



Attacks on Agro-Industrial Sites in Ukraine

Environment and Conflict Alert Ukraine

PAX

April 2023

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Cover image: A massive fertilizer explosion from fertilizers occurred after Russian shelling on the 'Golden Agro LLC' in Rubizhne, April 9, 2022. Source: Radio Liberty. Video posted on social media. Image upscaled using artificial intelligence for colour enhancement.



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Introduction

The Russian invasion of Ukraine continues, with airstrikes on and fighting in and around the locations of agro-industrial facilities. These can lead to severe damage and destruction that pose acute environmental risks, which in turn can have long-term impacts on human health. Since February 24, PAX has been monitoring damage to Ukraine's agro-industrial facilities, providing insight into the scale and intensity of the environmental dimensions of the war. This Environment & Conflict Alert (ECA) on Ukraine will outline the background of Ukraine's agro-industry and the public health and environmental risks associated with damaged facilities, as well as providing an analysis of the general findings, including a number of case studies taking a deep-dive into risks and impacts on the environment in Severodonetsk, Bakhmut and Mayaki. It is part of a wider series funded by the United Nations Environment Program (UNEP) and the Netherlands' Giro 555. The first ECA on Ukraine focused on the [attacks against energy infrastructure](#) in Ukraine and the consequences for the environment and public health. An overview of wider issues can be found in UNEP/GRID's [Preliminary Review](#) of various environmental impacts of the war in Ukraine, while there are also bi-weekly [updates](#) by the Ministry of Environmental Protection and Natural Resources of Ukraine.

Background

Ukraine is one of the world's largest agricultural [producers and exporters](#), with top-ranking positions for wheat, sunflower oil and corn, the export of which is critical for humanitarian aid in disaster and conflict-affected areas. Ukraine's agricultural sector covers nearly [42 million hectares](#), more than 70% of the country's land area. About 55% is arable land that is classified as agrarian land, mainly growing corn, wheat, barley and sunflowers, while this [industry](#) provides employment to 14% of the country's population. Ukraine's agriculture sector consists of crops and livestock encompassing farms, livestock housing, production and storage facilities for pesticides, animal waste tailings storages and chemical industrial plants producing fertilizer.

To maintain the industry, Ukraine developed large-scale chemical facilities for fertilizer production, with [OSTCHEM](#) being one of the leading fertilizer producers, ranking third in worldwide nitrate production and fourth in ammonia production. These facilities [include](#) specialized chemical production sites for liquid and solid substances, including nitric acid, liquid ammonia, methanol, vinyl acetate, urea, ammonia nitrate and other types of organic-type acids. The raw materials processed and products produced, whether gas, liquid or solid, can be acutely toxic, flammable, carcinogenic, or pose other health risks to people exposed.

In addition, large amounts of pesticides and herbicides are needed to spray the crops. Ukraine is [estimated](#) to use 100,000 tons of pesticides on an annual basis, often of dubious origin. Prior to the war, Ukraine struggled with illegal imports and domestic production of illicit pesticides, which made up about 25% of the total pesticide market in Ukraine, with many of the illegal pesticides kept in unsafe storage facilities. Reports by civil society groups [tracking](#) the issue indicate that one-third of the pesticides in Ukraine are classified as highly hazardous. Ukraine has joined the **Rotterdam Convention** on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, the **Basel Convention** on the Transboundary Movement of Hazardous Wastes and their Disposal and has also signed the **Stockholm Convention** on Persistent Organic Pollutants, but still has to deal with serious [legacy pollution](#) issues from unsafe management and storage of hazardous pesticides.

Ukraine also hosts large numbers of cattle, totaling 2.6 million in 2021 (1.6 million of which were used for dairy), as well as 5.7 million pigs. The poultry sector had over 202 million birds, with production of 1.5 million tons per year. A large proportion of the cattle is kept on household farms, while pigs and poultry are held at industrial scale at large facilities, with the present war and related damages having a serious [impact](#) on production figures. The presence of large numbers of animals at industrial facilities pose both

pathogenic health risks from diseases spreading as well as the accumulation of [huge amounts](#) of animal manure, containing ammonia, veterinary antibiotics and other hazardous substances, posing serious [environmental](#) risks in case of damage to waste reservoirs.

Prior to the Russian invasion, there were existing concerns over the 2014-2022 period of shelling across the contact line in Donbas, where the Bakhmut Agrarian Union in particular posed a serious risk of creating an environmental catastrophe. The large livestock facility, hosting over 90,000 pigs and poultry birds, is storing 1.1 million m³ of animal waste, containing toxic and pathogenic substances such as nitrates, nitrites, ammonium and pathogenic microorganisms. A direct hit on the storage reservoir could result in the waste flowing into the environment, contaminating the soil, surface and groundwater with widespread implications for lives and livelihoods in the region.

In sum, with thousands of large- and medium-scale industrial farms and agro-industrial hotspots spread out through Ukraine, damage to these facilities poses additional public health and environmental risks for nearby communities and civilians. They could face direct exposure to toxic substances, the spread of pathogenic diseases linked with slaughtered animals, as well as long-term impacts from contaminated soil and ground water from hazardous chemicals entering the local ecosystems, not to mention the loss of livelihoods from destroyed livestock and poultry.

The environmental risks of these attacks can be estimated using the [Flash Environmental Assessment Tool](#) (FEAT) 2.0, developed by the UNEP/OCHA Joint Environment Unit. Once designed for humanitarian response, PAX started to apply this tool in conflict settings in 2015 in [Syria](#) to improve our understanding of risks from conflict-pollution sources, and subsequently in [Mosul](#) (2016) and [Donbas](#) (2017). The utility of this tool approach is clear, as the FEAT is currently fully integrated by humanitarian organizations such as REACH, who have already used it in their 2020/2021 assessment of possible environment hotspots in eastern Ukraine.

