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UKRAINE WAR AND THE FORESTS

Visible Damage and Invisible Threats

By Lloyd C. Irland, Lidia Iavorivska, Sergiy Zibitsev, Brian Roth, and Andrii Bilous

The Ukraine War has already had serious effects on the country's forests, in the form of direct damage and fires caused by various munitions. Important damage, though, is not visible in drone images: extensive minefields, dud ordnance, and booby traps are causing forests to be closed to all activities. Planning is underway on an international basis for programs of demining, bolstering fire management systems, and initiating restoration programs. American foresters and agencies are sure to be involved.

European history is pockmarked with shellholes. On a church wall in Lviv, Ukraine, tourists are shown a cannonball removed from the masonry after a 17th-century siege by the Turks. World War One anniversaries in 2018 spawned assessments of the lingering effects of major battles; farmers continued to pull dud artillery rounds out of fields where they rose to the surface with the frost, like stones in New England fields (Hemmings 2018; Taylor 2019). Even in 1944, 26 years later, US soldiers moving through the killing fields at Verdun passed shellholes that had not yet revegetated (Ataman 2018; Irland 2004). Trenchments from World War Two, left as memorials, can be seen in Kyiv today.

War has returned to what historian Timothy Snyder memorably termed The Bloodlands (Plokhi 2023; Kimmage 2023). The unfolding tragedy of the Russian invasion is creating impacts on forests, woodlands, and rural landscapes of unprecedented geographic extent - likely long into the future.

Never the actual targets, the forests have suffered massive collateral damage. When the guns fall silent, those responsible for the forests, and those who live near them and depend on them, will face immense losses, long-term costs, and risks. Ukrainian Prosecutor General, Andriy Kostin, estimates that "approximately 30% of Ukraine's territory - 174,000 sq. km - is contaminated with explosive objects, and over 2.4 million ha of forests are damaged." Press attention to

Armored personnel carrier rolling through burning woods. Photo credit: Brian Milakovskiy.

the issue has been extensive (e.g., RFE/RL 2022; Economist 2023; Reese 2023, Giles 2023, WWF-Ukraine 2022) and refereed studies in English-language publications are appearing (Prins 2022; Myroniuk et al. 2023). The reactions of the international community have led to boycotts on Russian lumber exports, with significant effects (Irland 2023).

Ukraine's Forests: A Brief Sketch

Known as a major breadbasket for the world, forests do not spring to mind when we think of Ukraine. Ukraine contains roughly 10 million ha of forests (FAO 2010; World Bank 2006), about 17% of the land area (Map 1). In the rugged Carpathians along the western borders, forests of softwoods and hardwoods look familiar to any American visitor. Extensive spruce plantations from the Austro-Hungarian era are common. Across the heart of the country, small and large woodlots are common among the grain fields.

A broad belt stretches from the north-central borderlands with Belarus and Russia, around the eastern borders, and down to the Crimean Peninsula. These are termed the "steppe lands." This agricultural landscape is crisscrossed by wide networks of wide shelterbelts composed of hardwoods which often surround agricultural fields and degraded areas. Shelterbelts

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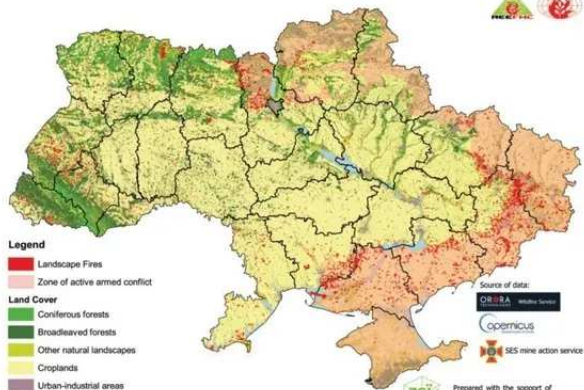


Figure 1. Burnt area index. Data from Sergiy Zibitsev.

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Publisher: Terry Baker
tbaker@safnet.org
Managing Editor: Morgan Fincham
mfincham@safnet.org
Editorial Assistant: Jackie Lamb
jlamb@safnet.org

Editorial Offices and Advertising Sales
2121 K Street NW, Suite 315
Washington, DC 20037
Tel (202) 938-3911
www.safnet.org

Correspondence: Address all editorial correspondence to the Editor at the above address. Advertising inquiries should be directed to Morgan Fincham at (202) 938-3911.

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President: Sam Cook
scook.wef@gmail.com
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A forest that has been blasted and burned. Photo credit: Andrii Bilous.

are sometimes harvested for producing fuel and timbers when stands are over-mature or when the area requires clearing for establishing new or supporting young plantations. In the southern portion of this area are Stalin-era pine plantations, established as shelterbelts to encourage grain harvests after the Second World War. These have performed poorly and are now a fire hazard.

