In the two decades leading up to Russia’s February 2022 invasion, Ukraine had become a major producer and exporter of numerous agricultural commodities. In the 2020–2021 harvest season—the last season unaffected by Russia’s full-scale invasion—Ukraine was the fifth-largest exporter of wheat, honey, and walnuts worldwide; the third-largest exporter of maize, barley, and rapeseed; and the world’s top exporter of sunflower oil, sunflower meal, and millet.

Due to Russia’s intentional attacks on all aspects of Ukraine’s agriculture sector, and collateral damage from hostilities, Ukraine’s production and exports are diminished today from prewar levels. As of June 2023, the Kyiv School of Economics estimated that Ukraine’s agriculture sector had incurred $8.7 billion in direct damages to agricultural machinery, equipment, and storage facilities, as well as from stolen or damaged agricultural inputs, such as fertilizers and seeds, and outputs, such as crops and livestock. The sector’s $40.3 billion losses represent farmers’ diminished incomes due to foregone production, lower selling prices for products, and higher operational costs across all stages of the agri-food value chain.

The Ukraine Rapid Damage and Needs Assessment, published in February 2023 by the World Bank in partnership with Kyiv School of Economics, the Ukrainian government, the European Union, and the United Nations, provides the most thorough evaluation of the war’s consequences for Ukraine and the investments required to ensure its future prosperity. However, the continuous and comprehensive nature of Russia’s assault complicates any estimate of damage and needs. Following the report’s publication, further losses and damages resulted from Russia’s withdrawal from the Black Sea Grain Initiative in July 2023 and its immediate intensification of attacks on agricultural export infrastructure along Ukraine’s Black Sea and Danube River coasts. Between July and October, 17 separate attacks on Ukraine’s ports, grain facilities, and civilian ships destroyed 300,000 metric tons of grain and further reduced the country’s export potential.

This destruction has resulted in a further downward spiral in Ukraine’s agricultural economy. Limited export routes have raised transportation costs and reduced the volume of goods farmers can sell, decreasing farmers’ incomes and eliminating profitability. While incomes have fallen, the costs of agricultural inputs have risen, and damage to farms and equipment imposes additional, heavy costs on farmers. As a result, many farmers are curtailing their activities and reducing the size of their harvests. And despite the Ukrainian government’s efforts to insulate agricultural workers from the draft, active war has drawn farmers to the battlefield, reducing the size of Ukraine’s agricultural labor force.

In aggregate, this has significantly decreased Ukraine’s agricultural production and exports. Still, in 2022, Ukraine managed to remain among the world’s top producers and exporters of corn, wheat, sunflower oil and seeds, and soybeans, due to the determination of Ukraine’s agricultural labor force, the commitment of Ukraine’s government, and support from numerous other partners, including governments, multilateral organizations, non-governmental organizations (NGOs), and research institutes. According to Kyiv School of Economics
president Tymofiy Milovanov, efforts to rebuild Ukraine's agricultural sector should continue even as conflict continues because it is unlikely there will be a "clear end to the war." Ukrainian president Volodymyr Zelensky established the National Council for the Recovery of Ukraine from the War just two months after the full-scale invasion began, and the council continues to develop the Ukraine Recovery Plan in partnership with Ukrainian civil society institutions, partner governments, and international organizations and companies. The overarching goal of this work is not just to reconstruct Ukraine, but to build on the country's reforms in recent years and transform Ukraine's economy for the future.

The importance of investing in Ukraine's agricultural sector is threefold: to bolster Ukraine's economy in wartime, to restore its capacity as a major global food supplier, and to strengthen its position as a bulwark to Russia's influence through its own agricultural exports. Rebuilding and transforming Ukraine's agriculture sector will require coordinated investments in its soil, labor force, agricultural institutions, and infrastructure. Adequate and low-cost routes must be secured for Ukraine's agricultural exports; damaged farm, storage, transportation, and port infrastructure must be rebuilt; destroyed and stolen equipment and goods must be replaced; farmlands must be demined, tested, and restored; farmers' access to seeds, fertilizers and other agricultural inputs much be secured; and farmers' needs for additional financing and training to continue agricultural activity must be met. Investments to address

**FIGURE 1: UKRAINE’S PRE- AND POSTWAR SHARE OF GLOBAL AGRICULTURAL PRODUCTION AND EXPORTS**
in million metric tons (mmt)

<table>
<thead>
<tr>
<th>Category</th>
<th>2020-2021</th>
<th>2021-2022</th>
<th>2022-2023</th>
<th>2023-2024 (projected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Production</td>
<td>3.08% (63.67 mmt)</td>
<td>3.97% (85.05 mmt)</td>
<td>2.60% (54.6 mmt)</td>
<td>2.71% (58.15 mmt)</td>
</tr>
<tr>
<td>Oilseeds Production</td>
<td>17.48% (28.44 mmt)</td>
<td>17.07% (29.62 mmt)</td>
<td>14.80% (27.5 mmt)</td>
<td>16.27% (30.6 mmt)</td>
</tr>
<tr>
<td>Grain Exports</td>
<td>10.87% (45.76 mmt)</td>
<td>11.36% (48.53 mmt)</td>
<td>10.95% (46.82 mmt)</td>
<td>7.85% (34 mmt)</td>
</tr>
<tr>
<td>Oilseeds Exports</td>
<td>34.50% (13.98 mmt)</td>
<td>31.70% (12.07 mmt)</td>
<td>31.60% (14.93 mmt)</td>
<td>33.30% (14.4 mmt)</td>
</tr>
</tbody>
</table>

**SOURCE**
immediate needs and obstacles are ongoing, but even more immense challenges will require international attention in the coming decades, including demining waterways, namely the Black and Azov Seas, modernizing the country’s irrigation infrastructure, and addressing the repercussions of the Kakhovka dam collapse on surrounding ecosystems and agricultural livelihoods. This work will take place in the context of Ukraine’s 2024 farmland market reform and the country’s candidacy for membership in the European Union, which will necessitate further reforms to Ukraine’s agriculture sector.