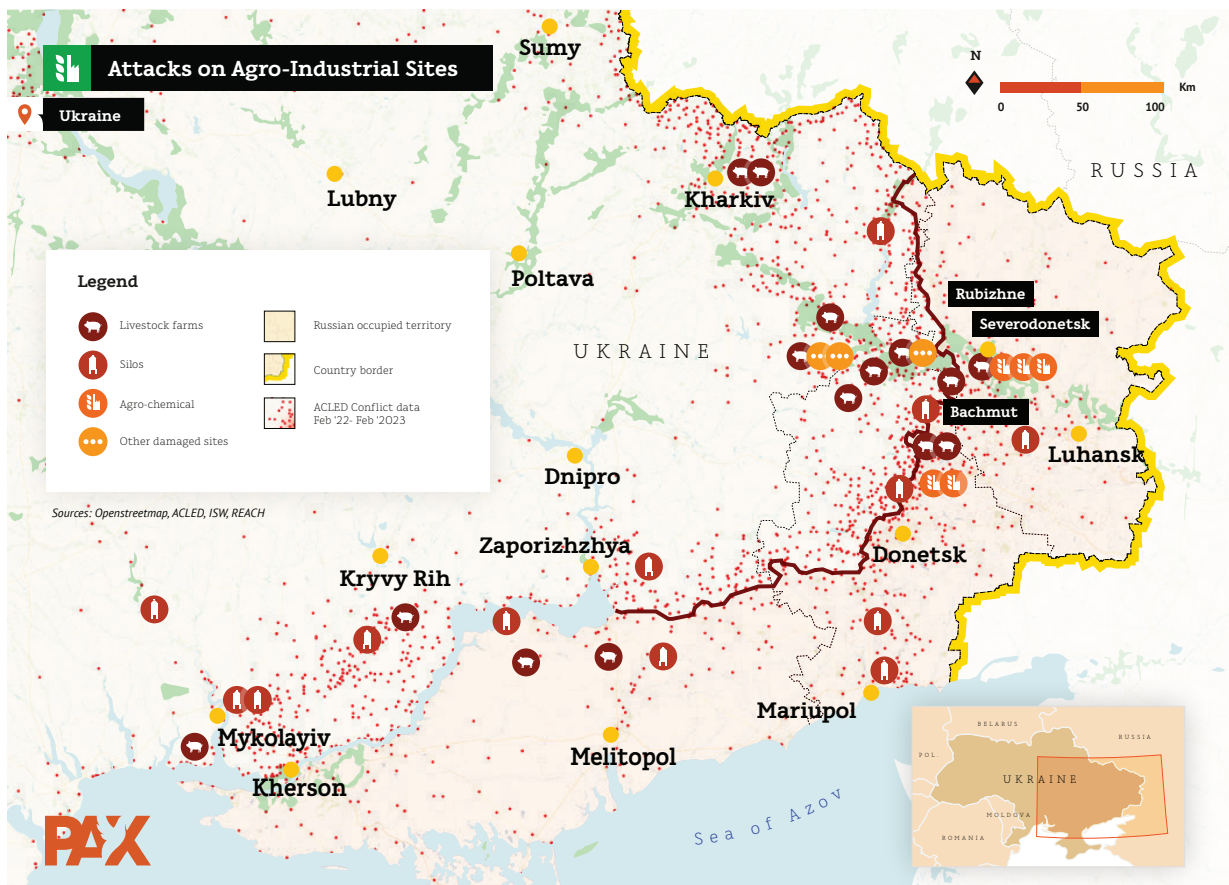
Documenting Attacks on Agro-Industrial Facilities

PAX began [monitoring](#) conflict-linked environmental incidents from military actions in Ukraine following the full-scale Russian invasion on February 24, 2022. Data collection is based on credible media reports and social media channels such as Facebook, Twitter and Telegram. PAX's database also includes information provided by [REACH](#) and the [Center for Environmental Initiatives EcoAction](#). Monitoring and verification of incidents is performed together with PAX's partner, the [Centre for Information Resilience](#) (CIR), which conducts wide-scale [monitoring](#) in Ukraine. Incidents are verified where possible through satellite imagery, using public high- and medium-resolution satellite images from NASA and ESA, as well as commercial very-high resolution imagery provided by Planet and MAXAR.

PAX's database contains information on 150 incidents involving agro-industrial facilities, 61 of which have been verified (last entry recorded in January 2023). As subcategories, the database includes large livestock farms, silos for grain or vegetable oils, agro-fields and agro-chemical facilities, particularly those involved in producing fertilizers and storing large amounts of hazardous substances.

Category in DB area of incidents	Number of incidents	Subcategory in DB affected facilities	Number of incidents
Agro-industrial facilities	61	3.1 Livestock farms	18
		3.2 Silos	27
		3.3 Agro-chemical facilities	6
		3.4 Agro-field	8
		3.5 Other agro-related locations	2

The attacked sites are located in eight regions of Ukraine. The greatest number of verified incidents happened in regions with active hostilities, namely Donetsk and Zaporizhzhia (21 and 11 respectively). There are 9 incidents in Kharkiv region and 8 in Luhansk, with the remaining damaged agro-sites belonging to the Mykolaiv (7 sites), Kherson (3 sites), Chernihiv (1 site) and Sumy (1 site) regions.



Below is a brief narrative summary of the main findings from the database with key infrastructure hits, followed by four case studies highlighting the most important risk locations.

From the onset of the invasion, air strikes, artillery shelling and intense fighting has taken place in and around heavy industrial facilities, in particular in eastern Ukraine. In Brovary, north of Kyiv, the country's largest agricultural food storage facility was **bombed** early in March 2022, **crippling** food storage and exports. During fighting around Kharkiv and Chernihiv, there were **direct** hits on the **Agromol** dairy farm and other smaller sites, while energy infrastructure near farms in **Bohoduhiv**, **Okhoche** and **Chornobayivka** were hit, with power outages leading to millions of dead chickens. Representatives of the livestock industry **estimate** that 300,000 pigs have been killed to date by the shelling of various industrial-scale animal farms. In Rubizhne, an industrial city in Luhansk region, a direct hit on a silo storing what seems to be ammonium-nitrate caused a massive **explosion** and possible exposure of **local residents** to the toxic residues of the red smoke plume.

The ongoing attacks also damaged many storage silos of grain and vegetables, resulting in on-site contamination and spills into nearby surface waters, including the Cofco **sunflower oil plant** in Mariupol in March 2022, which was again set on **fire** in July by Ukrainian partisan groups, and Russian drone **strikes** against Mykolaiv sunflower oil silos.

Small-scale farms were also hit, for example near **Bakhmut** and **Mykolaiv**, killing hundreds of livestock, while on-site storage tanks of ammonium-nitrate at farms were also frequently hit, resulting in enormous blasts that destroyed the farms and caused **concerns** over use of chemical weapons - local civilians were not familiar with the red-coloured smoke plumes, as can be seen at this **farm** at Dovhenke, southeast of Izyum.

In sum, this research identifies the following main types of damage to the agro-industry:

- ◆ **Damage to industrial-sized farms with large numbers of cattle or poultry.** The main health risks here are the spread of pathological diseases from dead animals, and large nearby tailing ponds with animal waste that could break and flood into nearby rivers.
- ◆ **Damaged agro-chemical facilities.** Damage to these locations has resulted in the release of chemical or toxic substances that can pose acute and long-term exposure risks for people, as well as damage to nearby ecosystems. Damage to wastewater ponds could also result in localized pollution.
- ◆ **Damaged silos storing vegetable oil.** Several large silos were hit, resulting in oil leaking into nearby rivers, contaminating lotic ecosystems, affecting soil and requiring remediation and clean-up.
- ◆ **Destroyed fertilizer storages at farms.** There have been a handful of incidents of secondary explosions of stored fertilizers. Beyond these explosive risks, and air pollution from large fertilizers plumes, the blasts at these farms also have the potential to impact stored herbicides and pesticides, often present at larger farms for crop spraying.
- ◆ **Damage to agricultural fields.** Some of the reported incidents are directly related to the destruction of the fertile layer of agricultural land due to the use of explosive weapons. This leads to soil pollution and land unsuitability for growing crops and the further use of agricultural products.

