Impact of Russia's War on Ukrainian Agriculture

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IMPACT OF RUSSIA'S WAR ON UKRAINIAN AGRICULTURE

German Association for East European Studies
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ANALYSIS

An Interim Assessment of the War-Induced Damages and Losses in Ukraine's Agriculture

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Abstract

The full-scale Russian invasion of Ukraine has inflicted massive damages and losses on Ukrainian agriculture and terminated or even reversed the growth of the last twenty years. This article makes an interim assessment of the financial consequences of the war-related damages and losses in Ukrainian agriculture. The assessment is performed based on data from regular monitoring by the Kyiv School of Economics. The estimated damages to physical assets caused by Russia's invasion have been found to total $10.3 billion, while economic losses have reached almost $70 billion. With an estimated 16 million hectares being at risk of landmine contamination, the estimated cost of demining Ukraine's agricultural lands ranges from $12.8 to $26.6 billion. The reconstruction and recovery needs of the agricultural sector beyond this demining are in turn estimated at $56.3 billion.

Introduction

Over the two decades preceding Russia's full-scale invasion, Ukraine had become an increasingly important global supplier of grains and vegetable oil (Figure 1). On average, it accounted for 10% of global wheat exports, 16% of global maize exports, and 50% of global sunflower oil exports over the 2018–20 period. Ukraine's agriculture is mainly crop-based and is also a key sector of the national economy. In 2020, the entire agri-food sector (i.e., primary agriculture and upstream/downstream sectors) amounted to roughly 20% of Ukrainian GDP, and 45% of Ukraine's exports. Abundance of black soils (one of the most fertile types of soils for agricultural production)—almost one-third of the total world stock of black soils is located in Ukraine—favorable climate conditions, landscape characteristics that allow for large-scale farming, suitable geographical location including access to the Black Sea, and investments in farming and in broader export supply infrastructure have paved the way for the substantial agricultural productivity increase observed in Figure 1. Nevertheless, crop yields still fell short of their full potential; so closing the agricultural productivity gap could make an even larger contribution to Ukraine's national economy and to global food supplies.

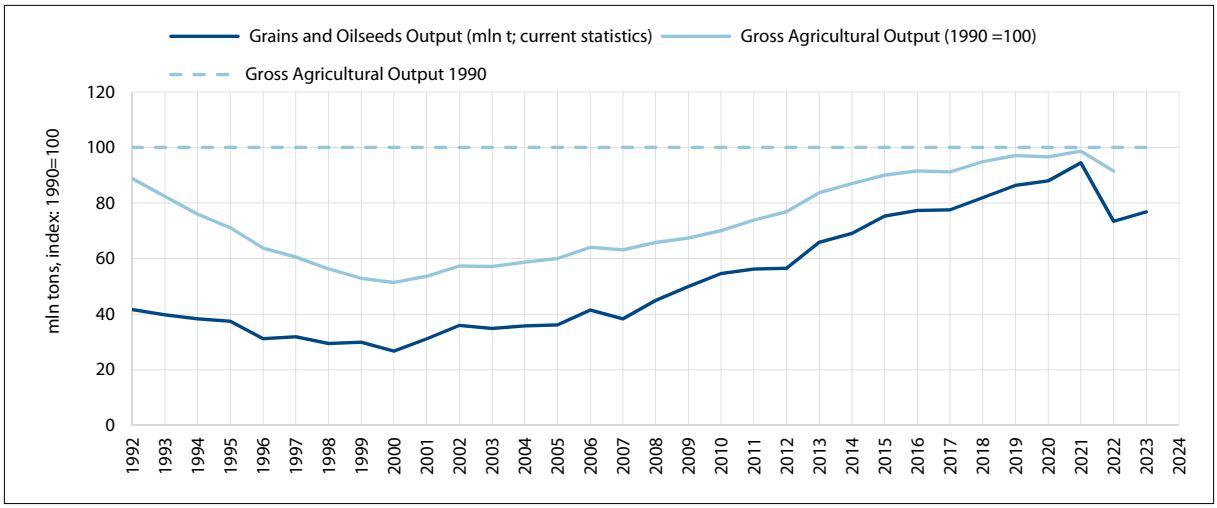
Russia reversed this trend by invading Ukraine in February 2022, and the price of this ongoing war is already immense. Ukraine's GDP plummeted by nearly 30% in 2022, and the most recent estimate of total war damages to Ukraine amounts to $155 billion, nearly equal to its 2022 GDP. More than 10 million Ukrainians have left their homes, including 6.4 million refugees recorded across Europe. Russia's war has caused massive damage and losses also to Ukrainian agriculture, which has halted and reversed the positive trends and contributions of the previous decades mentioned above.

This paper presents the results of these war-induced damages and losses in Ukrainian agriculture based on an ongoing monitoring of the impact of the Russian invasion on Ukraine's economy. The estimated damages to physical assets from Russia's invasion at the time of publication total $10.3 billion, while economic losses (i.e. foregone revenue and/or increased production costs) have mounted to almost $70 billion. We also single out damages to agricultural land due to mining, as this is not included in agricultural damages figures. The current estimated cost of demining agricultural lands ranges from $12.8 to $26.6 billion. In addition, we separately present our estimates of the financial consequences of the Kakhkovka dam disaster on Ukrainian agriculture, which has so far caused $1.18 billion in damages and losses to the sector. These findings are crucial for understanding the current state of Ukrainian agriculture and the scale of current reconstruction, as well as the level of recovery needed to set it back on a sustainable development path.

One-Third of Ukraine's Agricultural Sector Has Already Been Destroyed

Agricultural damages are estimated by the Center for Food and Land Use Research at the Kyiv School of Economics (hereinafter "KSE Agrocenter") based on secondary data collected from various sources on the value of completely destroyed or stolen physical assets or capital, as well as physical assets partially damaged but still suitable for reconstruction. The details on calculation of damages and losses (covered in a separate section below), data and exact methodology is available on the webpage of the Kyiv School of Economics.

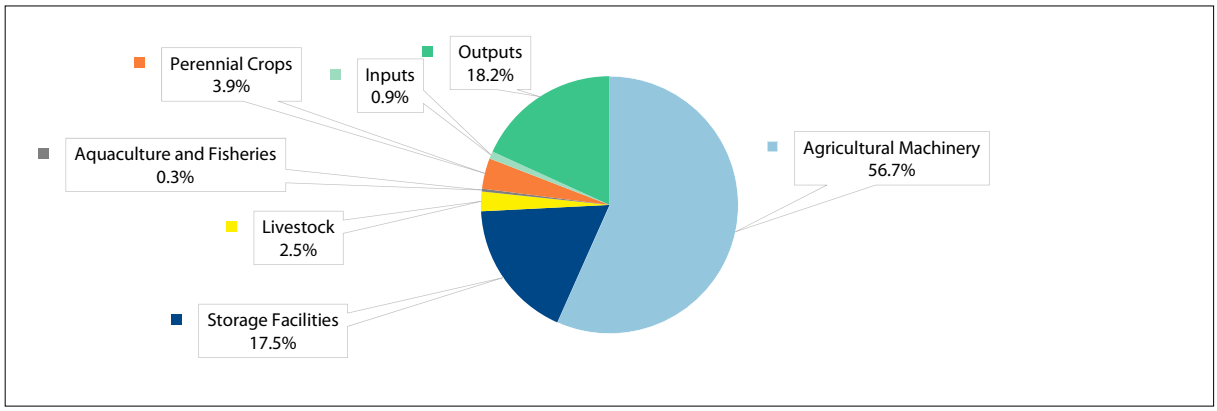
Figure 1: Agricultural Productivity Growth in Ukraine



Source: Own presentation using Ukrstat data. Time series through 2021 are presented as three-year moving averages to smooth out short-run fluctuations.

The damages are broken down into the following groups: agricultural machinery and equipment, storage facilities, livestock, bees, fisheries, aquaculture, key perennial crops, and stolen or lost inputs and outputs, with the structure of damages presented in Figure 2. As of December 2023, almost two years after the full-scale invasion, the cumulative damages suffered by Ukrainian agriculture are estimated at $10.3 billion, or more than a third of all capital stock accumulated in Ukrainian agriculture before 2022. The damages have been heaviest in the Ukrainian oblasts in the east and south that have seen the most fighting.

Figure 2: War-Induced Agricultural Damages as of December 2023 (Breakdown of Damages by Category)



Source: KSE Agrocenter. Note: lost inputs reflect damaged and stolen fuel and fertilizers, while lost outputs reflect damaged and stolen grain and oilseeds.

The largest category of damages is agricultural machinery, constituting almost 57% of all damages, or $5.8 billion; damages to tractors leads the way in terms of subcategories, with up to $1.6 billion lost. Overall, more than 21% of all available stock of agricultural machinery and equipment in Ukraine is completely or partially damaged.

The second-largest damaged category of assets is grain and oilseeds stocks. This category faced not only physical destruction, but also systematic theft by Russia, a topic widely covered in leading global media outlets. The estimated damages attributed to the destruction and theft of stored products amount to $1.9 billion at the time of publication, involving an estimated 4 million metric tons of grain and oilseeds.