Areas Affected by Military Operations

It is easily forgotten that the war actually began in 2014. While most of the visible damage is from present-day combat, most of the country has been vulnerable to sporadic rocket and other attacks for many years. The regions affected have changed over time (Maps 2 and 3). The incursions of Winter 2022 were quickly repulsed, leaving damage at lower levels than the intense combat in the eastern counteroffensive in Summer 2023. By the time you read this, areas of high activity could change again. The maps show the areas directly within range of artillery, say 40 km or more on either side of the margins of the occupied areas, at one time or another.

A depopulated zone, spanning 10 kilometers in width (about 10,000 km² area) and situated within range of Russian artillery, is taking shape along Ukraine's northern border with Belarus and Russia. Relentless shelling persists from across the border, resulting in forest fires (the region primarily consists of highly flammable pine forests), the destruction of homes, and pollution due to ammunition, including unexploded ordnance. Consequently, residents are fleeing the northern Ukrainian territories in the Chernihiv and Sumy regions and seeking refuge elsewhere. In the future, the frequency and intensity of forest fires in this zone may rise since foresters are unable to safely gain access to these wooded areas.



Bakhmut urban forest amid the rubble. Photo credit: Andrii Bilous.



Fires burning in Chernobyl Exclusion Zone where smoke plumes contain radioactive contaminants. Photo credit: Planet Labs PBC.

Chornobyl Exclusion Zone

The Chornobyl Exclusion Zone (CEZ) stretches more than 100 km near the state border of Belarus and Ukraine. It was occupied by invading Russian troops within one to two days, who established control of the decommissioned Chornobyl Nuclear Power Plant. Occupying troops were not informed about personal protective measures against radiation exposure. Many cases of radiation impact were reported (Radynsky 2023). Before February 2022, two major forest fires had occurred: in April 2020 of more than 70 000 ha and in March 2022 of 25 000 ha that damaged Scotch pine forests' health, productivity, and biodiversity. Massive contamination by unexploded ordnance (UXO), booby traps, and land mines were left behind by the retreating invaders near roads, along fighting positions, and other strategic points. These are major problems for protecting forests and responding to fires.

For the moment, UXO and landmines are major obstacles to managing forest health and forest fires. The Global Fire Monitoring Center in Freiburg, Germany, under the leadership of Professor Johann Georg Goldammer, developed a system of safe prescribed burning of contaminated terrains that soon may be tested in Ukraine in CEZ (Goldammer et al. 2016). If tests are successful, the government of Ukraine will seek opportunities to more widely apply the technology. Elsewhere, the forests suffer serious effects, some easily visible and others not obvious to the naked eye but far more widespread and long lasting.

Visible Effects

Increases in Fires

During the warmer seasons, large areas of eastern and southern Ukraine are prone to fire. Ignitions can be caused by artillery fire, rockets, phosphorus bombs, burning vehicles, and other munitions (Zibstev et al. 2023). A 20,000-acre fire in the Izyum Forest District was ignited by invader's



Oleksii Prokhodko stands in a crater. Photo credit: Andrii Bilous.

artillery. Ukraine has an extensive system that detects fire occurrences by satellite (Map 1 above). In January 2022, only 1,900 ha burned nationwide; in March, the area burned reached 307,000 ha during a time when fire activity is usually nominal. Using remotely sensed data, intensity of combat was compared with fire incidence in a series of "buffer" areas at greater distances from the front lines.

More than 45% of fires by the number and 42.9% by the burnt area occurred in the 5 km buffer, where the combats are most intense. In the buffer of 25 km, 62.1% of all fires by number and 66% by area were recorded (Figure 1).

To compare combustibility and fire density during the fire season 2022 with the fire norm before the war, an analysis of combustibility and fire density in buffers was also conducted for 2013, which is the best corresponding year with similar Fire Weather Index values and the absence of shelling. Combustibility in the same buffers was greater by 2.65 to 3.85 times compared with the 2013 fire season ($Ff = 7.9$ $p = 0.01$); fire density was higher by 1.77 to 2.44 times in 2022. This difference was also statistically significant ($Ff = 4.31$ $p = 0.05$) (unpublished research by S. Zibstev and co-workers).

Intensity and duration of fighting in different parts of the front line varied. In 2022, the Donetsk, Luhansk, Kyiv, and Kherson directions were the most intense, and the Kharkiv direction was somewhat lower. Forest districts on the eastern fronts of the Kharkiv Region were looted during occupation from February 2021 to October 2022. In addition to fire-fighting equipment, forest inventory equipment was also stolen. There is a need for metric GPS and inventory (calipers, clinometers, tape measures, etc.). Also, ATVs for mobile firefighting equipment.