These verified examples based on the data collected are just a fraction of the total destruction from Russia's invasion of Ukraine. A full and thorough assessment is warranted to get a clearer picture of the damage to the agro-industry as many other locations are likely not reported on, including the large amount of pesticide and herbicide that is frequently used in the agricultural sector. At the time of writing, there has been no information of any incidents of this type of pollution risk.



Exploded fertilizer storage at farm



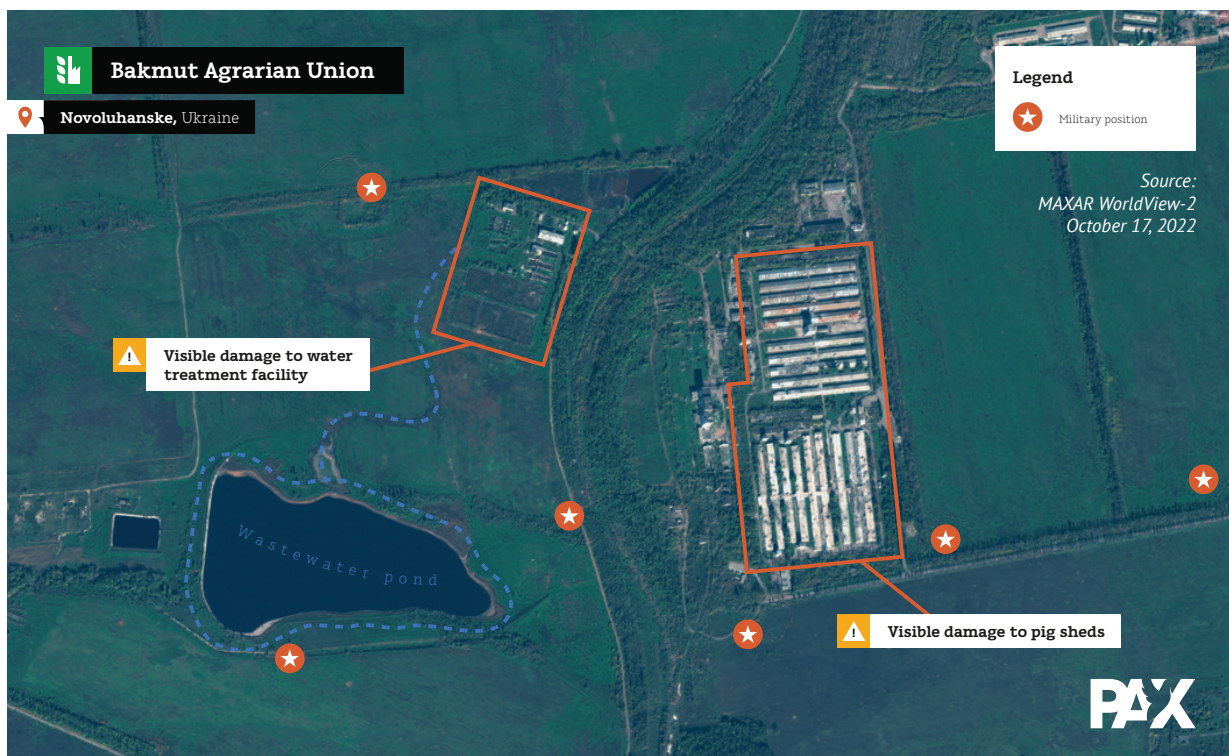
Dovhenke, Ukraine

Case studies

Bakhmut Agrarian Union, Donetsk region

One of Ukraine's largest industrial livestock facilities is located in Donetsk region, close to the town of Novoluhanske. Prior to the Russian invasion, the Bakhmut Agrarian Union (BAU) [Бахмутський аграрний союз] hosted over 90,000 pigs, while the nearby poultry farm had another 210,000 animals. The large collection of animals creates a huge amount of manure that is stored in a nearby tailing pond, containing roughly 1.1 million m³ of animal waste, which includes nitrates, ammonia, antibiotics and sulphites, among others. In 2014, the BAU was taken over by Russian-backed armed groups, but it was retaken in 2017 by Ukraine. The facility has since faced continuous shelling by heavy weaponry, partly due to the fact that Ukraine set up military positions around it to prevent it from being retaken. Considering the risk of direct impact on the wastewater reservoir, the OSCE conducted a study of the plant and its situation in 2020 to outline the risks.

From February 24, 2022, the BAU faced severe shelling. Based on Very High Resolution satellite imagery, provided by European Space Imaging since October 17, 2022, damage is visible all across the facility. The water treatment facility faced severe impacts from heavy artillery, as large craters can be seen around it, while the buildings themselves have taken numerous hits. The pig sheds and adjacent office buildings all witnessed clear impacts from munitions, with some sheds completely destroyed. Media reports from May and July 2022 indicated that although most of the animals were evacuated early after the invasion, the initial shelling combined with the subsequent lack of food and water killed over 17,000 pigs. As outlined in the OSCE study, damage to the nearby tailing pond and subsequent spill could lead to severe contamination on ground and surface waters, in particular the nearby Bakhmut river, which was already dealing with serious pollution from other enterprises prior to the Russian invasion. Further waste flow into the Seversky Donets river would pose a huge environmental health risk, as this is one of the main sources for local drinking water use.



Azot Agro-chemical plant, Luhansk region

Since Russian Armed Forces began focused and sustained offensive operations against the city of Severodonetsk [Северодонецьк] in Ukraine's Luhansk region, the Azot [Азот] chemical plant has been repeatedly targeted. The 5km² facility is one of Ukraine's largest nitrogen fertilizer production plants and, lying within the immediate boundaries of the city of Severodonetsk, houses toxic chemicals. Ukrainian authorities have claimed that all hazardous fertilizers and chemicals were removed from the facility within the opening days of Russia's invasion. However, evidence of an explosion of nitrate material on May 31, 2022, suggests **hazardous materials remained in the facility** well beyond that point. Satellite imagery and open-source data show **48 buildings and structures have been damaged**. Since the Russian occupation of the city and the plant, claims that the plant will be restarted have been [disputed](#) by the owners of the facility, and the Head of the Luhansk Military-Civilian Administration has [claimed](#) that the plant has been stripped for parts.