This white paper focuses on two aspects of Ukraine’s agricultural reconstruction that are crucial to supporting transformation throughout the sector: demining Ukraine’s farmland and improving access to fertilizers in Ukraine. The information and insights included herein are the result of CSIS research, with input from numerous experts in Ukraine, Europe, and the United States. Information and policy recommendations regarding rebuilding other aspects of Ukraine’s agriculture sector can be found in other CSIS publications and will be the focus of future scholarship.

The Scale and Nature of Landmine Use

Since Russia invaded Ukraine in February 2022, a significant proportion of combat has been waged across farmland in Ukraine’s rural areas, compromising Ukraine’s agricultural economy. The nature of the war’s impacts on Ukraine’s farmland varies by locale. War-related damage to Ukraine’s farmland includes craters and other physical destruction from munitions attacks; possible chemical contamination from munitions, fuel spills, shell remnants, and human remains; and depressions from armed vehicle tracks. According to the commander-in-chief of Ukraine’s Armed Forces, Valeriy Zaluzhnyi, Russian troops were firing between 40,000 and 60,000 shells at Ukrainian positions every day as of August 2022. Up to 20 percent of ammunition fired does not detonate, and Russian troops regularly place landmines in fields and forests. Among threats to Ukraine’s farmland, unexploded ordinance and the extensive placement of landmines remain widespread concerns.

A Reuters investigation into landmine use in Ukraine revealed “landmine contamination so vast it is most likely unprecedented in the 21st century,” with emplaced landmines numbering in the hundreds of thousands. By mid-2023, Ukraine had become the most mined country in the world, surpassing Afghanistan, Syria, Cambodia, and other countries in which landmines are a common feature of warfare. According to Ukraine’s Ministry of Internal Affairs, about 30 percent of Ukraine’s lands, or approximately 174,000 square kilometers (67,000 square miles), has been exposed to conflict and will require surveying and, if necessary, demining. According to Interfax, a further 13,500 square kilometers (over 5,200 square miles) of the Black Sea, Azov Sea, and Ukraine’s rivers and other inland bodies of water are potentially contaminated with landmines. Likewise, according to Human Rights Watch, the scale of landmine use in Ukraine has resulted in a “large, dispersed, and complex level of contamination that will threaten Ukrainian civilians and hinder recovery efforts for years to come.” One deminer (or “sapper”) is able to clear between 15 and 25 square meters per day, and given the current rate of progress, some estimate that complete demining of Ukrainian territory could take decades or even centuries.

Antipersonnel mines and anti-vehicle mines have been used in the ongoing war, with at least 13 types of mines identified in Ukraine to date, according to Human Rights Watch, which are located in at least 11 regions across central and eastern Ukraine (see Figure 2). The preponderance of landmines in Ukraine have been emplaced by Russia, which is not a signatory to the 1997 Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction (Mine Ban Treaty). Human Rights Watch has even identified in Ukraine several previously unseen Russian landmines produced as late as 2021, including antipersonnel mines. Though Ukraine is a signatory to the Mine Ban Treaty, Ukraine has used antipersonnel mines in at least one location since Russia’s invasion, according to Human Rights Watch.

Landmines used in the war have been hand-emplaced, mechanically laid, scattered by truck-mounted projectors, and delivered by rocket. They include small, plastic-cased PFM-1 antipersonnel mines, which can be easily mistaken for harmless objects and overlooked by metal detectors; POM-3 anti-personnel mines, which can be scattered by air and detonated with mere vibrations, such as nearby footsteps; metal- and plastic-encased anti-vehicle mines, which can be buried in shallow holes and penetrate vehicles’ under-armor upon detonation; and PARM anti-vehicle mines, which can be placed above ground and fire a projectile into their target. Russian forces are also employing “Zemledelie” systems, which can remotely lay mines in areas as large as several football fields in short periods of time, creating minefields of varying complexities across Ukraine. The “Zemledelie” system, Russian for “agriculture,” was developed by the Russian company Rostec and was first observed in use in March 2022.

Both the extent of Russia’s mine placements and the use of mining technology innovations within Ukraine have resulted in mine contamination of enormous complexity, scale, and lethality. As of September 2023, 246 civilians (including 13 children) had been killed by explosive devices, and 521 civilians (including 53 children) had been injured across Ukraine.

Ukrainian Government Efforts

While the war continues, the Ukrainian government’s assistance for demining efforts continues to evolve. The Ukrainian government was already supporting demining efforts in Ukraine when Russia invaded in February 2022; previously occupied areas of Luhans and Donetsk had been subject to demining efforts since 2015, following Russia’s 2014 invasion. In November 2021, the Ukrainian government announced the creation of the National Mine Action Authority, an interagency group led by Ukraine’s Ministry of Defence that is responsible for the development of national policy and plans for demining as well as coordination of all actors involved in demining.

Among Ukraine’s mined territory is a significant proportion of Ukraine’s farmland. The precise proportion of Ukraine’s farm-
land that has been contaminated by landmines is impossible to determine while hostilities continue. Estimates of Ukraine's farmland exposed to landmines range from 470,000 hectares (or 1,814 square miles), according to Ukraine's Ministry of Defense and Ministry of Agrarian Policy and Food, to 2.5 million hectares (or 9,652 square miles), according to Ukraine's first deputy minister of agrarian policy and food. GLOBSEC estimates that 5 million hectares (or 19,305 square miles, approximately 15.2 percent) of Ukraine's farmland are unsuitable for use due to landmines, contamination with explosive ordnance, and exposure to armed hostilities.

In March 2023, Ukraine's Ministry of Defence announced the creation of an Action Plan for Demining Agricultural Land to facilitate spring sowing and fall harvesting of crops in 2023 and after. The Ministry of Defence is responsible for ensuring implementation of the plan and coordination among Ukrainian and international partners. To expedite humanitarian demining nationwide, the Ukrainian government announced the formation of the Interagency Working Group on Humanitarian Demining in June 2023, chaired by the Ministry of Economy, and the working group held its first meeting in September 2023, emphasizing the importance of creating a mine action strategy for Ukraine. Later in September 2023, Ukrainian prime minister Denis Shmyhal convened the first Demine Ukraine Forum among Ukrainian government representatives and international partners.