In territory that was liberated in spring 2022 (Sumy and Chernihiv regions), the duration

and intensity were lower with significantly fewer fires. At the time of this writing in September 2023, prolonged action in the counteroffensive is producing locally extreme, high levels of artillery combat and resulting damage.

The evident consequence is the degradation and deforestation of forests in both the frontline and occupied regions. A study using remotely sensed data reveals that in 2022, more than 70,000 ha of these forests suffered severe destruction and damage due to shelling, fires, and illegal logging by occupying forces (Dr. Andrii Bilous, personal communication). Of particular concern is the extensive harm inflicted on plantations that play a crucial role in soil erosion prevention, as well as the substantial loss of shelterbelts. Urban trees also fell victim to the ravages of battle.

Entrenchments - Positional Warfare

By midsummer 2023, hundreds of miles of territory had been bisected by trench-lines. There are as many as three of them on the invader's side and at least one on the Ukrainian side. Where offensive operations attempt to penetrate the lines, artillery fire is concentrated in massive amounts, further churning up the landscape and leaving behind dud projectiles.

Invisible Threats

In contrast to the visible effects detectable from above or from roadside "windshield cruises," far wider areas are damaged by invisible effects. These are mines, shrapnel, duds, and booby traps.

Minefields

In front of the trenches are wide bands of minefields, totaling millions (HRV 2023; Sampson and Granados 2023). Modern engineering has provided fiendish devices for placing them: there are tracked vehicles that lay mines as if they were simply drainage pipes. Artillery shells exist which will lay antipersonnel mines, bury them for concealment, and never be touched by human hands. A mobile rocket launcher is capable of firing 50 mines in one volley with a range of up to 12 km. During offensives, demining is conducted only on lanes needed to move troops and vehicles to the points of contact. Thus, a defense line that has been breached has not been cleared of hazards over its entire length.

Antipersonnel mines pose a significant threat to both humans and wildlife. For instance, foxes, known for their curiosity and habit of digging the ground when intrigued by unusual scents, frequently fall victim. The invisible effect of mining activity can cause vast areas of forests to be declared off-limits to any activity until safe. The search and certification process will take many years, as accurate maps of minefields often do not exist.

Shrapnel

Shrapnel remains in trees from small-arms bullets, artillery bombardment, and tank clashes. This is invisible to aerial imagery, though often locatable on the ground by damage to foliage and branches. In areas of heavy artillery usage, trees peppered with shrapnel are likely in most of a stand. Most fuses will detonate on contact with branches. This is even more so in the case of deliberate airbursts above the canopy.

Area burned per 1000 ha, by zone from front lines or rest of landscape (Zibstev, unpublished)

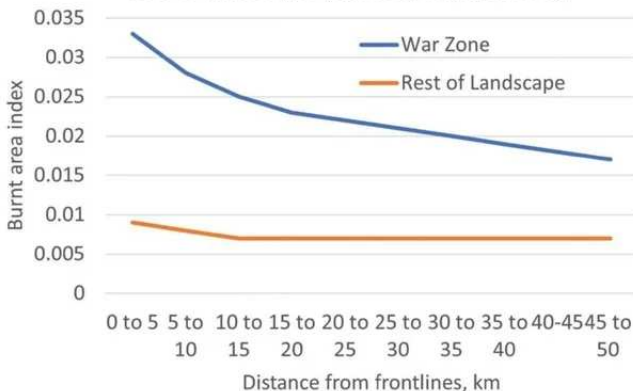


Figure 2. Forest map with fires in 2022. Source: Oleksandr Soshynskyi and Eastern Europe Fire Monitoring Center.

Unexploded Ordnance

Amidst the military jargon in the press, a new and ominous term enters our lexicon: UXO or unexploded ordnance. This is military speak for duds. The dud rate of fuses on Soviet-era ammunition is said to be high. While most of that has been expended by this writing, the UXO problem is daily becoming more severe. The duds are unattended mines.

In some areas, retreating invaders have left behind booby traps.

rounds produce craters about 1.7 meters in diameter (Kennedy 1982).

Forest strips are used as cover. Attacks on vehicles and entrenched positions in and near forests fill the trees with shrapnel, endanger them with fires, and leave behind numerous craters. Self-propelled artillery positions are now readily detected, so a unit must “shoot and scoot” to avoid counterbattery fires. Typically, artillery operates from a safe distance to minimize risks, often at its maximum ef-

Ultimately, the group aims to support local landmine and UXO disposal teams.

There is also a pressing need for substantial efforts and innovative strategies to address reforestation in southern and eastern Ukraine in the aftermath of the war and in the face of climate change. The loss of shelterbelts in these regions can result in future harvest failures due to rising droughts, sandstorms, soil erosion, and other environmental challenges. This, in turn, can jeopardize food security not only at the

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Generations will inherit an ongoing war against the dangers and costs of clearing mines and UXO, smoothing over shellholes and abandoned trenchlines, and restoring farms, fields, and forests to safe and normal uses.