The third-largest damaged category of assets is storage facilities, which account for 17.5% of all damages, or $1.8 billion. According to the assessment, out of Ukraine's initial storage capacity of 75 million tons prior to the invasion, nearly 11.3 million tons of storage capacity has been completely destroyed, and a further 3.3 million tons partially damaged. The impact on storage capacity becomes even more pronounced when considering that some facilities, though physically intact, are situated in occupied territories and are thus inaccessible to Ukrainian agricultural producers.

Farmland Damages and Demining

The above-mentioned agricultural war damages do not cover the damages to farmland caused by mines and various other sources of damage and pollution from military use, battles, etc. Ukraine is now faced with an immense challenge in this respect, as an estimated 16 million hectares are being at risk of mine contamination, which is more than a quarter of the country's total area. Out of these 16 million hectares, about 11.2 million hectares is farmland. To put this in perspective: this figure is comparable to the entire stock of all farmlands in Germany and poses an immense challenge.

A huge and sustained effort is needed to demine these lands in order to once again enable their safe cultivation. The total cost of farmland demining in Ukraine is currently estimated in the range of $12.8–26.6 billion. The process of demining consists of three steps:

The first step is a non-technical inspection in which the demining operators collect information on the territories at risk: whether there were any battles, any troops stationed in the area, or any reports on mine-related incidents. Based on interviews with demining companies in Ukraine, 84% of land is returned to regular service after a non-technical inspection, while the remaining 16% (or 1.8 million hectares of the 11.2 million hectares of farmland at risk of contamination) needs further examination. Non-technical inspection not only allows for the rapid return of the majority of land back to safe operation, but it is also inexpensive, i.e., on average about $8 per hectare.

In the second stage, the minority of farmlands not cleared in a first non-technical inspection are technically inspected. At this stage, deminers either manually carefully check the area with metal detectors and other equipment, or utilize demining machines. The main point of the technical inspection is to identify the location of mines and other unexploded ordnance. At the moment, about 1.8 million hectares must be technically inspected at the cost of about $3,000 per hectare. Allowing for determining which areas need actual demining and which do not, approximately 70% of technically inspected areas are returned to safe operation after technical inspection, while approximately 30% are found to require actual demining.

The actual demining comes last. An estimated 500,000 hectares of Ukrainian agricultural land requires actual demining at an estimated average cost of $25,600 per hectare.

Note on the Kakhovka Dam Disaster

On June 6, 2023, Russia destroyed the Kakhovka Dam, unleashing havoc in Southern Ukraine. The agricultural sector was among the hardest hit by this man-made disaster. The combined direct damages and long-term losses for primary agriculture are estimated at $1.18 billion (with losses amounting to $1.15 billion and direct damages accounting for $25.7 million, respectively).

The majority of direct damages were suffered by the fisheries sector, with an estimated $24.5 million based on calculations from the Ministry of Agrarian Policy and Food (MAPF), reflecting the value of fish killed directly following the incident; the rest of the direct damages were caused by damaged crops and drowned livestock. The losses, by contrast, are projected over the next five years, reflecting the anticipated time frame for rebuilding the Kakhovka Dam and its associated infrastructure; the largest portion of these losses ($909 million) arise from the disruption of irrigation to highly drought-prone farmlands in Southern Ukraine (about 262,000 hectares in total). The remaining long-term losses include those incurred by the fisheries sector ($242.3 million), livestock losses ($1.9 million), and the expenses related to land recultivation ($0.5 million).

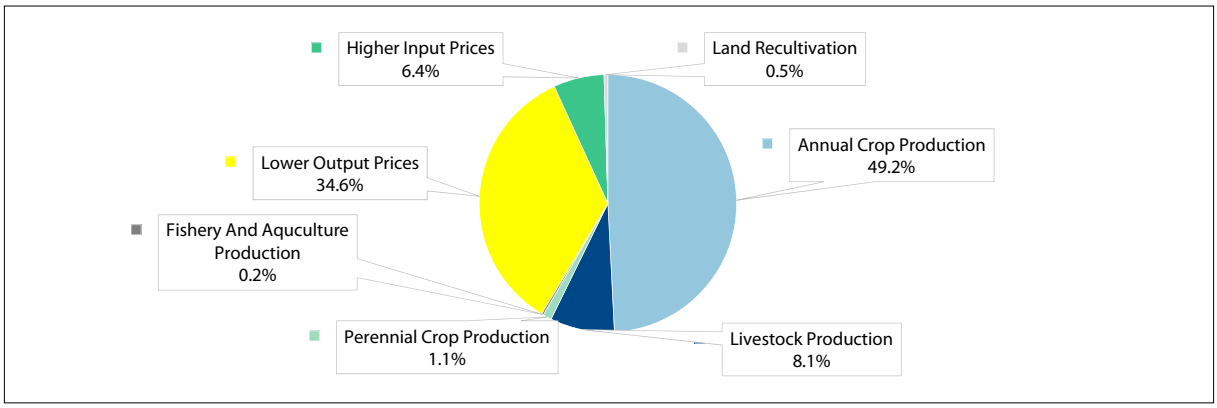
Total Agricultural Losses Now Exceed Pre-War Annual Agricultural GDP

According to our assessment, Ukraine's total agricultural losses are estimated at $69.8 billion; for orientation, this figure far exceeds entire Ukraine's agricultural GDP for 2021. In contrast to direct damages, agricultural losses are calculated based on the estimated foregone revenue due to lower production, decreases in prices, and increases in production costs resulting from the full-scale invasion.

The breakdown of losses by category is presented in Figure 3. The largest category of losses, constituting 49.2% of the overall total (or $34.3 billion), is attributed to lower crop production. For annual crop production, which comprises the majority of this category of losses, this decrease in production is estimated not only for the years 2022 and 2023, but also include further losses extending into 2024 due to decreases in sowing areas. Losses due to lower livestock, aquaculture and fisheries production amounted to $5.6 billion through December 2023.

The second-largest category of losses is export disruptions. Prior to the full-scale Russian invasion, over 90% of all agricultural products were exported from Ukraine via maritime routes (i.e., via the Black Sea). However, following the invasion, maritime exports were halted, forcing Ukrainian agricultural companies to re-route their exports through land corridors and the Danube river ports. This resulted in increased logistics costs and created bottlenecks in agrifood exports, which in turn suppressed domestic prices (Figure 4). Despite partial recovery of maritime exports

Figure 3: Structure of the War-Induced Agricultural Losses in Ukraine as of December 2023



Source: Own Calculations by the KSE Agrocenter Team.

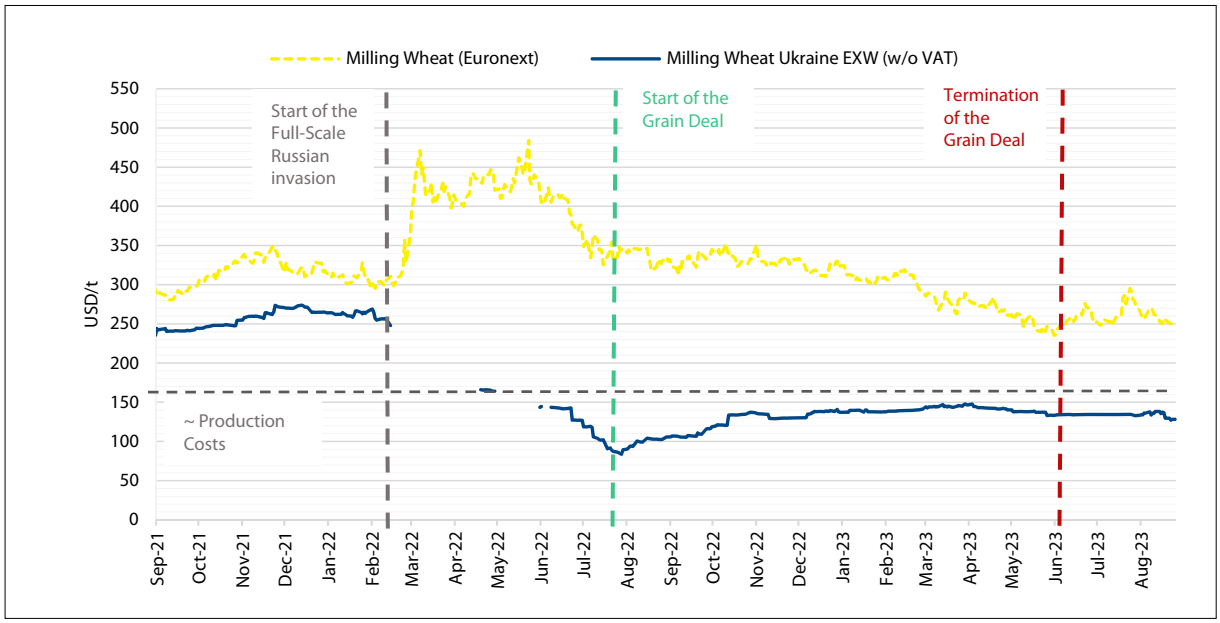
through the Black Sea Grain Initiative after August 2022, Russia still ensured exports remained insecure via delayed vessel inspections that failed to significantly lower logistics costs and to improve domestic prices; the Initiative was ultimately abandoned by Russia in July 2023.

