Mt. Hood and wheat fields near Dufur, Oregon, November 23, 2017 (Courtesy Jim Choate)

Weaponizing Wheat

How Strategic Competition With Russia Could Threaten American Food Security

By Karl A. Scheuerman

In the history of warfare, belligerents have often targeted food supplies to force opponents into submission. However, in America's wars over the last century, threats to domestic food security have been minimal. In many ways, the United States enjoyed insulation from combat conditions overseas that could have otherwise disrupted the country's ability to feed itself. Complacency in relative isolation from disruptive food shocks is no longer a luxury the United States can afford. We are now in an era of increased globalization, where food supply chains span the oceans. In addition, America faces the renewed rise of strategic competition as China and Russia seek to replace U.S. power across the globe. Given these new realities, timely evaluation of potential vulnerabilities to American food production is necessary.

Among rising strategic competitors, Russia has explicitly demonstrated a clear willingness to target food systems. In its current war against Ukraine, the Russian military has relentlessly attacked wheat supplies and production. Yet despite the critical importance wheat plays as the foremost American dietary staple, its production is indeed vulnerable to disruption should Russia choose to act. While a full-scale conventional war with Russia is unlikely because of nuclear

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deterrence, the Kremlin has repeatedly demonstrated a willingness to disrupt foreign interests over the past several years, from election interference to trade wars. Targeting the U.S. wheat industry could become another preferred option for the Kremlin to wage adversarial competition at a level below the threshold of armed conflict. Given the emerging global security environment, the U.S. Government should reevaluate current policies to ensure the resilience of the wheat industry against this threat.

Wheat Is King in America

Grain plays an enormous role in feeding the world. Approximately 47 percent of all human caloric intake today comes from grains, and the United States is a significant contributor to global grain supplies.[1] According to the United Nations (UN) Food and Agriculture Organization, the United States is the second largest grain producer in the world (behind only China), producing over 450 million metric tons, which represents 15 percent of the worldwide supply.[2] Of all grains the United States produces, Americans consume more wheat than any other, making it the country's most essential food staple.[3] U.S. farmers raise greater volumes of corn and soybeans, but most of those commodities are used for livestock feed and biofuels.[4] Due to wheat's central role in the American food system, consumer demand for products derived from wheat is "relatively stable and largely unaffected by changes in wheat prices or disposable income," according to the U.S. Department of Agriculture (USDA).[5] As shown in figure 1, demand for wheat in the United States continues to grow. Thus, wheat represents a worthwhile case study in evaluating U.S. resiliency to food disruption in the context of strategic competition, specifically with Russia.

Some may find it hard to envision a scenario where the United States would experience wheat shortages. However, recent examples of modern countries suffering significant wheat production losses exist. Russia, the world's largest wheat exporter, suffered extensive drought and wildfires in 2011 and lost one-third of its national wheat crop as a result.[6] China, the global leader in wheat production, suffered wheat crop losses of up to 16 percent between 2000 and 2018 due to pests and pathogens.[7] Another breadbasket of the world, Ukraine, will likely see its 2022–2023 wheat output decline by 41 percent compared to the previous year because of the Russia-Ukraine war.[8]

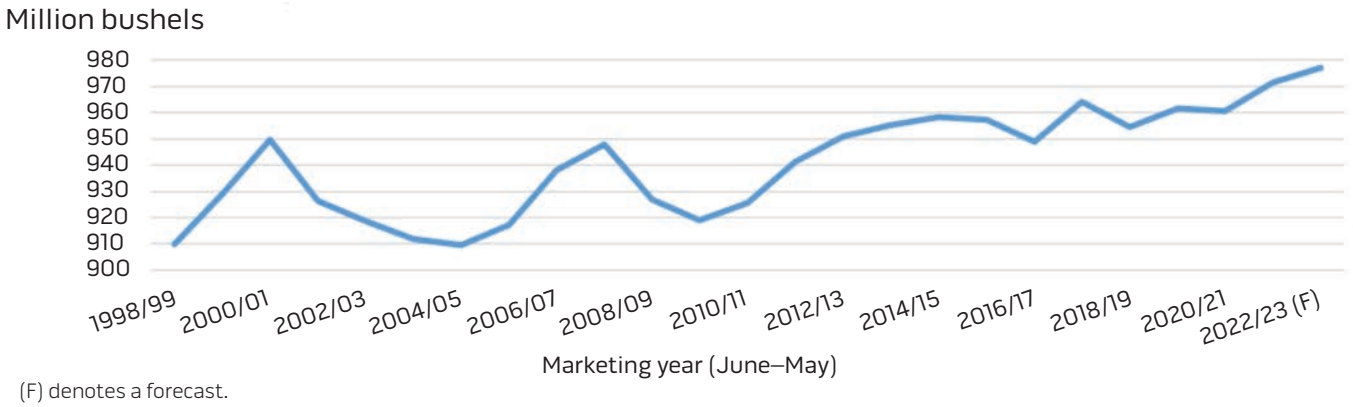
Implications of Domestic Wheat Shortages

If America were to experience wheat shortages, the implications would be significant. As the United States is the third largest wheat exporter on the global market, a drop in U.S. supplies would negatively impact world food prices.[9] Following the decline in Russian wheat exports in 2011, food prices spiked and contributed to dramatic instability in countries dependent on imports, helping give rise to the Arab Spring.[10] Trade partners, including key allies such as Japan and South Korea, who rely on U.S. wheat imports would likely feel the pinch most acutely in countering Russian and Chinese influence.

But significant domestic concerns could pose a greater risk. In 1906, journalist Alfred Henry Lewis presciently stated, "There are only nine meals between mankind and anarchy." Unlike any other commodity, food is the one we cannot survive without. If interruptions to the food supply occurred, the public's confidence in future availability might begin to erode, spreading fear. Those now living below the poverty line would suffer the most, but even the broader citizenry could start losing confidence in the government's ability to provide basic needs, fueling an already tense and polarized domestic political climate.

If disruptions affected U.S. wheat production, food substitutes would play a role in softening the impact. However, given wheat's primacy in our food system, the volume of substitutes needed could pose major challenges. A national grain reserve, similar in concept to the Strategic Petroleum Reserve, would be a logical buffer to mitigate shortages, but unfortunately, no such reserve exists. Despite producing more grain than any other country on earth, China has established a national reserve that reportedly now contains at least 2 years' worth of grain supplies should the country need it.[11] The United States has previously tried establishing a national grain reserve,

Figure 1. U.S. Wheat Food Use, 1998/99–2022/23



(F) denotes a forecast.
Source: USDA, National Agricultural Statistics Service; USDA, World Agricultural Outlook Board.

most recently with the Bill Emerson Humanitarian Trust. However, the trust sold off its commodity holdings in response to food price spikes resulting from the 2008 financial crisis and now only holds cash reserves to help pay for famine relief needs abroad.[12]

Should a worst-case scenario arise where the entire annual U.S. wheat harvest failed, existing stocks would quickly evaporate if current consumption levels remained constant. In the last crop year of 2021–2022, American farmers produced 1,646 million bushels of wheat, while domestic demand (comprised of human food use, animal feed, and seed) for the year totaled 1,117 million.[13] After factoring in exports and the previous year's residuals, the remaining stock of U.S. wheat after the previous crop year was 669 million bushels, and this is expected to decrease further next year to its lowest levels since 2007–2008 (table 1).[14]

Applying a "time-to-survive" analysis to the hypothetical worst-case scenario, which measures the maximum duration that supply could match demand (assuming the previous domestic demand level held constant and exports were canceled), existing domestic wheat stocks would last only about 7 months.[15] Unlike other industries, agriculture does not have the option of surging production when a crisis arises as it is constrained by annual growing seasons. The United States could not replenish its wheat stocks with domestic production until the next summer harvest season.