**Humanitarian Demining**

The ultimate purpose of mine removal dictates the level of investment—of time and funding—in demining efforts. Swiftly clearing an area of mines in the course of combat or immediately thereafter is called military, combat, or operational demining. Operational demining is conducted by special military units or other emergency services and is intended to clear a path for the safe advance or retreat of troops. Though it may quickly return access to roads, residential buildings, or other areas of common use, it does not necessarily guarantee the safety of these areas.

Humanitarian demining, by contrast, aims to "clear land so that civilians can return to their homes and their everyday routines without the
threat of explosive hazards,” according to the UN Mine Action Service (UNMAS). Humanitarian demining involves numerous, resource-intensive steps, all of which are required to guarantee that an area has been thoroughly searched and cleared of explosives and is safe for use. Steps required for humanitarian demining include a non-technical survey of land, involving interviewing communities and reviewing records of conflicts; a technical survey, involving the use of equipment or animals to determine the boundaries of minefields; mine removal, most commonly through mine detonation; and certification that mine removal is complete and land is safe for use.

According to Ukraine’s Ministry of Defence, humanitarian demining in Ukraine is presently carried out by 18 certified mine action operators, organizations, including NGOs (e.g., the Danish Refugee Council, HALO Trust, the Swiss Foundation for Mine Action, the Norwegian People’s Aid, and DanChurchAid), companies (e.g., Demining Solutions, GKh Group, and TetraTech), and Ukrainian entities (e.g., the Ukrainian Sappers Association, Ukrspecexport, and Ukroboronservice). Entities that wish to contribute to Ukraine’s demining efforts must complete a complex certification procedure before working as demining operators in Ukraine. In recognition of the need to expedite and streamline the certification process for demining operators, the State Emergency Service’s Interregional Center for Humanitarian Demining launched an online portal for interested organizations to apply for certification and keep apprised of the application’s status. After obtaining certification to demine its own farmland across Ukraine, the Ukrainian company Nibulon has recognized the use of its expertise across Ukraine’s farmland broadly and will offer its services to farmers and to the state. As of September 2023, 30 additional organizations are awaiting certification, including 18 governmental operators from Ukraine’s State Emergency Service, State Transport Special Service, and armed forces.

At present, the Ukrainian government does not fund humanitarian demining services, so most farmers must pay for demining services themselves. At the Demine Ukraine Forum, Minister of Economy Yulia Svyrydenko noted that Ukraine’s 2024 budget would include UAH 2.0 billion ($54.7 million) to partially compensate farmers for demining services. Minister Svyrydenko also announced the establishment of the Prozorro demining market, through which farmers are expected to select certified deminers. The Ukrainian government will compensate farmers for half the cost of demining through the Prozorro system, and the Ukrainian government is considering the best way to compensate farmers for demining costs borne before 2024. Ukraine’s state bank, “Ukragasbank,” has also launched a soft lending program to fund the demining of farmland within the framework of the “Affordable Loans at 5-7-9 percent” program, improving farmers’ access to demining financing and incentivizing farmers’ use of legal, certified demining operators.

Progress Demining Ukraine’s Agricultural Land

Under the Ministry of Defence’s Action Plan for Demining Agricultural Land, the Ukrainian government specified 470,000 hectares of agricultural land in nine regions of Ukraine (see Figure 2) that would need to be surveyed and, if necessary, demined. These regions are where “the problem of contamination is most urgent and the clearing of agricultural land is most feasible,” according to Ukraine’s Ministry of Defence. In addition to the National Mine Action Authority, coordinated by the Ministry of Defence, Ukraine’s Interagency Working Group on Humanitarian Demining, coordinated by the Ministry of Economy, also supports humanitarian demining across Ukraine. In a press release from the Ministry of Economy in June 2023, the Ukrainian government noted that the Ministry of Agrarian Policy and Food would update the identification of territories that would need to be demined. According to the Ministry of Economy, 100,000 of the 470,000 hectares specified in the action plan had been cleared by June, and by the end of 2023, up to 165,000 hectares of land could be cleared for agricultural use.

The Ukrainian government has continued to publicize progress under the action plan. By September 2023, the Ukrainian government had surveyed 188,600 hectares of agricultural land under the plan, of which over 124,000 hectares will require clearance, including through humanitarian demining. By October 2023, the Ukrainian government had surveyed more than 225,000 hectares of agricultural land identified in the action plan and had returned 170,000 hectares to economic use. In addition to these periodic updates, the State Emergency Service of Ukraine publishes daily updates regarding its progress demining Ukrainian territories through a portal that is only accessible within Ukraine. Between the beginning of the invasion and November 14, 2023, 454,827 explosive objects and 2,892 kilograms of explosive substance have been defused, including 3,124 aerial bombs. Ukraine’s Ministry of Defence has also partnered with the Geneva International Centre for Humanitarian Demining to maintain an interactive map of mine contamination across Ukraine.

Ukraine's Needs and International Support

Despite recent progress, the demining needs of the Ukrainian government remain staggering. As of February 2023, the cost of clearance of explosive ordnance across Ukraine was estimated at $37.6 billion, according to the Ukraine Rapid Damage and Needs Assessment produced by the Kyiv School of Economics, the World Bank, the Ukrainian government, the European Union, and the United Nations. This estimate represents the significant investments needed in equipment, training, and salaries, including to expand the strategic planning and operational capacities of Ukraine’s demining forces.

