The unsustainable environmental cost of making war

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Abstract Since the Earth has witnessed the dawn of mankind, it had to deal with conflicts and their consequences. The ongoing conflicts are continuing to increase year by year, as does the power of weapons at stake. Consequently, increasing is also the warfare impact on the total environment, which is already in crisis due to climate change and exponential population growth. Although now emphasis is mostly given to the necessity that cities and companies causing planetary harm should be stopped, by collating up-to-date data on the size of the footprint of various human activities, here we show that warfare implies the current unavailability of much more land for productive use than urbanization and other infrastructures have hitherto done and will do in the future. This means that wars are no longer bearable from an environmental point of view – as well as from the ethical, social, and economic ones – and this should be an additional, primary reason to prompt the international community to discourage conflicts to the maximum extent and work tirelessly with mediation to stop them where they are underway.

Only a concerted and friendly effort by all peoples can enable future generations' footprint on the planet to be sustainable.

Keywords atomic bomb, Anthropocene, cities, land take, soil, sustainability

"Who wishes to fight must first count the cost" (Sun Tzu, *The Art of War*)

The current international geopolitical crisis resulting from the war in Ukraine and the possibility of resorting to nuclear weapons, so triggering an endless escalation, brought the mass destruction scenario back to the present day. A suggestive aspect is that the Anthropocene, the current as-yet-unratified period within the geological timescale in which humans joined with other natural forces in influencing the Earth's outermost shell and biosphere, could end (because of drastic reductions of the population and its relative impact on the planet) for the same reason it started, *i.e.*, a nuclear explosion! In fact, what is nowadays most considered the beginning of the Anthropocene is the first experimental nuclear blast, happened in Alamogordo, New Mexico, on 16 July 1945 (Monastersky, 2015). The reason for basically preferring this event to many possible others is that it started a fallout that has left a global radiological signature in the geological record peaking in the mid 1960's (Lewis and Maslin, 2015). No doubt that the planet would go on also with a much fainter anthropic pressure or even without humans, with a new geological epoch possibly to be defined (actually, a problem that would not exist if humanity disappeared!). Ever since the Earth has witnessed the dawn of mankind, it has had to deal with conflicts and their aftermath. The traces of armed clashes gradually discovered have made it possible to backdate the dawn of inter-group violence up to late Pleistocene/early Holocene period (Lahr et al., 2016). Such a violence has never stopped and, although the absolute number of war deaths has been declining since its peak in WWII (1945), the ongoing conflicts are continuing to rise year by year (Roser et al., 2016). Because of that and the increase in the power of weapons at stake, increasing is also the warfare impact on the total environment, which is already in crisis due to climate change and exponential population growth. Some war effects

disappear within one or few generations and no trace remains of them except in historical documents. Other effects last much longer, possibly adding to those of previous wars. Many of these effects are purely physical and consist in the remodeling of the earth's surface for defensive purposes. Trenches, embankments, ramparts, and strongholds have been built almost everywhere in the world and much land has been involved in strategic earth movements to repel the attack of real or imagined enemies or hide from them. In modern times the impact of warfare on the landscape has become massive, such as to may consider this activity a major geomorphic agent. Impressive examples are the extensive and intricate tunnel systems excavated within the deep tropical soils of Indochina as active protective measures, starting from the late 1940' to reach their maximum during the Vietnam War, in the 1970's (Rottman, 2012). "Bombturbation" is called any event where soil is removed to some extent by an explosion, leaving a crater rimmed by the dismantled soil and possible fragments of manufacts (Hupy and Schaetzl, 2006). Surface morphology, hydrology and pedogenesis are distorted by bombturbation, which can also undermine soil health through pollution. Warfare includes maneuvers of heavy tracked and wheeled vehicles, whose repeated passage causes soil compaction and, consequently, increased surface runoff and erosion (Althoff, et al., 2010). In order to weaken the enemy's resistance, a variety of other damage can be inflicted on the environment. For example, burning crops and forests is a strategy that has always been used to expose the besieged to hunger and cold or in retaliation (Jaafar et al., 2022). In wars and guerrillas, forests can be transformed to cropland or cattle ranches, in some cases seriously endangering biodiversity (Álvarez, 2003). Often, landscape modifications are neither the most lasting nor the most serious wounds inflicted on the environment. The presence of unexploded mines discourages for years or decades any form of land reclamation and management, implying hazardous potential for those willing to risk and anyway a net loss of productive soil (Arensen, 2022). The same can happen because of harmful