Food shocks and price spikes resulting from the COVID-19 pandemic and Russia's war in Ukraine have helped Washington realize our food system's fragility. The latest National Security Strategy under President Joe Biden cites food security as one of the top five shared global challenges. It highlights global initiatives the United States is currently leading, including efforts to urge other states to commit to "keeping food and agricultural markets open, increasing fertilizer production, and investing in climate-resilient agriculture."[16] These efforts are worthwhile, but America must ensure its increased focus on global food insecurity does not turn a blind eye to potential vulnerabilities in domestic food production that a disruptive adversary such as Russia could exploit.

Moscow's Increasingly Disruptive Actions

Over the past two decades, while the Russian Federation has enjoyed a resurgence of economic growth and global influence under Vladimir Putin's leadership, the Kremlin has demonstrated a repeated willingness to undermine U.S. interests. The reasons for this approach are rooted in what has become characterized as the Primakov doctrine, which "posits that a unipolar world dominated by the United States is unacceptable to Russia."[17] In operationalizing the Primakov doctrine, Russia has been conducting a hybrid war in part to "foment chaos, create distrust in U.S. institutions, and target the preexisting divisions in the country."[18] Through these actions, Russia has earned a reputation as a perilous threat "with the goal of overturning key elements of the international order."[19]

There is no shortage of examples illustrating why Russia is now characterized this way. The United States has attributed several significant cyber attacks[20] targeting American industry and governmental organizations to Russia in recent decades.[21] The Kremlin has also gone to great lengths to interfere with the democratic process Americans cherish. The clearest example of this approach was during the 2016 Presidential election. According to the U.S. Intelligence Community and Department of Justice investigations, the Kremlin directed extensive information warfare operations to influence the election outcome, resulting in distrust among the U.S. citizenry in the reliability of our electoral system.[22]

Russia is now also seeking to undermine the U.S.-led global economic system. Suffering from unprecedented Western sanctions as punishment for its war in Ukraine, Russia is countering with its own strategies to establish a global economy that excludes the West. Not only have the Russians cut natural gas supplies to Europe, but they are also replacing access to Western marketing by increasing trade with China, India, and other countries. Russia has also been championing its own alternative to the SWIFT international financial messaging system.[23]

These examples demonstrate Russia's repeated attempts to undermine American strength and interests. Outcomes from these efforts have resulted in various levels of success in sowing seeds of domestic chaos to destabilize U.S. society. Should the Kremlin succeed in significantly disrupting Americans' ability to sufficiently access cheap and convenient food, the impact could become far more intense than what Russia has achieved to this point.

Experienced Cereal Killers

While their attempts to disrupt U.S. interests in the post–Cold War era have yet to target food directly, the Russians have found it a preferred tactic elsewhere. In fact, during their current war in Ukraine, attacking wheat storage and production has been a top priority,

Table 1. U.S. Wheat Supply, Crop Year 2021–2022

	Quantity (million bushels)	
Beginning stocks		845
Production		1,646
Imports		95
Total supply	2,587	
Domestic demand		1,117
Exports		800
Total demand		1,917
Ending stocks	669	

Source: Andrew Sowell and Bryn Swearingen, "Wheat Outlook: November 2022," USDA Economic Research Service.

Combine reloads wheat into bunker for further transportation during harvest near Krasne, Ukraine, July 5, 2019 (United Nations Food and Agricultural Organization)

and they have done so with remarkable efficacy. Ukraine is one of the world's most productive breadbaskets, producing over 85 million metric tons of wheat annually.[24] Ukraine was the world's fourth largest wheat exporter on the global market during the 2021–2022 crop year.[25] Recognizing Ukrainian grain as a critical center of gravity, Russian forces have employed a relentless multifaceted strategy to destroy that element of the Ukrainian economy.

The first element of this strategy is the theft of Ukrainian agricultural machinery. Since the early weeks of the war, media outlets have reported multiple instances of Russian forces ransacking Ukrainian grain stocks, shipping their contents back to Russian territory and sending it to Russian cargo vessels for export to global Russian trading partners.[26] Some estimates claim that millions of tons of grain from eastern Ukraine have been seized, triggering nightmares of the Soviet-induced Ukrainian famine of 1932–1933.[27] Russians looted farm machinery dealerships and stole combines, tractors, and implements.

The second component of the Russian strategy to eliminate Ukrainian wheat is destruction. Not only have battles prevented farmers in certain regions of eastern Ukraine from tending to their fields, but Russian forces have also laid waste to Ukrainian cropland by burning vast acreages across the Donetsk, Mykolaiv, and Kherson regions. Russian bombing and missile strikes have destroyed the logistical infrastructure essential to wheat production and delivery, including irrigation systems, grain elevators, and port terminals. Seeking to damage Ukraine's ability to recover from the conflict, Russia went so far as to target Ukraine's National Gene Bank located in Kharkiv, which served as the country's seed bank, housing some 160,000 specimens of plant and crop seeds.[28]

A third pillar of the Russian strategy undermining wheat production in Ukraine has focused on Ukraine's ability to export its grain. In the early days of the war, the Russian naval blockade of Ukraine's Black Sea ports strangled Ukrainian exports, cutting off essential means for Kyiv to participate in global markets. Agricultural commodities are Ukraine's top exports, including $4.61 billion worth of wheat alone in 2020.[29] Blockading the Black Sea ports was painful for Ukraine and the many countries relying on Ukrainian wheat to feed their populations, contributing to damaging global food price spikes and inflation over the ensuing months. Not until August 2022 did Russia agree to lift the blockade, based on a tenuous agreement brokered with assistance from the UN and Turkey. Even since the initial agreement, the Kremlin has unilaterally suspended it once and has threatened not to renew the deal.[30]

Secretary of State Antony Blinken participates in roundtable discussion on food security and Vision for Adapted Crops and Soils with agricultural leaders from public and private sectors, in New York City, August 4, 2023 (Department of State/Chuck Kennedy)

Ukraine's experience during the current Russian invasion reveals the lengths to which Russia is willing to go to intentionally attack wheat production and supplies, even when that grain is a vital component of the local and global food system. Based on this precedent, the United States and its allies must be prepared to defend against the variety of tactics Moscow could employ to attack wheat production elsewhere.

Russia's Emergence as a Global Food Power

Competition between Washington and Moscow that is centered around grain is nothing new. Following the U.S. Civil War in the 1860s, cheap American wheat flooded global markets for the first time, pushing Russian wheat exports out of Europe. The U.S.-Russian grain trade rivalry was a key factor in conditions that ultimately ushered in World War I.[31] Wheat has continued to play a major, albeit behind the scenes role in U.S.-Russian relations ever since.