Since then, with the help of active naval operations, Ukraine has finally become able to once again facilitate sea exports, hereby substantially increased its export capacity; the gap between domestic and world prices has, however, remained well above pre-invasion level, indicating that the invasion's effect on domestic prices persists. We have thus estimated losses due to export disruptions for grain stocks from the 2021 harvest and the entire 2022 harvest, using the average price difference between pre-war and post-war prices and weighted by monthly export volumes. We also assume that the 2023 harvest will also be sold at depressed domestic prices.

Another challenge faced by Ukrainian producers has been the rise in production costs. We have estimated the increase in prices for two crucial inputs: fuel and fertilizers. Assuming no changes in production technology, Ukrainian producers are projected to incur an additional $844 million in additional costs due to the post-invasion surge in fertilizer and fuel prices.

Recultivation of damaged farmland is another challenge, a concern separate from the demining mentioned in the previous section. Approximately 835,000 hectares need recultivation, which would require an additional $184 million in financing.

Figure 4: The War's Effect on Milling Wheat Prices in Ukraine



Source: Own presentation using Ukragroconsult data. Production costs data was received by informal discussion with medium and large-scale farmers in Ukraine.

Agricultural Reconstruction and Recovery Needs

For the Needs Assessment, the methodology was taken from the Post-Disaster Needs Assessment Guidelines developed by the Global Facility for Disaster Reduction and Recovery, World Bank Group, European Union, and United Nations, as well as discussions with the Ministry of Agricultural Policy and Food of Ukraine, Ministry of Finance of Ukraine, international development projects, and other stakeholders.

Table 1: Breakdown of Recovery and Reconstruction Needs (own estimations)

Category	Component	Total in Millions of USD
Reconstruction Needs	**(a) Support for Reconstruction**	**9,402**
	Storage facilities	2,163
	Farm equipment and machinery	6,415
	Perennial crops	477
	Livestock, fisheries, and aquaculture	346
Recovery Needs	**(b) Support for Short-Term Recovery of Agricultural Production**	**6,122**
	Interest rate compensation for agricultural loans	3,370
	Agricultural loan guarantees via a Partial credit guarantee fund for agriculture	631
	Grants and inputs for agricultural production by small farms (per hectare and per livestock unit)	1,071
	Recultivation of damaged farmlands	1,050
	(c) Support for Longer-Term Recovery of Ukrainian Agriculture	**35,513**
	Investment grants for promoting climate-smart technologies for arable crops	15,000
	Investment grants for investing in horticulture (orchards and greenhouses)	2,513
	Investment grants for livestock development	9,000
	Investment grants for integrated food-energy systems, including biogas development	8,000
	Investment grants for fisheries and aquaculture	1,000
	(d) Support for agricultural public institutions, including restructuring and compliance measures to accelerate EU accession	**5,020**
	TOTAL	**56,057**

The total required funding is estimated at $56.1 billion over the course of the next 10 years (Table 1). We have categorized these needs into two primary groups:

The **Reconstruction Needs** category is designed to address the compensation for and reconstruction of damaged physical assets. The costs for the reconstruction process are estimated with the 'build back better' principle in mind, which includes a 20% premium for certain damage categories.

The **Recovery Needs** category is focused on supporting production recovery efforts with the goal of returning to pre-invasion production levels. This category encompasses three distinct subcategories: 1) **Immediate Production Recovery** actions that need to be taken urgently to safeguard Ukrainian agriculture; 2) **Longer-Term Recovery of Agriculture** includes steps required to shape the future of Ukrainian agriculture; 3) **Support for Agricultural Public Institutions** aims at strengthening and supporting key agricultural public institutions due to higher workload resulting from the war, as well as addressing the rising capacity demands of public institutions due to Ukraine's plans of EU accession.

Overall, these needs extend over the course of the next years and might at first glance not seem extraordinarily high. However, as the war still rages and its resolution in the near future appears unlikely, the toll of the war will continue to mount. Moreover, the recovery and reconstruction needs presented above come on top of the regular fixed and working capital financing demand from agricultural producers that historically (excluding the high-price period of 2021–2023), according to the UKRSTAT data, has been around $25 billion per year. That means that despite the substantial and continuing support from donors to help Ukraine to mobilize the necessary funds for recovery and reconstruction, Ukraine will need to facilitate crowding in private sector investments that are essential not just for the reconstruction, but also for the long-term development of the sector. From the government's perspective, it is important for Ukraine to leverage scarce public/donor resources and undertake necessary reforms (or, as is often the case,

avoid actively harmful decisions) that would improve the investment climate in the country, reduce specific agricultural risks, and facilitate crowding in private investments that would further spur development and growth.

About the Authors

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Roman Neyter is a researcher in agricultural and land policy at the Kyiv School of Economics and a PhD student at Wageningen University (Netherlands) in the 'Agricultural Economics and Rural Policy Group.' His research areas include the land market in Ukraine, assessment of the development potential of local communities, and assessment of the damage, losses and needs for reconstruction and recovery of Ukrainian agriculture.

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ANALYSIS

Assessing the Impact of the Russian Invasion on Crop Production in Ukraine with Open Satellite Data

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Abstract

The Russian invasion of Ukraine resulted in substantial abandonment of fertile croplands due to combat operations, particularly along the front line. We used Sentinel-2 satellite imagery to estimate the extent of abandoned croplands on both sides of the front line after the onset of war. We find that at least 14,000 km^2 of former cropland have been left uncultivated along the front line as a result of the war, including 8,000 km^2 in areas controlled by Ukraine. It will take substantial time and effort to once again fully utilise these abandoned croplands, which are contaminated with countless mines, unexploded ordnance, and artillery craters.

Introduction

Before the full-scale Russian invasion of Ukraine in 2022, Ukraine was the sixth-largest producer of maize and the seventh-largest producer of wheat, respectively, and represented more than 30 percent of global sunflower seed production, according to the USDA Foreign Agricultural Service. By 2022, agriculture contributed approximately 10 percent to Ukraine's gross domestic product (GDP) and 42 percent of its export value. According to the State Statistics Service of Ukraine (SSSU), about three million Ukrainians, almost 20 percent of the labour force, were employed in agriculture before the war.

The Russian invasion led to substantial losses in agricultural production in Ukraine. The value added of Ukraine's agricultural sector decreased by 23 percent in 2022 compared to its 2016–2021 average (World Bank, 2024). Crop production decreased due to both the inability to cultivate some croplands and their ensuing abandonment due to their location near the front line, and because crop yields declined even in otherwise unaffected areas due to decreasing agricultural inputs. Annual statistical reports from the SSSU offer valuable information on cropland area and production of the main crops at the provincial (*oblast*) level from which the production losses after the Russian invasion can be inferred. However, statistical reporting is time-consuming, lacks spatial detail, and is prone to inaccuracies, especially in areas located close to the front line. Official statistics also do not allow for discrimination between abandoned cropland and land that is still cultivated, but is now located in occupied areas of Ukraine.

Publicly funded satellite platforms, such as those provided by the EU's Copernicus Programme, can fill this important gap by providing images at high spatial resolution, with frequent revisits, for large areas in near real time and at no additional cost. In this contribution, we summarise the impact of the war on crop production in Ukraine using official statistical data. We complement these data with information derived from satellite imagery to approximate the impacts of the war on the extent of cropland along the front line, where the most direct effects have been felt. We conclude with recommendations on how to use satellite imagery to advance monitoring and reporting of the impacts of the war on crop production in Ukraine.

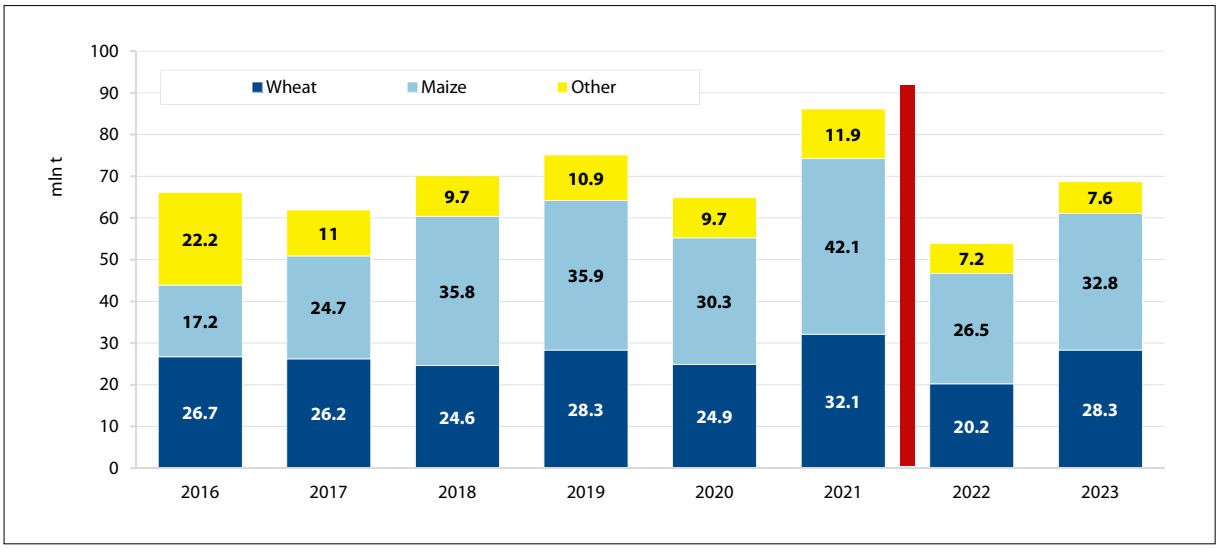
Effects of the Russian Invasion on Ukraine's Crop Production

According to official statistics, Ukrainian farmers harvested 54 million tons of grain in 2022, significantly less than in the years before the start of the full-scale invasion in February of that year (Fig. 1). Wheat production decreased by 15 and maize production by 26 percent in the marketing year 2022/2023 compared to their 2016–2021 averages, according to the SSSU. The agricultural operations in the south and east, where some of the most productive and intensively used agricultural areas in Ukraine are located, are particularly affected by the war.