Key events of the siege

The Severodonetsk/Rubizhne area is extremely industrialized, accommodating two chemical plants. The first verified incident relating to compromised chemical storage in the area was on April 5, 2022, at the Zarya plant in Rubizhne, north of Severodonetsk. The plant is known to produce industrial explosives, pharmaceutical chemicals, construction materials and chemicals used in household products. On April 5, 2022, the facility was allegedly bombed by advancing Russian forces after Ukrainian forces took up defensive positions around the plant. During the Russian shelling of the plant, a nitric tank was reportedly hit, creating a large red cloud, likely caused by the combustion of ammonium nitrate. The facility would eventually be captured by Russian forces around May 15, 2022.

May 2022. Based on surveys of popular social media channels in Severodonetsk, the territory of the Azot facility was first reported shelled on May 6, 2022. Claims were made that the facility's railway infrastructure had been set on fire by incoming Russian missiles, leaving 400m² of burned ground around the Azot facility. NASA's Fire Information for Resource Management Systems (FIRMS) platform, which provides alerts to active fires, detected a series of fires to the northern and western perimeters of the Azot facilities between May 5 and May 7, confirmed by Sentinel-2 imagery on May 8. The northern burned area is in very close proximity to a fiberglass composite production plant. Reports of regular shelling activity on the Azot facility continued, notably on May 15 and May 21, in which a cooling tower was allegedly damaged. In a reported strike on May 24, several individuals were allegedly killed or critically injured by the missiles launched against the facility, after the head of the Luhansk Military-Civilian Administration confirmed that the Azot facility was being utilized by Severodonetsk residents to shelter from Russian bombardment. On May 31, 2022, numerous national and international reports described a strike on the Azot facility which led to an uncontrolled explosion of nitric acid storage facilities. Satellite imagery analysis from the immediate aftermath of the strike showed an area of 200m² coated in a red substance as a result of the nitrate explosion and subsequent acid cloud. The head of the Luhansk Military-Civilian Administration provided guidance to civilians in the city, warning them to stay indoors and prepare improvised gas masks to protect themselves from the poisonous chemicals released by the strike.

June 2022. On June 8, damage was reported to ammonia production facilities, specifically the ammonia 1-B production workshop, although Ukrainian authorities claimed that the site was not storing any hazardous materials after their removal in February. A few days later, on June 11-12, there were reported fires at lubricant storage facilities at the Azot facility. User-generated imagery shows multiple fires across the northern area of the facility. In subsequent shelling, videos emerged on June 16, of shells landing directly on Azot facilities, specifically the potassium and sodium nitrate workshop in the southern half of the compound.

Stirol Plant, Donetsk region

The several concerning incidents happened at the Stirol chemical plant, a large chemical fertilizer plant in the occupied¹ city of Horlivka, Donetsk region. The plant has been nonfunctional since the region was taken over by separatist groups in 2014. The status of hazardous chemical materials at the facility remains unclear, but the Ukrainian Ministry of Defense [claimed](#) that containers of ammonia were delivered to the plant in the leadup to the February invasion. At the time of writing, this research found no evidence to confirm the origin of the reported strikes, nor evidence of specific munitions used. Damage to the facility has been verified where possible but no conclusions are possible regarding the origins of the damage (degradation, missile strikes, etc.).

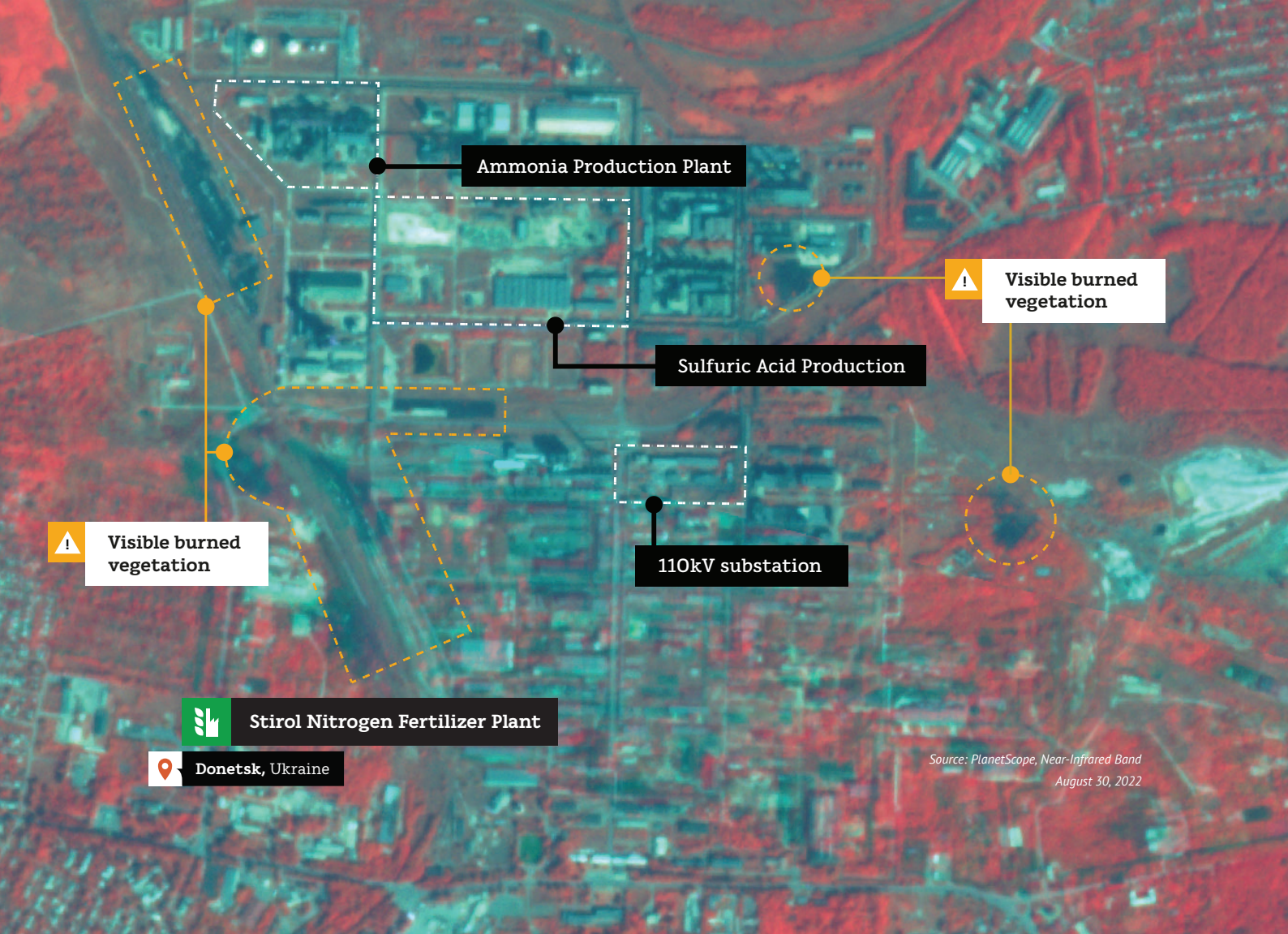
August 2022: On August 12, 2022, user-generated videos published to [VKontakte](#) and [Telegram](#) showed black smoke emerging from the site of the Stirol plant. The video was geolocated as filmed in the direction of a warehouse in the south of the compound. Later imagery would [reveal](#) that the warehouse, containing various materials including unknown barrels and apparent laminates, was ablaze at the facility. Wider damage to the facility's administrative buildings was also [recorded](#). Later in the month, on August 25, the facility's 110kV substation was allegedly targeted by Ukrainian forces, once again causing a large fire at the compound, visible throughout the city. While the strike appeared to primarily damage the substation infrastructure, the shelling resulted in secondary fires of dry vegetation throughout the facility, including within the territory of the northern site [containing](#) both the ammonia production plant and the sulfuric acid workshop. Occupation authorities [claimed](#) the strike presented no environmental risk due to the contained nature of the strike on the substation itself.