Honoring the Fallen

A sensitive issue arises after fierce battles, as numerous soldiers from both sides perished and were either buried in shelterbelts or left above ground. Moving forward, there is a need to locate and commemorate all of these fallen soldiers, and many forests will serve as memorials in their honor.

Artillery

On the muzzle of a 19th-century Prussian field gun was engraved the Latin motto “The Final Argument of Kings.” Experts describe this as an artillery war. Ammunition expenditures have been immense – surely more than ten million rounds of average-explosive-power higher than seen in past wars. Drone images illustrate vast fields of shell craters attesting to this.

The principal artillery of most modern armies is now the 155 mm howitzer. Howitzers are no longer basically “area fire” weapons. Improved metallurgy, highly accurate and prompt location data for both guns and targets, and electronic fire direction have improved accuracy and responsiveness. Guided shells exist but are costly. They are used against point targets such as tanks, missile launchers, and supply dumps. Projectiles weigh 90 to 100 pounds and have a casualty radius of up to 100 meters (Catovic and Kijuno 2021; UN 2014). The standard high-explosive shell splits into many fragments on detonation, injuring personnel, damaging vehicles, and any nearby trees.

Both sides now use cluster bombs, formally known in the US as innovative conventional munitions, or ICM (a euphemism if there ever was one). Even small-caliber artillery can deliver these, as can rockets. These are shells that open up above the ground and shower it with numerous small bomblets. Some of these fail to detonate and remain as hazards for some time.

Experienced, well dug-in, and well-led troops can withstand severe bombardment. This means that positional warfare leads to high ammunition expenditures in concentrated areas. Long ranges of current artillery mean that a swath up to 40 km on each side of the line of contact can be affected. Size and depth of shell craters vary by soil type, moisture content and many other factors. Research indicates that 155 mm

effective range. It relies on semi-permanent or permanent enclosed positions known as a “firebase” because finding a new suitable position is challenging. Frequent, long-distance movements of self-propelled artillery can make it more vulnerable to detection by enemy-occupied aerial vehicles at a faster rate.

Needs and Responses

A major need is to strengthen measures for organizing incident commands for individual fires (Zibisev et al. 2023). While the Ukrainian State Emergency Services has an incident command system, the state enterprise, Forests of Ukraine, charged with fire protection on over 7.2 million ha, does not. The existing fire protection system is designed for early detection and rapid response; it is not designed for the challenges now being faced with large campaign fires. The Ukrainian Fire Service is working to arrange for training in the US and Canada on management systems used for this purpose. SAF members with fire management and incident command experience will likely be involved. Huge amounts of specialized safety gear are needed for forest managers, loggers, and demining personnel.

A group of North American forest professionals concerned with developments in Ukraine have formed a non-profit, non-governmental organization called Forest Release (forestrelease.org) to assist with efforts to make Ukraine’s forests safe, productive, and sustainable. The term “forest release” refers to terminology from the International Mine Action Standards defining when an area is declared clear of landmines and UXO, so that forests can be safely entered for management, operations, and recreation.

Forest Release is based in Maine and is led by Brian Milakovsky and Dr. Brian Roth. Its mission is to improve the livelihoods and well-being of forest users and managers in former conflict zones. Roth has received training from the Geneva International Centre for Humanitarian Demining on information management system for mine action. The group provides humanitarian support for the donation and distribution of forest firefighter safety gear, funding for Ukrainian UXO education, and non-technical survey teams.

regional level but also on an international scale. Furthermore, it is crucial to adapt the timber processing industry in Ukraine to include the detection of metal fragments within the wood.

Peace Will Bring a New and Different War

This war is not over (Walker 2023). Yet one day the guns will fall silent. Thereafter, generations will inherit an ongoing war against the dangers and costs of clearing mines and UXO, smoothing over shellholes and abandoned trenchlines, and restoring farms, fields, and forests to safe and normal uses. Care for the forests will necessarily take a lower priority after basic human needs, restoration of active agriculture, and rebuilding of housing, cities, and infrastructure. Combat will be followed by a prolonged, costly, and dangerous cold war against the long-term invisible threats described here, as well as restoration actions. Young soldiers now serving will be old men before these tasks are completed. **FS**

Lloyd Ireland made a brief Fulbright Visiting Scholar and other trips to Ukraine. Lidiia Iavorivska is a Ukrainian native and leads the Ukrainian Rural and Agriculture Development Program at Pennsylvania State University. Serhiy Zibisev is a professor at the National University of Life and Environmental Sciences of Ukraine. Brian Roth is the executive director of Forest Release. You may contact Brian at brian.roth@forestrelease.org to learn more. Andrii Bilous is a professor at the National University of Life and Environmental Sciences of Ukraine and is serving on the frontlines in the Ukrainian army.

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