When Putin became president in 2000, Russia relied on imports to meet half its domestic food needs. Prioritizing food security, the Russian president has since successfully executed initiatives to boost food production, and grain has been a critical focus. By 2017, Russia had become the world's top wheat exporter, and the Kremlin has no plans to cede its pole position. Despite unprecedented sanctions from the West as punishment for its war in Ukraine, Russia still has plenty of buyers for its wheat exports in the Middle East and Asia as it strives to outproduce and outcompete American farmers.[32] Even China began importing Russian wheat this year after previously placing a ban on it due to concerns about the presence of a crop disease (dwarf bunt fungus).[33] The Kremlin's agriculture minister is now on a mission to increase the value of agricultural exports by 50 percent by 2024.[34]

Recent global supply chain disruptions from events such as the war in Ukraine and the COVID-19 pandemic have highlighted Moscow's privileged position in terms of food security. Russia is the world's top exporter of not only wheat but also fertilizer.[35] Given its relative strength in this area and a demonstrated willingness to attack Ukrainian wheat, attacking the domestic American wheat industry could become a viable option in Russia's arsenal of hybrid warfare tactics against U.S. interests. Specific strategies Russia could employ to target U.S. wheat production can be organized into four categories of attack:

- cyber attacks targeting grain storage and transport infrastructure
- restricting fertilizer exports to U.S. and/or global markets
- manipulating international wheat markets
- agricultural biowarfare.

The following sections will explore each of these options in depth.

Disruption Option 1: Cyber Attacks Targeting Grain Infrastructure

Among the cyber-security industry, many consider Russia to be the most capable and stealthiest of America's cyber adversaries. In addition to the notable intrusions mentioned earlier, suspected Russian adversary groups have earned their reputation for several reasons, including developing sophisticated malware that employed novel command and control techniques, exhibiting rapid breakout times, and leading the way in targeting cloud infrastructure.[36]

Cyber attacks crippling the food industry are not unprecedented. For example, suspected criminals successfully compromised the network of JBS S.A., a global meat processing company, hampering livestock slaughter operations and causing wholesale meat prices to spike.[37] Should the Kremlin set its sights on disrupting the U.S. wheat industry via cyber means, a likely approach would be targeting the infrastructure used for grain transport and storage, specifically the grain storage elevators throughout wheat production regions. These facilities comprise an essential component of the Nation's food system, which the Department of Homeland Security (DHS) has identified as 1 of the 16 sectors of critical infrastructure.[38] Farming cooperatives operating grain elevators increasingly leverage automation technologies to handle loading and unloading functions. If an adversary gained remote access to the industrial control system (ICS) network environment, they could shut down operations, preventing grain transportation to trade markets and food processors.

Russian state-sponsored adversaries are known to have successfully targeted a critical infrastructure ICS environment, causing kinetic effects. A cyber unit within the Russian military was responsible for the attack on the Ukrainian power grid, resulting in nearly a quarter-million Ukrainians losing power for about 6 hours.[39] A similar attack chain methodology could disrupt control systems for other sectors of critical infrastructure, such as grain storage facilities.

A less sophisticated means of attack on grain elevators would be to infect the traditional computer networks operating at these facilities in attempts to affect operations. This has already happened on several occasions. Between the fall of 2021 and early 2022, six U.S. grain cooperative elevator facilities experienced ransomware attacks on their business networks that inhibited processing as some were forced to adjust to manual operations. Recognizing the threatening trend, the Federal Bureau of Investigation (FBI)'s Cyber Division issued a Private Industry Notice to assist grain cooperative organizations better prepare their defenses.[40] The FBI's report also noted the potential for an impact on commodities trading and stocks that could result in food security and inflation concerns.

Another potential cyber attack against the wheat industry that could lead to severe outcomes would be a more typical intrusion into agriculture industry business networks. Large agriculture firms have not been immune from network intrusions aimed at stealing intellectual property. Unlike the other attacks mentioned, where the objective is to perform sabotage or shut down a network for ransom, cyber-security firms have noted that intellectual property theft intrusions targeting agriculture firms are on the rise.[41]

Should Russian-aligned adversaries gain access to sensitive agriculture industry data, they could facilitate further disruptive strategies. For example, stolen documents and data could be altered and then leaked publicly, delivering damaging false messages like the hackers who doctored data stolen from Pfizer to undermine public trust in vaccines.[42] Similarly, grain pathology and trade experts note that false claims of wheat crop disease would have dramatic adverse effects on American grain exports.[43] Undermining American interests related to global trade introduces additional options at the Kremlin's disposal for disrupting U.S. wheat production.

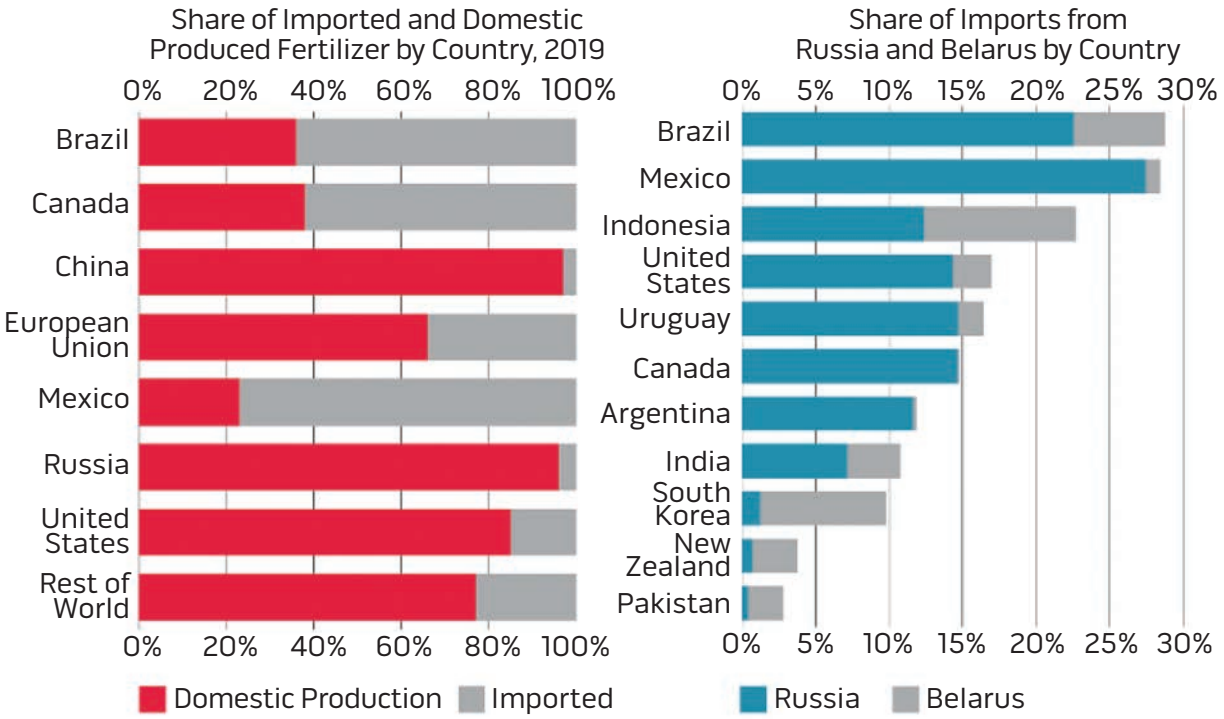
Disruption Option 2: Restricting Fertilizer Exports