Cropland abandonment occurs when cultivation becomes dangerous, unprofitable, or logistically unfeasible. Unexploded landmines and grenades can remain hidden beneath the surface of the land, as seen in the frequent reports in the media of Ukrainian farmers and agricultural workers being killed or wounded by explosions in fields. The effects of war on crop production are also felt further away from the front line, for example when inputs such as fertilisers become too expensive for farmers or they are no longer able to sell grain abroad due to blocked transportation routes.

According to the SSSU, the total planted area in 2022 decreased by 52,000 km^2, or 18 percent of the total cropland area in 2021 (Fig. 2). However, these data do not distinguish between abandoned croplands and croplands in

Figure 1: Crop Production in Ukraine in the Years Before and After the Full-Scale Invasion



Source: Data for 2016 to 2022 are from the State Statistics Service of Ukraine (SSSU); data for 2023 are taken from the forecast from the September 2023 EU JRC MARS Bulletin (Claverie et al., 2023). Data for 2022 may be imprecise due to difficulties in collecting data near the front line.

territories now occupied by the Russian Federation. Indeed, by autumn 2023, Russia had gained control of nearly three-quarters of Kherson and Zaporizhzhia Oblasts, although their administrative centres remain under Ukrainian control. Russia conquered almost the entire area of Luhansk Oblast (less than two percent was under Ukrainian control at the time of analysis) and currently has control over 57 percent of Donetsk Oblast.

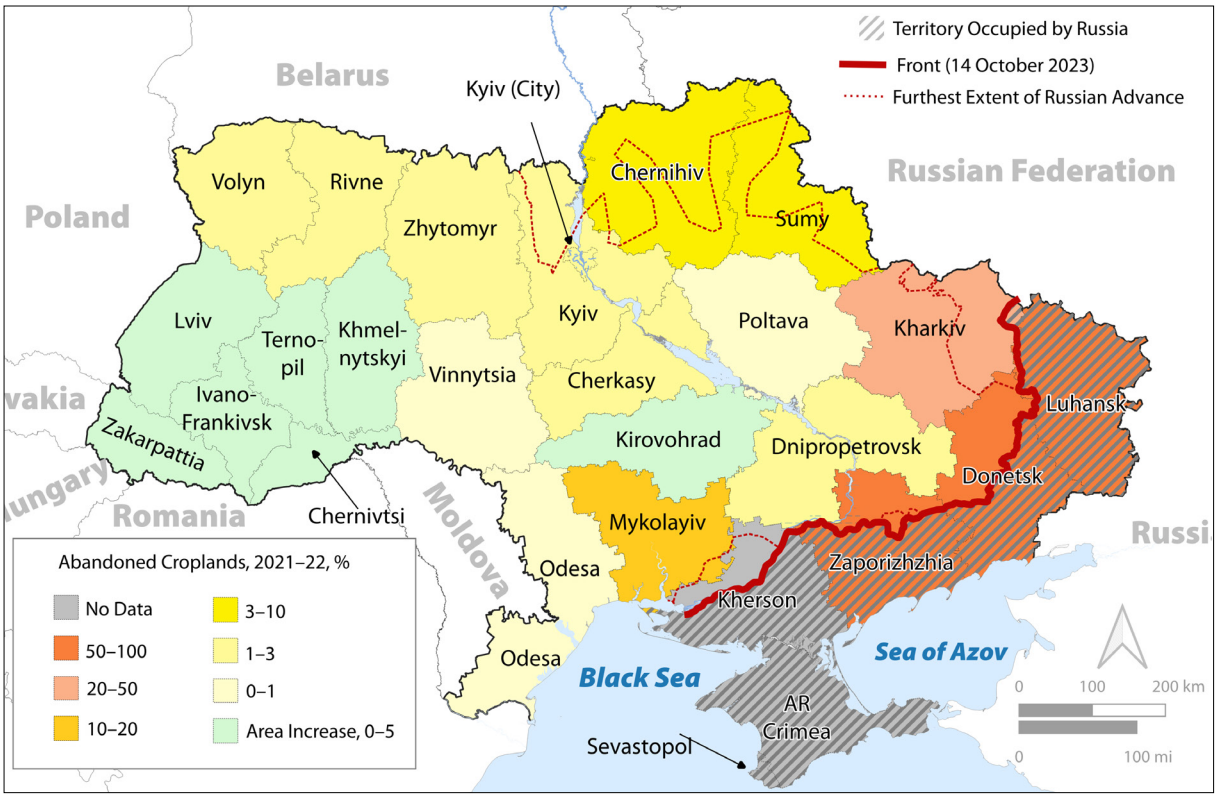
This suggests that a significant portion of the reported decline in cropland area can be attributed to the extensive occupation of Ukrainian territory by the Russian Federation, resulting in the SSSU no longer receiving data from these regions. The Russian official government gazette reported 13,000 km^2 of croplands in the Russian-occupied part of Kherson Oblast as of April 2023, of which around 1,200 km^2 (nine percent) have been abandoned (Rossiyskaya Gazeta, 2023). The Ukrainian online media outlet Texty.org.ua estimated around 16,400 km^2 of wheat and 11,100 km^2 of sunflower crops in 2023 in the Russian-occupied territories, with a prospective production of around 4.6 and 2.0 million tons, respectively (Texty.org.ua, 2023).

By contrast, cropland areas increased in regions located away from the front line and the borders with Russia and Belarus, for instance in western Ukraine along the border with Poland and Romania (Fig. 2). This may reflect the fact that some agricultural enterprises relocated some of their activities to safer regions, where they started to develop more marginal and previously unused lands.

Lower agricultural inputs are another factor contributing to the reduction in production. Production of nitrogen fertilisers in Ukraine decreased nearly 80% in 2022 compared to the previous year, according to Ukrainian officials, mainly because Russia occupied Ukraine's largest producer, the Azot plant in Severodonetsk, in 2022 (Ekonomichna Pravda, 2023). In addition, nitrogen fertilisers from Russia and Belarus were obviously no longer available, and prices for imported nitrogen fertilisers rose substantially due to the raised natural gas prices and the devaluation of the Ukrainian hryvnia. Ukraine also imported 69 percent of its potash fertilisers from Belarus in 2021 (Ukrainian Agribusiness Club, 2023). As a result, the consumption of nitrogen and potash fertilisers in Ukraine decreased between 50 and 70 percent in 2022 compared to 2021, according to an expert from Group DF, the largest producer of nitrogen fertilisers in Ukraine (Interfax-Ukraine, 2022).

The effects of lower input intensity on yields occurred throughout the country, but spatially refined data on yield declines have been lacking to date. Furthermore, yield variations are substantial in Ukraine as a consequence of the predominant (volatile) weather conditions, and typically explain up to 60 percent of year-on-year wheat yield variability (Schierhorn et al., 2021). In southeast Ukraine, for example, low yields often result from the droughts frequently experienced there. The yield declines in 2022 can indeed be attributed in part to unfavourable weather conditions for most crops, with a cold spring, a summer drought in the south, and a rainy autumn that hampered and delayed harvest. For these reasons, the largest yield declines in 2022 occurred not in the most war-affected oblasts, but in the southern part of the country where the unfavourable weather conditions were most pronounced (Fig. 3).

Figure 2: Changes in Cropland Area Between 2021 and 2022



*Source: State Statistics Service of Ukraine (SSSU); GIS data: Openstreetmap (*https://www.openstreetmap.org/copyright*) and Conflict Investigations (*https://github.com/conflict-investigations/nzz-maps*).*

Satellite Remote Sensing to Assess Cropland Abandonment along the Front Line

For more than 50 years, satellite remote sensing has been the workhorse for tracking changes in land cover, natural ecosystems, and the distribution and condition of agricultural crops. The analysis of satellite imagery is ideally suited to monitoring land surface changes caused by wars, especially when these damages extend over large areas and are clearly visible from space. The provision of high-resolution, freely available imagery in near-real-time, such as Sentinel imagery that can be accessed through Copernicus, the Earth observation component of the EU's space programme, or Landsat imagery from NASA allows accurate and timely assessments of changes in land cover without extensive field work. Cloud storage and computing platforms, such as the Google Earth Engine (GEE), enable free access to vast archives of image data and provide tools for image analysis, including algorithms for image pre-processing such as automatic masking of clouds and shadows.