war-induced contamination. Extreme in this regard is the case of nuclear explosions, where visible damages heal much earlier than invisible ones, the half-life of some radionuclides being several thousand years (if not even millions, as in the case of ^{235}U). Atolls in the northern Marshall Islands still show dangerous levels of residual radioactivity because of the fallout from the Castle Bravo test carried out in 1954 (Corcho-Alvarado et al., 2021). Overall, warfare is one of the most polluting activities on the environment and the number of toxic substances scattered to harm the enemy is considerable (Certini et al., 2013). Among them there are nitroaromatic explosives like 2,4,6-trinitrotoluene (TNT), nerve agents like tabun and sarin, 3-Quinuclidinyl benzilate (QNB), arsines, blister agents like lewisite, phosgene, herbicides like Agent Orange, defoliants like napalm. Other elements or compounds, such as heavy metals, hydrocarbons, organic solvents, surfactants, synthetic phenols, cyanide, and dioxins are toxic residues indirectly released by ordnance or vehicles. The persistence of these chemicals in the soil, where generally they end up, can be high due to intrinsic recalcitrance to volatilization, hydrolysis, and biodegradation or the physical protection afforded by anoxic niches (Fig. 1). Like some chemicals, all biological weapons are prohibited for a long time by international conventions. However, there are documented cases of biological warfare, although most of the supposed uses of such horrific weapons never really took place or are poorly substantiated (Seth Carus, 2015). Over fifty are the pathogens used or usable in weaponry, such as *Clostridium botulinum*, *Clostridium tetani*, *Bacillus anthracis*, *Francisella tularensis*, and *Yersinia pestis*.

In the future major changes are expected in the way of waging war, but it is objectively difficult to predict them and their possible consequences on the environment. An increase in the use of robots and artificial intelligence will probably reduce human involvement in conflict and environmental damage. Indeed, there could be a significant migration of aggressive attacks to the impalpable world of the cyberspace or the more real outer space. For the moment, however, the

problem is here on Earth. A ramification of the ongoing wars and the generalized tension from the war in Ukraine is the slowing down of that arduous process of mitigating climate change chiefly through the progressive abandonment of fossil fuels. This collective interest seems in fact to have partly waned in the face of more tangible emergencies (Holden Thorp, 2022).

The confrontation between countries or blocks of countries with threats and with the so-called "cold war" has shown that excess human load is most often the cause of environment degradation. There are in fact enlightening examples of no man's lands which over time have become hot spots of biodiversity. One is that between North and South Korea, known as the Demilitarized Zone (DMZ), which is now home to thousands of species (Healy, 2007). A commendable initiative focused on the conservation and restoration of the natural heritage of Europe left along the line of the former Iron Curtain, which divided the European continent into East and West for nearly 40 years, is the “European Green Belt” (https://www.europeangreenbelt.org/). It extends for more than 12,500 kilometers – from the Barents Sea at the Russian-Norwegian border, along the Baltic Coast, through Central Europe and the Balkans to the Mediterranean Sea – and aims to function as an ecological network connecting high-value natural landscapes whilst respecting the economic, social, and cultural needs of local communities.

It is honestly illusory to think that there will be no more wars by virtue of some world agreement. But the planet where we live is fragile and finite, and our pressure on it is already beyond the limit even in a hypothetical situation of global peace. So, can we afford to further fight on such an exhausted battlefield? A basic estimate of ours clearly show that areas at present involved in wars exceed by far the land consumed to build cities or major infrastructures, such as roads, railways, or airports (Table 1). Hence, although urban sprawl and the activity of some unscrupulous companies are indicated as the main cause of loss of habitats and other planetary

harms (Bai et al., 2022), equal concern in this regard should arouse the large extension of territory currently used as a theater of war. Just think that a legacy of WWI is Zone Rouge, a chain of non-contiguous areas throughout northeastern France, originally covering more than 1,200 km^2, which was interdicted right after the war because made too dangerous for human habitation. Although the unavailable terrains have been greatly reduced over time, still today – after more than a century – deminers are still clearing many unexploded ordnance, which continues to be a source of environmental contaminants (Bausinger et al., 2007). Such an example reveals how unsustainable the environmental impact of wars is today, in a world where there is less and less healthy and fertile soil available to support an ever-growing world population.