The United States is a net exporter of food. As such, some assume the country is self-sufficient in meeting domestic food needs. However, that conclusion is tenuous because American agriculture depends on imports of foreign synthetic fertilizer. Less than 1 percent of U.S. farmland is organic.[44] Farming the remaining 99 percent involves conventional methods. One characteristic of conventional agriculture is the "extensive use of pesticides, fertilizers, and external energy inputs."[45] Despite the United States having a relatively robust fertilizer production industry, it does not currently provide for all domestic farming needs. According to the USDA, "The United States is a major importer and dependent on foreign fertilizer and is the second or third top importer for each of the three major components of fertilizer."[46]

The three primary fertilizer nutrients required to grow crops are nitrogen, phosphorus, and potassium. Nitrogen fertilizer is derived from the Haber-Bosch process, which uses natural gas for fuel to extract nitrogen from the air to form ammonia. Phosphorus fertilizer comes from mining of nonrenewable phosphate rock. Potassium fertilizer is derived from mining nonrenewable potash. As of 2021, the United States imported 12 percent of its nitrogen, 9 percent of its phosphate, and 93 percent of its potash.[47] While America imports these materials from many friendly states, some come from less-trusted trading partners. This is especially true of potash. Russia and its close ally, Belarus, combine to provide 12 percent of America's potassium requirements and more than 15 percent of total U.S. fertilizer imports (figure 2).[48]

Should Russia choose to disrupt wheat production by stopping potash exports, America would need to find ways to ramp up domestic mining and production or close the gap by increasing imports from friendly trade partners such as Canada, which already supplies 83 percent of potash used in the United States. A more significant cause for concern is that Russia is the world's largest fertilizer exporter when considering all fertilizer components and is responsible for over 15 percent of total

Figure 2. Fertilizer Import Dependence by Country



Source: Cited in "Impacts and Repercussions of Price Increases on the Global Fertilizer Market," USDA Foreign Agricultural Service, June 30, 2022, https://www.fas.usda.gov/data/impacts-and-repercussions-price-increases-global-fertilizer-market.

global fertilizer exports.[49] Leveraging that influence, Russia could attempt to manipulate availability on the global market, resulting in worldwide price shocks that would cascade to American consumers and place additional pressure on poorer countries already suffering from food security challenges.

Russian impacts on global fertilizer trade have already contributed to financial instability. Fertilizer prices tripled after the beginning of the war in Ukraine because Russia limited exports. These limits included restrictions on exports of natural gas, which, as noted, is a crucial component for producing nitrogen fertilizer.[50] Russia also shut down an ammonia fertilizer pipeline from its Volga region to a Black Sea port to further restrict global supplies.[51] The USDA characterized the situation as "Putin's price hike on farmers."[52] These events contributed to soaring food costs, leading to the highest inflation rates in the United States in four decades.[53]

In late 2022, the UN warned that if fertilizer prices were not reduced, the world would face a "future crisis" of food availability. UN officials have since worked to convince Russia to increase fertilizer output.[54] Thanks to rebounding global fertilizer production, fertilizer price fears have dampened for the near term.[55] Nevertheless, the situation demonstrates how the Kremlin can leverage its fertilizer superiority to harm the interests of not only the United States but also the world. Unfortunately, fertilizer availability is not the only way Moscow can flex its muscle in undermining American wheat production. Undercutting U.S. grain exports is another area where the American wheat industry is vulnerable to Russian meddling.

Disruption Option 3: Undercutting U.S. Wheat Exports in Global Markets

America's farmers have historically benefited from growing more wheat than the country consumes and being able to sell excess grain to overseas markets. In crop year 2021–2022, the United States exported $7.3 billion of wheat, making it the world's third largest wheat exporter, behind Russia and Australia.[56] According to the USDA, in the early 2000s, the United States was responsible for roughly 25 percent of the world's wheat exports, but that dominance has dwindled now to 13 percent.[57] America's share of global wheat exports has shrunk over the past 20 years as Russia has strengthened its position as the world's wheat superpower.

Increasing international competition in wheat trading has strained U.S. wheat exports in recent years, and this trend is expected to continue. Competition from Russia, especially in African and Middle Eastern markets, poses a significant challenge.[58] Russia has shown it is willing to use food trade as a tool of diplomatic force. When Bulgaria ceased transiting Russian gas to Europe, Turkey agreed to facilitate its transit in exchange for receiving wheat imports from Russia. Elsewhere, Russia sold wheat to Iran as part of a deal to help sell Iranian oil. Moscow willingly

enters commodity trade markets even if it means undercutting its allies, as Iran experienced this year when Russia discounted its steel exports and grabbed Iranian market share.[59] Wheat industry analysts expect Russia to continue pushing boundaries to secure access to wheat export markets, especially in regions with rapid population growth, like southeast Asia.[60]

Waging information warfare would be another scheme the Kremlin could employ to win in export markets. As mentioned, crafting and communicating a hoax that falsely claims American wheat supplies are contaminated with disease would cause buyers to seek alternative sources.[61] Rules over grain disease quarantines can be a sensitive political subject between traders, even without misinformation campaigns. When coupled with stolen and altered data derived from a coordinated cyber intrusion, the United States would have difficulty eliminating concerns about the quality of American wheat stocks.

Complicating the issue is that prior incidents of contaminated U.S. wheat exports could strengthen Russian hoax claims. The Soviet Union and several other countries complained of dirty, rotting, and insect-ridden U.S. grain in the 1980s.[62] In the mid-1990s, the USDA had to institute a regulatory program to certify wheat shipments were free of fungal disease after a Karnal bunt outbreak in the United States.[63] Recent research suggests that the Environmental Protection Agency scientific integrity and transparency failures related to pesticide use have eroded global trust and are undermining U.S. agricultural exports.[64]

If Russia succeeds in taking global wheat export markets from the United States, American farmers will undoubtedly be threatened. With less market access and increasing input costs, the incentive for growing the preeminent American staple crop would dwindle, resulting in lower output and production capacity. Such an outcome, combined with other disruptive options identified in this essay, could accelerate Russian aims of undermining U.S. global power.

Disruption Option 4: Agricultural Bioterrorism

Another vector for attacking U.S. wheat production, and one carrying potentially the broadest impact, would be a Russian attack involving pests or pathogens designed to damage crops. Such an attack would likely be done covertly to provide plausible deniability. Before the Biological and Toxin Weapons Convention of 1972 (BWC), several countries, including the United States, developed and maintained offensive biological weapons research programs.