We evaluated the extent of abandoned croplands in a belt along the front line, covering five oblasts that are directly impacted by ongoing warfare, with Sentinel-2 imagery. We estimated cropland abandonment along the front line in the areas controlled by Ukraine and by Russia. We used data from a global land cover product, the ESA WorldCover project, to approximate cropland distribution in 2021 (Zanaga et al., 2022). Cultivated cropland is characterised by a tessellated pattern of fields with different crop types at different growing stages; by contrast, abandoned cropland becomes overgrown with natural vegetation and typically displays a more uniform pattern. With sufficiently high summer precipitation, abandoned croplands appear greener than cultivated fields throughout the growing season, exemplified by the clearly visible abandoned plots in the centre of the Sentinel-2 image taken in summer 2023 (Fig. 4). To estimate the area of abandoned cropland, we manually digitised the areas with conspicuous patterns of abandonment on a satellite image from summer 2023 and overlaid this belt with the cropland mask taken from the 2021 WorldCover product.

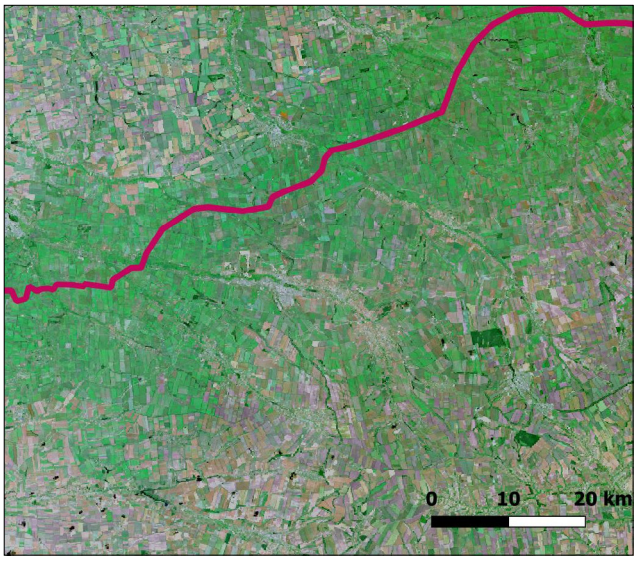
Although some croplands in Donetsk and Luhansk Oblasts in eastern Ukraine had already been abandoned after hostilities began in 2014, cropland abandonment accelerated after the beginning of the war in 2022, particularly in Zaporizhzhia and the western part of Donetsk Oblasts, which have been the focal points of military confrontation from early 2022 through the present. As a result, an approximately 60-km-wide belt of abandoned land has formed

Figure 3: Changes in Grain Yields from 2021 to 2022

*Source: State Statistics Service of Ukraine (SSSU); GIS data: Openstreetmap (*https://www.openstreetmap.org/copyright*) and Conflict Investigations (*https://github.com/conflict-investigations/nzz-maps*):*

around the front line, with few changes over the past year and a half (Fig. 5). Extensive military fortifications and mine fields are present on both sides of the front line, making the reclamation of these lands a difficult and costly task, even after an eventual end of hostilities.

Figure 4: Abandoned Croplands Along the Front Line (marked in red), Ukraine, Visible in the Sentinel-2 L2A True Colour Image Taken on June 22, 2023



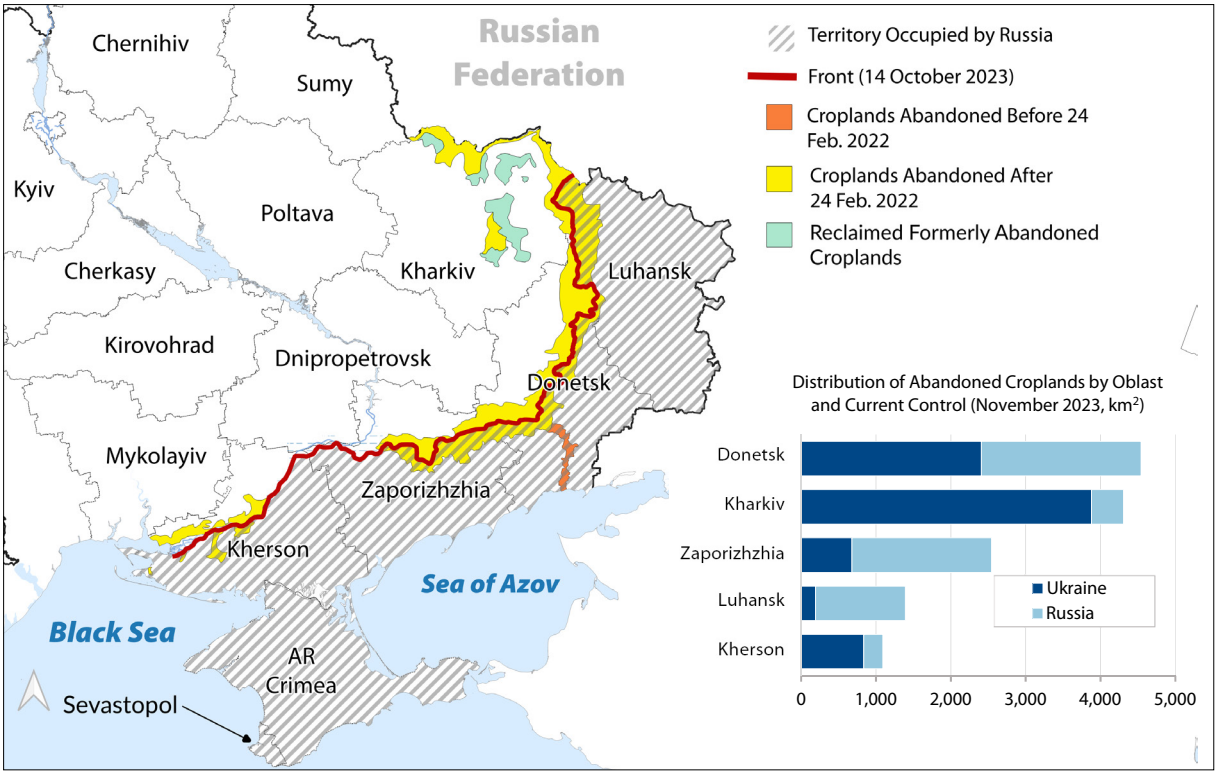
Source: Copernicus Date Space Ecosystem.

Shortly after the start of the full-scale invasion in February 2022, Russian forces conquered nearly half of Kharkiv Oblast, heavily disrupting crop cultivation in this region. Most of this area was retaken by Ukrainian forces later in the year. Owing to the comparatively low intensity of the fighting and the short duration of Russian occupation, much cultivation in this region has already resumed (Fig. 5). Only croplands in the far eastern and northern parts of the Oblast remain abandoned due to their location near the present front line.

A belt of abandoned croplands also emerged on both banks of the downstream Dnipro River in Kherson Oblast; however, abandonment is less extensive in this region because the river forms a natural barrier that weakens the intensity of the fighting. Patches of abandoned cropland can also be seen far from the combat area, mainly caused by indirect impacts of war such as high input costs, lack of labour and machinery, and poor logistics.

We estimate the total area of abandoned cropland at 13,900 km^2, of which 8,000 km^2 (57 percent)

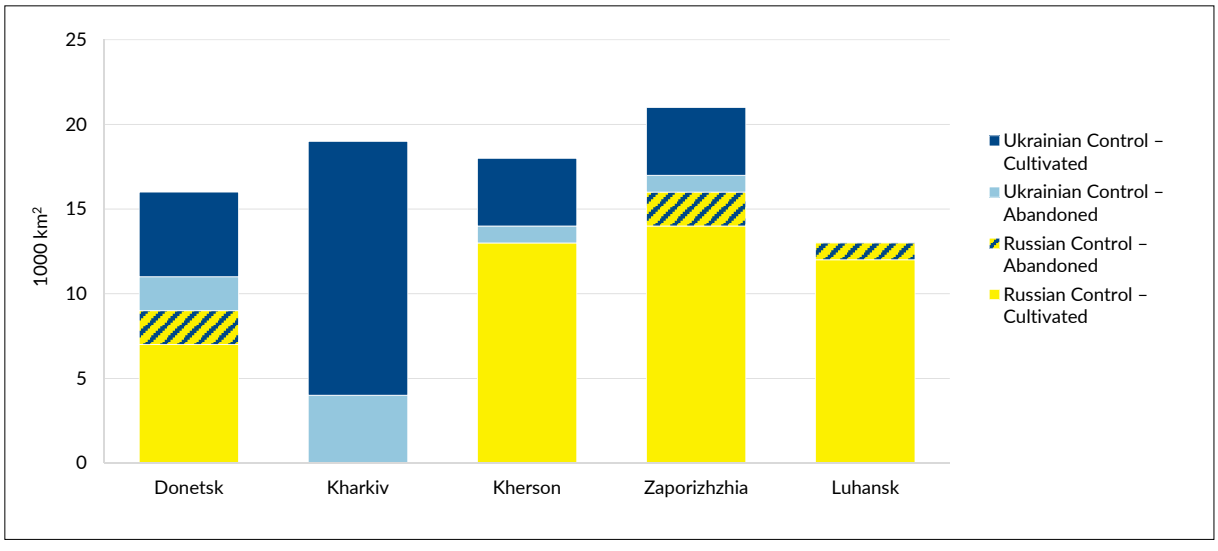
Figure 5: The Extent of Abandoned and Restored Croplands Along the Front Line as of November 2023



