86</sup> Bullets that are left in the ground release lead into the soil over time too. Speeding up the processes to remove metallic substances also requires a difficult, long effort.<sup>87</sup>

Training zones have displayed other environmental effects of military operations. In addition to metallic contamination and concentrated bombturbation effects, repeated passes of heavy machinery compacts soil to troublesome levels.<sup>88</sup> Soil compaction leads to erosion and runoff because water is harder for the soil to absorb. Naturally, frequent traffic compacts the soil more than single pass traffic which concentrates effects on high traffic training areas. Much of what is observed on training grounds can also be observed on the battlefield. Both foot traffic and heavy machinery usage on the desert surface of Kuwait during the 1991 Gulf War

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<sup>80</sup> Stanford Magazine, "What Bikini Atoll Looks Like Today."

<sup>81</sup> Wall, "This Dome in the Pacific Houses Tons of Radioactive Waste – and It's Leaking."

<sup>82</sup> Ibid,

<sup>83</sup> McDougall, "Natives and Exotics: World War II and Environment in the Southern Pacific," 208.

<sup>84</sup> "The Sleepy History of 'Litter'."

<sup>85</sup> Bennett, "Preface: Was the Environment a Stage or an Actor?" In *Natives and Exotics*, xix–xxvi.

<sup>86</sup> Certini et al., "The Impact of Warfare on the Soil Environment," 3.

<sup>87</sup> Ibid, 5.

<sup>88</sup> Ibid, 4.

“increas[ed] the amount of sediment available for transport and thus accelerat[ed] the formation of dunes.”<sup>89</sup> Dunes could then migrate and cause problems for local populations. The effects of military activity in Kuwait were categorized as both onsite and offsite. Onsite effects were “terrain deformation and resource depletion” while offsite effects were an “increase in the rates of sand transport and dust fallout.”<sup>90</sup> As seen here, the movement of heavy ground machinery and troops has a lasting and damaging effect.

### ***Bouncing Back***

War leaves differing legacies for abandoned areas, training grounds, and battlefields. Training sites and DMZs (Demilitarized Zones) have shown increased biodiversity in relation to wartime activities.<sup>91</sup> Thor Hanson writes that some endangered species like the Karner blue butterfly and blue-winged grasshopper thrive in the conditions created by training operations.<sup>92</sup> Certini also writes that the DMZ separating North and South Korea is now an “an important reservoir of biodiversity.”<sup>93</sup> Conflict largely halted in 1953 with the creation of the DMZ and there is evidence that the wildlife in the DMZ is thriving due to the lack of human activity related both to combat and ongoing metropolitan life.<sup>94</sup> Abandoned zones can actually foster regrowth and enhanced biodiversity. Areas untouched by war are important reservoirs of life which is undoubtedly better than the alternative.<sup>95</sup>

This isn't to say that those areas impacted by war are lost forever; the answers are adaption or restoration. Despite the increased destruction of the environment due to industrialized warfare, people find ways to live with warped landscapes. Craters left by B-52 bombers during the Vietnam War were creatively altered by the Vietnamese people for fish nurseries.<sup>96</sup> There have been some restorative efforts in recent history. Following a cleanup effort of the Danang airport in Vietnam, the United States USAID program funded a \$183 million effort to clean up the Bien Hoa airport where they used to store Agent Orange. Bien Hoa airport is said by the US to be the biggest remaining hotspot for the harmful chemical dioxins discussed earlier.<sup>97</sup> In addition, the West Virginia Department of Environmental Protection (WVEP), working in conjunction with the US Environmental Protection Agency (EPA) and the US Department of Defense (DOD) are working to clean up sites where hazardous materials were

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<sup>89</sup> Al-Dabi et al., “Evolution of Sand Dune Patterns in Space and Time in North-Western Kuwait Using Landsat Images,” 17.

<sup>90</sup> Misak et al., “War-Induced Soil Degradation, Depletion, and Destruction (The Case of Ground Fortifications in the Terrestrial Environment of Kuwait),” 126.

<sup>91</sup> Misak et al., “War-Induced Soil Degradation, Depletion, and Destruction (The Case of Ground Fortifications in the Terrestrial Environment of Kuwait),” 2.

<sup>92</sup> Hanson, “Biodiversity Conservation and Armed Conflict: A Warfare Ecology Perspective,” 52.

<sup>93</sup> Certini et al., “The Impact of Warfare on the Soil Environment,” 2.

<sup>94</sup> Brady, “How Wildlife Is Thriving in the Korean Peninsula's Demilitarized Zone.”

<sup>95</sup> Hanson. “Biodiversity Conservation and Armed Conflict: A Warfare Ecology Perspective,” 56.

<sup>96</sup> Certini et al., “The Impact of Warfare on the Soil Environment,” 2.