Many historians and scientists claim that while other signatories to the BWC ceased their offensive biological weapons programs after the convention went into effect in 1975, the Soviet Union secretly continued its program despite being a signatory to the treaty. Research has shown that the Soviet program was the longest and most sophisticated the world has ever seen, beginning in 1928 and lasting until at least 1992. Its scope was massive, involving over 65,000 workers.[65] A specific component of Soviet biological warfare research operated under the code name *Ekologiya* and focused on developing pathogens that would kill animals and plants, including crops such as wheat. It eventually became the largest ever offensive biowarfare project focused specifically on agriculture.[66]

Should the Russians choose to conduct a biological attack against American grain crops, wheat rust could likely be the weapon of choice. Wheat rusts are a type of fungus belonging to the genus *Puccinia* that can affect different parts of the wheat plant. Also known as "the polio of agriculture," it has been the worst wheat disease in history, capable of causing catastrophic crop failures. During the first half of the 20th century, rust destroyed one-fifth of America's wheat crops in periodic epidemics.[67] Before the BWC outlawed offensive biowarfare programs, many countries sought to weaponize wheat rust because of its potent effects in targeting crops. Relative to other biological agents, it remains viable for an extended period of time under cool storage (2 years) and spreads quickly after release.[68] In addition, plant rust fungal spores are easily dispersed, durable to withstand transportation and transmission, and easy to produce in sufficient quantities. If the specific variety of targeted wheat is known, attackers could use tailored strains of wheat rust that would have the greatest likelihood of successfully killing and spreading while protecting their own crop with specific strain-resistant varieties.[69]

According to some claims, the Soviet program did not stockpile anti-agricultural weapons like wheat rust but maintained several facilities "equipped as mobilization capacities, to rapidly convert to weapons production should the need arise."[70] A historian of the *Ekologiya* program described one of the project's main facilities as possessing the world's largest "unique collection of fungal pathogens against wheat."[71] Another facility, the Scientific Research Agricultural Institute in Gvardeyskiy, Kazakhstan, was reportedly a key testing site for newly developed anticrop (including antiwheat) pathogens in greenhouses measuring a total area of 100 square meters.[72] In total, four separate program facilities maintained laboratories focusing on rust species research.[73]

Project *Ekologiya* has several implications for the security of U.S. wheat production today. First, the Russian Federation inherited the offensive Soviet biological weapons program and its decades of research, development, and technological capability. While the Kremlin claims the program ended after the Cold War and that it has since complied with the BWC, the United States argues otherwise. In 2021, the State Department reported the following: "The United States assesses that the Russian Federation maintains an offensive BW program and is in violation of its obligation under Articles I and II of the BWC. The issue of compliance by Russia with the BWC has been of concern for many years."[74]

Not only is there a possibility Russia has maintained a biological weapons program with agricultural components, but a second implication for U.S. national security is that conventional American farming is potentially vulnerable to biological attack because intensive farming,

Wheat fields in midsummer in Ukraine, Oblast Lviv, July 19, 2012 (Courtesy Raimond Spekking)

as practiced today, "involves limited diversification of crop and cultivar genetics over large areas," helping create "an ideal environment" for new pest establishment and spread.[75] As small, diversified farms have been overtaken by today's larger farming operations for the sake of profit and efficiency, the United States has inadvertently made its crops potentially more vulnerable to biological attack. Some experts note that pests and the plant diseases they can carry would be "an ideal means of waging 'asymmetric' war" in scenarios that fall below the threshold of conventional armed conflict.[76]

Exacerbating the problem is that our germplasm seed banks are potentially insufficient in possessing the diversity required to rebound from a devastating biological event. New varieties with resistance would be essential in a successful attack scenario because wheat rust can persist over the winter and remain viable to infect the following year's crop. During the Cold War, germplasm collections were better stocked and more robust to ensure resilience against known pathogens. Those efforts have fallen behind in recent decades.[77] For example, a new strain of wheat stem rust emerged in Uganda in 1998, commonly known as Ug99.[78] Since then, scientists have evaluated roughly 200,000 wheat varieties for natural resistance to Ug99. Less than 10 percent demonstrated adequate resistance.[79] Not until 2017 did researchers discover a gene that provided resistance to Ug99, making it possible to develop wheat varieties naturally capable of surviving the disease.

It should be noted that debate exists around the degree of risk posed by a supposed lack of biodiversity. Some wheat pathology experts argue that concerns of insufficient biodiversity in American wheat crops are overblown. While wheat as a species is a monoculture grown in vast quantities across the United States, there are many dozens of commercial wheat varieties grown today, providing a reasonable degree of genetic diversity within the species to mitigate massive impacts from disease or pest outbreaks.[80]

Although fungi are the most likely form of intentional biological threat to wheat due to the relatively ease with which they can multiply and spread, other pathogens like viruses and bacteria can also affect grain crops. Defending against viruses is problematic. Treatments against viruses are generally not as effective as using chemicals to control fungi and bacteria. Disturbingly, the Soviet biowarfare program reportedly included a facility based in Uzbekistan, the Central Asian Scientific-Research Institute of Phytopathology, that "focused on viral diseases of wheat."[81] These claims are corroborated by a declassified 1977 U.S. Defense Intelligence Agency report stating that the Soviet antiplant biowarfare program conducted work on wheat and barley mosaic streak viruses.[82]

Another intentional wheat industry disruption scenario could involve the malicious introduction of wheat parasites that carry harmful bacteria. For example, *Rathayibacter tritici* is a bacterium that infects wheat via parasitic nematodes to cause a toxic gumming disease.[83] While not currently present in the United States, introducing the associated nematode vectors to American wheat crops could at least result in wheat export quarantines, as trade partners would balk at accepting potentially contaminated grain shipments.[84]

Biological attack against wheat production could also be an attractive objective for an adversary like Russia because of the costs imposed by recovery. Pests and pathogens can disperse and reproduce at dramatic rates, providing the potential to wreak havoc across vast amounts of American farmland. For example, a small outbreak of Karnal bunt in the American Southwest in 1996 resulted in $250 million in damages.[85] In Texas, the cost of mitigating effects on agriculture from nonnative fire ants is

more than $1.2 billion annually. Expenses for protecting crops from a nonnative insect carrying Pierce's Disease that has plagued California grapevines since 1989 are also substantial.[86] Beyond just the recovery costs, pathogen outbreaks could also easily lead to trade embargoes as destination countries resist the risk of importing contaminated U.S. wheat. Thus, a widespread infestation damaging American wheat crops "could lead to potential economic losses of immense proportions."[87] A former member of the Soviet biological weapons program agreed, citing antiagricultural biological weapons as "particularly suitable" for disrupting a target country's economy.[88]

Intentional infestations targeting agriculture for nefarious purposes are not without precedent. Analysts strongly suspect manmade causes behind a debilitating outbreak of the fungus *Moniliophthor perniciosa*, also known as witches' broom disease, among cocoa fields of Bahia, Brazil, beginning in 1989.[89] Potentially motivated by the perpetrator's desire to destroy the chocolate industry to punish its wealthy landowners, the suspected attack nearly exterminated the area's cocoa plantations over the following decade. By 2001, "Brazil went from being the world's third-leading cocoa producer to being the 13th."[90] Given this potential for covert bioterrorism to exact large economic costs to a country's agricultural industry, Russia could consider it as an increasingly attractive option as strategic competition with the United States escalates.