¹ Here and further in the text, "occupied" means the temporarily occupied territory according to the Law of Ukraine "On Ensuring the Rights and Freedoms of Citizens and the Legal Regime in the Temporarily Occupied Territory of Ukraine" – the law that determines the status of the territory of Ukraine temporarily occupied as a result of the armed aggression of the Russian Federation, establishes a special legal regime in this territory, determines the specifics of activity in the conditions of this regime, observance and protection of the rights of individuals and legal entities.



Burned materials in a warehouse at the Stirol plant. Source: Telegram

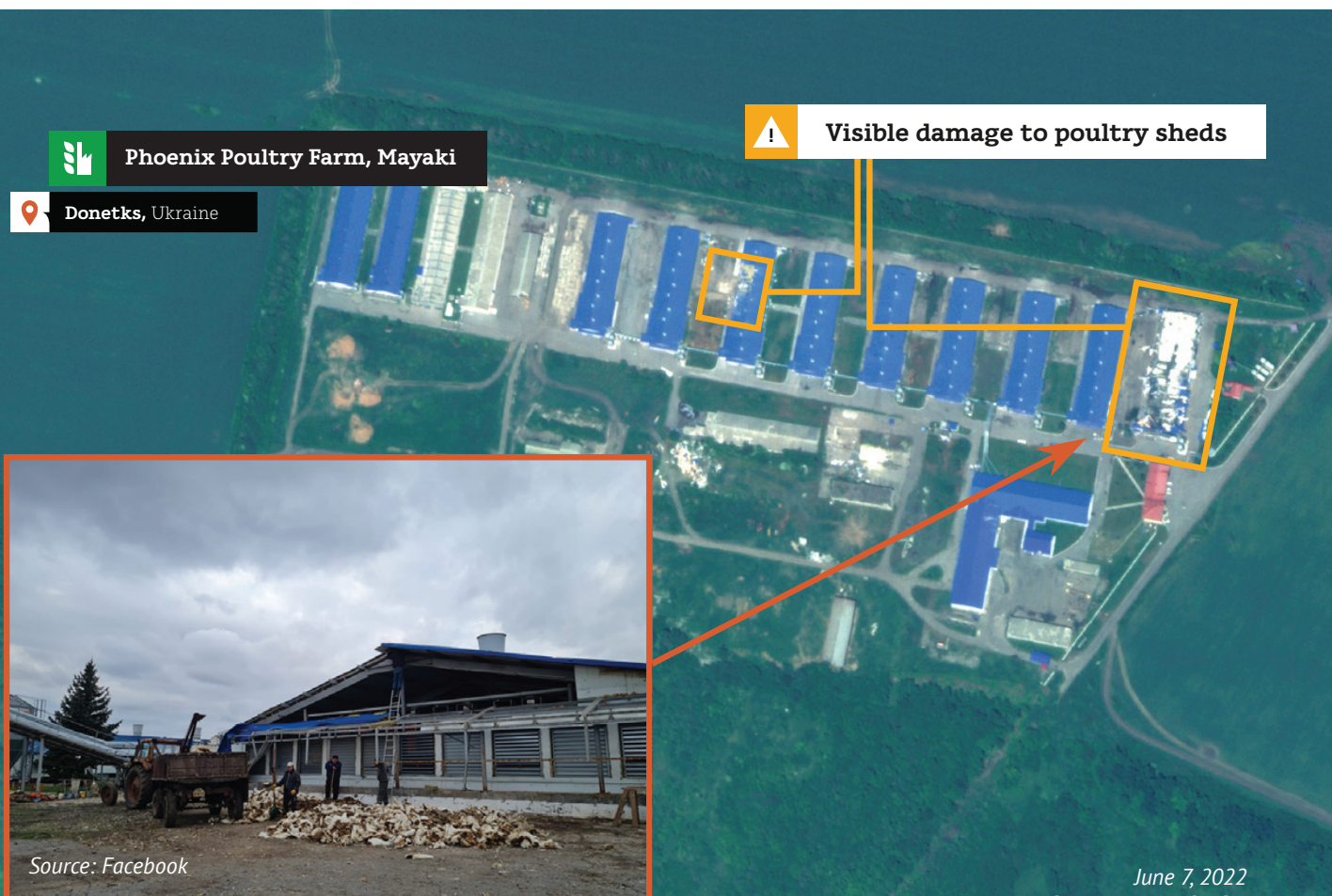
December 2022: Damage was also reported at the Stinol facility at several points in early December, 2022. Most concerning was the damage to the structure of the ammonia plant facility on December 6, 2022. Images show damaged production equipment, reportedly in the ammonia plant itself. Reporting from local Telegram channels of further incidents persisted throughout the remainder of December, including a strike on the facility's checkpoint on December 7; it was later claimed by Russian authorities that this shelling resulted in fires in a sulfur storage facility, increasing the risk of acid rain (this research was unable to verify evidence of a fire at the facility at this time). Damage to the enterprise's mechanical repair shop was reported on December 13, 2022, and damage was reported in the vicinity of the saltpeter warehouse and the carbamide workshop on December 25.



Poultry Farms

The Phoenix poultry farm in northern Donetsk region held over 800,000 hens prior to extensive shelling, allegedly by Russian forces throughout the 2022 invasion. The first damage recorded to the site was detected on May 2, 2022, to a single shed at the east side of the compound. However, by October 2022, imagery showed extensive damage to the facility, as well as [reports](#) of catastrophic shocks to the flock's population. Based on reporting from local officials, the farm lost 800,000 hens at a value of 3.2 million USD.