The ongoing war in Ukraine is causing humanitarian and environmental disasters, including air pollution, greenhouse gas emissions, and biodiversity loss. The soils of that country, among the most fertile in the world, are undergoing major negative impacts that risk to make them unproductive (Dmytruk et al., 2022; Pereira et al., 2022). The international community should indeed begin to seriously consider that the main victim of a possible large-scale war, or even WWIII, may be not so much one or both belligerents, but the total environment that has ever generously supported us and has evolved away with us. Now, however, it may no longer be willing to bear our tantrums. Objectively, what US President John Fitzgerald Kennedy spoken in his 1961 address to the UN General Assembly seems to make sense like never before: “Mankind must put an end to war, or war will put an end to mankind”.

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Table 1. Land consumed, or severely limited in carrying out its ecosystem services, by anthropic activities. Ice-free land is 130 million km^2 (*source* IPCC, Climate Change and Land, 2019)

Type of land consumption	Surface involved (million km^2)	Percentage of ice-free land
Urban land area[#]	3.63 (2010)	2.8
	5.87 (2030)	4.5
Roads[^]	0.20 (2008)	0.1
Railways[#]	0.004 (2016)	~0.0
Airports[§]	0.03 (2022)	~0.0
Water reservoirs[†]	0.34 (2006)	0.3
Mining areas[‡]	0.06 (2020)	~0.0
Minefields[‖]	0.22 (2022)	0.2
War-affected areas[*]	19.95 (2011)	15.3

[#] The World Bank, https://data.worldbank.org/indicator/AG.LND.TOTL.UR.K2?end=2010&start=1990 (2010 data) Seto *et al.* (2012) (2030 forecast)

[^]assuming 6 meters as average road width. Wolfram|Alpha Knowledgebase 2022, https://www.wolframalpha.com/input?i=length+of+all+roads

#assuming 4 meters as average track bed width. Wolfram|Alpha Knowledgebase, 2022. https://www.wolframalpha.com/input?i=global+length+of+all+railways

[§]multiplying half the average floor area of the ten largest airports in the world by the 17,678 commercial airports present in the world in 2015. Multiplying half the World's tenth largest airport (Beijing Capital International Airport) by the about 2600 commercial airport operating

worldwide, according to Annual World Airport Traffic Dataset, 2022 Ed. Kairos Institute, https://www.kairosinstitute.in/blog-detail?postid=671

Airports Council International (ACI), https://store.aci.aero/product/annual-world-airport-traffic-dataset-2022/

[†]https://www.currentresults.com/Environment-Facts/number-reservoirs-in-world.php (from doi:10.4319/lo.2006.51.5.2388).

[‡]from doi:10.1038/s41597-020-00624-w

[‖]The World Bank, https://databank.worldbank.org/source/landmine-contamination-casualties-and-clearance-(lc3d)

[*]The UCDP/PRIO Armed Conflict Dataset concerns territories where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battles [PRIO Conflict Site 3.0 (1989-2008) https://doi.org/10.1177/0738894211433168]. The dataset lists every conflict as defined by a center point decimal degrees, and a radius center point to the most distant point in the conflict zone, rounded upwards to the nearest a conflict (methodological setting from Buhaug and Gates, 2002). Latitude: The geographical center of the conflict zone is given as decimal degrees where southern latitudes and western longitudes have negative values. Longitude given as latitude. The radius of the conflict zone is given in 50-kilometer intervals, rounded upwards. If a conflict took place within a single spot the radius is set at 50 kilometers. Area of the conflict zone in square kilometers. Only terrestrial areas in the countries listed in the conflict site variable are included (Hallberg, 2011).

Figure 1. Landsat images showing before, during and after the release of 1.5 billion barrels of oil in northern Kuwait during the Gulf War (1991) by the withdrawing Iraqi forces. Such oil spill, which is still the largest in human history, implied ten months of burning and finally left about 300 lakes of oil and about 5 percent of Kuwait's land blanketed by a fallout-derived top layer of soot and oil, preclusive for plant growth and the full performance of other soil ecosystem services. (Credit: NASA's Goddard Space Flight Center).