Risk Analysis

Risk is a function of likelihood and consequence and can be mathematically described as *Risk = Likelihood of an Event x Consequence (loss due to the event)*.[91] To aid in measuring likelihood and consequence of the four attack strategies Russia could employ to target U.S. wheat production, an expert survey was conducted. Data was collected from 30 participants in the United States who are professionals with expertise in fields related to the wheat industry, including farming, academia, information technology, and global trade. Due to the potential security concerns of identifying the experts in the survey, it was decided that all participants would remain anonymous. The survey asked each participant to assess the likelihood and consequences of the four Russian disruption scenarios: cyber attacks targeting grain infrastructure, restricting fertilizer exports, undercutting U.S. wheat exports, and agricultural bioterrorism.[92] Participants assessed the likelihood of each scenario using a 5-point Likert scale converted to the following percentages to enable calculations (table 2). Participants assessed consequence using the following 5-point Likert scale based on expected economic losses ranging from less than $1 million to more than $20 billion (table 3). Survey results for likelihood and consequence are captured in figures 3 and 4 and risk scores are presented in figure 5. Calculated mean scores for likelihood

Table 2. Likert Scale With Associated Percentages for Measuring Likelihood

Scale	Likelihood	Percentage Chance
1	Very unlikely	0
2	Unlikely	25
3	Even chance	50
4	Likely	75
5	Very likely	100

Table 3. Likert Scale With Associated Dollar Cost Ranges for Measuring Consequence

Scale	Consequence
1	Less than $1 million
2	$1 million to $100 million
3	$100 million to $1 billion
4	$1 billion to $20 billion
5	More than $20 billion

Figure 3. Survey Results for Likelihood of Disruption Scenarios

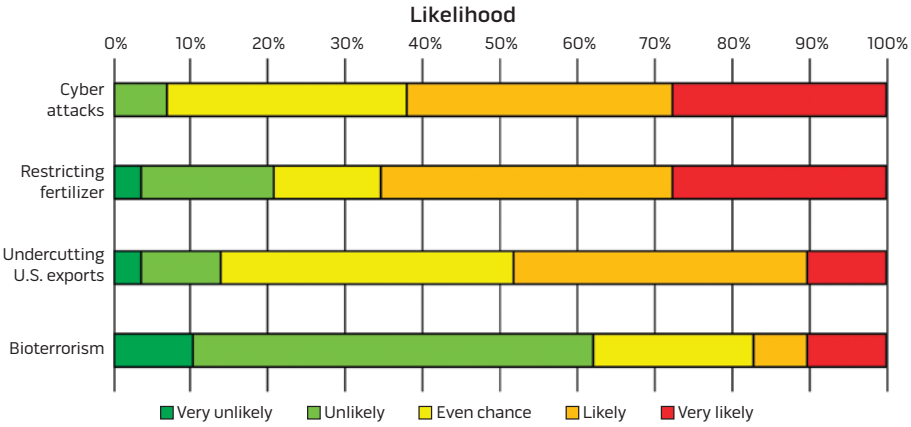
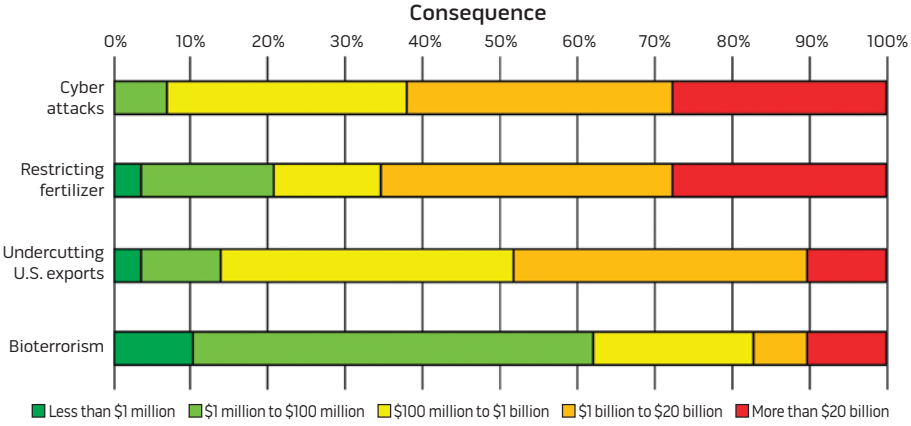


Figure 4. Survey Results for Consequence of Disruption Scenarios



and consequence for each attack scenario are found in table 4.

Further refinement of the results was conducted to ultimately generate a more robust measurement of overall risk for each scenario. To calculate an overall likelihood percentage, the sum of response percentage values (as shown in table 2) was divided by the total available percentage of all responses. To calculate the dollar value associated with the overall consequence score, the mean score for each scenario was assessed as a percentile within the associated dollar range (as shown in table 3).

To then calculate the final risk for each scenario, the calculated likelihood percentage was multiplied by the consequence dollar value to determine the overall amount of risk in terms of dollar cost, as shown in table 5.

Limitations in this study include those intrinsic to Likert scale surveys (for example, not able to capture all opinions, subjective results, etc.) and the small sample size of expert participants. Another limitation of this study is the inherent biases of the participants who come from a range of professional backgrounds related to the wheat industry. Therefore, deeper analysis is needed to provide more robust risk measurements of wheat industry disruption scenarios. Still, results from this survey point to potential prioritization in policy considerations to address the threat of potential Russian disruption of the U.S. wheat industry.

Figure 5. Chart of Disruption Scenario Risk Scores

Table 4. Mean Results of Likelihood and Consequence Responses

Scenario	Likelihood (Mean)	Consequence (Mean)
Cyber attacks	3.83	2.67
Restricting fertilizer	3.69	3.08
Undercutting U.S. exports	3.41	2.96
Bioterrorism	2.55	3.17

Table 5. Calculated Economic Risk Cost for Each Attack Scenario

Scenario	Likelihood	Consequence (millions)	Risk (millions)	Rank
Cyber attacks	0.71	$600	$424	4
Restricting fertilizer	0.67	$1,583	$1,065	2
Undercutting U.S. exports	0.60	$863	$520	3
Bioterrorism	0.39	$3,304	$1,282	1

Note: Numbers are rounded.

Cultivating Resilience

The United States must act to ensure resilience of domestic wheat production, storage, and transportation to mitigate the risks outlined above. First, additional research is needed to measure domestic food security risks more accurately. A Likert survey of experts like the one conducted in this study that encompasses a greater number of experts and uses finer granularity in the scales would be beneficial. A Delphi study could also serve to identify a stronger consensus of risk to the U.S. wheat industry from potential Russian action.[93] Beyond improving the survey, policymakers and wheat industry leaders should consider the following measures, which are listed in prioritized order to address risks from highest to lowest based on the expert survey results shared above.