<sup>97</sup> “Agent Orange: US to Clean up Toxic Vietnam War Air Base.”

held, as well as sites where there are unexploded ordnance.<sup>98</sup> As mentioned before, the Halo Trust charity helps sweep mines from places who cannot necessarily afford it.<sup>99</sup> Bechtel, an “engineering, construction and project management” company also works on environmental cleanup. They were hired to lead an effort to restore Kuwaiti oil fields from 1991 to 1993.<sup>100</sup> They worked on combating the oil spill and clearing unexploded ordnance from the area. The project reportedly cost \$2.3 billion.

Repair efforts are difficult, long, and expensive. Some aeration efforts have shown success over long periods of time.<sup>101</sup> Compaction of soil can take as little as one year to recover, but total recovery can take longer for soils that have higher levels of compaction.<sup>102</sup> Depending on the chemical contamination of the soil, soil remediation can take decades and the ecosystem can be contaminated even longer.<sup>103</sup> Remediation efforts are often underfunded and require a lot of hard work to pull off.<sup>104,105</sup> The biodiversity of replanted forests tends to be lower than natural ones because they are often artificially replaced using fewer variations of trees and other flora.<sup>106</sup> Replanting efforts like these lead to ecosystems that have lower vitality and are less sustainable. Recovery efforts today should focus on biodiversity as a part of the problem they are trying to solve.<sup>107</sup>

Another challenge is that perpetrators of environmental degradation are often unmotivated to lead clean-up operations. The Marshallese people have requested assistance in repairing the Runit Dome from the United States. However, the US has deflected stating that “the dome is on Marshallese land and therefore the responsibility of the Marshallese government,” to which the Marshallese government has expressed confusion.<sup>108</sup> Some even call for the criminalization of what is called ecocide. In December of 2019 the Maldives made their 5th plea to the International Criminal Court (ICC) to criminalize abuses of the environment.<sup>109</sup> While this plea primarily pertains to issues of sea level rise and climate change, its implications could theoretically spill over and affect future wars.

## ***Conclusions***

War is inherently destructive. Sadly though, the forces of war have become more harmful since the west's industrial revolution. This paper looked at the ways that strategy and weaponry

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<sup>98</sup> “Federal Facilities Restoration Program.”

<sup>99</sup> Cooke, “Inch by Inch: How Angola Is Clearing Its Killing Fields.”

<sup>100</sup> Bechtel, “See How the Kuwait Oil Fields Were Restored.”

<sup>101</sup> Aeration allows for important exchanges of gasses to take place and is important for soil productivity.

<sup>102</sup> Hanson, “Biodiversity Conservation and Armed Conflict: A Warfare Ecology Perspective,” 52.

<sup>103</sup> *Ibid*, 57.

<sup>104</sup> McNeill and Mauldin, eds. *A Companion to Global Environmental History*, 349.

<sup>105</sup> Certini et al., “The Impact of Warfare on the Soil Environment,” 5.

<sup>106</sup> Coca, “Learning from the Past: Japan's Tree-Planting Efforts Provide Lessons for Other Countries.”

<sup>107</sup> Reforestation efforts in China focused too much on combating soil erosion and efforts in Brazil too much on water provisions and carbon sequestration. (See Coca)

<sup>108</sup> Rust, “How the U.S. Betrayed the Marshall Islands, Kindling the next Nuclear Disaster.”

<sup>109</sup> Written Statement of the Republic of Maldives.

has changed in its impact on the environment. Overall, we looked at trenches and other defensive mechanisms, deforestation, fire, and biological warfare as the most relevant elements of ancient warfare, particularly through the Peloponnesian War. The use of fire showed similar effects on soil between ancient and post-industrial warfare. We then looked at the development of biological and chemical warfare programs in the United States and Iraq through WWI, WWII, the Vietnam War, and the 1991 Gulf War. Then we looked at the impact of oil, explosives, and nuclear weaponry. These types of weapons are very chemically destructive and lead to both short term and long-term negative effects on local ecosystems and human lives. We then talked about the ways that training sites and battlefields can present similar problems, particularly the compaction effects of heavy machinery like trucks. Nuclear weapons, particularly their testing in the Marshall Islands are one of the more pressing issues today as the Runit Dome is threatening to expose extremely toxic nuclear waste to an abused population.

Last, we discussed some successes and failures of cleanup efforts in the 20th and 21st centuries. There is still a lot of work to do in rehabilitating the environment that was abused over the last 125 years. It is important to understand that while efforts to recover lost environments we must also push for military strategy, especially in the west, to consider the environment as more than just another variable. We must understand the planet as more than just a place that we live but a complex living thing that humans have a relationship with. The west is a hugely influential character on the world stage. Once more of us understand that the world is more than a *landscape* but an *environment*, then we can start enacting real change. Only then can we sustainably look to a better future.

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