*Source: Own analysis; GIS data: Openstreetmap (*https://www.openstreetmap.org/copyright*) and Conflict Investigations (*https://github.com/conflict-investigations/nzz-maps*).*

is within the Ukrainian-controlled area (Fig. 6). Another 52,400 km² of Ukrainian croplands ended up in Russian-occupied territory after the onset of war. Therefore, the total loss of Ukrainian croplands (both that land abandoned but still controlled by Ukraine and land taken over by Russia) amounts to more than 60,000 km², or 18 percent of the entire cropland area of Ukraine in 2021.

Figure 6: Cultivated and Abandoned Croplands in Ukrainian- and Russian-Controlled Territory in the Five Oblasts Along the Front Line as of November 2023



Source: Own analysis.

Outlook

Future developments in cropland cultivation will depend on the unpredictable dynamics of the war and the duration of hostilities. Changes in front line position, fortification construction, and additional infrastructure damage could lead to the abandonment of more croplands and a further reduction in agricultural production. In times of war, satellite remote sensing has obvious advantages over methods that rely on field data collection to assess the extent of the effects of war on cultivation. Some farmers may not be accessible or report on time, and inspecting areas near the battlefield is dangerous. Remote sensing imagery, however, can be easily acquired and promptly analysed, regardless of the situation on the ground.

At present, statistical data from areas under Russian occupation are missing (except for sporadic data of dubious reliability from Russian sources). Satellite remote sensing can fill these information gaps, and is already widely used to monitor crop production in Ukraine during the current war. For example, the NASA harvest consortium published satellite data–based estimates of crop production in Ukraine already in 2022, including for Russian-occupied territories (NASA Earth Observatory, 2022), and the EU Joint Research Centre uses satellite data for its regularly published detailed forecasts of the current state of the Ukraine's crop (see Claverie et al., 2023).

Future efforts should be directed toward establishing a monitoring system that processes satellite data in near-real-time and on an ongoing basis to detect changes long before the arrival of the ground data. Such a monitoring system could be integrated into the official reporting routine to provide more reliable and timely statistical information. Satellite imagery can also help estimate the amount of damage inflicted on abandoned croplands and assess the feasibility of their recovery.

Advanced methods of image processing and analysis, particularly machine learning methods, offer more flexibility, versatility, and robustness compared to traditional statistical approaches and permit the derivation of valuable additional information, such as the current extent of croplands and of particular crops. The total production lost as a consequence of the war can be estimated by multiplying the extent of abandoned croplands with prospective yields. Multiplying the estimated production loss by market prices would allow for a monetary valuation of losses, which, in turn, can form the basis for quantifying eventual reparations demands.

Investments in cropland monitoring should include the development of human resources, including in the use of radar imagery that provides valid information regardless of cloud cover and the proper harmonisation of satellite-based information and field reporting. Furthermore, the collection of training and validation data for high-resolution crop-type monitoring, for instance from ongoing farming operations and images with very high resolution, should receive high priority. A functioning crop-type monitoring system would also facilitate the establishment of a land parcel information system, which would be the cornerstone for the administration and control system for disbursing EU agricultural subsidies after an eventual EU accession.

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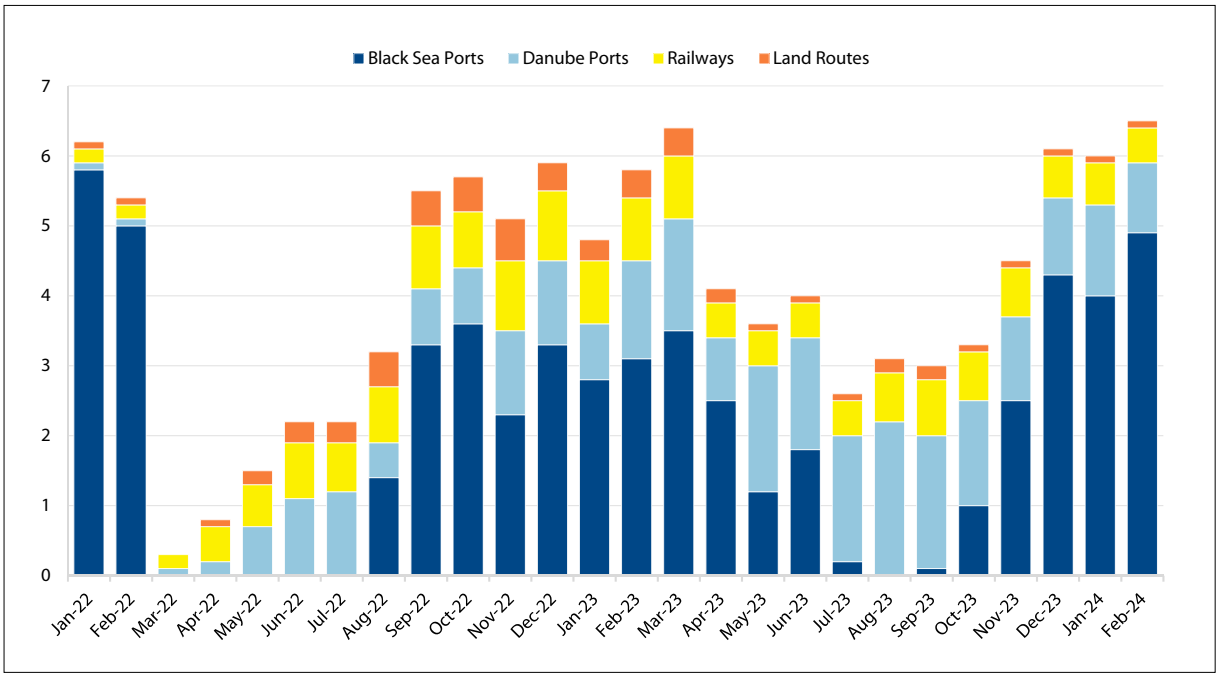
STATISTICS

Grain Exports

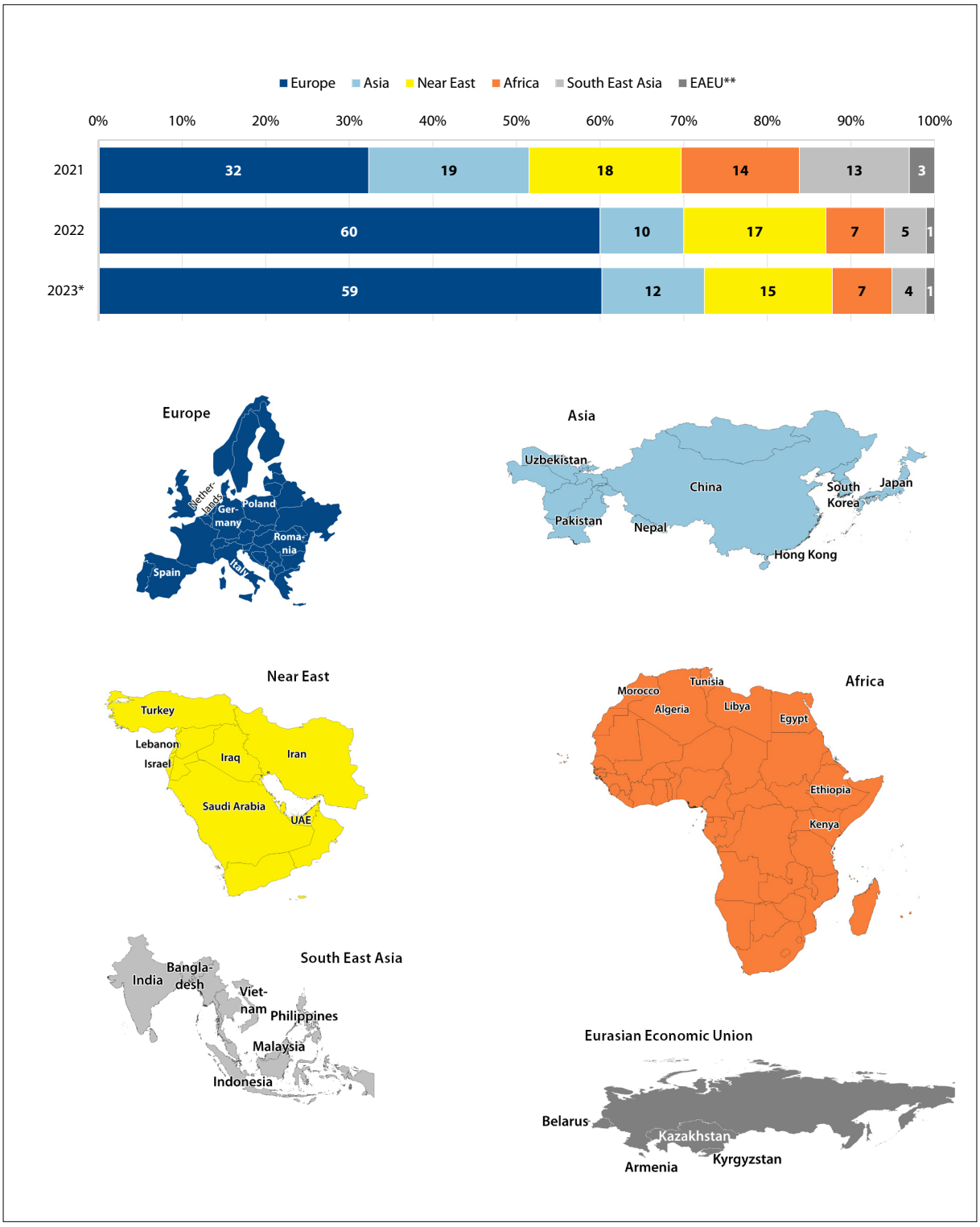
Figure 1: Ukrainian Grain and Oilseeds Exports (million tonnes)