USDA: Proactively Defend Against Biological Warfare Targeting Crops by Ensuring Sufficient Genetic Diversity of American Grains. Industrial wheat breeding has helped increase yields over the past century, but some argue that this has come at the expense of genetic diversity: "Modern breeding techniques narrowed the genetic base of germplasm used to develop varieties for cultivation."[94] Genetic uniformity in modern wheat crops means greater potential vulnerability to new pathogens. Ensuring a source of genetic variation in wheat is essential for disease resistance. Landrace wheats play a vital role in doing so. Landraces are premodern grains that developed naturally over millennia while adapting to local environmental conditions. Many landraces were lost during the 20th century as farmers abandoned them in favor of modern varieties

championed in the Green Revolution.[95] Due to their wide variety, landraces do not possess the genetic bottleneck of modern hybrid wheats.

Landraces typically produce yields lower than modern wheats, which can seemingly put them at odds with rising global food demands. Nevertheless, they serve a critical role in preserving genetic diversity to ensure American wheat crop resilience should new pathogens wreak havoc on modern varieties. It is also worth noting that landrace wheats are reported to have better yields and higher quality attributes than modern varieties "under organic and low-input farming systems."[96]

Landraces can and have been preserved in seed banks, which is worthwhile, but there are limitations in preserving them this way. Landraces are heterogeneous, meaning that individual specimens of the plant's spikes stored in banks do not necessarily possess all the genetic diversity in the landrace variety. In addition, most biologists agree that active cultivation of landraces is essential to preserve cultivation knowledge.[97] Given these circumstances, USDA should find ways to collaborate with American farmers and researchers to incentivize and ensure sufficient production levels of landrace wheats.

USDA and DHS: Prepare for Adequate Response to Biological Attack Against U.S. Wheat Crops. USDA–National Institute of Food and Agriculture and the Department of Homeland Security established the National Plant Diagnostic Network (NPDN) during growing fears of bioterrorism following 9/11 and the 2001 anthrax attacks.[98] The NPDN serves as a network of diagnostics laboratories across the country that help rapidly identify plant disease and pest outbreaks. Since its establishment, funding and support for the NPDN have begun to erode.[99] As the original sponsoring agencies, USDA and DHS should evaluate the current state of the program to make sure its capabilities are sufficiently resourced to perform adequate early monitoring and detection of a biological attack against domestic crops.

In addition to shoring up early warning capabilities, USDA should also review the agriculture industry's preparedness to respond to bioterrorism. If an outbreak of disease against U.S. wheat crops occurs, agrochemical suppliers will need to deliver treatments to limit damage. However, supply chains for pesticides can be brittle, as was the case during the COVID-19 pandemic.[100] Further analysis of domestic pesticide treatment inventories and supply chains would help identify what is needed to boost the resilience of U.S. farms in a worst-case scenario.

USDA: Pursue and Encourage Alternatives to Conventional Fertilizer. The American wheat industry's reliance on conventional fertilizer has become increasingly challenging due to rising prices, global supply disruptions, and environmental costs. Greater emphasis is needed on adopting renewable fertilizers. While multiple solutions may be required to fill the gap, transitioning American agriculture to a more sustainable and regenerative approach is key.[101] The Biden administration has tried moving on this front and recently announced $500 million in funding for boosting domestic fertilizer production that is "independent, innovative, and sustainable."[102] This effort is worthwhile to help transition the United States off foreign fertilizer dependence. It does not, however, preclude the need to continue transitioning to more sustainable and regenerative agriculture.

One facet of sustainable agriculture that would help provide a viable alternative to synthetic fertilizers is the greater use of cover crops. Growing the same monoculture crop in the same field for years on end, as most conventional U.S. farmers do, damages the soil microbiome as the same nutrients are depleted over time. Conventional agriculture deals with this problem by applying large amounts of synthetic fertilizer to the soil. When cover crops are added to crop rotation, the cover crop plants naturally fertilize and rejuvenate soil health. Furthermore, a growing body of scientific research shows that yields from sustainable agricultural systems are comparable to that of conventional systems.[103]

The downside to cover crops is the inability to grow a desired crop (for example, wheat) for that growing season, which would reduce overall American wheat output. Options exist to compensate for drops in annual grain yields that would result from the broader use of cover crops. Addressing all options is beyond the scope of this essay, but one example is choosing cover crops that can act as cash crops that produce food and simultaneously amend the soil. An example of this would be cover crop legumes, which fix nitrogen to the soil that would be available for the next season's wheat.

Funding is another limiting factor and will be necessary to incentivize American farmers to widely adopt the use of cover crops. Sustainable agriculture receives little government funding compared to industrial agriculture. The most recent Farm Bill (a package of legislation Congress passes every 5 years to support U.S. agriculture) provided less than 7 percent of its funding for conservation practices.[104] USDA can increase funding for cover crop implementation by reducing Farm Bill spending in other areas overdue for adjustment, like conventional corn subsidies.[105]

USDA: Establish a National Strategic Grain Reserve. As previously noted, if Russia succeeded in some capacity to disrupt U.S. wheat production, resulting in domestic grain shortages, no current national wheat reserve exists to reduce the ensuing effects. Given how essential grain is to the U.S. food supply and the increasing probability of climate change's impact on global grain production, a strategic grain reserve makes sense. The need for a reserve has risen in recent times. For instance, droughts in 2012 affected corn production to such an extent that the United States had to import corn from Brazil, a surprising development for America as the world's leading corn producer.[106] Converting any remaining funds within the Bill Emerson Humanitarian Trust into a physical grain reserve and supplementing it by redirecting funding from conventional commodity crop subsidies could provide this much-needed resilience in our national food security.

State and Commerce Departments: Encourage Import-Dependent Countries to Boost Domestic Food Production to

Ukrainian President Volodymyr Zelensky, right, walks with Minister of Infrastructure Oleksandr Kubrakov during visit to Chornomorsk Sea Trade Port to watch Turkish-flagged dry cargo ship *Polarnet* loaded with grain for export, July 29, 2022, in Chornomorsk, Odesa Oblast, Ukraine (Ukrainian Presidential Press Office/Ukraine Presidency/Alamy Live News)

Minimize Exposure to Russian Grain Trade Manipulation. Having export markets available to American wheat not only can be lucrative for farmers and commodity traders but also can undermine efforts in those destination countries to develop greater self-sufficiency in food production. The United States will always need to produce more wheat than it consumes on average because this helps buffer against the effects of unforeseen production shortfalls regardless of the cause. It also assists trade partners in meeting their food requirements when they experience unexpected shortages or find themselves in positions where they cannot realistically become fully self-sufficient in their own food production. However, in a world where Russia is a global food power and can use inputs and commodities as weapons to win concessions, allies and partners should be encouraged to reduce their dependence on foreign food sources. Although this could reduce U.S. wheat exports in the long run, it would, more importantly, mitigate Russia's ability to exploit vulnerable countries to enhance their Great Power status.

DHS: Harden Information and Operational Technology Networks Used for Grain Production, Storage, and Transportation. Cyber security remains a challenge for organizations across all industries, but implications for breaches to critical infrastructure networks such as those in the grain industry are more severe and require greater attention to ensure proper security practices. For wheat industry organizations' information technology and operational technology networks, like other industries, known best practices provide the greatest defense against cyber attacks. However, many businesses fail to implement the full range of best practices due to limitations in understanding and the failure of company executives to invest appropriately in network defense.