Numerous countries, multilateral organizations, and NGOs have provided financial and other support for demining in Ukraine, including for the demining of agricultural land. In June 2023, the UN Food and Agriculture Organization (FAO) and the UN World Food Programme (WFP) announced a joint plan to clear landmines and other explosive remnants of war from agricultural land, in collaboration with the Fondation Suisse de Déminage and with support from the UN Ukraine Humanitarian Fund and private donors. In July 2023, the Ukrainian government announced that numerous partners—including the United States, the European Union, Japan, Germany, the United Kingdom, Norway, Sweden, Italy, Lithuania, the Netherlands, Denmark, Canada, Austria, Switzerland, South Korea, and the Howard Buffett Foundation—together had pledged $244 million for humanitarian demining clearance. In July 2023, South Korea pledged to provide demining equipment to Ukraine, and Japan has similarly offered technical assistance in 2023. In September 2023, the U.S. Department of State announced $90.5 million in humanitarian demining assistance to Ukraine, in addition to the $47.6 million the State Department had announced in September 2022 for a similar purpose. Croatia hosted the first International Donors’ Conference on Humanitarian Demining in Ukraine in October 2023, attracting representatives from more than 40 countries, and Switzerland,
local Ukrainian media (authors' translation): One farmer in Kharkiv fitted with panels stripped from Russian tanks, to scan his fields with handheld metal detectors, marking potential mines with flags. Three of this farmer’s employees scanned his farmland we understood it wouldn’t happen, so we decided to do it ourselves. “At first we waited for the state to demine our fields. Then we understood it wouldn’t happen, so we decided to do it ourselves.” Three of this farmer’s employees scanned his farmland with handheld metal detectors, marking potential mines with flags. Another farmer operates a remote-controlled tractor, outfitted with panels stripped from Russian tanks, to scan his fields for landmines. One farmer in Kharkiv explained the situation to local Ukrainian media (authors’ translation):

Out of 3,000 hectares, I have 1,000 hectares mined. I left the application for demining immediately after the de-occupation. The emergency department says that they will not clear the mines in the near future because they do not have time. We are now communicating with the neighboring farms to clear the fields [ourselves]. The situation with the neighbors is still worse, their land has been demined. A report from the NGO Mine Action Service of Ukraine carry an unexploded missile near the village of Hryhorivka, Zaporizhzhia region, on May 5, 2022.

Dimitar Dilkoff/AFP via Getty Images

In this context, many farmers opt to use the services of uncertified or “dark deminers,” who charge prices lower than certified deminers but who cannot guarantee that land they survey is clear of mines and safe for use. Among farmers who use dark demining services, accidents are reportedly common.

And among farmers in regions exposed to conflict, not only the presence but the fear of landmines can keep farmers from working their land, according to CSIS interviews. Kyiv School of Economics president Timothy Milovanov characterized the current situation as two systems of demining at tension within Ukraine: the “legacy” system, whose adherence to international mine action standards renders it slow and expensive but best able to guarantee the safe clearance of lands, and the alternative system made up of Ukrainians that “have to work . . . [and] protect their children,” who “innovate right now, whether it’s certified or not.” Such demining “innovations” are borne from farmers’ need to continue agricultural activity for their livelihoods, but the risks of uncertified demining are severe. A farmer in Kherson who opted against planting in the face of mine contamination told Reuters, “I have no moral right to send workers to fields as it is dangerous for life.” CSIS interviews revealed the same tension between these two systems, with some Ukrainian entities advocating for equipping farmers with demining machines to expedite the process, and others insisting that farmers are not professional deminers and their participation in the process would risk lives and complicate the government’s coordination and planning.

The U.S. Department of Agriculture (USDA) reports that while overall production and export levels have fallen since Russia’s invasion, agricultural yields per acre have risen compared to last season for Ukraine’s major commodities, although the USDA estimates include crop production in Crimea and occupied territories, where Russia reaps the benefits of favorable harvests. For wheat, for example, yields are estimated at a 4.5 tons per hectare, up 17 percent from 2022 and 13 percent from the five-year average. This suggests that production losses are due primarily to reduced planting; the USDA estimates that harvested area has fallen 26 percent from the five-year average. In fact, farmland exposed to hostilities since February 2022 has left an impact visible from space, according to NASA’s Harvest program, which estimates that up to 2.8 million hectares (or over 10,800 square miles) of Ukraine’s agricultural land have been abandoned as a result of the war.

Unique Considerations for Agricultural Land

The presence, or even the fear, of landmines on agricultural land has affected farmers’ harvests across Ukraine. At the same time, the process of demining farmland could also depress agricultural yields, as some farmers may experience long-term impacts once their land has been demined. A report from the NGO Mine Action

The Reality for Farmers

Despite the Ukrainian government’s recent progress on its Action Plan for Demining Agricultural Land and considerable support from international partners, many farmers face difficulties accessing humanitarian demining services. One licensed company, for example, is reported to have offered demining services to farmers for $200 per acre of farmland. Because the war has reduced harvests and incomes, and increased the costs of inputs, most farmers are unable to afford such prices. Furthermore, Ukraine’s byzantine bureaucracy can lead to long wait times for demining services. Duplication of services across ministries and the constant evolution of priorities and plans can lead to bottlenecks, which the Ukrainian government admits and is seeking to redress.

In the meantime, some farmers are resorting to conducting demining activities themselves. As one farmer reported to Foreign Policy, “At first we waited for the state to demine our fields. Then we understood it wouldn’t happen, so we decided to do it ourselves.” Three of this farmer’s employees scanned his farmland with handheld metal detectors, marking potential mines with flags. Another farmer operates a remote-controlled tractor, outfitted with panels stripped from Russian tanks, to scan his fields for landmines. One farmer in Kharkiv explained the situation to local Ukrainian media (authors’ translation):

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Review, with funding from the Norwegian, Canadian, and Swiss governments, details the numerous destructive effects of demining on soil. The most common machinery employed in demining is equipped with flails, tillers, and rollers, which can disrupt soil structure, accelerate soil erosion, and disrupt water, carbon, and nutrient cycles. While the most expedient and safest method of landmine disposal is through remote detonation, detonation generates a crater that displaces topsoil while compacting subsoil into the crater. Finally, the detonation of landmines can release toxic pollutants into soils and waterways, including from explosive substances as well as the breakdown of other munitions components. In Cambodia, for example, researchers found that the content of heavy metals such as arsenic, cadmium, and copper increased by 30 percent in soil in a 1-meter radius of the detonation point.