	Black Sea Ports	Danube Ports	Railway	Trucks	Total
January 2022	5.8	0.1	0.2	0.1	**6.2**
February 2022	5	0.1	0.2	0.1	**5.4**
March 2022	0	0.1	0.2	0	**0.3**
April 2022	0	0.2	0.5	0.1	**0.8**
May 2022	0	0.7	0.6	0.2	**1.5**
June 2022	0	1.1	0.8	0.3	**2.2**
July 2022	0	1.2	0.7	0.3	**2.2**
August 2022	1.4	0.5	0.8	0.5	**3.2**
September 2022	3.3	0.8	0.9	0.5	**5.5**
October 2022	3.6	0.8	0.8	0.5	**5.7**
November 2022	2.3	1.2	1	0.6	**5.1**
December 2022	3.3	1.2	1	0.4	**5.9**
January 2023	2.8	0.8	0.9	0.3	**4.8**
February 2023	3.1	1.4	0.9	0.4	**5.8**
March 2023	3.5	1.6	0.9	0.4	**6.4**
April 2023	2.5	0.9	0.5	0.2	**4.1**
May 2023	1.2	1.8	0.5	0.1	**3.6**
June 2023	1.8	1.6	0.5	0.1	**4**
July 2023	0.2	1.8	0.5	0.1	**2.6**
August 2023	0	2.2	0.7	0.2	**3.1**
September 2023	0.1	1.9	0.8	0.2	**3**
October 2023	1	1.5	0.7	0.1	**3.3**
November 2023	2.5	1.2	0.7	0.1	**4.5**
December 2023	4.3	1.1	0.6	0.1	**6.1**
January 2024	4	1.3	0.6	0.1	**6**
February 2024	4.9	1	0.5	0.1	**6.5**

Source: Center for Economic Strategy: Ukraine War Economy Tracker, 26 March 2024, https://ces.org.ua/en/tracker-economy-during-the-war/.

Figure 2: Most Important Export Markets for Ukrainian Agricultural Products by World Regions (2021–2023, volume in mln. US Dollar)



** January–October 2023*

*** Eurasian Economic Union*

The main customer countries are listed by name on the maps (see Table 1 overleaf).

Sources: State Customs Service of Ukraine; GIS data: https://gadm.org/index.html, https://hub.arcgis.com/datasets/07610d73964e4d39ab62c4245d548625/explore *and* https://cartographyvectors.com/map/223-europe-outline-with-countries

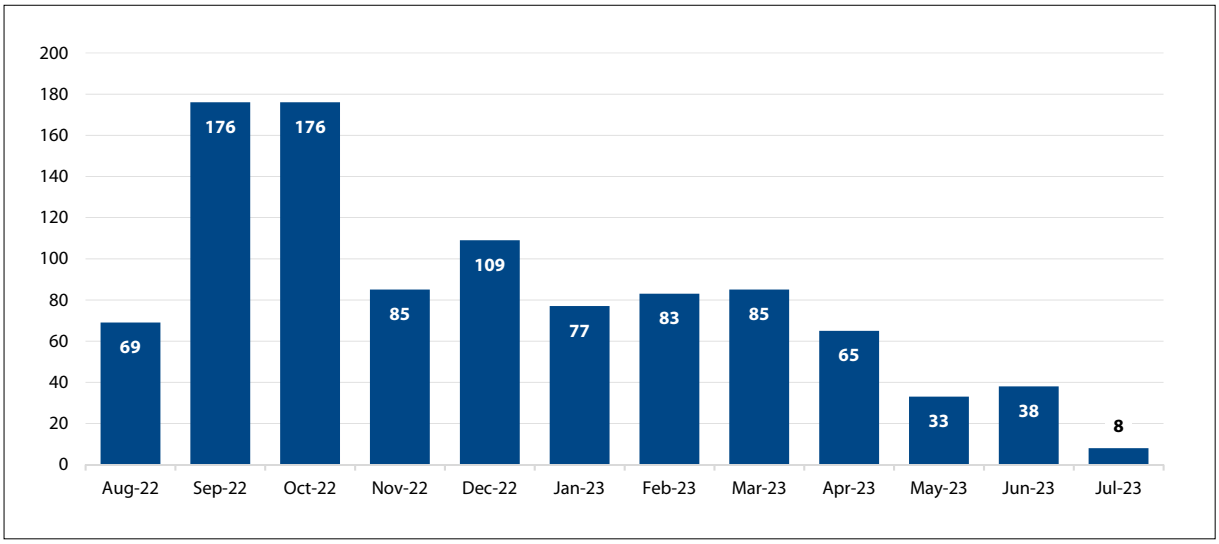
Table 1: Most Important Export Markets for Ukrainian Agricultural Products by World Regions (2021–2023, volume in mln. US Dollar)

	2021	(in %)		2022	(in %)		2023*	(in %)
Europe	**8,974**	**32**	**Europe**	**13,879**	**60**	**Europe**	**10,532**	**59**
Netherlands	1,762		Poland	2,631		Romania	2,498	
Spain	1,168		Romania	2,554		Poland	1,444	
Poland	981		Spain	1,306		Spain	1,215	
Germany	842		Netherlands	1,189		Netherlands	996	
Italy	718		Italy	907		Italy	812	
Asia	**5,385**	**19**	**Asia**	**2,307**	**10**	**Asia**	**2,044**	**12**
China	4,282		China	1,883		China	1,877	
Pakistan	572		South Korea	203		South Korea	45	
South Korea	236		Pakistan	124		Uzbekistan	26	
Japan	125		Uzbekistan	37		Nepal	20	
Uzbekistan	62		Japan	27		Hong Kong	17	
Near East	**4,851**	**18**	**Near East**	**3,885**	**17**	**Near East**	**2,700**	**15**
Turkey	1,464		Turkey	2,206		Turkey	1,710	
Saudi Arabia	646		Saudi Arabia	360		Saudi Arabia	221	
Iran	612		Israel	256		Israel	215	
Iraq	467		Iraq	228		United Arab Emirates	131	
Israel	450		Lebanon	209		Iraq	115	
Africa	**3,740**	**14**	**Africa**	**1,633**	**7**	**Africa**	**1,212**	**7**
Egypt	1,600		Egypt	652		Egypt	788	
Libya	416		Libya	221		Tunisia	107	
Morocco	347		Algeria	192		Libya	89	
Tunisia	315		Tunisia	163		Kenya	49	
Ethiopia	168		Morocco	64		Ethiopia	34	
South East Asia	**3,512**	**13**	**South East Asia**	**1,202**	**5**	**South East Asia**	**767**	**4**
India	1,954		India	793		India	310	
Indonesia	761		Malaysia	123		Bangladesh	185	
Bangladesh	299		Bangladesh	94		Malaysia	105	
Malaysia	119		Indonesia	92		Indonesia	40	
Philippines	106		Vietnam	31		Vietnam	36	
Eurasian Economic Union	**835**	**3**	**Eurasian Economic Union**	**240**	**1**	**Eurasian Economic Union**	**134**	**1**
Belarus	520		Kazakhstan	108		Kazakhstan	88	
Kazakhstan	164		Belarus	69		Armenia	34	
Armenia	75		Armenia	38		Kyrgyzstan	12	
Kyrgyzstan	31		Kyrgyzstan	22				

**: January–October 2023*

Source: State Customs Service of Ukraine.