Wheat industry leaders can leverage the National Institute of Standards and Technology cyber-security framework for guidance.[107] Taking this proactive approach to network defense will limit exposure to disruptive intrusions like the ransomware attacks that recently plagued Midwestern grain elevators.

Conclusion

As a rival in strategic competition and as the emerging food superpower, Russia is uniquely positioned to disrupt U.S. wheat production, storage, and delivery. Moscow has already demonstrated its intentions to attack U.S. interests in adversarial competition at levels below armed conflict, and future attempts to do so could realistically involve targeting the American wheat industry. As the

most important food staple in America, wheat supply degradation could have significant consequences for domestic food security and, by extension, trust in the U.S. Government. Should Russia pursue such a strategy, its tactics could range from cyber attacks on grain infrastructure to manipulating global fertilizer and wheat export markets to covert antiagriculture biowarfare.

To mitigate these threats, American policymakers should consider a range of policy options. First, further research is needed to measure risks of Russian disruption to the U.S. wheat industry. Results would more accurately prioritize policy considerations. In the meantime, prioritized policy considerations should include:

- improving biodiversity in U.S. wheat production
- ensuring sufficient resourcing for detection and response to a biological attack against U.S. crops
- enhancing sustainable agriculture to reduce dependence on imported fertilizer
- establishing a national grain reserve
- reducing global exposure to Russian grain trade manipulation
- encouraging the improved implementation of cyber security best practices throughout the wheat industry.

With an increased focus on reducing food system vulnerabilities, U.S. leaders and the world's citizens can reap a harvest of improved global security. **JFQ**

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[83] Jungwook Park et al., "Comparative Genome Analysis of *Rathayibacter Tritici* NCPPB 1953 with *Rathayibacter Toxicus* Strains Can Facilitate Studies on Mechanisms of Nematode Association and Host Infection," *The Plant Pathology Journal* 33, no. 4 (August 2017), 370–381, https://doi.org/10.5423/PPJ.OA.01.2017.0017.

[84] Murray, interview.

[85] Lila Guterman, "One More Frightening Possibility: Terrorism in the Croplands," *The Chronicle of Higher Education*, October 26, 2001, https://www.ph.ucla.edu/epi/bioter/croplandsterrorism.html.

[86] Lockwood, *Six-Legged Soldiers*, 245–248.

[87] Rimmington, *The Soviet Union's Agricultural Biowarfare Programme*, 3.

[88] Alibek, "The Soviet Union's Anti-Agricultural Biological Weapons," 219.

[89] Marcellus M. Caldas and Stephen Perz, "Agro-Terrorism? The Causes and Consequences of the Appearance of Witch's Broom Disease in Cocoa Plantations of Southern Bahia, Brazil," *Geoforum* 47 (June 2013), 147–157.

[90] Joanne Silberner, "A Not-So-Sweet Lesson from Brazil's Cocoa Farms," NPR, June 14, 2008, https://www.npr.org/2008/06/14/91479835/a-not-so-sweet-lesson-from-brazils-cocoa-farms.

[91] Ortwin Renn, "Concepts of Risk: An Interdisciplinary Review," *GAIA—Ecological Perspectives for Science and Society* 17, nos. 1–2 (March 2008).

[92] Participants were provided with the following additional clarification: "Cyber attacks targeting grain storage/transport infrastructure could include the following actions: ransomware attacks against grain cooperative or port business networks; intrusions into industrial control systems networks involved in grain storage or transport." Participants also were provided: "Undercutting U.S. wheat exports in global markets could include the following actions: short-term price manipulations or subsidies to domestic wheat production to make Russian wheat exports more competitive in global markets; applying further diplomatic pressure on potential trade partners; spreading false claims about the health and quality of U.S. grain."

[93] The Delphi method is a structured technique used to achieve consensus among experts by conducting multiple rounds of questions. For further information, see Bernice B. Brown, *Delphi Process: A Methodology Used for the Elicitation of Opinions of Experts* (Santa Monica, CA: RAND, 1968), https://www.rand.org/pubs/papers/P3925.html.

[94] John Lidwell-Durnin and Adam Lapthorn, "The Threat to Global Food Security From Wheat Rust: Ethical and Historical Issues in Fighting Crop Diseases and Preserving Genetic Diversity," *Global Food Security* 26 (September 2020).

[95] The full extent of the landrace variety loss since the Green Revolution is unknown. For further explanation, see Maria R. Finckh et al., "Cereal Variety and Species Mixtures in Practice, With Emphasis on Disease Resistance," *Agronomie* 20, no. 7 (November 2000), 813–837.

[96] Abdullah A. Jaradat, *Wheat Landraces: Genetic Resources for Sustenance and Sustainability* (Washington, DC: USDA Agricultural Research Service, n.d.), https://www.ars.usda.gov/ARSUserFiles/50600000/products-wheat/AAJ-Wheat%20Landraces.pdf.

[97] Lidwell-Durnin and Lapthorn, "The Threat to Global Food Security from Wheat Rust."

[98] For more information about the National Plant Diagnostic Network, see https://www.npdn.org/.

[99] Murray, interview.

[100] Tom Polansek, "'Off the Charts' Chemical Shortages Hit U.S. Farms," Reuters, June 27, 2022, https://www.reuters.com/markets/commodities/off-charts-chemical-shortages-hit-us-farms-2022-06-27.

[101] According to the USDA, *sustainable agriculture* is defined as practices that "are intended to protect the environment, expand the Earth's natural resource base, and maintain and improve soil fertility." For more information, see "Sustainable Agriculture," USDA, https://www.nifa.usda.gov/topics/sustainable-agriculture.

[102] "Biden-Harris Administration Makes $500 Million Available to Increase Innovative American-Made Fertilizer Production," USDA, September 27, 2022, https://www.usda.gov/media/press-releases/2022/09/27/biden-harris-administration-makes-500-million-available-increase.

[103] For a summary of this research, see *The Fertilizer Trap: The Rising Cost of Farming's Addiction to Chemical Fertilizers* (Minneapolis: Institute for Agriculture and Trade Policy, November 8, 2022), 11, https://www.iatp.org/the-fertiliser-trap.

[104] "Farm Bill Spending," USDA, https://www.ers.usda.gov/topics/farm-economy/farm-commodity-policy/farm-bill-spending/.

[105] Tara O'Neill Hayes and Katerina Kerska, "PRIMER: Agriculture Subsidies and Their Influence on the Composition of U.S. Food Supply and Consumption," *American Action Forum*, November 3, 2021, https://www.americanactionforum.org/research/primer-agriculture-subsidies-and-their-influence-on-the-composition-of-u-s-food-supply-and-consumption/.

[106] Howard Schneider, "In Sign of Growing Clout, Brazil's Corn Helps Hold Up U.S. Market," *Washington Post*, November 18, 2012.

[107] For more information, see "Cybersecurity Framework," National Institute of Standards and Technology, https://www.nist.gov/cyberframework.