Mitigation measures for such effects of landmine detonation are unclear, and data on the environmental impacts of landmine detonation are limited. The extent to which the detonation of landmines could affect soil fertility and water quality in heavily mined territories has not been widely examined or reported. Only one international covenant, the International Mine Actions Standard 07.13, addresses the impacts of demining on agricultural land, stating that national authorities and mine action operators have the responsibility to “ensure that all mine action activities…are carried out in accordance with applicable legislation, safely, effectively and efficiently, but also in a way that minimises any adverse impact on people, wildlife, vegetation and other aspects of the environment.” The standard further specifies that mechanical clearance and bulk demolition, or the process of clearing land with machines designed to detonate ordnance, require greater oversight than other clearance methods given that “these processes have the ability to severely impact the environment.”

Although detonation carries risks for agricultural land, leaving landmines in the ground can also lead to chemical contamination as the munitions age and corrode. The leaching of hazardous chemicals into soil and groundwater can take anywhere from 10 to 90 years, but Ukraine’s farmland may experience pollution from buried ordnances sooner rather than later. Russia has reportedly used Soviet-era landmines against Ukraine, which would corrode faster than landmines produced more recently. Further, the characteristics of Ukraine’s fertile soils that enable plants to thrive also enable the soil to “cling on to a lot of these toxins following the war,” according to soil geomorphologist Joe Hupy.

Efforts to identify the impacts on agricultural soil and groundwater resulting from exploded ordnance, unexploded ordnance, and landmines have only just begun within Ukraine, and CSIS interviews with in-country experts and operators revealed that more investment, time, and resources are needed before these impacts can be accurately determined. The Ukrainian Researchers Society, FAO, and WFP have partnered to map munition craters, soil pollution, and the presence of “bombturbation,” or incidences of explosives cratering, compacting, displacing, and ejecting hazardous materials into soil. Their preliminary study of contamination in the Kharkiv Oblast using remote sensing and soil sample analysis shows that over 420,000 craters across roughly 655,072 hectares of arable land have resulted in over 1.3 million cubic meters of displaced soil, 4,214 hectares of bombturbated soil, and 28,286 hectares of potentially contaminated soil, with only 1.76 percent of assessed soils found to be contaminated with heavy metals. A CSIS interview with the FAO Ukraine office confirmed this level of contamination is not concerning for the safe consumption of crops, but rather for the potential of reduced agricultural production in the future.

A collection of researchers across Ukraine, Lithuania, Portugal, and Spain have conducted a similar assessment within the Kharkiv Oblast, also finding that explosions on and within soil have damaged soil structure and released heavy metals into sur-
The Ukrainian government is prioritizing humanitarian demining at the highest levels, including by the leadership of the Ministries of Economy and Defence, as well as by the prime minister.

In the course of adapting demining services to the ongoing war, the Ukrainian government recognizes that inefficiencies remain and is attempting to expedite the provision of humanitarian demining services and reduce the cost to Ukraine’s farmers through the recently launched demining market on the Prozorro system and through soft loans to farmers.

The Ukrainian government is also tracking the resources needed to demine Ukraine’s farmland, including demining equipment and training for deminers.

The Action Plan for Demining Ukraine’s Agricultural Lands aims to synchronize humanitarian demining of Ukraine’s farmland, and the Ukrainian government is attempting to unify all Ukrainian government demining activities under a forthcoming mine action strategy, which the Interagency Working Group on Humanitarian Demining is presently drafting.

At the same time, the Ukrainian government should continue to take steps to reduce the prevalence of “dark demining” of Ukraine’s agricultural land and demining by farmers themselves, recognizing risks to the safety of farmers and other civilians.

Furthermore, the Ukrainian government is coordinating regularly with international partners to fill gaps and prevent overlaps in services, including through the International Donors’ Conference on Humanitarian Demining in Ukraine.

Finally, the Ukrainian government and its partners appear to be aligning activities with UNMAS’s Five Pillars of Mine Action, including mine education, with Minister of Economy Svyrydenko recently emphasizing the need for a “nationwide awareness campaign to educate children from an early age about the dangers of explosive ordnance.”

The complete humanitarian demining of Ukraine will require 10,000 sappers, necessitating an additional 7,000 deminers to supplement the 3,000 specialists working across the country today, according to Prime Minister Shmyhal. Funding for deminers’ training and salaries must be increased, with training for one sapper costing up to $6,000.

Conducting non-technical surveys prior to other humanitarian demining procedures is the most cost-effective way to confirm the presence of landmine contamination and efficiently release non-contaminated land. In its action plan and national mine action strategy, the Ukrainian government should formalize the release of low- and no-risk land through non-technical surveys before conducting technical surveys in order to release more land for economic use as quickly as possible.

In completing non-technical surveys, technical surveys, and mine removal, sappers should have access to advanced demining technologies, including drones, ground-penetrating radar, and satellite imagery analysis enhanced by artificial intelligence, in order to expedite humanitarian demining and increase the safety of deminers.

Ukraine should continue to invest in its capacity to manufacture advanced demining equipment locally.

In the face of the rapid evolution of Ukrainian government demining processes, the Ukrainian government should continue to clearly communicate the steps farmers must take to access certified demining services and receive compensation for them, including through the newly announced demining market under the Prozorro system.

The Ukrainian government and international partners should also attempt to reduce the cost to farmers of humanitarian demining of their agricultural land, recognizing that any costs borne by farmers will detract from investments in agricultural production, resulting in lower farmer incomes, production, and exports nationwide.

Given the urgent need for actionable information about the impacts of demining on agricultural land, and the fragility of the ecosystems on which agricultural activity depends, Ukraine’s government and international partners should invest in research on the impacts of demining agricultural land and disseminate best practices for demining Ukraine’s farmland to minimize impacts on soil fertility, water, and agricultural productivity. Such considerations and steps should be codified in plans for demining Ukraine’s farmland today and in the future, for the awareness of Ukrainian and international deminers.

The Ukrainian government and partners should also increase the availability of soil testing to ensure the absence of chemical contamination and the safety of crops produced.
FERTILIZER

Ukraine is endowed with uniquely fertile farmland. Nearly two-thirds of Ukraine's total arable land is covered in black soils, a highly fertile soil type containing ideal clay content for plant growth and high quantities of organic matter, such as humus, and nutrients, including calcium, nitrogen, phosphates, and potassium. Ukraine's wealth of fertile soil facilitated its rise as a major global food supplier, even as it applied less fertilizers per hectare compared to neighboring countries.