Other poultry farms also experienced massive flock fatalities. Most notably, the largest chicken farm in Europe, Chornobaivska Poultry, Kherson region, reported losses of 4 million hens since Russia's invasion of Ukraine. The farm reported that interruptions to the energy grid, due to Russian shelling of the power station, resulted in [interruptions](#) to the bird feeding system, while the occupation of Kherson presented extreme challenges to importing chicken feed. The farm sits on the banks of the Verevchyna river, which feeds into the lower Dnieper estuary. In December 2022, the Prosecutor General of Ukraine launched a formal investigation into the facility on the grounds of ecocide, [citing](#) dangers of a 'mass death of birds', warning that 'bacterial contamination of a large area could have occurred' as a result of the deaths.

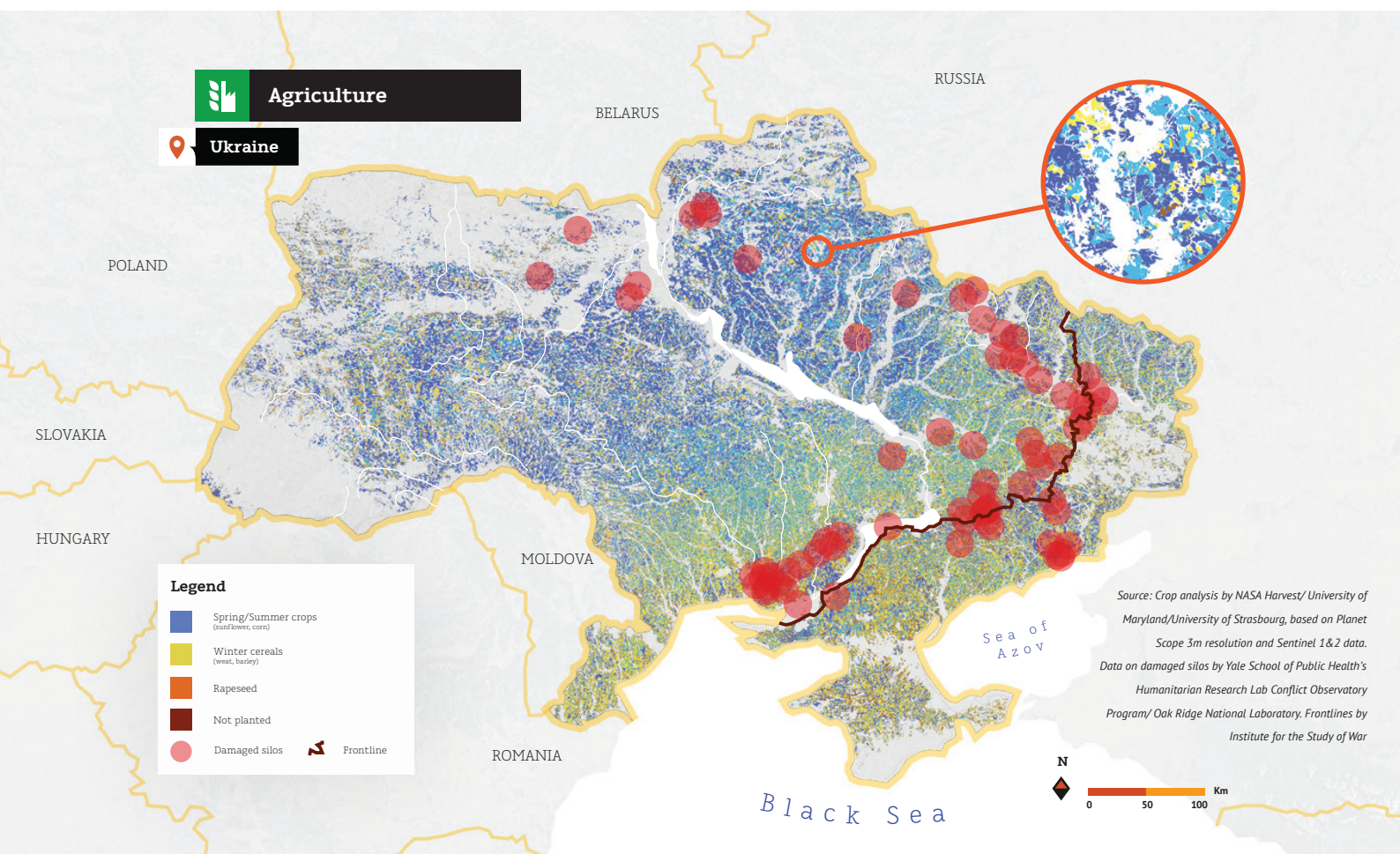


Reported impact on food security

Conflict-linked damage to Ukraine's agrarian sector and the implications for food security have also been covered by numerous [think tanks](#), UN agencies such as the [Food and Agriculture Organisation \(FAO\)](#), and humanitarian organizations, providing useful insights as to the scale and impact. A [survey](#) carried out by the humanitarian organization REACH noted that in Dnipropetrovsk region alone, multiple fires damaged industrial and agricultural facilities, causing concerns among nearby residents of toxic emissions. Thousands of hectares of fertile agricultural land went up in flames before the harvest could start. In a separate report, the organization also [recorded](#) the destruction of at least 25 grain-holding objects between March and July 2022 across the country. The US Department of Agriculture [estimates](#) that wheat harvest dropped from 17 to 10 million metric tons, while an FAO [assessment](#) in December 2022 warned of serious problems with the 2023 harvest due to a lack of fertilizer, pesticide, seeds and fuels. The organization also [warned](#) that the war is likely to impact Ukraine's ability to control animal diseases, in particular African Swine Fever outbreaks, that could lead to further problems for its agrarian sector and possibly also human health.

Public Health and Environmental Risks

The incidents and case studies described above give an understanding of how intense conflict has resulted in damage to Ukraine's agro-industrial sector. The damage includes partial or full destruction of machinery and equipment, storage facilities, livestock, and perennial crops, as well as stolen inputs and outputs and [agricultural land that needs recultivation](#).



Risks from Agro-Industrial Accidents

One of the highest environmental risks from armed conflict is an industrial accident with consequences on both the local and transboundary level. With regards to agro-industry, there are various facilities such as the storages of fertilizer, pesticide and animal waste with toxic and pathogenic substances that are hazardous to all components of the environment and human health in an immediate as well as long-term context.

Hazardous substances can be released into the environment by four pathways: air (wind), surface water, soil, and groundwater, as shown on the figure below.