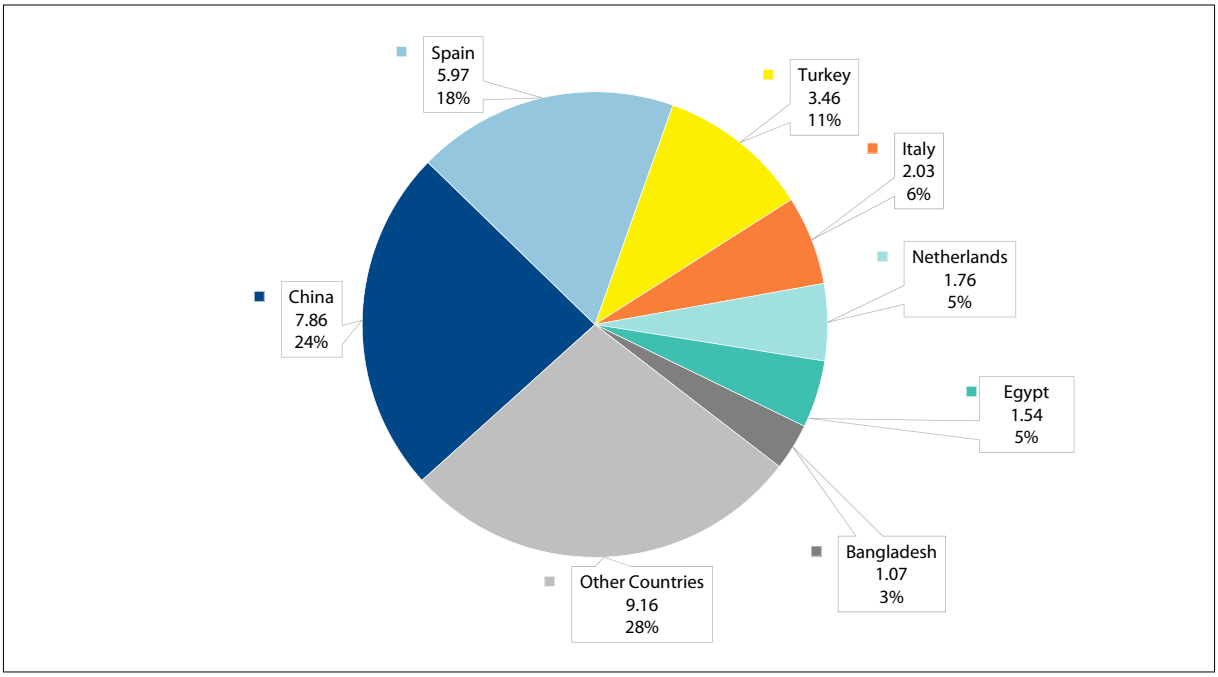
Figure 3: Data on the Grain Corridor: Number of Vessels Which Left Ukrainian Ports via the Grain Corridor from 01 August 2022 to 16 July 2023



Total number of vessels: 1004

Source: Ukrainian Grain Association. Export of agricultural products via grain corridor, https://uga.ua/en/results-of-the-grain-corridor-work/.

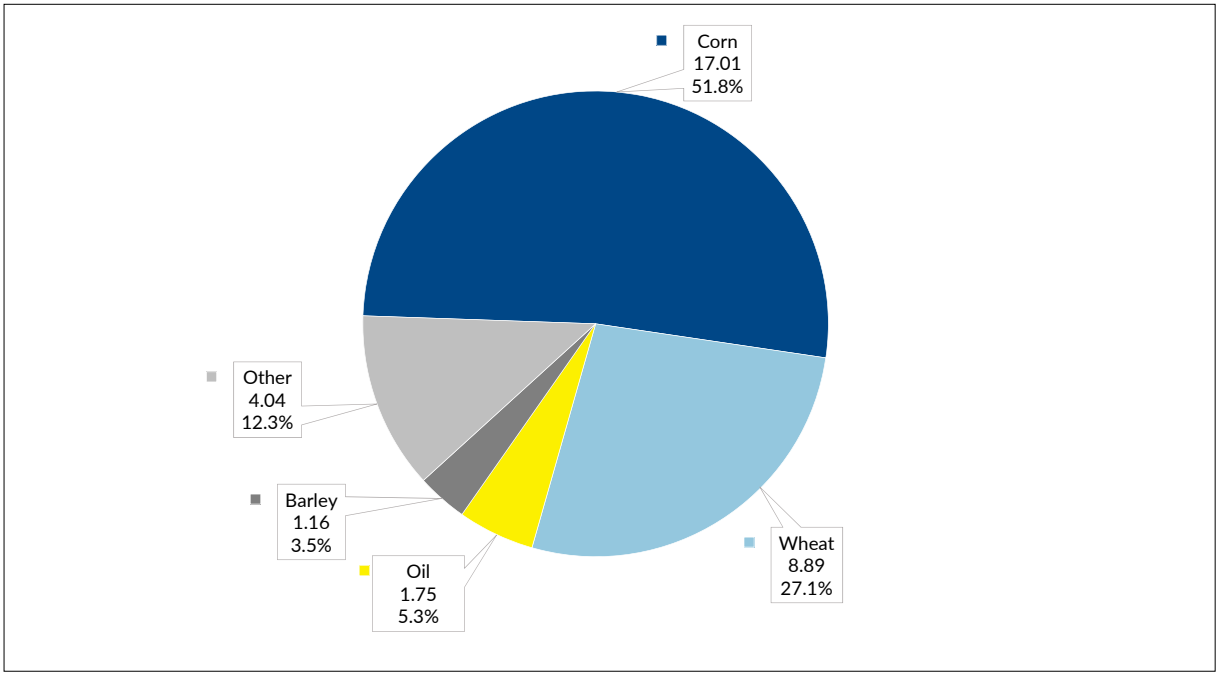
Figure 4: Data on the Grain Corridor: Main Export Destinations (export volume in bln. tonnes and in %)



Total tonnage: 32.86 bln. tonnes

Source: Ukrainian Grain Association. Export of agricultural products via grain corridor, https://uga.ua/en/results-of-the-grain-corridor-work/.

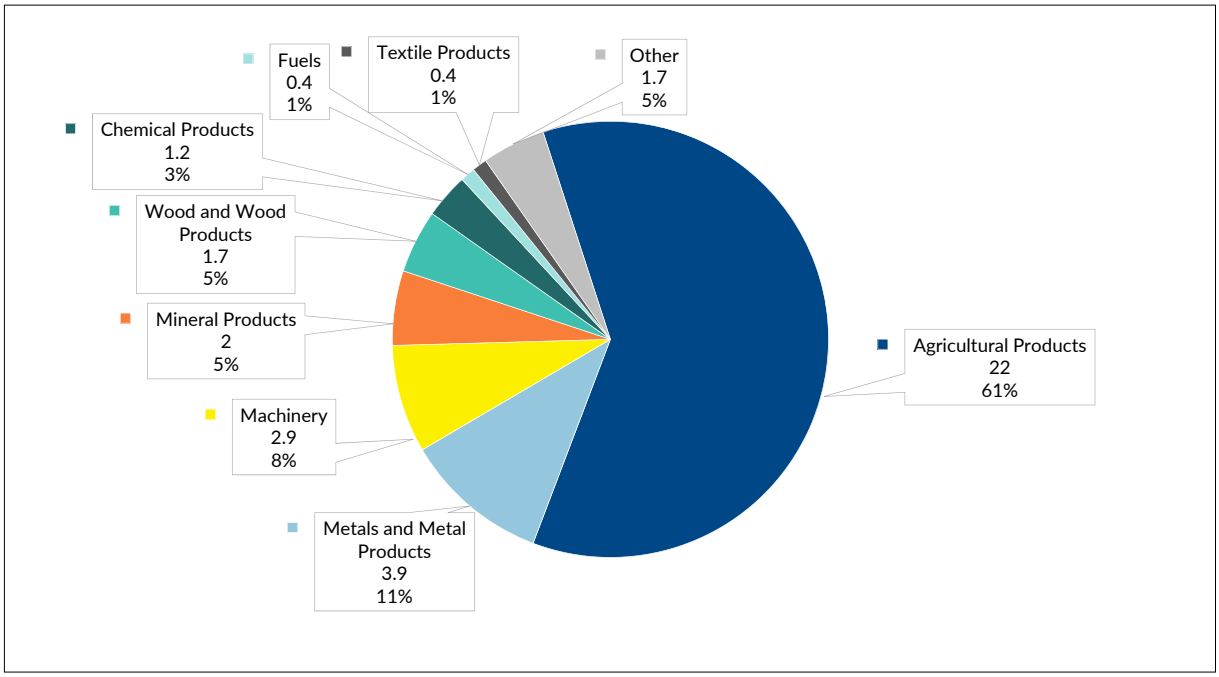
Figure 5: Data on the Grain Corridor: Goods Exported via the Grain Corridor (export volume in bln. tonnes and in %)



Total tonnage: 32.86 bln. tonnes

Source: Ukrainian Grain Association. Export of agricultural products via grain corridor, https://uga.ua/en/results-of-the-grain-corridor-work/.

Figure 6: Ukrainian Export Goods 2023 (in bln. US dollars and in %)



Total value: 36.2 bln. US dollars

Source: State Customs Service of Ukraine.

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