While harvesting crops removes essential nutrients from soils, mineral fertilizers replace these nutrients for subsequent harvests. Ukraine's major agricultural harvests require application of nitrogen, in the form of ammonia nitrate, urea, anhydrous ammonia, and other forms; phosphorus, in the form of diammonium phosphate, monoammonium phosphate, and other forms; and potassium or potassic fertilizer, in the form of potash. Worldwide, fertilizers have accounted for a large share of agricultural productivity growth over the past century.

Impacts of Russia’s Invasion on Fertilizer Use in Ukraine

Ukraine's increased agricultural production and exports over the past two decades are largely due to an increase in the use of fertilizers by Ukrainian farmers. Russia’s invasion has disrupted Ukrainian farmers’ ability to purchase and apply fertilizers since 2022. According to the State Statistics Service of Ukraine, Ukrainian farmers applied 27.7 percent less fertilizer in 2022 than 2021, using roughly 20.8 million metric tons of mineral fertilizers in 2022 compared to 28.8 million metric tons in 2021, representing declines in the use of nitrogenous, phosphatic, and potassic fertilizers. Reductions continued into the 2022–2023 season: compared to average rates from 2018 to 2022, a March 2023 survey of 119 agricultural enterprises in Ukraine found that nitrogen application decreased by 16 percent for corn and wheat, 19 percent for sunflower, 21 percent for canola oil crops, and 24 percent for soybeans. A survey conducted by the Ministry of Agrarian Policy and Food shows that access has not improved as the country heads into its third growing season since Russia’s invasion: most Ukrainian farmers will be able to apply only half the fertilizers necessary for the 2024 harvest season, with only 10 percent of respondents fully equipped to meet their crops’ fertilizer needs.

Insufficient fertilizer use impacts the quality and quantity of current and future harvests. According to the first deputy minister of Ukraine's Ministry of Agrarian Policy and Food, a decrease in fertilizer application by 30 percent or more can reduce yields by 50 percent. The consequences of reduced fertilizer application can vary from farm to farm, depending on the nutrients applied, the crops cultivated, the season’s soil and climatic conditions, and the practices farmers employ throughout the season. A farm’s history of crop cultivation also determines which nutrients are present in the soil at the time of planting and which nutrients need to be applied for a specific crop’s optimal yield. Excessive application of one or more types of nutrients can likewise impact the quality and quantity of an upcoming harvest. Fertilizer application is not a one-size-fits-all practice, and many agricultural enterprises seeking to reduce any adverse effects of excessive mineral fertilizer application rely on soil testing to tailor the nutrients applied to the specific needs of their soil. As Ukrainian farmers have faced difficulties accessing and affording a range of mineral fertilizers, they have resorted to applying whatever nutrients are available in their own stores or from local suppliers, often not within recommended timeframes, which may have long-term impacts on Ukraine’s soil.

Fertilizer and Ukraine’s Agricultural Economy

Access to fertilizer is necessary for the livelihoods of Ukraine’s farmers and for Ukraine’s agricultural output, two related but distinct facets of Ukraine’s agricultural economy. Across Ukraine, roughly 2.7 million people were engaged in agricultural activity in 2021, comprising 17.3 percent of Ukraine’s total labor force. Access to fertilizers is important to small-scale farmers (farmers cultivating less than 500 hectares), who operate 82.4 percent of Ukraine’s agricultural enterprises, as it is central to the prosperity of their farms. Access to fertilizers is critical for medium- and large-scale producers, who operate the remaining 17.6 percent of Ukraine’s agricultural enterprises and are responsible for the majority of Ukraine’s agricultural exports and export revenues: agricultural enterprises cultivating over 500 hectares of farmland made up nearly 80 percent of Ukraine’s cereal and legume crop production in 2022. Medium- and large-scale enterprises are better able to access and afford fertilizers than small-scale farmers: the 10 percent of agricultural enterprises surveyed by the Ministry of Agrarian Policy and Food that can meet their crops’ fertilizer needs in 2024 are medium- or large-scale...
operations, with no surveyed small-scale farmers reporting that their fertilizer needs are met for the upcoming season. As fertilizer prices remain high within Ukraine, Ukrainian farmers are adjusting their sowing plans to plant crops whose nutrient requirements they can meet with current fertilizer stores. Ukraine’s Ministry of Agrarian Policy and Food also observes farmers basing their plans on the needs of domestic markets as export routes remain limited, sowing their fields with more peas, barley, millet, and oats relative to prewar harvests.

According to the FAO’s January–February 2023 survey, nearly 20 percent of small-scale farmers in Ukraine, defined by the FAO as cultivating 250 hectares or less, had stopped purchasing fertilizers due to high prices. Of the 1,927 agricultural enterprises interviewed by the FAO, 81 percent expressed a need for more fertilizers to continue agricultural activities. Ukrainian farmers, especially small- and medium-sized producers, have resorted to a barter system with input suppliers in which fertilizers are purchased with grains and agricultural products.

**Factors Restricting Access to Fertilizers in Ukraine**

Ukrainian farmers’ reduced access to fertilizer is due to numerous, concurrent shocks, including the invasion, curtailed nitrogenous fertilizer production within Ukraine, and high logistics costs due to Russia’s obstruction of Ukraine’s primary trade routes.