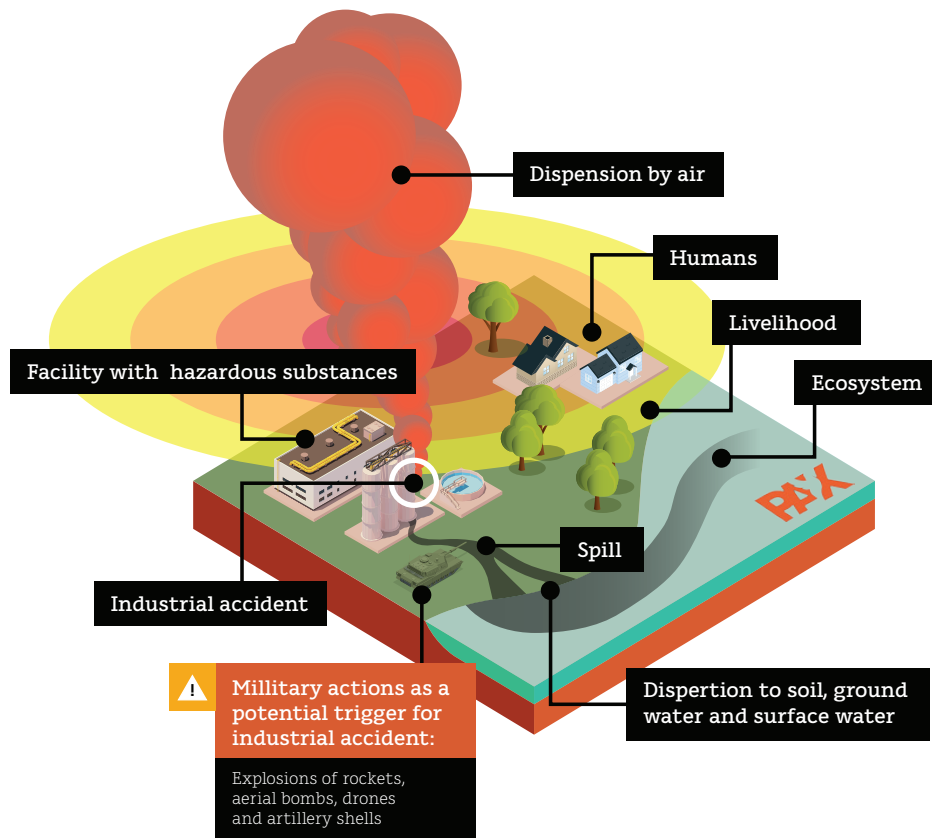


Figure 1. Infographic: Visualizing the military trigger and distance-related expected impacts of an industrial accident. (Adapted from "the UN Environment / OCHA Joint Unit (2017) Flash Environmental Assessment Tool 2.0 Reference Guide")

Each type of hazardous agro-industry facility contains certain materials with substances that can negatively impact environmental and human health in the event of their release. Examining the properties of these substances during their interaction with the environment allows the identification of risks associated with a particular facility.

- ◆ Harmful compounds present within **animal waste** along with general pollution of water bodies can increase rates of eutrophication, in the process of which there is enrichment with biogenic elements, which is accompanied by a decrease in the productivity of reservoirs and watercourses due to the rapid development of blue-green algae. Entry into the water environment of pathogenic microorganisms of animal waste can cause mass death of fish and make the water unfit for consumption, as well as potentially causing outbreaks of various diseases.
- ◆ Another high risk is attacks on **fertilizer production facilities**. Damage to **storages of flammable gas**, such as **anhydrous ammonia**, methane and hydrogen, can lead to explosions when these gasses mix with oxygen in the air. Such explosions can transfer highly toxic substances to the air, soil, and water bodies. The blast wave can also cause extensive damage to other hazardous facilities at fertilizer plants, such as chemical storage facilities. The production of fertilizers uses chemicals such as **ammonia** and **liquid nitric acid**, which can cause serious health problems to humans including lung damage, delayed pulmonary edema, pneumonitis, bronchitis and other conditions. In high concentrations, these chemicals pose an immediate danger to any living organism due to the **acute inhalation toxicity of nitric acid and ammonia**. Nitric acid can also corrode any metal it comes into contact with.
- ◆ Accidental damage to **pesticide sites** risks causing harmful ecological and health effects, depending on their class and concentration. The main pathways of release are soil and water, which make wildlife and aquatic organisms most vulnerable to pesticide exposure. The effects can be direct (fish die from a pesticide entering waterways), or indirect (a hawk becomes sick from eating a mouse that died from pesticide poisoning). Humans or any other living organisms exposed to pesticides may contract acute toxicity effects and chronic diseases over time after exposure. Pesticides are linked to cancer, Alzheimer's disease, ADHD and birth defects, as well as damage to the nervous system, the reproductive system and the endocrine system.

Land degradation from military actions

The environment is changed dramatically by war. Each explosion impacts the environment directly by destroying and polluting Ukraine's highly fertile soil. Pollutants and contaminants migrate to groundwater and surface water which feeds into agricultural land, a double blow to the agricultural potential of the state. The table below outlines the main **soil problems with secondary influence on water resources during hostilities in Ukraine**, due to which agricultural land is being lost.

In addition to the inability of using mined land for agriculture, the detonation of land mines damages or destroys existing crops. Over a quarter of Ukrainian territory, 27%, is claimed to be in need of clearance from contamination with unexploded ordnance, including mines, meaning a territory of about **300,000 square km²** needs to be searched for unexploded ordinances (UXOs). Ukraine is presently one of the most mined countries in the world.

Impact of military actions on soil	Reason of Impact	Environmental and public health risks	Consequences
Physical soil destruction by explosions and military equipment	The use of explosive weapons and the movement of ground-based military equipment lead to the destruction of the upper fertile layer of the soil, which was formed over centuries	Destruction of fertile soil of agricultural land. Damage of land in areas of forests or wetlands.	Risk of losses of biodiversity and ecosystem service, including agricultural land
Soil pollution from explosive weapons, unexploded ordnances (UXO) and explosive remnants of war (ERW)	Explosions and unexploded ordnance from artillery shells, missile and rocket warheads, mortars, and aircraft bombs provoke the release of a number of toxic compounds into the soil, including heavy metals such as chromium, cobalt, nickel, copper, zinc, cadmium, mercury, lead etc. Toxic munitions constituents such as per- and polyfluoroalkyl substances (PFAS) , RXD, PBX, TNT and propellant from missiles and rockets are also expelled into the soil.	Heavy metals and PFAS enter the soil, migrate to groundwater and/or surface water, and eventually enter the food chain, affecting both animals and humans.	Risk of long-term toxic exposure of soil, biota, surface and groundwater, as well as human health
Soil pollution with fuel and lubricants	The movement of ground-based military equipment pollutes soil with fuel, lubricants and other oil products.	Water permeability decreases, oxygen is displaced, and biochemical and microbiological processes are disturbed. As a result, the nutrition of plants is disturbed, their growth and development are inhibited or destroyed	Risk of long-term toxic exposure of soil, surface and groundwater. Risk of losses of biodiversity
Soil pollution from mass burials during war	Mass burials (deceased people and animals of livestock farms) are carried out without compliance with sanitation and hygiene requirements	The decomposition of the bodies of the dead under the influence of precipitation or floods can cause long-term soil and groundwater contamination by pathogenic microorganisms (bacterium, viruses) and chemical compounds (ammonia, hydrogen sulfide, mercaptans, etc.), that result from decay	Risk of long-term bacteriological exposure of soil, surface and groundwater Risks of epidemic outbreak
Mined farming fields	Land contaminated by mines	No safe access to farming fields	Risk of loss of land for agriculture purposes

At present, there is no exact data on the either number of mined agricultural fields or on the degree of contamination of these fields. All the negative impacts of military operations on the soil listed in the table above are a theoretical description of potential risks that need to be explored further at a practical level through the application of evidence-based methods and laboratory analyzes to determine the degree of contaminant migration and places of contaminant accumulation according to soil type in Ukraine.