**Global Price Spikes**

Despite carveouts for food and fertilizer exports, international sanctions on Russian and Belarusian banking, trade, and energy sectors have reduced the two countries’ share of the world’s fertilizer trade, estimated at 18 percent in 2020, triggering global price spikes for all mineral fertilizers. In Ukraine, farmers’ fertilizer stocks helped insulate them from initial fertilizer price spikes, but domestic prices rose by the fall of 2022 after farmers exhausted their fertilizer supplies. The implementation of the Black Sea Grain Initiative in July 2022 expanded agricultural exports, increasing farmers’ working capital—and increasing demand for fertilizers and other agricultural inputs. As farmers prepared for the spring 2023 sowing campaign, fertilizer prices increased. For example, prices for potassium nitrate, or saltpeter, rose from UAH 27,000 (roughly $750) per metric ton to UAH 37,000 (roughly $1,025) per metric ton from July to October 2022. By February 2023, farmers spent UAH 8,000–9,000 (roughly $220–250) for the nitrogenous fertilizers needed to cultivate...
just one hectare of corn, excluding additional costs for fuel, potassic and phosphatic fertilizers, and other inputs, compared to prewar prices of roughly UAH 6,000 (roughly $165).

In addition to disruptions in global fertilizer markets, energy price spikes affected global fertilizer prices in the months following Russia’s invasion. Global price spikes for natural gas and coal, key ingredients in the manufacturing of fertilizers, reduced fertilizer production capacity and added further upward pressure on fertilizer prices around the world. Europe’s fertilizer industry was hit especially hard as countries slashed imports of Russian natural gas, coal, and oil. High manufacturing costs forced plants to close across the region, reducing Europe’s overall fertilizer production by approximately 70 percent and its nitrogenous fertilizer production capacity by 50 to 60 percent in 2022. China’s ammonia production also contracted in response to high coal prices following Russia’s invasion. China’s October 2021 restrictions on fertilizer exports kept its 25 percent share of the global trade off global markets until December 2022, which pushed fertilizer prices even higher during the first year of Russia’s full-scale invasion.

**Reduced Domestic Production of Nitrogenous Fertilizers**

Prior to Russia’s invasion, Ukraine produced enough nitrogenous fertilizer to meet over 70 percent of domestic demand. In 2021, domestic production exceeded 5.2 million metric tons, while Ukraine imported 1.4 million metric tons of nitrogenous fertilizers. After Russia’s invasion, only two of Ukraine’s five nitrogenous fertilizer factories remained operational, causing domestic production to fall by 78.3 percent to 1.1 million metric tons in 2022, and imports to triple to 4.3 million metric tons. By February 2023, the Cherkasy Azot and Rivneazot factories increased production capacity by 40 percent and 50 percent, respectively, but Ukrainian farmers still saw a shortage of mineral fertilizers, including nitrogenous fertilizers, ahead of the 2023 spring sowing campaign.

**High Logistics Costs due to Obstructed Trade Routes**

Russia’s blockade of Ukraine’s Black Sea ports obstructed trade routes that were previously responsible for over 90 percent of Ukraine’s agricultural exports and a majority of its fertilizer imports. This sudden lack of access to its primary, high-volume trade routes forced Ukrainian traders and agricultural enterprises to turn to road, rail, and river routes for fertilizer supplies from new sources. According to Ruslan Voytovych, the director and founder of Arus Trade, a fertilizer importer in Ukraine, his company’s shift to road transport routes significantly limited the volume of supplies he could import and raised delivery costs by 60 percent in the months following Russia’s invasion. Taras Ivashchenko, the head of Belor Ukraine, another Ukrainian fertilizer importer, found that the Danube River ports can only handle 30,000 to 40,000 metric tons of fertilizer imports per month, which is “almost nothing” for the Ukrainian market.

**Ukrainian Government and International Efforts to Improve Access to Fertilizers**

Ukraine’s Ministry of Agrarian Policy and Food has supported farmers’ applications for fertilizer aid through the State Agrarian Register and coordinated agricultural aid through this system, while Ukraine’s bilateral and multilateral partners have invested to improve Ukrainian farmers’ access to fertilizers. The U.S. Agency for International Development (USAID) launched the AGRI-Ukraine initiative in July 2022 to help meet the needs of Ukrainian small- and medium-scale farmers for agricultural inputs, financing, improved export logistics and infrastructure, and capacity for drying, storing, and processing harvests. As of July 2023, USAID contributed $350 million, leveraged an additional $250 million from other donors and the private sector, and was seeking to leverage a further $250 million for the initiative. As of the time of publication, AGRI-Ukraine had provided 12,892 small-scale Ukrainian farmers (defined, in this case, as cultivating less than 500 hectares of farmland) with approximately 18,300 tons of complex and nitrogenous fertilizers for the 2023 spring and autumn campaigns. This September, the initiative announced a partnership with South Korea to deliver to Ukrainian farmers $5 million of fertilizers donated by South Korea’s Ministry of Foreign Affairs.

International agricultural aid packages have largely targeted
the small- and medium-sized enterprises otherwise unable to sustain operation in wartime, but assistance also funnels through the Ukrainian government’s “Affordable Loans at 5-7-9 percent” program, which offers low-rate subsidized lending for agricultural enterprises of all sizes. Launched in early 2020, the program provides loans up to UAH 90.0 million (roughly $2.5 million), depending on the loan type and the enterprise’s size and activity. The program has received direct financing from the World Bank through USAID’s AGRI-Ukraine initiative and provided UAH 158.0 billion (nearly $4.4 billion) to agricultural enterprises through 40,509 loan agreements since February 2022. Combined with the FAO’s cash transfers, this assistance has enabled farmers to afford the purchase of fertilizers at elevated prices from in-country suppliers. According to CSIS interviews, Ukraine’s Ministry of Agrarian Policy and Food has encouraged partners to concentrate investments into this soft loan program over procuring and distributing in-kind fertilizer donations, as this financing concurrently empowers farmers to decide which inputs to prioritize purchasing and sustains business for Ukrainian fertilizer suppliers. Farmers in front-line oblasts, however, benefit more from in-kind fertilizer donations, as active conflict disrupts these farmers’ ability to obtain fertilizer on local markets.

Securing Long-Term Alternative Fertilizer Suppliers

Ukraine fertilizer imports were down significantly in 2022 compared to 2021, ranging from a decline of 65 percent for nitrogenous-based fertilizers to over 85 percent decline for potassic fertilizers. Historically, Russia and Belarus supplied fertilizer and fertilizer ingredients to Ukraine. While Ukraine instituted an embargo of Russian fertilizer imports in 2018 due to Russia’s 2014 invasion of Donbas and the Crimea annexation, it was still heavily dependent on Belarusian supplies when Russia’s full-scale invasion began in February 2022. Over 2019–2021, Belarus alone accounted for 71 percent of Ukraine’s potash imports, 58 percent of its urea imports, and 41 percent of its complex fertilizers imports, or fertilizers containing all three nitrogenous, phosphatic, and potassic elements. With Belarusian imports essentially ending with Russia’s full-scale invasion in late February 2022, Ukraine relied on other trade partners such as Poland, Germany, Uzbekistan, and Turkmenistan for its potash imports in 2022. As Ukraine’s trade relationships with two of the world’s largest fertilizer producers are now severed, the government of Ukraine and Ukrainian agricultural enterprises are struggling to identify alternative sources to fill the

SOURCE

considerable supply gap left by foregone Russian and Belarusian imports.

Ukraine faces different challenges accessing nitrogenous, phosphatic, and potassic fertilizers. Even with curtailed domestic production capacity, Ukraine can meet some of its domestic demand for nitrogenous fertilizers, and Ukraine’s trade partners can supply additional nitrogenous fertilizer as well as phosphatic fertilizers. However, securing alternative potash suppliers will remain a challenge for Ukraine’s agricultural enterprises. The global potash market is highly concentrated, with Russia and Belarus accounting for 41 percent of global potash trade in 2020. The world’s top producer of potash is Canada, with 39 percent of global market share, but transporting supplies from Canada to Ukraine would require long and costly freight shipments in addition to overland transport through Europe. This inherently expensive route introduces complex logistical issues and would likely only result in high potash prices on domestic Ukrainian markets if attempted. Kernel, Ukraine’s largest producer and exporter of vegetable oils, procured two vessels of complex fertilizers and potash from Morocco’s OCP Group and Jordan’s Arab Potash Company in the summer of 2023. However, concerns remain as to whether these potential trade partners could supply enough potash to meet the significant needs of Ukrainian farmers, especially as food producers around the world are anticipating higher demand for potash in the coming decades. To meet domestic needs, Ukraine will likely have to turn to smaller potash producers that are closer to home, such as Germany, Israel, and Jordan.

**Recommendations**

As the war continues to suppress agricultural production in Ukraine, the Ukrainian government continues to help improve Ukrainian producers’ access to fertilizer, and access to fertilizer remains a priority within support packages from Ukraine’s partners to its agricultural sector. This aid has been essential to maintaining Ukrainian agricultural production since February 2022. Nonetheless, the amount of assistance has been insufficient to meet farmers’ immediate needs, indicating the importance of additional efforts in this regard.

Following is a description of ongoing best practices and additional steps needed to increase access to fertilizer.

**SOURCE**

- Improved information about the specific fertilizer needs of Ukraine’s farmland, including through investing in both remote sensing and traditional laboratory soil-testing programs could enable farmers to purchase the right quantity of the right nutrients and inform the government’s projections for domestic fertilizer requirements.

- Investment in Ukraine’s national infrastructure for geospatial data would enable high-quality, rapid soil analysis that could predict Ukraine’s fertilizer needs with greater accuracy.

- As international partners such as USAID, the FAO, and others continue to support Ukrainian farmers’ access to fertilizers, improved information sharing regarding the long-term plans for Ukraine’s fertilizer market would help partners align their assistance with the needs of Ukrainian farmers and fertilizer producers.

- At the same time, Ukraine’s partners should support rebuilding Ukraine’s capacity to produce nitrogenous fertilizers domestically, restoring—or even exceeding—Ukraine’s prewar production capacity, which will require an uninterrupted supply of raw materials, particularly natural gas.

- As Ukraine rebuilds its capacity to produce fertilizers domestically, the Ukrainian government and partners should continue to calibrate assistance so as not to reduce demand for Ukrainian-produced fertilizers and fertilizers secured by domestic suppliers.

- Ukraine’s candidacy for membership in the European Union will necessitate further reforms to its agriculture sector and production standards as the European Union aims for climate neutrality by 2050. For instance, aligning with the European Union’s common agricultural policy requires Ukraine certify 3 percent of its total agricultural land as organic by 2030. As Ukraine and its partners work to secure sufficient mineral fertilizer suppliers to fill the gap left by foregone Russian and Belarusian imports, concurrently incentivizing increased use of organic fertilizers would help sustain production and soil fertility, as well as support the country’s path to EU integration.

- Finally, international partners should support Ukraine’s efforts to secure long-term suppliers of fertilizer, especially potash, to replace foregone inputs from Belarus and Russia.

Ukraine’s agriculture sector has been a major front in Russia’s war since Russia launched its full-scale invasion in February 2022. The systematic destruction of Ukraine’s farmland, agricultural equipment and infrastructure, and export capacity has contributed to a global food crisis that continues to affect millions around the world. For Ukraine to strengthen its economy to fend off Russia’s continued assault, restore its role as a major global food supplier, and maintain its counterweight to the influence Russia wields through its own agricultural exports, unprecedented support is necessary to restore Ukraine’s natural resources and transform its agricultural institutions, infrastructure, and labor force.

As urgent needs—related to agriculture and all sectors affected by the war—occupy the attention of Ukraine and its international partners, they should not lose focus on a resource central to Ukraine’s rise as a global agricultural powerhouse: its black soils. The focus of this report has been the safe and expeditious demining of Ukraine’s farmland and increasing farmers’ access to fertilizer. Essential to both endeavors is soil testing, which could both ensure the safety of agricultural land once it has been cleared of mines and help farmers determine the appropriate types and levels of fertilizer to apply to their land. Rebuilding Ukraine’s agriculture sector from the ground up must involve identifying the optimal set of soil testing methods for Ukraine’s agricultural soils and scaling up a national infrastructure for such testing within Ukraine in the face of numerous, concurrent challenges imposed by Russia’s war.

PHOTO
Farmers use combine harvesters to harvest a wheat field near the city of Bila Tserkva on August 4, 2023, in Kyiv Oblast, Ukraine.

Ed Ram/AFP via Getty Images
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