Ukraine, as an agrarian country, plays a crucial role in the export of various types of food products to different countries around the world. [Ukraine's top agricultural exports in 2021](#) consisted of:

Sunflower oil

	1 st	Ukraine
	2 nd	India
	3 rd	European Union
	4 th	People's Republic of China

Corn

	1 st	Egypt
	2 nd	Iran
	3 rd	Turkey
	4 th	Ukraine

Wheat

	1 st	Egypt
	2 nd	Indonesia
	3 rd	Turkey
	4 th	Pakistan
		Bangladesh
	5 th	Ukraine

Rapeseed

	1 st	European Union
	2 nd	Pakistan
		United Kingdom
	3 rd	Ukraine

Barley

	1 st	People's Republic of China
	2 nd	Turkey
	3 rd	Saudi Arabia
	4 th	Ukraine

Long-Term Impacts of the War Beyond Ukraine

The stability of globalized agricultural and food systems has been shaken in recent years by various shocks such as the pandemic, climate change, and geopolitical and energy crises. The Russian invasion of Ukraine in 2022 is demonstrating how armed conflict between two significant agricultural countries affects food security around the world.

How the Russian invasion of Ukraine impacts global food security

Russia's military aggression has brought enormous economic and environmental problems, as well as unprecedented damage and aggregate losses (USD [\\$28,3 bln by August 2022](#)) to Ukraine's agricultural sector, threatening food security worldwide as a result.

- ◆ **Damage to the agricultural sector.** As of August 2022, [the assessment of damages](#) showed that "machinery and equipment" (41.4%) and "storage facilities" (12%) are the two most affected asset types. 32.7% of damages are due to "stolen inputs and outputs" as a result of Russian occupation. Plus the total damage to positions of "Livestock", "Perennial crops" and "Farmland requiring recultivation" is 13,8%, a significant input towards decreased agricultural production.

- ◆ **Disruption of logistics chains.** Ukraine's Black Sea ports were blocked from February to July 2022, meaning that agricultural commodities were mostly transported by rail and river with a significantly lower capacity compared to sea freight. Damaged storage, processing and transport infrastructure further constrained the country's ability to complete harvests and export. The grain storage deficit caused by the war is estimated at 10–15 million tons.
- ◆ **Lack of necessary means for agricultural production.** Along with the direct destruction of agrarian facilities, fields and livestock, there are major difficulties regarding crop and livestock production: low benefits from the sale of products, no access to fertilizers or pesticides and seeds, lack of fuel, and interruption of electricity to power equipment, water and gas supply. Russian attacks on [fossil fuel infrastructure](#) and on [energy facilities](#) have significantly impacted the agro-industry as Ukraine is forced to prioritize critical infrastructure and defense facilities.
- ◆ **Labor shortage.** The loss of able-bodied people in military actions and the massive displacement of Ukrainians from the country has led to a significant shortage of labor in general, including for the agricultural sector.
- ◆ **Loss of agricultural land.** There has been an estimated 40% reduction in the use of Ukraine's agricultural land due to fertile soil destruction and pollution by mines and unexploded ordnance, combined with a slump in producer prices, high energy costs and limited labor. An additional impact is that about [25% of Ukrainian land area for agriculture is located in Russian-occupied territories](#).

All these war-related factors triggered the interruption and degradation of Ukraine's agricultural production in 2022. The fall in Ukraine's [2022/2023 exports](#) is forecasted as anywhere from 20-40%, depending on the product; wheat, for example, is forecasted to fall 23% below the five-year average level.

Despite the efforts of the international community to launch the Black Sea Grain Initiative, as well as to boost export capacity through non-marine channels, the pace of exports still remains below the average of pre-war levels. Another concern is that war-induced damage to infrastructure, deficit of energy carriers and reduced crop production could keep exports of grains and vegetable oils below their potential.

Considering the downward trend in Ukrainian agri-food exports, there is a high risk that the current food access crisis will escalate into a food availability crisis over the next several years, leading to an exacerbation of global food insecurity.

Conclusion

A year of Russia's invasion of Ukraine has brought huge losses in Ukraine's agricultural sector. The intense and widespread use of explosive weapons has already resulted in damaged equipment, critical infrastructure and disrupted logistics; destroyed and contaminated farming fields and rural households; and displaced and killed civilian farmers. At the same time, a significant part of damages is accounted for by stolen agrarian goods and agricultural lands occupied by Russia. All this has combined to produce a significant decrease in agricultural production.

The findings of this research show how direct attacks against agro-industrial facilities pose acute and long-term health and environmental impacts from toxic and hazardous substances, including the risk of spreading airborne pathogens and wider consequences for food security. Beyond these impacts, there is widespread damage to agricultural areas due to use of explosive weapons.

Recommendations for evaluation and prevention of environmental degradation

The following recommendations to the international community, including donors and relevant expert organizations, should be of guidance in addressing the environmental dimensions of the conflict, in particular for the agro-industrial sector.

Data collection and verification are key in order to create a reliable database of conflict-related environmental damage. Mapping and prioritizing of destroyed/damaged sites for clean-up/remediation measures planning should be implemented, including the use of FEAT. In addition, this will require remote sensing analysis of affected agricultural land, including damage assessments for all relevant facilities that could pose a direct or long-term threat to public health, ecosystems and/or food security.

Environmental monitoring: Monitoring of air, surface and groundwater quality is crucial to track and record the dynamics of environmental pollution from military incidents. This includes the application of a broad spectrum of monitoring equipment, research methods and tools to monitor war-related changes in the environment and to decrease risks for human health.

Assessment of contaminated sites: When security allows, relevant government authorities should start on-site assessments, taking samples and conducting laboratory analysis of affected sites and agro-fields, including health surveillance of nearby communities and inclusion of civil society groups in their work. A full assessment of damaged sites is needed to provide a baseline for further research on war-related risks to the environment and public health.

Harm mitigation: Emergency response to incidents resulting from military actions is a key part of immediate actions to prevent the further spread of hazardous substances and thus mitigate environmental harm. Additional capacity and expertise is needed for cleanup of contaminated sites, including demining activities, land remediation and restoration to prevent and minimize environmental degradation.

Agricultural fields peppered with artillery impacts, Dovhenke, July 6, 2022